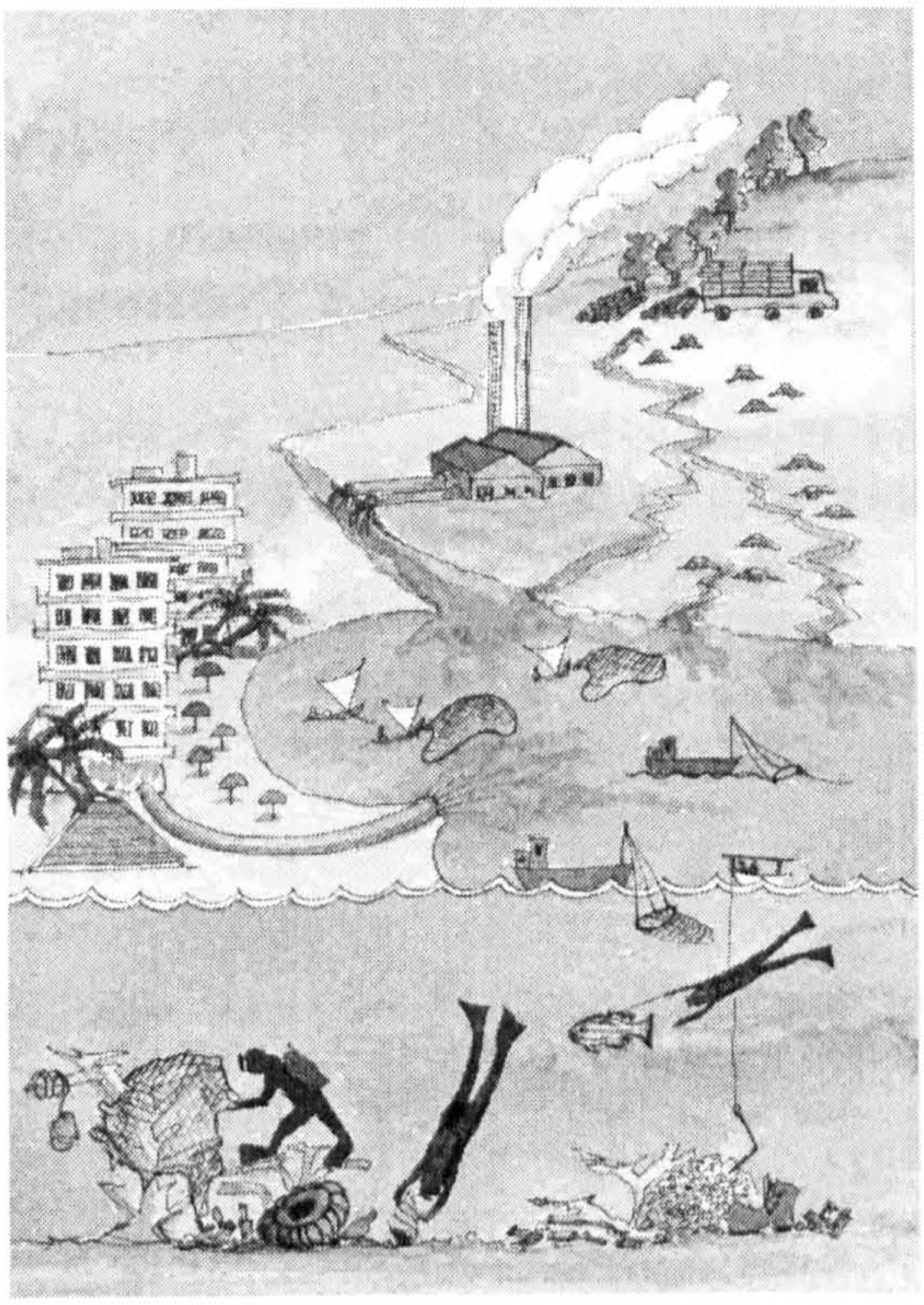
Integrated coastal management in the tropics: identifying the impediments and evaluating management tools



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PhD Thesis

May 2001

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Contents

Abstract

Tropical coastal resources including coral reefs, mangroves and seagrass beds are some of the most productive ecosystems in the World. They support a variety of goods and services that may often form the backbone of the local community. In many cases they provide the main source of food, as well as providing employment and recreation opportunities. However, coastal ecosystems are increasingly under threat from high population growth rates, rapid coastal development, over exploitation of the resources, loss of critical habitats and vulnerability to natural hazards. These tropical ecosystems are sensitive and vulnerable to damage and environmental change. Their worldwide loss has led to cause for concern and widespread calls for improved management.

Integrated coastal management (ICM) is seen as the way forward in dealing with this complex mix of interests, activities and demands being placed on today's coastal zones. The definition of the coastal zone will vary between locations, ideally capturing and enabling the resolution of all major coastal issues, reaching as far inland or seaward as is required to reach the goals and objectives of the management programme. ICM encompasses the management of all aspects of the coastal zone taking a multi-disciplinary approach. It includes the management of existing economic activities, planned developments, natural resource conservation and utilisation as well as being able to deal with the different user conflicts. ICM involves the integration of different institutions and stakeholder groups at and across the local to international management levels.

Even though ICM efforts are increasing, there are few examples where it is really being implemented and working effectively. In this study, three ICM case studies identified similar patterns of impediments although their scope was recognised as too narrow to make generalisations. As a result, a survey was developed to build up a broader picture of the issues blocking the development of successful ICM at several locations. The survey identified the current status of ICM in the tropics and identified the main impediments to implementing effective ICM. The survey found that few locations were actually implementing, monitoring and evaluating ICM, however a number were in the process of it. It was the step between analysis and implementation that was halting many of these efforts. Tropical coastal zones can be seen to share a number of common challenges exacerbated by poverty and conflicts between coastal users. Conflict management needs to be incorporated into the management process in a way that pays particular attention to the over-extraction of resources and destructive resource use.

Although the concept of integrated coastal management (ICM) has been identified as the way to deal with the multiple objectives, interests and uses of the coastal zone, in practice it is a complex process and many countries are having difficulty in implementing ICM. The most common impediments to ICM in the tropics were identified through the survey as were their impact on implementing ICM. The extent to which ICM is achieved can be linked to the impediments, described by a series of criteria, which could be used in assessing the ability of an area to implement ICM as well as identifying priority areas for concern. The results show that although public participation is commonly accepted as a major part of ICM and is one of the main impediments, it is rarely fully realised. Gaining political support and empowering agencies with sufficient authority to enforce ICM were also identified as major impediments, without which ICM efforts may well be blocked.

Decision making for integrated coastal management involves multiple decision makers and multiple stakeholders, often with conflicting needs and interests. Decision support systems (DSS) can be developed to improve our understanding of the inter-relationships between the natural and socio-economic variables and hence result in improved decision making. The question is whether this decision making environment is actually too complex for the development of useful and useable decision support systems. An ICM-DSS needs to be able to involve multiple decision makers and take into consideration multiple issues. This requires different disciplines to be drawn together into an integrated modelling framework. There are many techniques available to deal with different modelling needs, the constraints of inadequate data and the multi-objective decision making environment. There are also different ways of developing decision support systems and each can play a different, but non-the-less important role within ICM.

Three coastal DSSs were evaluated in terms of their design and roles in integrated coastal management and are used to evaluate the potential to develop ICM-DSSs. One of these DSSs, CORAL, is examined in detail as a case study. The model is an example of an integrated ICM model where the final result is a score-card of criteria that measure economic, environmental, social and institutional objectives. CORAL was developed for the island of Curaçao in the Caribbean and the Republic of the Maldives. The development process involved stakeholder meetings and interviews to ensure that all their interests and concerns in the coastal zone were accounted for and included in the DSS. The model development was carried out in the Netherlands and on return was presented to the stakeholder groups. A second phase of the project in Curaçao allowed the model to be installed on a wide number of computers. An ICM course was established as well as individual training given to the stakeholder groups involved. However, the final use of the DSS was still limited. Lessons are drawn from the CORAL experience that may assist in the development of future DSSs such as the need to involve a key organisation in the development and enable them to continue its development and maintenance after the end of the project. In addition, flexibility, adaptability and update-ability are paramount if the system is to be used beyond educational goals.

The impact of ICM on a coastal system is not always readily measured and quantified, least of all in monetary terms. Economic valuation is being increasingly applied to tropical coastal ecosystems to assess their benefits in monetary terms. From the point of view of ICM, economic valuation could give monetary values to, for example, changes in production resulting from management and hence highlights the importance of management. Likewise, it can highlight the costs of inaction by quantifying the benefits of a situation with ICM and one without ICM. This not only requires the ability to link monetary values to certain environmental situations but also to model the potential changes in goods and services provided by the ecosystem as a result of management. Past analyses in ICM have often focused on the costs of management versus economic gains while change to the environment has been measured in physical terms. Economic valuation provides a potential to compare like with like and hence bring the importance of ecosystems, such as coral reefs, to the fore. Some goods provided by these coastal ecosystems are marketed and consequently have a market-defined value associated with them. However, these ecosystems also provide a number of non-use benefits, which are not directly marketed and as a result, certain economic techniques have been developed to deal with these issues. The contingent valuation methodology (CVM) was developed as a tool to measure non-marketed goods and services of ecosystems so they can be included into cost-benefit analyses. However, it is a complex technique surrounded by much controversy. Even so, CVM and economic valuation in general is likely to be a useful management tool in its ability to raise political and public awareness of the importance of the environmental resources and present changes resulting from management in comparable monetary terms. This benefit to management may far outweigh the need to provide a precise and accurate monetary value, rather a range of values or indication of value may be sufficient. On a more practical basis, the results of the studies can be used to identify user fees and the feasibility of establishing trust funds to support conservation efforts. For a greater impact, an economic valuation should be carried out in a broader ICM context, which includes a stakeholder analysis. This not only helps identify the causes behind destructive practices but also identifies areas of potential resistance to management efforts.

In conclusion, in order to move ICM further forward, analysis of the impediments needs to be undertaken at each specific location. These can be prioritised and tackled in order of the severity of their impact on blocking the implementation of ICM efforts, rather than carrying out the more easily-achieved management tasks. This may not provide funding agencies or policy makers with immediate results, but it may well ensure a higher level of success with ICM in the long term and therefore reduce the current overexploitation and degradation of coastal resources. In addition, there are a series of management tools that may well be useful in raising awareness, both public and political, and understanding of the links and issues in the coastal zone. These need careful design and development in order to successfully tackle the issues at hand.

Acknowledgements

This thesis may well be the result of my own determination and stubbornness, but more importantly, it is the result of the opportunities, inspiration and support that many different people have given me during the last five years and well before that. Consequently, there a number of people I would like to thank.

Firstly, I would like to thank those who have prodded and guided me through the development of ideas and structuring of a piece of work worthy for submission as a PhD. Having spent the majority of my time away from Newcastle regular supervision was somewhat of a challenge but it was there whenever I needed it and I am grateful to both Dr. John Bythell and Dr. Alasdair Edwards for their continual guidance and encouragement. My thanks also go to Dr. Jeremy Hills for his ideas and help on the statistics and Dr. Nick Polunin and Prof. Peter Burbridge for their support as panel members. I am also grateful to many others in the Department for making me feel welcome and a part of the Department whenever I visited.

I have carried out the work for this thesis on a part-time basis whilst working in the field of marine and coastal conservation. A substantial proportion of the material for this work was produced through the projects I have been fortunate enough to work on with a number of entertaining and inspirational colleagues. My thanks go to all those who have had an influence on my thinking during these projects, in particular to those from Resource Analysis, the Bonaire Marine Park and the CORDIO programme.

I started work on my PhD whilst still working for Resource Analysis a consulting company based in Delft the Netherlands that is dedicated to the sustainable management of natural resources where I spent 2 years working on a project to develop a decision support system for coral reef areas in Curaçao and the Republic of the Maldives, called CORAL. The World Bank, Latin American Environment and Urban Development Division (LA3EU) funded the project. The application in Curaçao and the Maldives was part of a larger project to develop a cost-effectiveness analysis of coral reef management strategies and subsequently value the benefits of increased reef health. The task manager in the World Bank was Richard Huber and project manager in Resource Analysis was Frank Rijsberman who together with Jack Ruitenbeek, Mark Ridgley and Steve Dollar developed the conceptual background to the project that was applied in Jamaica.

I spent several months in 1995 in Curaçao during the development of CORAL carrying out stakeholder interviews to identify the main aspects of the model together with my colleague Leanne Fernandes. Together we developed the structured interview that has provided me with valuable material forming a detailed ICM case study that is reported in Chapter 3. I am grateful to Leanne for her input and ideas and to all the stakeholders in Curaçao who supported the project and gave us their time, in particular to Jeff Sybesma who was our local sounding board. After the field work I returned to the Netherlands to develop the decision support system which was made possible with the mentoring support from Frank Rijsberman and the technical expertise in programming from Christiane Kloditz and Diederick Wardenburg.

Returning to Curaçao in 1997 for 7 months enabled me to fully test the model and evaluate its use. Imma Curiel at the University of the Netherlands Antilles and Manfred van Veghel from the Radulphus School were both supportive of the model's use and set up the possibility to use the model in both adult and children education and training programmes. In addition, the honesty and interest of the local community into CORAL made this evaluation possible. My involvement in the development of CORAL and other decision support systems such as the coastal management model, COSMO, the role play CORONA, Coastal Management Model for Africa, COMA and WESTOOL, a DSS for the Western Scheldt in the Netherlands during the 5 years I worked at Resource Analysis has given me valuable insights into the practical development of these types of integrated decision support tools and forms the basis of Chapters 5 and 6 of this work.

The second phase of the project in Curaçao was set up to carry out an economic valuation of coral reef biodiversity. My role was to support Clive Spash to re-develop the CVM survey, originally developed for Jamaica, for application in Curaçao. In Curaçao, together with assistance from Tamara Cruis, we trained surveyors, pre-tested the survey, suggested adaptations and carried out the final survey. The resulting database, along with the direct use valuation data I collected during this time has been a useful contribution to Chapter 7 of this thesis. I left Resource Analysis after carrying out some basic analysis of the data. Clive Spash subsequently analysed the data exploring the more theoretical aspects of CVM. I would like to thank all my colleagues I worked with during that time at Resource Analysis for these opportunities and the experience gained.

In November 1997, I joined the Bonaire Marine Park as assistant manager. My position was created to cover the maternity leave of the manager, Kalli de Meyer. I am extremely grateful to Kalli for giving me the chance to work with her and learn all the different aspects of marine park management. My tasks involved law enforcement, maintenance of the park infrastructure of moorings, establishing and organising educational and research programmes and advising government. The park functions with a full time permanent staff of five persons, a manager and four rangers which is minimal staffing for such an active and extensive park. The park thrives on the co-operation and dedication of the local dive operators and a group of local volunteers. This experience has given me an amazing practical insight into the real issues facing coastal managers in these tropical areas. This experience has formed one of the ICM case studies in Chapter 3 but also forms a huge part of the underlying experience framing the whole research.

After leaving the Bonaire Marine Park in early 1999, I joined the CORDIO (Coral Reef Degradation in the Indian Ocean) project team. The project was funded through the Africa Environment Department of the World Bank, coordinated by Indu Hewawasam and the Swedish International Development Agency (Sida) coordinated by Olof Linden. I worked along side Dan Wilhelminsson, Jean Pascal Quod and David Obura as regional coordinators of the programme and was involved in establishing the socio-economic assessment for the whole region. This assessment involved a number of people. Together with Herman Cesar, Lida Pet Soede and Joop de Schutter we established a format for the evaluation. My focus on the tourism impact in Zanzibar and Kenya was made possible by the dedication of Irene Ngugi who was a fantastic field worker and gained great support from all those at the Institute of Marine Sciences in Zanzibar as well as all those who were interviewed in Zanzibar and Mombasa. Jessica Andersson played a key role by allowing us to adapt her existing survey and have access to her pre-bleaching dataset as well as providing input in the analysis of the data. This work has provided me with a further case study of economic valuation for Chapter 7.

Finally, I would like to thank numerous friends and family for their support and contributions. I thank my proofreaders who went through various drafts of this thesis and provided helpful and useful comments, namely, my two supervisors, John Bythell and Alasdair Edwards as well as Bill Toleman, Rus Westmacott and Herman Cesar. I also owe a great deal to my friends and family who have unquestioningly provided me with a roof over my head or even lent me their house at various stages of my somewhat nomadic lifestyle, in particular my parents – Rus and Virginia Westmacott and Mark Tomson, but also, Sue and Phil Sparrow, Beverly and Tony Gower Jones, Peter van de Koning, Tim and Caroline van den Brink, Ian and Lisa Walker, John and Mary Bythell, Dave and Helen Tomson, and Peter Jones for providing me with some last minute office space. I would also like to thank my sister, Emma for picking me up when I needed it most. Finally, I would like to dedicate this work to my Granny, who probably inspired my initial interest in the environment and the world we live in and sadly died the week I submitted it. Granny - I'll miss you.

Bibliography

The work within this thesis has been published or submitted for publication, either as the Chapters stand or as contributions to larger pieces of work.

Kloditz, C., F. Rijsberman, S. Werners and S. Westmacott 2000. Development of the User Interface - Coral-Curacao, Coral-Maldives and COCOMO. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 153-158. Washington, DC: The World Bank.

Meesters, E. H., R. P. M. Bak, S. Westmacott, M. Ridgley and S. Dollar. 1998. A Fuzzy Logic Model to Predict Coral Reef Development under Nutrient and Sediment Stress. *Conservation Biology* 12: 957-965.

Rijsberman, F. and S. Westmacott 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of Curacao. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 49-66. Washington, DC: The World Bank.

Spash, C. L., J. van den Werff ten Bosch, S. Westmacott and J. Ruitenbeek 2000. Lexicographic Preferences and the Contingent Valuation of the Coral Reef Biodiversity in Curaçao and Jamaica. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 97-118. Washington, DC: The World Bank.

Westmacott, S. 2000a. Are we tackling the main issues constraining Integrated Coastal Management in coral reef areas? *Paper presented at the ISRS 9th International Coral Reef Symposium, Bali, October 2000. Reviewed and forwarded for publication in the proceedings.*

Westmacott, S. 2000b. Developing decision support systems for integrated coastal management in the tropics. Is the ICM decision making environment too complex for the development of a useable and useful DSS? *Environmental Management, in press.*

Westmacott, S. 2000c. Identifying the main impediments to integrated coastal management in the tropics. *Paper submitted to Ocean and Coastal Management, October 2000.*

Westmacott, S. 2000d. Where should the focus be in tropical integrated coastal management? *Paper submitted to Coastal Management, September 2000.Reviewed and resubmitted for publication.*

Westmacott, S., H. Cesar and L. Pet Soede 2000a. Socio-economic assessment of the impacts of the 1998 coral reef bleaching in the Indian Ocean: a summary. In *Coral Reef Degradation in the Indian Ocean: Status Report 2000,* eds., D. Souter, D. Obura and O. Linden, 143-159. CORDIO/SAREC Marine Science, Sweden CORDIO Programme.

Westmacott, S., H. Cesar, L. Pet Soede and O. Linden 2001. Assessing the socio-economic impacts of the 1998 coral bleaching in the Indian Ocean. In *Coral Bleaching: Causes, Consequences, and Response. Papers presented at the 9th International Coral Reef Symposium session on "Coral Bleaching: Assessing and Linking Ecological and Socioeconomic Impacts, Future Trends and Mitigation Planning,* eds., H. Schuttenberg, Narragansett, RI: Coastal Resources Center.

Westmacott, S., H. Cesar, L. Pet-Soede and O. Linden 2000b. Coral Bleaching in the Indian Ocean: Socio-Economic Assessment of Effects. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 94-106. Stockholm, Sweden: Sida Press.

Westmacott, S. and F. Rijsberman 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of the Republic of the Maldives. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 67-82. Washington, DC: The World Bank.

Westmacott, S. and F. R. Rijsberman. 1995. CORAL, Coastal Management Model for the Sustainable Development of Coral Reef Areas. *Physics and Chemistry of the Earth* 20: 245-250.

Westmacott, S., K. Teleki, S. Wells and J. West. 2000c. *Management of bleached and severely damaged coral reefs.* Gland Switzerland and Cambridge, UK: IUCN.

List of acronyms

CRMP	Coastal Resources Management Project, Philippines
CV	Contingent Valuation
CVM	Contingent Valuation Method
DIN	Dissolved inorganic nitrogen
DSS	Decision Support Systems
EC	*E. Coli*
EEZ	Exclusive Economic Zone
EoP	Effect on Production
GDP	Gross Domestic Product
GIS	Geographical Information Systems
ICM	Integrated Coastal Management
IUCN	World Conservation Union
MCA	Multi-criteria analysis
MDS	Multi-dimensional scaling
NAF	Netherlands Antilles Florins
NGO	Non-governmental organisation
NOAA	National Oceanographic and Atmospheric Administration, United States
P	Phosphate
PRIMER	Plymouth Routines in Multivariate Ecological Research
SPM	Suspended Particulate Matter
UNCED	United Nations Conference on Environment and Development
USAID	United States Agency for International Development
WTA	Willingness to Accept
WTP	Willingness to Pay
WWF	World Wide Fund for Nature

INTRODUCTION

1 Introduction

1.1 Rationale

Coastal zones are unique in the sense that they include both terrestrial and marine activities, which influence and depend on one another. Tropical coastal zones include distinctive resources such as coral reefs, mangroves and seagrass beds, which are highly productive and renewable. These ecosystems provide numerous functions and services vital to the survival of many coastal populations (Spurgeon, 1992; Moberg & Folke, 1999; Cesar, 2000). The most important goods and services of tropical coastal ecosystems are presented in Table 1. The value of these goods and services is substantial, although debatable, because much of the value lies outside the commercial market and is not quantified in terms comparable with economic services and manufactured capital (Costanza et al., 1997; Costanza, 1998). Many of these goods and services have been seen as 'free' services such as waste treatment and coastal protection and decision makers may not give adequate attention to their conservation in policy decisions.

Table 1: Important Goods and Services of Tropical Coastal Ecosystems. Source: adapted from Cesar (2000), based on original structure of Moberg & Folke (1999).

Goods	Renewable resources	• Seafood products • Raw materials and medicines • Wood from mangrove cutting and thinning • Curios and jewellery
	Mining	• Coral blocks, rubble / sand for building • Raw materials for lime and cement production
Ecological services	Physical structure services	• Shoreline protection from reefs, mangroves and seagrass beds • Build up of land and generation of coral sand
	Biotic services within ecosystem	• Maintenance of habitats • Maintenance of biodiversity • Regulation of ecosystem processes and functions • Biological maintenance of resilience
	Biotic services between ecosystems	• Biological support through 'mobile links' • Export organic production etc. to pelagic food webs
	Biogeochemical services	• Nitrogen and carbon fixation • CO_2 and CH_4 budget control • Waste assimilation • Run off control and sediment reduction
	Information services	• Monitoring and pollution record (corals)
	Social and cultural services	• Support recreation • Aesthetic values and artistic inspiration • Sustaining the livelihood of communities and providing food security • Support of cultural, religious and spiritual values

Coral reef species provide a vital source of protein for many of the World's poor (Bryant et al., 1998). Artisanal coral reef fisheries have been reported to account for 90 percent of the fish production of Indonesia and up to 55 percent in the Philippines (Clark, 1996). However, the importance of coral reef fisheries on a global scale may not be in their absolute yield (0.5 million tonnes yr^{-1}), but their contribution to the catch of low-income fishers with little alternative for employment (Russ & Alcala, 1996; Pet Soede, 2000).

One of the increasing activities in the coastal zone is tourism. World tourism now accounts for 11 percent of the global gross domestic product (GDP), creating almost 200 million jobs. For an area such as the Caribbean, where tourism is linked closely to the coast, it accounts for 20 percent of the GDP and creates an estimated 3.6 million jobs (World Travel and Tourism Council, 1999). Coastal environments may even be the backbone of the coastal economy. In small island states, the marine resources form the mainstay of the whole island economy. In Barbados and the Bahamas, the travel and tourism industry accounts for over 50 percent of the islands' GDP. In the British Virgin Islands, the contribution to the national accounts from travel and tourism reaches over 80 percent of the GDP (World Travel and Tourism Council, 1999).

Coral reefs can only be found in restricted environmental conditions making them particularly vulnerable to changes in these conditions. Of the 255 000 km^2 of coral reefs worldwide (Spalding & Grenfell, 1997), it is estimated that 10 percent are already degraded beyond recovery and another 30 percent are likely to decline significantly within the next 20 years (Wilkinson, 1992; IUCN, 1993; Jameson et al., 1995). The map-based assessment of reefs at risk estimates that 58 percent of the world's reefs are potentially threatened by human activity. These activities range from coastal development and habitat destructive practices to the over exploitation of resources, marine pollution, runoff from inland deforestation and farming (Bryant et al., 1998). In addition to these direct anthropogenic threats, are threats from global environmental change. The 1997-1998 El Niño event, on top of increasing average ocean temperatures, resulted in extensive coral bleaching and subsequent mortality (Wilkinson et al., 1999; Goreau et al., 2000; Wilkinson, 2000). Mortality of the reef building corals reached as high as 90 percent on some reefs (Goreau et al., 2000; Wilkinson, 2000). This event highlighted the immediate threat to coral reefs from global environmental change which is now seen as posing an equal or even greater threat to coral reefs than direct human impacts (Wilkinson, 2000).

Even though these coastal resources are unquestionably vital to the survival of many coastal communities, they are continually degraded through their misuse (Wilkinson & Salvat, 1997; Bryant et al., 1998; Hodgson, 1999). Increasing coastal populations and their inherent need for food has led to substantial pressures being placed on reef fisheries. The expansion of the fisheries on tropical coasts is likely to be the most widespread human exploitative activity on coral reefs (Jennings & Polunin, 1996). The ability to predict the movements of reef fish in space and time has increased the risk of their over-exploitation. This, coupled with our ability to catch fish faster than they reproduce has lead to widespread depletion of reef fisheries (Bohnsack, 1993). Successful fishing not only reduces the abundance and biomass of the fishery (Alcala, 1988; Jennings et al., 1995; Polunin & Roberts, 1996), it has also been shown to have profound effects on the structure and function of the reef ecosystem

(McClanahan & Muthiga, 1988; Hughes, 1994; McClanahan, 1995; Roberts, 1995; McClanahan et al., 1999).

Sustainable tourism requires careful planning and conservation of the environment that the tourists have come to visit. Tourism is dependent on the quality of the coastline, water, beaches and reefs, both from an aesthetic and public health viewpoint. Where scuba diving is involved, a high diversity of fish and benthic species becomes increasingly important (Polunin et al., 2000; Westmacott et al., 2000). Even so, rapid development of areas with inadequate provisions made for infrastructure has led to an erosion of the resource base on which the tourism was originally founded.

Coral reefs are not the only ecosystem in decline. Mangroves and seagrass beds are also cleared and dredged as development proceeds. An estimated 182 000 km^2 of mangrove forest wetlands occur in the coastal areas of subtropical and tropical countries (WWF & IUCN, 1998). These mangroves provide fuelwood and charcoal, timber for construction, a variety of food sources, honey, fish and shellfish. They also act as a barrier to flood and storm waters (Clark, 1996). Mangroves provide a habitat for over 2,000 species of fish and benthic species; the large quantity of nutrients manufactured sustains this marine life, which forms the first link in a food chain believed to sustain some important offshore fisheries (WWF & IUCN, 1998). Even though mangroves provide many resources, they are often seen fdccccas a wasteland unless they are 'developed', e.g., drained to provide additional land or turned into aquaculture ponds (Clark, 1996). Seagrass beds also provide a coastal protection function, helping to protect shorelines from coastal erosion. They also trap sediment, which retains the water clarity (WWF & IUCN, 1998). In addition, they provide a feeding ground for turtles, manatees, dugongs, juvenile fish and important shellfish such as conch (Nagelkerken et al., 2000).

Maintaining the integrity of coastal ecosystems will in turn maintain the economic base for many coastal communities. However, degradation of these ecosystems continues. In a large part, loss and degradation of coastal resources is due to a failure to appreciate and account for the full range of goods and services they provide (Crooks & Turner, 1999). Management of coastal zones must be able to deal with anthropogenic pressures as well as with the future uncertainty regarding climate change, accelerated sea-level rise and changing storm patterns (Crooks & Turner, 1999; Turner, 2000). Much of the damage occurring in coastal zones is the result of activities originating outside the coastal area, within the wider drainage basin and beyond (Turner & Bower, 1999). The continuing decline of coastal resources has lead to special attention being brought to the management of these areas. The complex interaction of the economic, social and environmental systems, as well as the spatial complexity of activities affecting the coastal zone, has necessitated this composite approach to management. This is now known as integrated coastal management. Although there are views that integrated coastal management is not socially desirable as it is seen to open up coastal zones to aggressive state and global capital investment (Nichols, 1999), this is not the view held here. There are many forms of integrated coastal management. It is an evolving process, which can be adapted to each individual situation.

1.2 Defining the coastal zone

The interface between the terrestrial environment and the marine environment is affected by numerous activities and influences. Special attention to the management of these areas demands some sort of definition of their boundaries. However, regardless of how the boundaries of the coastal zone are defined there will always be external processes or influences; social, economic and environmental, that will cross the boundaries of the coastal zone (Burbridge, 1999). Consequently, the definition of the coastal zone has met with much contention. Numerous definitions can be found around the world (Sorensen & McCreary, 1990). They differ depending on the legal, administrative and natural boundaries found in each area. No single definition would be applicable to all coastal zones. Each definition needs to be flexible and able to adapt to the specific situation.

The boundaries of the coastal zone should be designed to capture and enable the resolution of all major coastal issues. It needs to be as far inland or seaward as is required to reach the goals and objectives of the management programme (Sorensen & McCreary, 1990; Clark, 1992). The broad array of issues found in coastal zones means there will be a broad array of management boundaries. However, stating the boundary should include all areas that have an influence on the coastal zone, could be politically defeating because it would lead to such a broad area of control. One principle of the definition of the seaward boundary is that it should reflect different legal regimes such as internal waters and territorial seas (Clark, 1992). This could be the edge of the continental shelf or the EEZ. The definition of the coastal zone will need to be limited in order to retain the possibility of achieving success. However, being too limited may compromise the effectiveness of management by omitting the major impacting factors.

1.3 Defining integrated coastal management

Integrated coastal management has been described by many authors under several different names, e.g., coastal zone management, coastal area management, integrated coastal zone management, integrated coastal management (Lowry & Wickremeratne, 1988; Bijlsma et al., 1993; Chua, 1993; Cicin-Sain, 1993; Cicin-Sain et al., 1995; Salomons & Turner, 1999). During the development of the coastal management concept, there has been a major change in emphasis from *coastal zone management* to *integrated coastal management* (Burbridge, 1999). This reflects a move from management of the area defined as the coastal zone to management of the activities affecting the coastal zone. This requires a broader integrated approach and may actually lie outside the defined coastal zone. As a result, the term *integrated coastal management*, abbreviated as *ICM* is used throughout this work. This has been selected as the most unambiguous term that can be applied to all forms of integrated management within the coastal zone. The term "integrated" is important because it emphasises the complex nature of the management being discussed. "Coastal" is utilised rather than "coastal zone" so that the area under discussion is not limited to one definition. Instead, it is applicable to many coastal situations.

The concept of coastal management has been around for more than 30 years during which time there have been major advances in the development of management tools and the understanding of the issues (Cicin-Sain et al., 1995; Christie & White, 1997; Cicin-Sain & Knecht, 1998; Burbridge, 1999). However, the results of the management efforts have been mixed (Bijlsma et al., 1993; Burbridge, 1999). Concern for the continued degradation of coastal resources, particularly in the tropics and the apparent inability of coastal management efforts to deal with this was the initial trigger for this study. These issues of ICM and the ability within the tropics to implement effective ICM strategies are the focus of Chapters 2-4 of this thesis.

1.4 Developing management tools

When the concept of ICM was initially developed, there was limited expertise in the field. Over time, the capacity to deal with the complex issues has been developed (Crawford et al., 1993; Cicin-Sain et al., 1995; Christie & White, 1997; Linden & Granlund, 1998; Moffat et al., 1998; Burbridge, 1999; Christie & White, 2000; Hale et al., 2000). A variety of management tools has been developed to assist in the analysis and planning of ICM. For example, decision support systems (Gustavson et al., 2000), economic-ecological modelling techniques (Turner et al., 1998), multi-criteria analysis (Saaty, 1991; Beinat et al., 1994; Nijkamp & van den Burgh, 1997), conflict resolution (Rijsberman, 1998), database management (Fedra, 1995), remote sensing (Green et al., 1996) and geographical information systems (GIS) (Mumby et al., 1995).

Understanding the interactions between the coastal zone and global changes cannot be achieved by observational studies alone. Modelling key environmental processes is seen as a vital tool that must be used if coastal management is to achieve its overall goals and objectives (Turner et al., 1998; Turner & Salomons, 1999; Turner, 2000). Modelling approaches to ICM need to integrate a number of disciplines from within both the physical and social sciences. There have been a number of ICM modelling efforts developing this integrated economic-ecological approach for ICM (Engelen et al., 1995; Westmacott & Rijsberman, 1995; Fabbri, 1998; Turner et al., 1998; Hogarth, 1999; van der Weide & De Vrees, 1999; Gustavson et al., 2000). Each system or approach aims at supporting the ICM decision making capacity by providing a means to compare the impacts of different management strategies. However, their acceptance and use is dependant on a number of factors and the complex decision making environment challenges the developer's ability to provide a useful and useable system. These issues are the focus of Chapters 5 and 6 of this work.

Part of the problem of ICM lies in the difficulty of convincing politicians and senior managers responsible for sectoral agencies that there are significant advantages to be gained by investing time, effort and funds in developing coastal management (Burbridge, 1999). Much of the continued degradation of coastal resources has been linked to the failure to appreciate the full value of the beneficial functions provided by such systems (Crooks & Turner, 1999). Techniques developed in the field of economics have enabled goods and services, previously unvalued by traditional markets, to be valued. As the costs of degradation and unsustainable resource use can now be identified, decision makers are able to make a more informed trade off between economic development and environmental protection. However, these methods can be controversial and are often based on hypothetical markets, identifying hypothetical values. The final component of this work evaluates the potential for economic valuation to be used as a tool for ICM. This is reported in Chapter 7.

1.5 Research Structure

The research can be seen to form two main components. The first component is the identification of impediments to integrated coastal management throughout the tropics (Part I: Chapter 2, 3 and 4) and the second component is the investigation of the use of selected management tools in overcoming these impediments (Part II: Chapter 5, 6 and 7). The research objectives, the research strategy and an introduction into the methodologies used can be found in the following sections.

Research objectives

Much of the literature focuses on the theory behind ICM (Sorensen & McCreary, 1990; Bijlsma et al., 1993; Chua, 1993; Resource Analysis & Delft Hydraulics, 1993; Vallega, 1993; van der Weide, 1993; Bower et al., 1994; Post & Lundin, 1996; Turner & Adger, 1996; Cicin-Sain & Knecht, 1998; Olsen et al., 1998). Documentation of the progress and success of ICM has also been covered in various documents (Sorensen, 1993; Cornforth, 1994; Yap, 1996; Christie & White, 1997; Shah et al., 1997; Sorensen, 1997; White et al., 1997; Chua, 1998; Olsen & Christie, 2000; Sorensen, 2000). The continued decline of tropical coastal resources and the apparent inability of ICM to tackle these issues in most areas have stimulated this work. It takes the assessment of ICM a step further by evaluating what the main issues are in tropical coastal zones and identifies the main impediments to implementing effective ICM in the tropics. The second part of the work evaluates the possibilities of developing management tools, specifically decision support systems and economic valuation techniques to overcome these impediments.

More specifically, this study aims to answer the following questions:

- To what extent is ICM actually being implemented throughout the tropics?
- Are there similar patterns of impediments, standing in the way of ICM, throughout the tropics?

- Do different impediments affect the ability to implement ICM in different ways; for example are some completely obstructive, while others will just slow the process?
- Can computer based decision support systems (DSS) be developed to assist ICM?
- Can economic valuation be useful in overcoming impediments to ICM?
- Is ICM an achievable task?

Research Strategy

The research followed the basic pattern shown in Figure 1. The first step in the research set out to identify the status of ICM in the tropics and to quantify the extent to which these coastal areas are achieving ICM. This set the stage for more detailed analysis of the main impediments standing in the way of successful ICM. This was achieved through detailed case studies and broader questionnaires, supported by a thorough study of the literature. This forms the first part of the thesis (Chapter 2-4). These findings created a framework for the assessment of the selected management tools. The specific tools, computer-based decision support systems and economic valuation, were selected because of their importance and increasing use in the field of ICM. Chapters 5-7 cover these issues. The research is then wrapped up in the concluding Chapter 8, which draws together the main findings of the status of ICM and identifying the impediments and the assessment of the management tools.

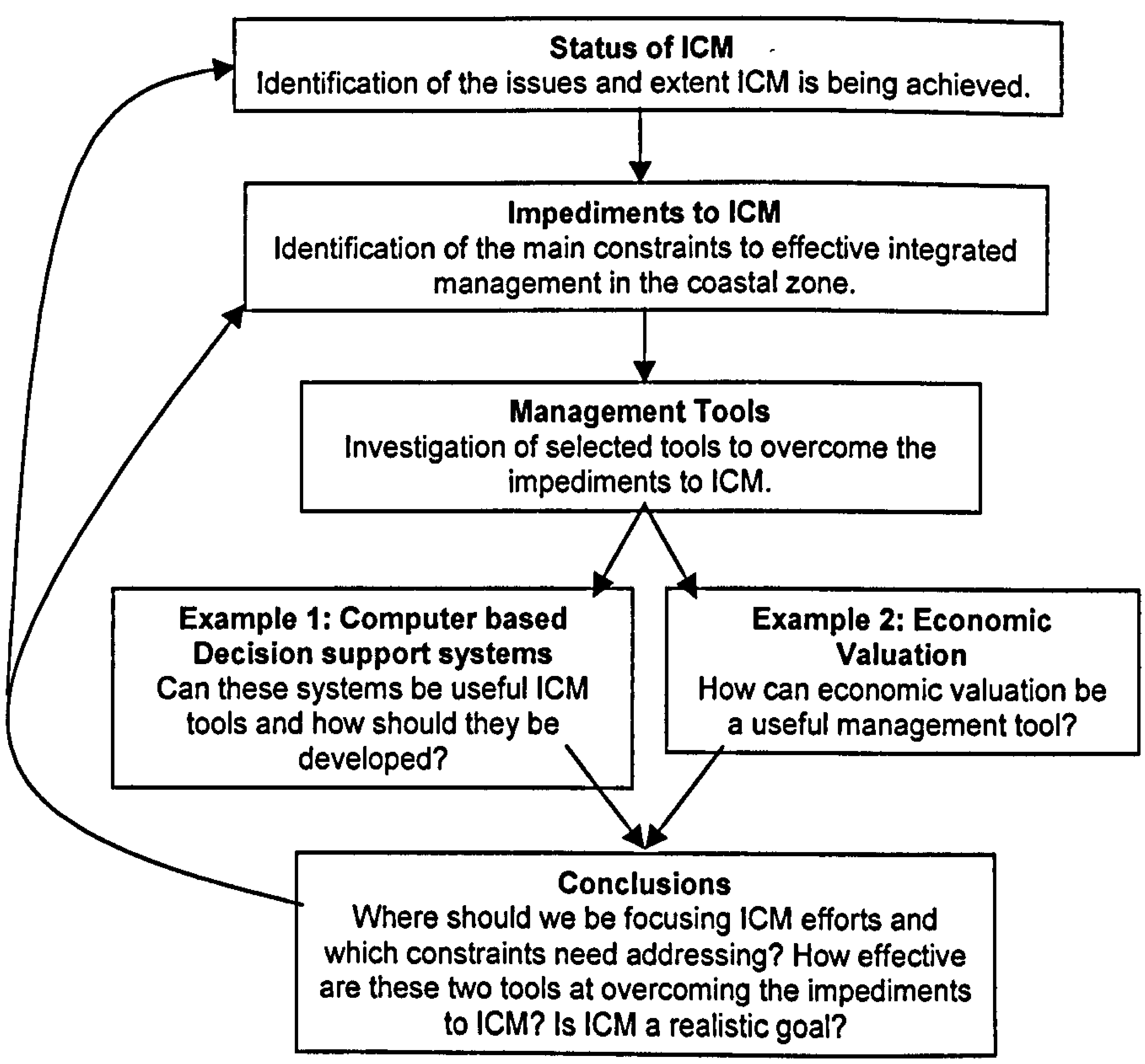

Figure 1 Flow diagram illustrating the various components of the research and the links between them

Research methodologies

In order to investigate the research questions, a mixture of methodologies was used. These methodologies cover qualitative as well as quantitative techniques.

PART I:

Assessment of the status of ICM and identification of the main issues facing coastal managers was carried out through a quantitative questionnaire. This was sent to a broad spectrum of ICM experts covering as wide a geographical area as possible (see Appendix A and Chapter 2). To identify the impediments to ICM, three detailed case studies were selected. These case studies provided a broad coverage of the various ICM issues so that it was possible to identify generalities between them. Structured interviews were carried out to obtain information from selected stakeholders at each case study site (see Appendix B and Chapter 3). Interviewees were selected for their involvement in ICM in the region. They covered the public and private sector as well as the development and conservation perspectives. Participatory observation was utilised for one of the case studies, which enabled first hand experience of the ICM process to be attained (see Bonaire case study, Chapter 3). In addition, to support these findings a thorough investigation of the literature was carried out (Chapter 3). To broaden the scope of the case studies and to ensure that they had identified most of the generic issues relating to impediments towards ICM, a further ICM survey was carried out. In practice, this was combined with the initial ICM survey, which was divided into two parts, identification of the impediments being covered in the second part where a series of qualitative questions were designed to identify the impediments to ICM (see Appendix A and Chapter 4). The resulting information enables a quantitative analysis to be carried out based on the experts perception of how the various impediments affect the ability to implement ICM. The analysis was carried out using multidimensional scaling procedures able to cope with the multiple criteria that affect the ability to implement ICM (See Chapters 2 and 4).

PART II:

Assessing the management tools used various techniques. The overview of computerised decision support systems was carried out by utilising the various models and developing a qualitative scale for assessment (see Chapter 5). The CORAL model was assessed in the field where it was presented to the various stakeholders and used in educational courses. This assessment was based on the qualitative information given by these stakeholders (see Chapter 6). The assessment of economic valuation was carried out by examining several different valuation case studies. These case studies utilised a number of valuation techniques; the contingent valuation methodology, direct use valuation based on production and market prices and the identification of consumer surplus and willingness to pay (see Chapter 7). These case studies were then examined to identify where in the management process they could be applied as useful tools.

1.6 Introduction to the chapters

The work is presented in this thesis as a series of self-contained chapters. Each Chapter has an introduction to the issue, a description of the methods used and a results and conclusions section. References can be found at the end of each chapter. A short synopsis of each Chapter is given below.

PART I: IDENTIFYING THE IMPEDIMENTS

Chapter 2: Where should the focus be in tropical integrated coastal management?

Integrated coastal management (ICM) has been seen as the way to deal with the challenges currently facing managers of our coastal zones. In the tropics, resources such as coral reefs and mangroves that are able to support a variety of activities and provide a range of services typify these areas. ICM takes a multi-disciplinary approach that involves the integration of the different institutions and stakeholder groups with one another in the coastal zone. A survey, carried out for this study, of tropical coastal locations revealed that implementing, monitoring and evaluating integrated coastal management is limited, with many programmes apparently failing at the implementation stage. These coastal zones share a number of common challenges exacerbated by poverty and conflicts between the coastal activities. Conflict management will need to be incorporated into the management process, paying particular attention to the over-extraction of resources and destructive resource use.

Chapter 3: Categorising the impediments to tropical integrated coastal management from case studies of Curaçao, Bonaire and Zanzibar

Integrated coastal management (ICM) is facing difficulties throughout the tropics and only a limited number of locations are successfully implementing it. This Chapter studies three tropical coastal areas, Curaçao and Bonaire in the Caribbean and Zanzibar in the Indian Ocean in order to identify major trends in the impediments standing in the way of achieving ICM. Similar impediments were identified and six categories were defined. These were: 1) weak institutional structure, 2) limited institutional capacity, 3) conflicting and weak legislation, 4) lack of political support and participation, 5) lack of public attitude and participation and 6) the limited scientific support for management. Even though these categories are developed from just three case studies, a review of the literature suggests they are widespread across the tropics.

Chapter 4: Identifying the main impediments to integrated coastal management in the tropics

The concept of integrated coastal management (ICM) has been identified as the way to deal with the multiple objectives, interests and uses of the coastal zone. In practice, ICM is a complex process and many countries are having difficulty in implementing ICM. This Chapter identifies the most common impediments to ICM in the tropics and their impact on implementing ICM. The extent to which ICM is achieved can be linked to the impediments, described by a series of criteria, which could be used in assessing the ability of an area to implement ICM as well as identifying priority areas for concern. The results show that although public participation is commonly accepted as a major part of ICM, it rarely takes place. Gaining political support is also identified as a major impediment without which ICM efforts may be blocked.

PART II: ASSESSING MANAGEMENT TOOLS

Chapter 5: Developing decision support systems for ICM in the tropics:

Integrated coastal management (ICM) in the tropics requires the conservation of vulnerable and diverse ecosystems such as coral reefs and mangroves as well as the management of land and marine based human activities. Decision making for ICM involves many decision makers and stakeholders often with conflicting needs and interests. Decision support systems can be developed to improve our understanding of the inter-relationships between the natural and socio-economic variables and hence result in improved decision making. The question is whether this decision making environment is actually too complex for the development of useful and useable decision support systems. This Chapter describes the components of the decision making environment and the components of a decision support system. It also explores the various techniques available to deal with different modelling needs, the constraints of inadequate data and the multi-objective decision making environment. In addition, the way in which a decision support system is developed can play an important role in ICM. Three coastal decision support systems are evaluated in terms of their design and role in ICM and are used to evaluate the potential role of decision support systems in ICM.

Chapter 6: Developing a decision support system as a tool for integrated coral reef management: Lessons learned from CORAL

CORAL is a decision support system developed to assist with integrated coastal management (ICM) in Curaçao and the Republic of the Maldives. Development took place with the involvement of the stakeholder community whose needs were identified during a series of stakeholder interviews at the start of the development process. Model development occurred away from the locations and the final model was presented back to the stakeholders, after which they were trained in its use. A second phase of the project in Curaçao allowed the model to be more fully evaluated as to its use. Training sessions and interviews with those involved in its development identified a number of lessons that can be learned from the development of such models. Simply involving the local community was not enough to ensure its use. Flexibility, adaptability and the ability to be updated are paramount if such a system is to be used. However, such systems can play an important educational and awareness building role for coral reef management as well as acting as a forum for discussion of ICM issues.

Chapter 7: Assessing economic valuation as a tool for integrated coastal management in coral reef areas

Degradation of environmental and in particular coastal resources, will continue as long as decision makers and managers are unable to appreciate the full value of these resources and account for the costs of inaction or inappropriate action. Integrated coastal management (ICM) can bring numerous benefits although these are not always easily measured and quantified. Economic valuation is being increasingly applied to tropical coastal ecosystems to assess these benefits and the costs of inaction in monetary terms. Three case studies using different valuation techniques are used to evaluate the use of economic valuation as a tool for ICM. The case studies look at the ability of market-defined values, as well as those generated from hypothetically constructed markets, to value coastal resources. Economic valuation appears to be a useful management tool, enabling comparisons to be made between the costs of protection and management of these resources and the benefits gained through a change in environmental health or increase in productivity. This also enables a value to be placed on marketed products from the resource, which can be directly used in bargaining for its protection. In addition, economic valuation may be used to identify the underlying causes of resource degradation by identifying who the main beneficiaries are and who the main losers are. Even though the applicability of economic valuation as a tool for ICM may be heavily debated, it is likely to prove a key issue in raising awareness of decision makers and managers. This is likely to be far more important that the actual value identified.

CONCLUSIONS

Chapter 8: Conclusions: Is integrated coastal management an achievable task?

Integrated coastal management (ICM) has been around since the early 1980s and efforts to introduce it have more than doubled in the last 8 years. Even so, degradation of coastal resources continues. Even in the light of having identified the main reasons limiting the effectiveness of ICM, progress is likely to be difficult and slow. There are no simple solutions to the problems relating to the lack of political will and public support. However, these are the impediments where attention needs to be focused. Managing the current over extraction of marine resources and degradation of these coastal ecosystems, will take strong leadership that is prepared to face the repercussions of potentially unpopular decisions for the longer term sustainability. Without this type of leadership, the economic basis of many coastal communities will continue to be undermined. Tools that facilitate education and awareness of the benefits of sustainable use of the coastal zone will be vital to this process. Future projects and programmes need to focus their resources and skills on these issues if ICM is to move forward.

References

Alcala, A. C. 1988. Effects of Marine Reserves on Coral Fish Abundances and Yields of Philippine Coral Reefs. *Ambio* 17: 194-199.

Beinat, E., P. Nijkamp and P. Rietveld. 1994. Value Functions for Environmental Pollutants: A technique for enhancing the assessment of expert judgements. *Environmental Monitoring and Assessment* 30: 9-23.

Bijlsma, L., M. Crawford, C. Ehler, F. Hoozemans, V. Jones, R. Klein, B. Miermet, N. Mimura, R. Misdorp, R. Nicholls, K. Ries, J. Spradley, M. Stive, L. de Vrees and S. Westmacott. 1993. *World Coast Conference Report.* Ministry of Transport, Public Works and Water Management, National Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, the Netherlands.

Bohnsack, J. A. 1993. Marine Reserves: They Enhance Fisheries, Reduce Conflicts, and Protect Resources. *Oceanus* 36: 63-71.

Bower, B. T., C. N. Ehler and D. Basta, J. 1994. *A framework for planning for integrated coastal zone management.* National Oceanographic and Atmospheric Administration (NOAA), Washington DC.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. *Reefs at Risk. A Map-Based Indicator of Threats to the World's Coral Reefs.* World Resources Institute, Washington DC.

Burbridge, P. 1999. The Challenge of Demonstrating the Socio-Economic Benefits of Integrated Coastal Management. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 35-54. Berlin Heidelberg: Springer-Verlag.

Cesar, H. 2000. Coral Reefs: Their Functions, Threats and Economic Value. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 14-39. Stockholm, Sweden: Sida Press.

Christie, P. and A. White. 2000. Introduction to Special Issue on Tropical Coastal Management. *Coastal Management* 28: 1-4.

Christie, P. and A. T. White. 1997. Trends in Development of Coastal Area Management in Tropical Countries: From Central to Community Orientation. *Coastal Management* 25: 155-181.

Chua, T.-E. 1993. Essential Elements of Integrated Coastal Zone Management. *Ocean and Coastal Management* 21: 81-108.

Chua, T.-E. 1998. Lessons Learned from Practicing Integrated Coastal Management in South East Asia. *Ambio* 27: 599-610.

Cicin-Sain, B. 1993. Sustainable Development and integrated coastal management. *Ocean and coastal management* 21: 11-43.

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated coastal and ocean management: concepts and practices.* Washington DC and Covelo, California: Island Press.

Cicin-Sain, B., R. W. Knecht and G. W. Fisk. 1995. Growth in Capacity For Integrated Coastal Management Since UNCED - an International Perspective. *Ocean & Coastal Management* 29: 1-3.

Clark, J. R. 1992. *Integrated management of coastal zones.* Food and Agricultural Organisation of the United Nations, Rome.

Clark, J. R. 1996. *Coastal zone management handbook.* CRC Press.

Cornforth, R. 1994. Integrated Coastal Zone Management - the Pacific Way. *Marine Pollution Bulletin* 29: 1-3.

Costanza, R. 1998. Introduction: Special Section: Forum on Valuation of Ecosystem Services, the value of ecosystem services. *Ecological Economics* 25: 1-2.

Costanza, R., R. D'Arge, R. de Groot, S. Farber, M. Grasse, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton and M. ven den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Crawford, B. R., J. S. Cobb and A. Friedman. 1993. Building Capacity for Integrated Coastal Management in Developing Countries. *Ocean and Coastal Management* 21: 311-337.

Crooks, S. and R. Turner. 1999. Integrated Coastal Management: Sustaining Estuarine Natural Resources. *Advances in Ecological Research* 29: 241-289.

Engelen, G., R. White, I. Uljee and P. Drazan. 1995. Using Cellular Automata for Integrated Modelling of Socio-environmental Systems. *Environmental Monitoring and Assessment* 34: 203-214.

Fabbri, K. P. 1998. A methodology for supporting decision making in integrated coastal zone management. *Ocean & Coastal Management* 39: 51-62.

Fedra, K. 1995. Decision-Support For Natural-Resources Management - Models, GIS, and Expert-Systems. *AI Applications* 9: 3-19.

Goreau, T., T. McClanahan, R. Hayes and A. Strong. 2000. Conservation of Coral Reefs after the 1998 Global Bleaching Event. *Conservation Biology* 14: 5-15.

Green, E. P., P. J. Mumby, A. J. Edwards and C. D. Clark. 1996. A Review of Remote-Sensing For the Assessment and Management of Tropical Coastal Resources. *Coastal Management* 24: 1-40.

Gustavson, K., R. M. Huber and J. Ruitenbeek. 2000. *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.* Washington, DC: The World Bank.

Hale, L. Z., M. Amaral, S. I. Abdulrahman and B. A. J. Mwandotto. 2000. Catalyzing Coastal Management in Kenya and Zanzibar: Building Capacity and Commitment. *Coastal Management* 28: 75-86.

Hodgson, G. 1999. A Global Assessment of Human Effects on Coral Reefs. *Marine Pollution Bulletin* 38: 345-355.

Hogarth, A. N. 1999. SIMCOAST. *CoastNET.*4: 6.

Hughes, T. P. 1994. Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science* 265: 1547-1551.

IUCN. 1993. *Reefs at Risk.* IUCN Marine Coastal Areas Programme, Gland, Switzerland.

Jameson, S. C., J. W. McManus and M. D. Spalding. 1995. *State of the Reefs - Regional and Global Perspectives.* International Coral Reef Initiative, US Dept of State, Washington DC.

Jennings, S., E. M. Grandcourt and N. V. C. Polunin. 1995. The effects of fishing on the diversity, biomass and trophic structure of Seychelles' reef fish communities. *Coral Reefs* 14: 225-235.

Jennings, S. and N. V. C. Polunin. 1996. Impacts of Fishing On Tropical Reef Ecosystems. *Ambio* 25: 44-49.

Linden, O. and A. Granlund. 1998. Building Capacity for Coastal Management. *Ambio* 27: 589.

Lowry, K. and H. J. M. Wickremeratne. 1988. Coastal Area Management in Sri Lanka. *Ocean Yearbook, University of Chicago.*

McClanahan, T. R. 1995. A coral reef ecosystem-fisheries model: Impacts of fishing intensity and catch selection on reef structure and processes. *Ecological Modelling* 80: 1-19.

McClanahan, T. R. and N. A. Muthiga. 1988. Changes in Kenyan coral reef structure and function due to exploitation. *Hydrobiologia* 166: 269-276.

McClanahan, T. R., N. A. Muthiga, A. T. Kamukuru, H. Machano and R. W. Kiambo. 1999. The effects of marine parks and fishing on corals reefs of northern Tanzania. *Biological Conservation* 89: 161-182.

Moberg, F. and C. Folke. 1999. Ecological goods and services of coral reef ecosystems. *Ecological Economics* 29: 215-233.

Moffat, D., M. Ngoile, O. Linden and J. Francis. 1998. The Reality of the Stomach: Coastal Management at the Local Level in Eastern Africa. *Ambio* 27: 590-598.

Mumby, P. J., P. S. Raines, D. A. Gray and J. P. Gibson. 1995. Geographic Information-Systems - a Tool For Integrated Coastal Zone Management in Belize. *Coastal Management* 23: 111-121.

Nagelkerken, I., G. van der Velde, M. Gorissen, G. Meijer, T. van't Hof and C. den Hartog. 2000. Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. *Estuarine and Coastal Shelf Science* 51: 31-44.

Nichols, K. 1999. Coming to terms with 'Integrated Coastal Management': Problems of Meaning and Method in a New Arena of Resource Regulation. *Professional Geographer* 51: 388-399.

Nijkamp, P. and J. C. van den Burgh. 1997. New advances in economic modelling and evaluation of environmental issues. *European Journal of Operational Research* 99: 180-196.

Olsen, S. and P. Christie. 2000. What are we learning from Tropical Coastal Management Experiences? *Coastal Management* 28: 5-18.

Olsen, S. B., J. Tobey and L. Z. Hale. 1998. A Learning Based Approach to Coastal Management. *Ambio* 27: 611-619.

Pet Soede, L. 2000. The effects of coral bleaching on fisheries in the Indian Ocean. In *Assessment of the socio-economic impacts of the 1998 coral reef bleaching in the Indian Ocean: report prepared for the CORDIO programme, African Environmental Department of the World Bank,* eds., S. Westmacott, H. Cesar and L. Pet Soede, 23-37. Delft and Amsterdam: Resource Analysis and Institute for Environmental Studies.

Polunin, N., I. Williams, J. Carrier and L. Robertson. 2000. *Ecological and social impacts in planning Caribbean marine reserves.* University of Newcastle & Department for International Development, Newcastle & London, UK.

Polunin, N. V. C. and C. M. Roberts. 1996. *Reef Fisheries.* London: Chapman and Hall.

Post, J. C. and C. G. Lundin. 1996. *Guidelines for integrated coastal zone management.* Washington DC: International Bank for Reconstruction and Development & The World Bank.

Resource Analysis and Delft Hydraulics. 1993. *How to Account for the Impacts of Climate Change in Integrated Coastal Zone Management: Concepts and Tools for Approach and Analysis. Version 2.0.* World Coast Conference (WCC'93) Organising Committee, Ministry of Transport Public Works and Water Management, The Hague, the Netherlands.

Rijsberman, F. 1998. *Conflict Management and Consensus Building for Integrated Coastal Management in Latin America and the Caribbean.* Washington DC, US: Sustainable Development Department, Inter-American Development Bank.

Roberts, C. M. 1995. Effects of fishing on the ecosystem structure of coral reefs. *Conservation Biology* 9: 988-995.

Russ, G. R. and A. C. Alcala. 1996. Marine reserves: Rates and patterns of recovery and decline of large predatory fish. *Ecological Applications* 6: 947-961.

Saaty, T. L. 1991. *Multicriteria Decision Making: The Analytic Hierarchy Process.* Pittsburgh, USA: RWS Publications.

Salomons, W. and R. K. Turner. 1999. *Perspectives on Integrated Coastal Zone Management.* Berlin Heidelberg: Springer-Verlag.

Shah, N. J., O. Linden, C. G. Lundin and R. Johnstone. 1997. Coastal management in Eastern Africa: Status and future. *Ambio* 26: 227-234.

Sorensen, J. 1993. The International Proliferation of Integrated Coastal Zone Management Efforts. *Ocean and Coastal Management.* 21: 45-80.

Sorensen, J. 1997. National and international efforts at integrated coastal management: Definitions, achievements, and lessons. *Coastal Management* 25: 3-41.

Sorensen, J. 2000. *Building a Global Database of ICM Efforts.* University of Massachusetts, Boston.

Sorensen, J. C. and S. T. McCreary. 1990. *Institutional Arrangements for Managing Coastal Resources and Environments.* Washington DC: National Parks Service, US Department of Interior.

Spalding, M. D. and A. M. Grenfell. 1997. New estimates of global and regional coral reef areas. *Coral Reefs* 16: 225-230.

Spurgeon, J. P. G. 1992. The Economic Valuation of Coral Reefs. *Marine Pollution Bulletin* 24: 529-536.

Turner, R. 2000. Integrating natural and socio-economic science in coastal management. *Journal of Marine Systems* 25: 447-460.

Turner, R. and W. Adger. 1996. *Coastal Zone Resource Assessment Guidelines.* LOICZ IPO, Texel, The Netherlands.

Turner, R., W. Adger and I. Lorenzoni. 1998. *Towards Integrated Modelling and Analysis in Coastal Zones: Principles and Practices.* LOICZ IPO, Texel, The Netherlands.

Turner, R. and B. Bower 1999. Principles and Benefits of Integrated Coastal Zone Management (ICZM). In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 13-34. Berlin Heidelberg: Springer-Verlag.

Turner, R. K. and W. Salomons 1999. Introduction and Overview. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 1-9. Berlin Heidelberg: Springer-Verlag.

Vallega, A. 1993. A Conceptual Approach to Integrated Coastal Management. *Ocean and Coastal Management* 21: 149-162.

van der Weide, J. 1993. A Systems View of Integrated Coastal Management. *Ocean and Coastal Management* 21: 129-148.

van der Weide, J. and L. De Vrees 1999. Methods and Tools to Support CZM. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 69-88. Berlin Heidelberg: Springer-Verlag.

Westmacott, S., I. Ngugi and J. Andersson 2000. Assessing the impacts of the 1998 coral reef bleaching on tourism in Tanzania and Kenya. In *Assessment of the socio-economic impacts of the 1998 coral reef bleaching in the Indian Ocean: report prepared for the CORDIO programme, African Environmental Department of the World Bank,* eds., S. Westmacott, H. Cesar and L. Pet Soede, 115-137. Delft and Amsterdam: Resource Analysis and Institute for Environmental Studies.

Westmacott, S. and F. R. Rijsberman. 1995. CORAL, Coastal Management Model for the Sustainable Development of Coral Reef Areas. *Physics and Chemistry of the Earth* 20: 245-250.

White, A. T., V. Barker and G. Tantrigama. 1997. Using Integrated Coastal Management and Economics to Conserve Coastal Tourism Resources in Sri Lanka. *Ambio* 26: 335-244.

Wilkinson, C. 1992. Coral Reefs of the World are facing widespread devastation: Can we prevent this through sustainable management practices. *7th International Coral Reef Symposium,* eds., International Society of Reef Studies, 11-21. Guam, Micronesia. University of Guam Marine Laboratory.

Wilkinson, C. 2000. *Status of Coral Reefs of the World: 2000.* Cape Ferguson, Queensland, Dampier, Western Australia: Australian Institute of Marine Science.

Wilkinson, C., O. Linden, H. Cesar, G. Hodgson, G. Rubens, J. Rubens and A. E. Strong. 1999. Ecological and Socioeconomic Impacts of 1998 Coral Mortality in the Indian Ocean: An ENSO Impact and a Warning of Future Change? *AMBIO* 28: 188-196.

Wilkinson, C. and B. Salvat 1997. The Global Coral Reef Monitoring Network: Reversing the Decline of the World's Reefs. In *Coral Reefs: Challenges and Opportunities for Sustainable Management: proceedings of an associated event of the fifth annual World Bank Conference on Environmentally and Socially Sustainable Development,* eds., M. E. Hatziolos, A. Hooten, J and M. Fodor, 16-19. Washington DC: World Bank & International Centre for Living and Aquatic Resources Management (ICLARM).

World Travel and Tourism Council. 1999. *1999 Travel and Tourism Satellite Accounting Research Estimates and Forecasts*. World Travel and Tourism Council (WTTC), London.

WWF and IUCN. 1998. *Creating a Sea Change: The WWF/IUCN Marine Policy.* World Wildlife Fund and the World Conservation Union, Gland, Switzerland.

Yap, H. T. 1996. Attempts At Integrated Coastal Management in a Developing Country. *Marine Pollution Bulletin* 32: 8-9.

PART I

IDENTIFYING THE IMPEDIMENTS

Presented at the International Society for Reef Studies (ISRS) 9th International Coral Reef Symposium in Bali, October 2000, accepted for proceedings, April 2001.

2 Where should the focus be in tropical integrated coastal management?

Chapter accepted for publication in Coastal Management, May 2001.

2.1 Introduction

The coastal zone is a unique system where land meets the seas and oceans. In the tropics, coastal zones include distinctive resources such as coral reefs, mangroves and seagrass beds, which are highly productive and renewable. These ecosystems provide numerous functions and services and are able to support a variety of livelihoods. Consequently, coastal areas have seen rapidly growing populations that are increasingly reliant on marine and coastal resources to survive. Development has often outstripped the ability to manage the impacts of and waste produced by the various activities. The result is the degradation of the coastal environment and depletion of the coastal resources upon which many coastal people depend. Estimates have been made that 58% of the world's coral reefs are threatened by human activities (Bryant et al., 1998). Rapid population growth, deteriorating environmental quality, loss of critical habitats, diminishing levels of fish and shellfish, reduced biodiversity and increasing vulnerability to natural hazards are typical issues found in tropical coastal zones (Wilkinson, 1992; Ehler & Basta, 1993; IUCN, 1993; Bower et al., 1994; Jameson et al., 1995; World Bank, 1995; Turner & Adger, 1996; Bryant et al., 1998; Cicin-Sain & Knecht, 1998).

Management of the coastal zone cannot be confined to the coastal and marine areas that may fall within the administrative boundaries of the coastal zone. These areas are affected by upstream developments, which can impact the coastal ecosystem as rivers transport sediment or their flow is altered through irrigation and damming. Pollution can be transported through fresh and marine waterways simultaneously affecting all coastal interests. An additional complication, typical of the coastal zone, is the phenomenon of common property resources. Marine and coastal resources are often freely accessible with no specific ownership, e.g., coastal waters, coral reefs, mangrove forests and fisheries. Tight governmental control is required to avoid over-exploitation of these resources. Lack of control has lead to the overexploitation of these resources, e.g., in Kenya and Tanzania (McClanahan et al., 1999).

This pressure on the coastal resources, which provide the backbone to many local economies, triggers the need for management action. The coast requires special management and planning principles able to link the different affected interests and agencies together (Clark, 1992). The interrelated nature of the coastal land and marine systems means that management needs to have a broader vision than the more traditional sector-based approaches have often had. Integrated coastal management (ICM) has been proposed as the way forward in dealing with the increasing pressures on the world coastal zones (Bijlsma et al., 1993; Post & Lundin, 1996; Cicin-Sain & Knecht, 1998). The World Wildlife Fund (WWF) and the World Conservation Union (IUCN) have stated that the promotion of ICM as an underlying principle in the sustainable management of marine and coastal ecosystems is one of their 5 policy objectives (WWF & IUCN, 1998).

The objective of this study is to:

1. Provide a brief overview of the main concepts behind ICM
2. Present a review of some current ICM efforts and the issues associated with ICM
3. Assess to what extent ICM is being implemented in the tropics
4. Identify the main issues that ICM should focus on

The study is based on an ICM survey of tropical coastal locations that explores the level of ICM achievement, identifies the main coastal activities and management priorities and indicates the main issues management must deal with in the coastal zone. The study concludes on the main areas where ICM may need to focus in order to be able to progress to the next stage of ICM.

2.2 Integrated coastal management

ICM encompasses the management and integration of existing economic activities, planned developments, natural resource conservation and utilisation as well as being able to deal with the different user conflicts. It seeks to utilise the ecosystem approach to management by managing the coastal zone and its watershed as a single unit (WWF & IUCN, 1998). Several definitions containing similar concepts have been given for ICM and are currently in use around the world (Sorensen & McCreary, 1990; Bijlsma et al., 1993; Bower et al., 1994; Cicin-Sain & Knecht, 1998; Turner & Bower, 1999). The following definition presents the main essence of ICM:

ICM is a continuous, dynamic, iterative, adaptive and participatory process in which an integrated strategy is developed and implemented for the allocation of environmental, socio-cultural and institutional resources to achieve the conservation and sustained multiple use of the coastal zone whilst taking into account traditional cultural and historical perspectives and conflicting interests and uses.

As defined above, coastal renewable resources should be managed to produce benefits on a long-term, sustainable basis. Agenda 21 emphases the need for coastal areas to develop integrated coastal management in order to achieve "sustainable development of oceans and coastal areas" (UNCED, 1992). Sustainable development being defined as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (World Commission on Environment and Development, 1987). Management approaches focusing on short-term gain will tend to overlook this concept of sustainability and are likely to lead to resource depletion in the longer term. Management of the coastal zone is often *ad hoc* where developments have been undertaken without a complete assessment of their impacts and the alternatives. The dominant consideration is often short-term economic gain in a single sector, rather than long-term sustainability (Pernetta & Elder, 1993).

Elements of integrated coastal management

Many authors have described the elements of ICM (Bijlsma et al., 1993; Chua, 1993; Pernetta & Elder, 1993; van der Weide, 1993; Bower et al., 1994; Post & Lundin, 1996; Bower & Turner, 1998; Chua, 1998; Cicin-Sain & Knecht, 1998; Turner & Bower, 1999; Christie & White, 1997). As with other planning and management activities, ICM can be seen to have distinct phases from management inception to implementation and evaluation (see Figure 1 and Table 1). Specific to ICM is the integration across all the various ICM institutions and stakeholders (see Figure 1). This integration requires co-ordination at a number of scales, values, interests and goals, many of which may be in competition (Kenchington & Crawford, 1993).

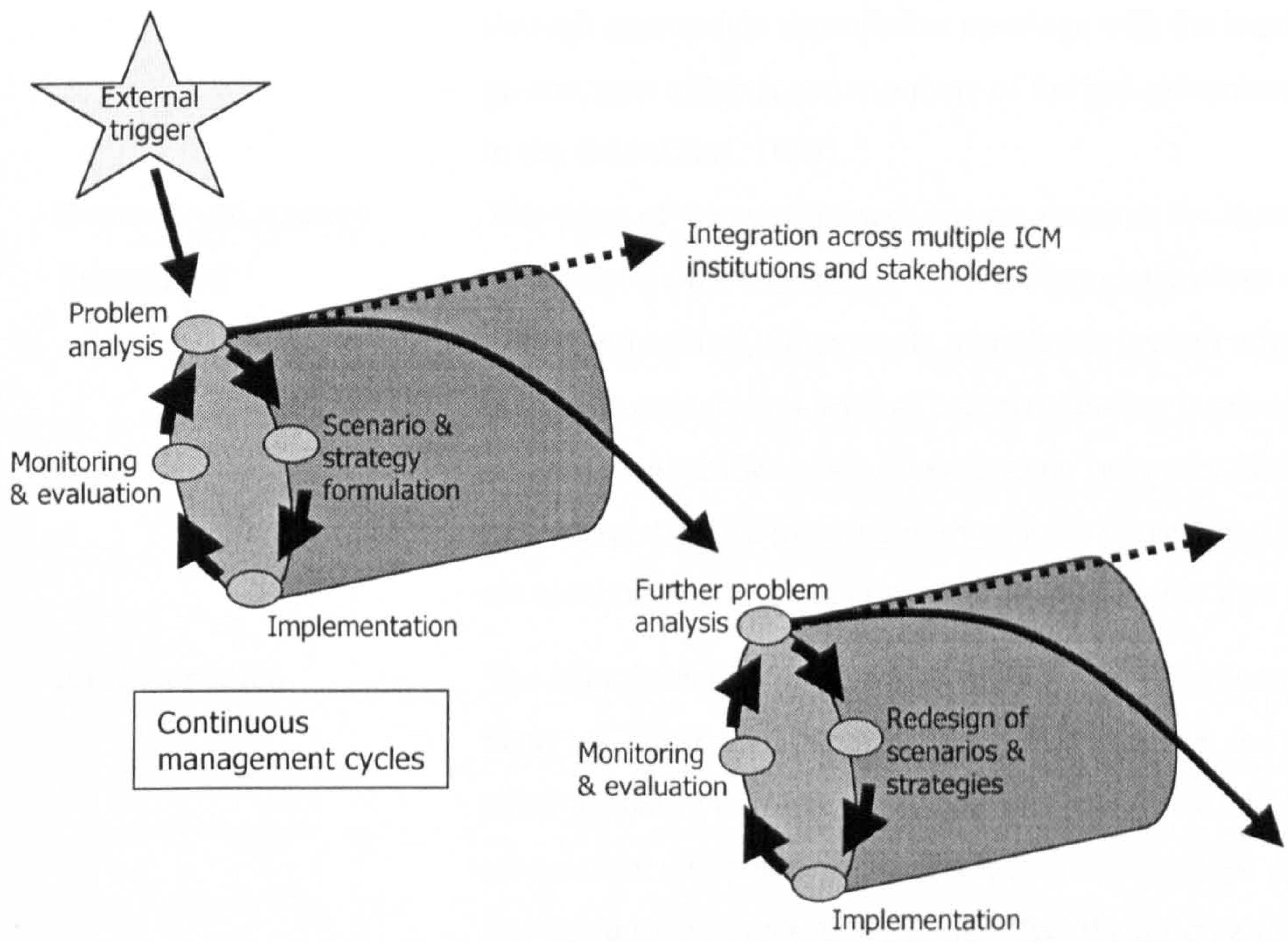

Figure 1 Five steps of ICM shown in the continuous management cycle along with the integration across all ICM institutions and stakeholder groups

Table 1 The main steps of ICM

Stage	Description
External Trigger	An initial trigger sets the cyclical process in motion. This may be dissatisfaction with the current situation or an impulse brought about by a disaster. The most commonly reported trigger for initiating ICM is the decline or degradation of a coastal resource (Sorensen & McCreary, 1990; Bower et al., 1994). Cicin-Sain and Knetch (1998) found that 56% of the respondents of their cross-national survey of ICM experts stated the initial trigger to ICM was some kind of environmental problem such as the depletion of resources, pollution or ecosystem damage.
Problem analysis	The problem analysis phase involves the identification of the management issues which can be grouped under four broad categories of resource utilisation, environmental quality, institutional concerns and natural hazards. Some issues are obvious and can be easily identified on site inspection, while others may require more detailed field investigation. In most cases, ICM issues can be identified through appropriate consultative meetings with the local communities, local government officials and members of the non-governmental organisations working in the field (Chua, 1993).
Scenario and strategy formulation	This stage of the management process requires the identification of the scenarios, which are the uncertainties in the management process over which the manager has little or no control, for example, population growth rates, tourism demand, economic growth, and level of external funding received. Individual management actions are identified, such as wastewater treatment facilities and the development of a comprehensive mooring buoy system. Once identified the management actions are combined to form an integrated strategy rather than a set of disparate measures.
Implementation	The effectiveness of the implementation may be influenced by several site-specific factors (Cicin-Sain & Knecht, 1998). For example, the perceived seriousness of existing coastal problems, the level of awareness of the benefits of ICM within the government structure and the presence of user groups and local communities interested in initiating ICM can all affect the acceptability of ICM. The availability of necessary resources (trained staff, coastal information and data, finances) and the existence of political will within the government to take the necessary steps to initiate and put in place an effective ICM programme are also important factors in implementation. The implementation of an ICM programme may take many years to come into effect. Olsen (1998) estimates 8-15 years as a time frame for carrying out the first cycle of ICM.

Stage	Description
Monitoring and evaluation	Monitoring is vital for evaluation of the success of the programme to be carried out. Monitoring may cover the different programme components as well as the 'health' of the coastal ecosystems. Evaluation is the core of the learning process. The results of the evaluation should be fed back into the management cycle where the management actions are refined and new ones are identified and adopted. This leads to a cyclical process, shown in Figure 1 that is able to learn from experiences and improve.
Further problem analysis and redesign	Once the evaluation has been completed, new issues may be identified. These may be new aspects that need attention or certain aspects of the programme that are not functioning optimally and require change. This can be achieved through initiating the cycle again. Instead of starting from initial problem analysis, review and addition issues can be examined and added to the initial situation. Likewise, redesigning programmes and adjusting programmes may be required rather than initiating completely new ones.

2.3 Current efforts in integrated coastal management

The ICM concept has been around for more than 30 years (Burbridge, 1999). Tropical ICM has passed through several phases classified by Christie and White (1997) as precolonial, centralised, community based and co-management. Some of the most innovative approaches to ICM are found in the tropics (Christie & White, 2000). The 1982 Law of the Sea Convention and Chapter 17 of UNCED's Agenda 21 contain most of the necessary prescriptions for ICM (Cicin-Sain & Knecht, 1998). ICM efforts have been increasing in number, in 1993, there were about 142 ICM efforts being undertaken by about 57 countries (Sorensen, 1993). Since this time, the number of ICM efforts has continued to increase (Cicin-Sain & Knecht, 1998). A new survey has revised this 1993 number of efforts to 180 and has estimated the current number of ICM efforts at 380 in 92 nations and semi-sovereign states (Sorensen, 2000). Analysis of ICM through its development shows an increase in interdisciplinary research and the integration of this research into management, an increase in the use of traditional knowledge and management systems and an increase in local participation in the ICM effort (Christie & White, 1997). However, even though ICM is stated as the way to deal with the multi-objective decision making environment of the coastal zone, there are few examples of its successful implementation. It is an ambitious task requiring a common vision between the different coastal stakeholders. In a world where individual interests and desires hold primary importance, the common good is often overlooked and ICM may face a series of difficulties.

The success of ICM programme implementation has been the subject of debate due to the lack of common evaluation criteria (Chua, 1998). Evaluation of ICM efforts is also only possible when there is a defined set of objectives and measurable criteria on which it can be evaluated. Agreement on the objectives for the ICM effort can often be the first stumbling- block in a multi-objective environment. How to measure success will depend on the 'type' of ICM that is being implemented. This may be the more traditional externally funded programme where success is measured in terms of project components implemented as shown by Chua (1998). Alternatively, ICM may be the 'learning-by-doing' approach typified by Olsen et al (1998) where success is measured in terms of a hierarchical number of outcomes from formalising institutional structures to sustainable environmental quality. A third approach being lead by the community may have a different set of success indicators where success would be measured in terms of the change in quality of life for the local community, for example change in the level of economic and environmental sustainability. This lack of specifically defined measurable objectives has caused evaluation of programmes to be based on the number of project components implemented rather than the success of each component. New initiatives can learn from the experiences of past efforts (Table 2).

Table 2 Review of some current integrated coastal management efforts

Area	Description
South-East Asia	Chua (1998) evaluated eight ICM programmes in Southeast Asia based on the implementation of various programme components. The programmes had been established over thirteen years, however, only one of the eight programmes had achieved most of the implementation criteria. He attributed this partly to project design and partly to the host country's lack of realisation, that implementation was the task of government rather than the project authority. After the evaluation, local governments did take up some implementation activities. This evaluation process highlighted the importance of ensuring that ICM programmes are integrated into the planning and development programme cycle of local governments at the outset.
Sri Lanka	ICM in Sri Lanka is often cited as one of the successful programmes. In 1977, the Government initiated a full-scale ICM programme, which was followed in 1978 by the establishment of the Coastal Conservation Department and the Coastal Conservation Act in 1981 (Lowry & Wickremeratne, 1988; Samaranayake, 2000). This Act gave jurisdiction of the coastal zone, 2km seaward and 300m inland, to the Coastal Conservation Department who produced a new coastal zone management plan in 1988 (Cicin-Sain & Knecht, 1998). This plan addressed coastal erosion, degradation and depletion of natural habitats and resources, loss of historic, cultural and archaeological sites and monuments of significance and loss of physical and visual access to the ocean (Cicin-Sain & Knecht, 1998). However, reports state that the management of the coral reefs in Sri Lanka is poor despite government departments with a mandate to manage and conserve reef resources (Rajasuriya et al., 1995; Rajasuriya & White, 1995). Although there have been projects that have published management plans and action plans, it appears that few of these have actually been implemented. Special Area Management projects at Hikkaduwa Marine Sanctuary and Rewaka lagoon have not been sustained after project completion in 1996 and the areas have begun to revert to their former state.

	Implementation of laws protecting the marine environment is difficult due to lack of alternative employment, trained personnel, financial resources and equipment (Rajasuriya et al., 1999).
Barbados	Barbados is another location with a specific Coastal Zone Management Unit, established in 1987 (Cicin-Sain & Knecht, 1998). However, the status of the reefs from 1982-1992 shows a decline in coral diversity by 24% and abundance by 34% and an increase in the amount of dead coral from 22% to 43% over 20 years (Smith et al., 1998). The challenge for the Coastal Zone Management Unit is to attempt to reverse or slow these trends by working closely with other coastal institutions to control the reported expansion of coastal developments and eutrophication of the coastal waters.
Belize	The management of Belize's coastal zone has moved from a species-specific sectoral fisheries approach to a broader ecosystem-wide approach to ICM (Gibson et al., 1998). The successful management of Belize's coral reefs will depend, however, on the coastal activities of the adjacent countries, Guatemala, Mexico and Honduras. The reefs are linked by currents and therefore affected by pollutants and larvae transported by these currents (Gibson et al., 1998).
Philippines	The Philippines have been practicing ICM over the last two decades in an effort to halt the damage to coastal and marine habitats and decline of fish production (Courtney & White, 2000). Coral reefs and mangroves are being depleted at a rapid rate because of a variety of activities and impacts, gradually eroding the area's potential for future sustainable resource use. Philippine institutions are responding to this challenge and realise the need for stronger and more effective institutions to tackle the lack of control they have had over all coastal activities in the past (Courtney & White, 2000).
Tanga, Tanzania	The Tanga Coastal Zone Conservation and Development Programme in Tanzania has approached ICM in a fully participatory process. This programme started in 1994, supported by Ireland Aid. It has had to prioritise and tackle issues such as declining fish catches, use of destructive fishing techniques, mangrove cutting and coastal erosion. However, there is a widespread perception among the resource users that this management is inadequate. Although the processes used are reported to be fairly successful, they are limited in dealing with some of the important management and enforcement issues (Makoloweka et al., 1997). Zanzibar and Kenya have recently used donor agencies to build the capacity of local initiatives (Hale et al., 2000).

The World Coast Conference in 1993 brought together over 90 coastal nations, 20 international organisations and 23 non-governmental organisations (Bijlsma et al., 1993). One of the Conference's concluding statements, based on the information produced during the Conference and prior to the Conference during the preparatory activities was: *Coastal states that are in the process of defining and implementing a national programme for integrated coastal zone management have encountered obstacles that constrain the effective development of national programmes* (Bijlsma et al., 1993). This underlines the fact that worldwide, nations are having difficulty implementing an integrated form of management in the coastal zone.

The inter-disciplinary approach of ICM is designed to enable the complex economic and ecological, terrestrial and marine issues specific to coastal zones to be tackled. The approach links different management sectors from local to national governmental levels. This is the theory; but the reality is often very different and the links maybe broken by personal relationships and interests or gaps within the data and information chain. ICM is an ambitious undertaking that requires the consensus of many different stakeholders. It requires financial and trained human resources to establish and implement ICM programmes.

2.4 Methods

Reported ICM efforts have more than doubled since 1993 (Sorensen, 2000), however, there has been no evaluation of the actual status of these reported efforts. As a result, a survey was developed to assess the way tropical coastal zones are currently being managed and to identify the main issues that they are facing (see Appendix A). The survey was not a survey of ICM programmes in existence; it was a survey of the potential of coastal areas to effectively manage their coastal zones. Areas where specific ICM efforts have been undertaken were also included, such as Sri Lanka and Tanga in Tanzania. In the survey, ICM was defined as the "ideal" situation where ICM institutions work in an integrated manner, managing diverse uses, with the goal of achieving the conservation and sustained multiple use of the coastal zone. ICM institutions were defined as those agencies, stakeholders or organisations at national to local level which have an interest or are involved in the management of the coastal zone. The coastal zone was defined as having a variable boundary that should include all coastal and marine activities and resources that are specific to the land-water interface and have an influence on one another.

Respondents were selected for their knowledge on all aspects of ICM in their chosen area. Care was taken to ensure that a broad coverage of the tropics was achieved, whilst maintaining a focus on coral reef areas. At the outset, one respondent was identified in as many countries or island groups as possible, where more potential respondents were identified or known, they were also requested to complete a survey. This meant that the sample used in the questionnaire was based on a non-probability design in which the respondents were selected for their knowledge of the area rather than randomly within an ICM institution where they may be unable to complete the survey (Czaja & Blair, 1995). Respondents were also asked whether they had colleagues or knew people with similar experience who could also complete the survey, known as 'snowball' sampling (Czaja & Blair, 1995). Ideally, the respondents had no stake in the outcome of the survey and had experience and background knowledge of management of the area they selected. In order to ensure that respondents felt comfortable in giving their true opinion, the individual survey results were kept anonymous; the respondents were made aware of this before completing the surveys. With an adequate sample size and multiple surveys within a country, any individual bias that may be present in the survey should not significantly alter the overall results. Initially a sample size of 50 was set as the target.

The survey allowed information to be gathered from a wide range of locations and was sent via mail and e-mail and distributed by hand to the respondents. A remote (mailed) survey can result in a poor response rate; one assumption being that the respondent understands what is expected of him. It also has problems with ensuring that the person sent the survey actually completes it and answers the questions in the order they are intended (Oppenheim, 1992). These were all considered in the design of the survey and were addressed in a covering letter accompanying the survey that also gave details for respondent to e-mail any queries and receive assistance before completing the survey. The surveys were followed up by e-mails to attempt to increase the response rate, a covering letter was included with the survey to explain its aims and give some explanatory definitions of terms used.

Of the 74 surveys sent via mail, e-mail and by hand, 43 were completed and returned. The surveys extensively covered tropical coastal areas throughout the world from Australia through the Indo-Pacific, Asia, the Indian Ocean, East Africa, the Red Sea, the Caribbean and Central and South America (see Figure 2). The primary focus was coral reef areas and so little attention was given to areas such as West Africa. Initially 50 surveys were set as a target but it was soon apparent that achievement of this target would be difficult. A previous global ICM survey that was conducted with key ICM experts covered 29 countries in both developed and developing countries (Cicin-Sain & Knecht, 1998). The survey carried out in this study focused on a smaller geographical area being limited to the tropics. It was carried out over a period of 8 months, resulting in information being collected from 43 locations. The difficulty in collecting more surveys from tropical ICM experts could be seen as a reflection of the limited expertise around the world for ICM, and after 8 months, it was felt that a representative coverage of this expertise had been achieved. Of the 43 respondents, there were 14 researchers in ICM or coastal ecology, 12 ICM consultants, 10 project managers (ICM or marine protected area projects), 5 marine protected area managers and 2 Government employees. All but 3 of the consultants and 4 researchers were locally based, living and working in the region selected.

Figure 2 Global distribution of ICM survey responses

The survey was divided into two sections. The first section and focus of this study gathered information on the status of ICM, the major management priorities in the coastal zone, the different coastal activities and management institutions involved in ICM in the area they selected. The second section, explored the respondents' perceptions of the impediments to ICM (see Chapter 4, Westmacott, 2000). Initial development of the survey was based on three detailed case studies of coastal management situations, which were examined through research interview techniques and personal experience (see Chapter 3). These case studies identified the main activities, institutional structures as well as the impediments to ICM in these locations. The three case studies used were from Curaçao and Bonaire in the Netherlands Antilles and Zanzibar in East Africa. It was recognised that these were limited in both number and type of location they represented. For this reason it was decided to explore the literature further and to continue with the development of the broader survey. The results are presented as follows:

1. Assessment of the status of ICM achievement throughout the tropics
2. Analysis of the coastal activities found at the different locations and identification of the similarities between the locations
3. Identification of the different conflicts between the coastal activities
4. Analysis of the management priorities found at the different locations and identification of similarities between the locations
5. Assessment of the institutional infrastructure found at the different locations

The analysis of similarities between the locations' coastal activities and management priorities was carried out using PRIMER (Plymouth Routines in Multivariate Ecological Research), which was originally developed for the analysis of biological data (Clark & Warwick, 1994). Non-metric multidimensional scaling (MDS) analysis was carried out on a matrix of dissimilarity coefficients (Euclidean distance) between respondents. Non-metric MDS was chosen over principal components analysis (PCA) or factor analysis because of the fewer assumptions about the nature and quality of the data. One survey was omitted from the results, as the questions relating to the coastal activities in the area were not completed.

The results of the multi-dimensional scaling (MDS) analysis were displayed as 2-D plots for ease of interpretation. In all cases, the stress values were below 0.23 indicating that a 2-D representation of the higher-dimensional similarities was adequate. The analysis was separated into three parts, (1) the analysis and visualisation (MDS ordination) of the coastal activities and management priorities (2) the analysis of the destructive coastal activities in each location and (3) analysis of the relative effect of environmental variables on the similarities seen. It was hypothesised that the similarities could be explained by:

- Survey location – which could indicate cultural differences and regional issues
- Poverty and wealth indices – which could affect management priorities, for example placing conservation below the basic provision of health, water and sanitation facilities
- Development indices of education level and level of reliable communications – which could potentially affect the issues found in the location

The analysis of the relative effect of these 'environmental variables' was also carried out in PRIMER under the BIO-ENV routine, which identifies the environmental variables that 'best explain' the multivariate pattern seen in the MDS. Again, two analyses were carried out, first on coastal activities and management priorities seen in each location and secondly on the destructive coastal activities.

2.5 Results

Status of ICM achievement in the tropics

The results show that ICM is being effectively implemented and evaluated in few locations in the tropics (Table 3). Only 12% of the survey locations were implementing, monitoring and evaluating their management plans. For a concept that has been in existence since the early 1980's (Cicin-Sain & Knecht, 1998) this result can be seen as disappointing. However, even if only a small percentage of countries are fully implementing ICM, an encouraging number are actively undertaking the process. The results showed that 50% of the locations surveyed were undertaking some level of ICM be it planning, implementation or monitoring and evaluation. In addition, a further 38% of the locations stated the coastal problems were actually known to management. This could indicate that the ICM process is being initiated or, alternatively, interpreted as a lack of desire from ICM management institutes to tackle the situation.

Table 3 The extent to which formal or informal ICM is being achieved in the tropics based on the survey responses

Level of management	% Locations
There is no management	12
The problems are known by management	38
Integrated plans are being formulated	19
Integrated plans are being implemented	19
Monitoring and evaluation of ICM plans	12

Even though the extent of fully implemented ICM (implementing, monitoring and evaluating) was limited, there were other forms of resource management in place. Fishing regulations were present in 86% of the locations and marine protected areas in a further 93%. However, although the survey did not explore this in detail, the effectiveness of these regulations could be questioned as 76% of the locations stated over-fishing was a problem in their location. Regulations may exist but are likely to be ineffective without either local support or adequate enforcement (see Chapter 4, Westmacott, 2000). Experience from Soufriere in St. Lucia found the system completely broke down without adequate enforcement (Sandersen and Koester, 2000). An additional point to note is that without integration into the ICM process these management efforts are likely to be limited in their ability to manage the resource effectively (Kelleher, 1999).

Coastal activities

It may be expected that coastal zones face a different set of challenges, in different political and public settings and consequently require a different management focus. However, the issues that ICM faces are remarkably similar over a wide range of societies and geographical settings (Olsen & Christie, 2000). Challenges are even similar in both developed and developing nations. The differences lie in the prevalence of poverty and the pace of social and ecosystem change (Olsen & Christie, 2000). The survey aimed to identify to what extent the same ICM coastal activities were found in tropical coastal zones. The results showed that hook and line fishing, trap fishing, snorkelling and scuba diving were occurring in over 80% of the locations (Figure 3). Destructive activities were found occurring in fewer locations, however they are still relatively widespread.

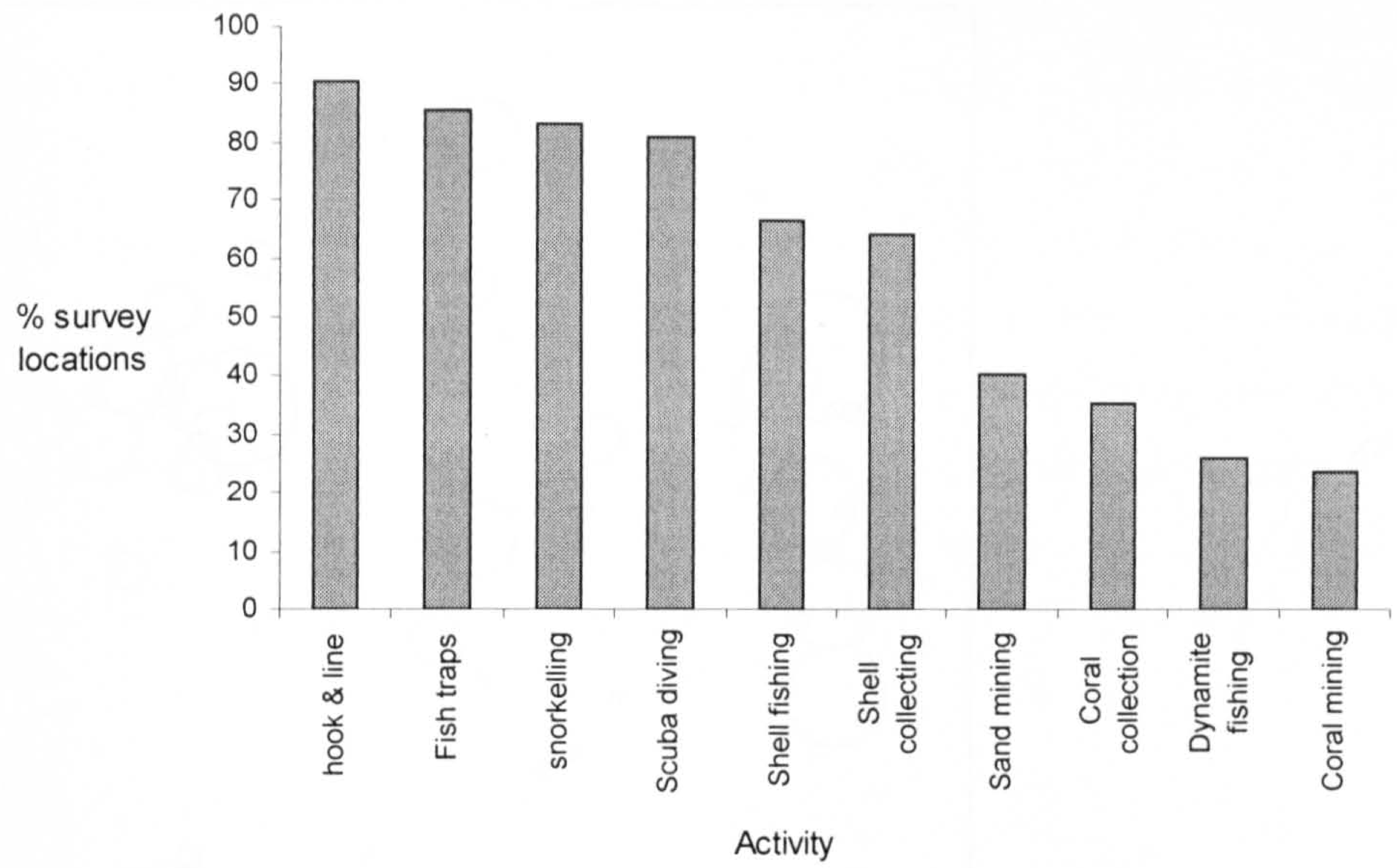

Figure 3 Percentage of survey locations where selected coastal activities can be found

The multidimensional scaling plot (MDS) of the survey locations' different coastal activities showed some similarity between respondents (Figure 4). The BIO-ENV routine was then used to identify which variables best explained the multivariate pattern. The result identified the human poverty index as having greatest influence (spearman rank correlation coefficient, r = 0.25) on the similarities between the locations' coastal activities. It should be noted that the poverty index is only part of the explanation and that a multitude of other factors influence the similarity matrix, although to a lesser extent than the poverty index. Similarities in coastal activities can be found in areas of high poverty (see Figure 4). The plot indicates that although the issues are generally widespread across the tropics, the level of poverty appears to have some influence on the activities in the coastal zone. A proportion of these activities relate to unsustainable, destructive activities that are sometimes linked to poverty. Carrying out the same analysis on the data set relating only to the habitat destructive activities highlights the similarities of those areas with a high poverty index (Figure 5), emphasising the relationship between poverty and habitat destruction.

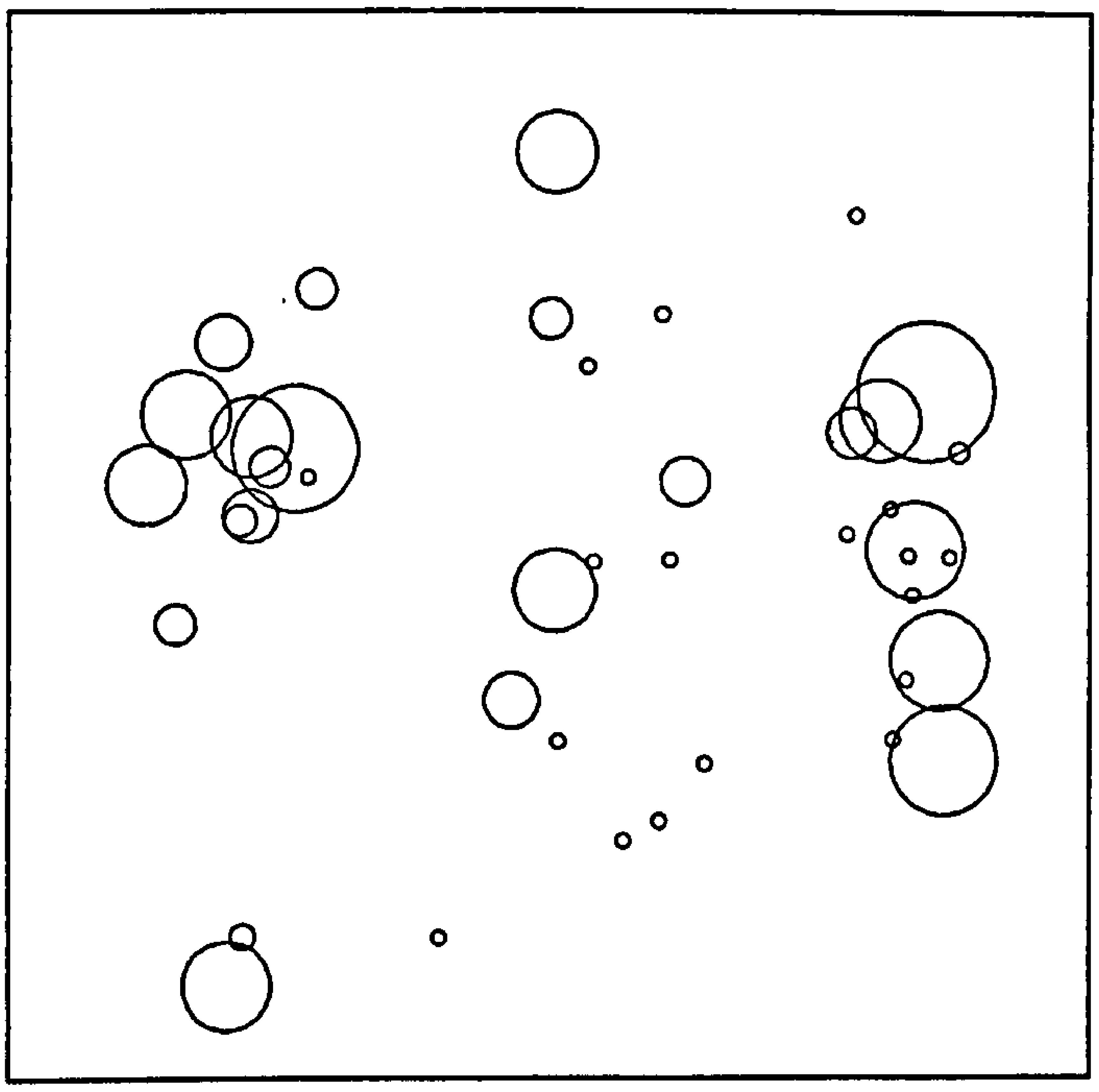

Figure 4 Multi-dimensional scaling (MDS) plot of similarities (Euclidian distance) in coastal activities between respondents. The proximity of the circles indicates their similarity to one another; the size of the circle indicates the level of poverty represented by low human poverty index (small) to a high human poverty index (large). Stress = 0.23 which indicates that this representation is a good representation of the higher-dimensional similarities between samples (respondents).

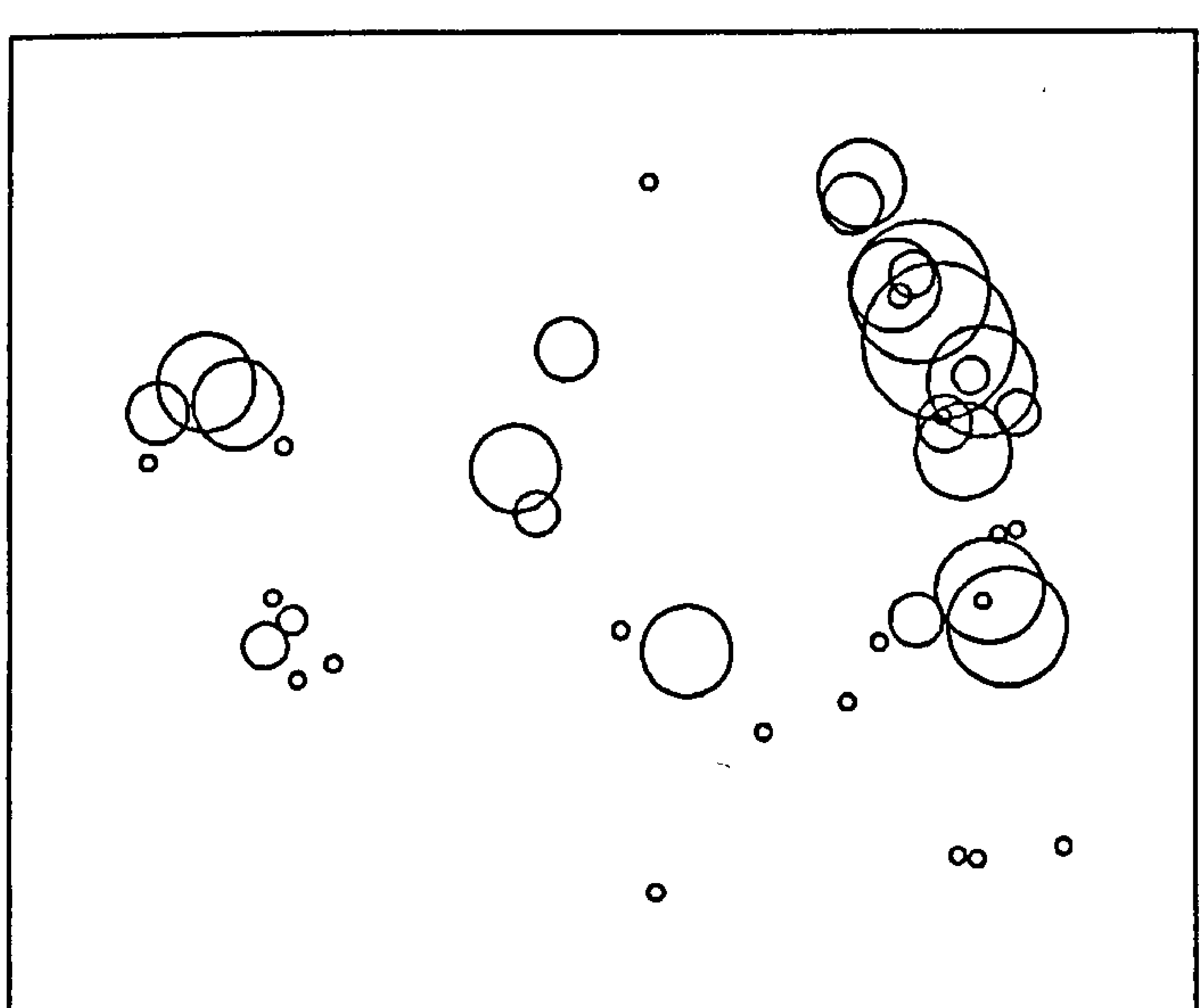

Figure 5 Multi-dimensional scaling (MDS) plot of similarities (Euclidian distance) in habitat destructive coastal activities between respondents. The proximity of the circles indicates their similarity to one another; the size of the circle indicates the level of poverty represented by low human poverty index (small) to a high human poverty index (large). Stress = 0.23 which indicates that this representation is a good representation of the higher-dimensional similarities between samples (respondents).

Conflicts between the activities

The wide range of activities supported by the coastal zone resources often leads to conflicts (Rijsberman, 1998). Conflict management is typically a central function of ICM with some programmes paying more attention to the issue than other programmes (Cicin-Sain & Knecht, 1998). The results of the survey showed that in 90% of survey locations there was some level of conflict between coastal activities. Conflicts were identified between fishing, tourism, reef conservation, development, industry and poor land use practices (see Figure 6). Over half (61%) specifically stated this was between fishing and tourism (also described as scuba diving and snorkelling) or more generally as extractive and non-extractive activities.

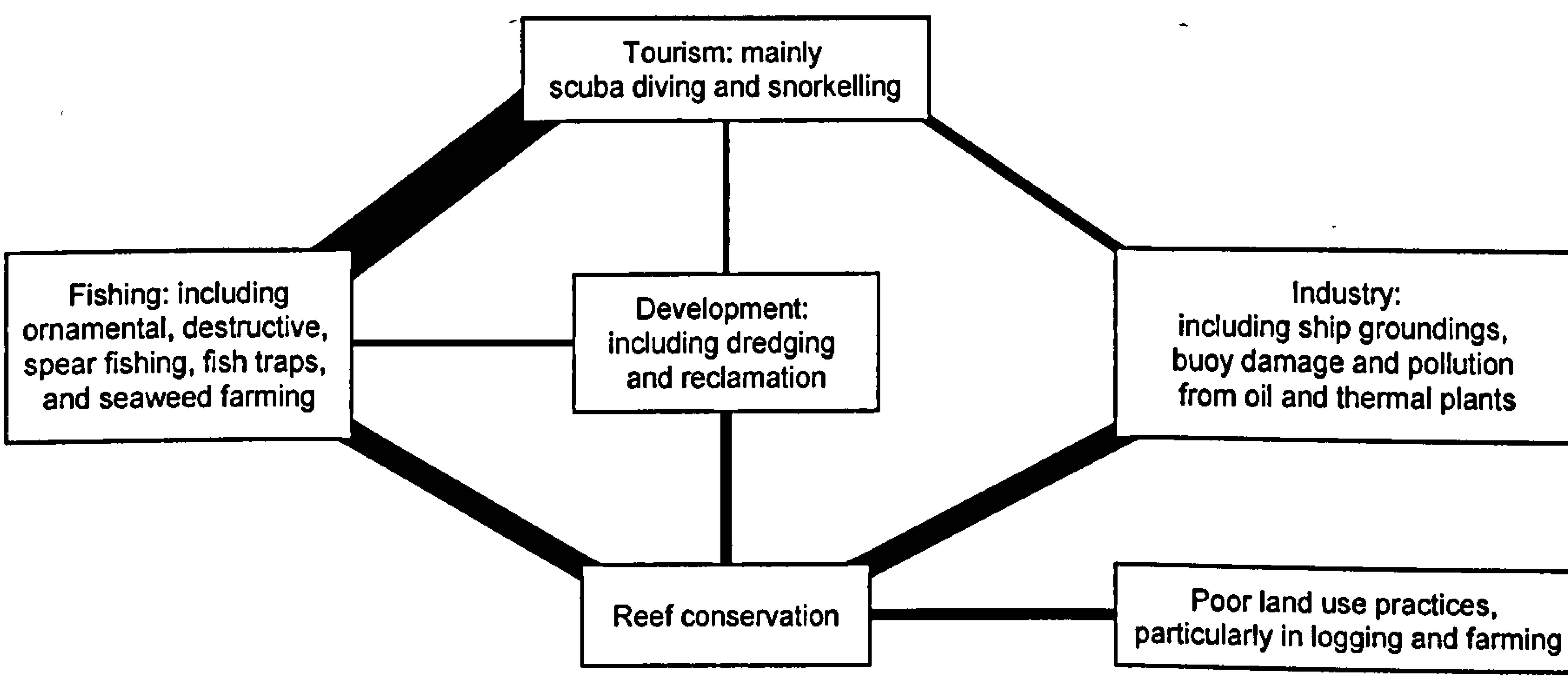

Figure 6 Diagram showing the conflicts between the different coastal activities identified by the survey respondents. The width of the line between the activities represents the frequency the conflict between those two activities was mentioned by the respondents (wider = more frequent).

The results show that conflicts are likely in coastal locations where multiple activities can be found. Reef conservation is apparently in conflict all other activities apart from tourism. Careful explanation of the benefits of reef conservation in terms of the long-term economic and environmental sustainability of the region will be needed to proceed with ICM. Likewise a balance between tourism and fisheries will be needed, focusing on encouraging those fishing techniques that will not adversely affect the integrity of the reef and hence affect the long-term sustainability prospects of the region for both tourism and fisheries.

Management priorities

The survey asked the respondents to rank the level of priority that management has for some of the typical coastal zone issues highlighted earlier. Included in this list were additional broader issues of poverty and unemployment to establish to what extent these were considered priority management issues at each of the survey locations. The respondents ranked the issues in terms of their level of priority (high, medium, low and non-issue). The results identified the most frequent priority management issue as the diminishing level of fish and shellfish (Table 4). This was supported by the fact that in 79% of the locations over-fishing was perceived to be a problem. The second most significant management issue is poverty, followed closely by the environmental issues described as deteriorating environmental quality, loss of critical habitats and loss of biodiversity.

Table 4 Level of priority of major management issues in tropical coastal zones (in % of survey responses)

Management Issue	High	Medium	Low	Non issue
Diminishing levels of fish & shellfish	43	45	12	0
Poverty	33	29	26	12
Deteriorating environmental quality	32	53	15	0
Rapid population growth	31	47	17	5
Loss of critical habitats	29	52	19	0
Loss of biodiversity	29	43	26	2
Unemployment	29	40	19	12
Vulnerability to natural hazards	27	41	27	5

An MDS analysis showed no clear similarities between respondents. The BIO-ENV routine identified a combination of three variables as having the greatest significance (spearman rank correlation coefficient, r=0.390) in explaining similarities between the locations' management priorities. These were purchasing power parity (PPP) per capita, human poverty index and the contribution of travel and tourism to the country's economy. The first two variables are indicators of wealth of the population. This is not too surprising considering the results from the previous analysis of coastal activities where poverty was identified as having the greatest influencing on the similarities between areas with destructive activities. It is interesting that the importance tourism has in an area apparently influences the priority of the management issues listed. This could indicate that tourism does have an influence on raising the priority for conservation and biodiversity protection. Although often identified as an alternative to the non-sustainable use of the coastal zone, sustainable tourism management may even raise the profile of biodiversity and environmental protection.

A combined analysis of the coastal activities and management priorities in a location also showed no clear clustering, particularly when related to ICM. This would indicate that the types of coastal activities in an area and consequent prioritisation of management do not play an important role in the achievement of ICM. Other factors must have a greater influence. The BIO-ENV routine on the combined results identified the level of poverty and the importance of tourism to the economy having the greatest significance (r=0.283) in explaining the multivariate pattern.

Institutional Structure

The survey collected information on the different ICM institutions, organizations and stakeholders (referred to collectively as ICM institutions) present in the coastal zone. The mean number of ICM institutions per location involved in coastal management was 6. The maximum recorded was 11. These numbers emphasise the complexity of the institutional structure in most coastal locations. The most commonly cited agency was the Department of Fisheries (see Table 5). This was followed by the Department of Environment (including conservation and forestry) and the Marine Park Authorities. Some respondents just cited Government in general, which included local, regional and national governments. The next most frequently cited organisations were non-governmental and included research and academic organizations, the Tourism and Fisheries Associations and the NGO's. Interestingly only 24% of the respondents mentioned the local community, which could reflect the limited level of public participation currently found in coastal areas. Only two locations (Sri Lanka and Belize) listed a specific ICM authority showing this is not a widely established type of agency.

Table 5 Frequency of involvement of ICM stakeholder groups identified by the survey respondents Note: Some of the categories overlap because respondents were free to define their own categories of stakeholders

STAKEHOLDER	% of locations identified
Department of Fisheries	59
Environment, Conservation and Forest Department	49
Marine Parks Authorities	49
Government (local, regional, national)	43
Research foundation, local college, University	32
Tourism and hotel association	32
Fishermen (recreational and commercial) and fishing cooperatives	30
Non Governmental Organisations (NGOs)	30
Residents, landowners, local community	24
Scuba associations/ dive operators	19
Land use planning Department	16
Yachting and Boating Associations/ Charters	16
International organisations and projects	14
Marine police, Coast Guard, Navy, Military	14
Ports Authority	14
Local Chiefs, council of chiefs	11
Public Works Department	11
Industry	8
Tourists	8
ICM Authority	5
Department of Finance	3
Department of Ocean Development	3
Department of Tourism	3
Department of Water Resources	3
Farmers	3
Pollution Control Board	3

2.6 Conclusions

Although integrated coastal management (ICM) efforts have increased over the last 10 years (Cicin-Sain & Knecht, 1998; Sorensen, 2000), this study has shown that only a few locations (12%) are actually implementing, monitoring and evaluating coastal management plans in the tropics. A further

12% have no management at all and 38% are only recognising the management problems in the coastal zone. Chua (1993) states that although ICM is the recommended approach of coastal and marine management it is a difficult one to implement. He blames failure of plans on the lack of a comprehensive, systematic, procedural and integrative approach and when plans are implemented failure can be connected to poor interagency co-ordination, insufficient policy and functional integration or inadequate feedback due to lack of monitoring and evaluation.

This survey has been able to quantify the extent ICM is being implemented in the tropics. It has also highlighted the fact many ICM programmes fail at the transition between planning and implementation. The lack of monitoring and evaluation in ICM is highlighted by the survey. Without monitoring and evaluation, the cyclical process will be broken and there will be no further problem analysis and redesign of the plan as experience in ICM progresses.

The survey showed that fishing and tourism are widespread activities throughout tropical coastal zones and highlighted the fact that habitat destructive activities are still occurring in a number of locations. The analysis of similarities between the locations showed that these destructive activities are more frequent in areas with greater poverty. Poverty on tropical coasts forces people to search opportunistically for employment and engage in unsustainable methods of farming and fishing for fear of income loss (Christie and White, 1997). ICM managers need to identify the driving force behind unsustainable activities in their location, which may well be poverty. Although poverty is widespread throughout the tropics, those situations where poverty exacerbates the degradation of the coastal resources, attention needs to be given in the short term to halt these activities and identify alternative livelihoods for those concerned.

ICM aims to conserve coastal resources for sustainable use in order to ensure the livelihoods of coastal populations now and in the future (Cicin-Sain & Knecht, 1998). However, this may not be seen as an immediate priority for a Government faced with the various issues relating to poverty such as inadequate food, health facilities, water supply and sanitation and education facilities. Without attention to curbing destructive activities, the coastal zone's resource base will gradually become eroded and poverty will worsen in the longer term.

Tackling the issues of depleting fish and shellfish resources as well as poverty was identified in the survey as the major management priority before conservation becomes a priority. Overfishing was identified as a problem in 79% of the survey locations. This indicates that sustainable fisheries management should be seen as a priority of ICM in order to protect the coastal zone's resource base for the future. This does pose difficulties, particularly in the poorer areas where people may be less able to find alternatives to fishing. Management needs to provide these communities with alternatives to fishing as well as providing them with their necessities while these alternatives become established. Fisheries management must be well enforced to ensure that firstly, the displaced fishermen are not replaced by others moving to the area and secondly, that as fish stocks recover they are not immediately depleted again. As the fish stocks recover, a strongly regulated management regime will be required to maintain sustainability and avoid depletion. It should be remembered that fisheries management will be most effective if undertaken within an ICM framework (Olsen & Christie, 2000).

The institutional setting provides the framework or institutional infrastructure within which management functions are carried out and management instruments are applied (Sorensen & McCreary, 1990). This framework includes the Government structure, the legal framework of laws, conventions and decrees and the set of traditional and social norms represented by the various user groups (Awosika et al., 1993).

This survey has shown that

- In 90% of the coastal locations surveyed conflict management would be needed
- The main conflicts were between fishery and tourism interests or more generally extractive and non-extractive uses
- Institutional complexity means that at least 6 institutions with their own agendas and objectives are likely to come into play when formulating coastal plans

This indicates that conflict management needs to play a key role in ICM in order to deal with the multi-objective environment that is typical of ICM. The main conflicts are between the different user groups characterised by different resource use objectives. The situation in Soufriere, St. Lucia has seen a shift in the balance of power in order to achieve co-management. This has demanded commitment, flexibility and patience on the part of all stakeholders (Sandersen & Koester, 2000). Dealing with an imbalance of power in a society will require vision, leadership and courage (Olsen & Christie, 2000). However, this may be necessary to overcome some of the constraints blocking success in ICM (see Chapter 4, Westmacott, 2000).

Traditionally ICM has been approached through a systems analysis methodology (van der Weide, 1993). This implies the development of a value system enabling the ranking of various alternative outcomes. The solution to the problems tackled can be expressed as the search for an efficient means of reaching a defined objective or goal. The idea of soft systems thinking was brought into systems analysis due to the failure of traditional approaches to applications where the problem was far from structured and where objectives were unknown (Checkland, 1984). ICM could benefit greatly from this type of approach to both the problem analysis and implementation of ICM plans. The methodology is based on a learning process where the analyst assists stakeholder groups to understand the problem area and the different perspectives and interests that exist within that problem area (Checkland, 1985). The stakeholders then identify possible actions that can be taken within the problem area. It allows the different groups to explore and understand each other's interests and use this structured process to learn and develop solutions together. In a situation such as ICM where the more defined 'hard' approaches appear unable to deal with the complexities of human indecision and conflict, the 'soft' systems approach may at least allow an understanding between the various groups to develop.

Only 24% of the respondents identified the local community as an ICM stakeholder, indicating that the local community is rarely thought of as a major stakeholder in the ICM process. Past ICM experiences in Tanzania are reported to have ignored the local coastal community who are the foremost stakeholders and were most often not consulted in coastal planning decisions and implementation of projects and thwarting the process (Masalu, 2000). Involvement of all coastal users and stakeholders is paramount to the effective implementation of ICM. Planning and implementation time scales may need to be revised as a full participation process is likely to exceed most of the current project time scales which are often 3 to 5 years. (Olsen, 2000). The process of integration and involvement needs to start at the outset of the planning process. Davos (1998) states that ICM will never be able to achieve co-operation from stakeholders as long as the 'best' policy is determined by expert-based rational analysis rather than selecting the 'correct' policy which is drawn from the maximum available stakeholder support.

Attempts should be made to involve and educate the local community about the benefits of ICM. However, simply imparting information and enhancing the experience of the coastal users can only be partially effective in achieving the management goals (Kelly, 1992). Educational activities need to be focused on changing beliefs, knowledge and perceptions of appropriate behaviour before changes in actual behaviour are seen. Environmentally responsible behaviour is also linked to the knowledge and skill necessary to carry out the desired behaviour (Kelly, 1992), hence information is also needed on what environmentally responsible behaviour is. Poverty may also stand in the way of local participation in the management process. Community based participation may not occur as readily or as successfully as its advocates would hope in areas where coastal communities are struggling to make a living with severe social and economic problems such as poverty, long-standing economic stagnation, rapid population growth and environmental deterioration (Hackel, 1999).

There are many similar challenges faced worldwide in ICM. The challenge for the coastal manager will be to identify those activities driving the destructive and unsustainable use of coastal resources. Poverty may add to the management problems and even restrain the desire of local communities to become involved in management activities. Poverty alleviation and increased food security will likely to be priority management activities before conservation will be considered. Sustainable fisheries management is a priority in many areas as it forms one of the major sources of food. However, it will only be achieved if alternatives to the over exploitation of the resource are tackled first. Successful ICM will require suitable conflict management techniques to be undertaken at all stages of the management cycle from objective definition to implementation and enforcement of the plan.

Participatory and soft systems techniques may be more applicable in achieving agreement or understanding about the different objectives of the multiple stakeholder groups. Involvement of all stakeholder groups from the outset and an educational focus on changing user behaviour rather than simply informing user groups of the benefits of ICM will be an important part of successful implementation.

For ICM to be successful it needs to focus on the constraints against implementation. The next step in this analysis has been to identify the impediments to the implementation of ICM (see Chapter 3 & 4, Westmacott, 2000).

References

Awosika, L. S., S. Boromthanarat, R. Cornforth, M. Hendry, R. Koudstaal, M. Ridgley, J. Sorenson, L. de Vrees and S. Westmacott. 1993. *Management Arrangements for the development and implementation of coastal zone management programmes.* World Coast Conference Organising Committee, Noordwijk, the Netherlands.

Bijlsma, L., M. Crawford, C. Ehler, F. Hoozemans, V. Jones, R. Klein, B. Miermet, N. Mimura, R. Misdorp, R. Nicholls, K. Ries, J. Spradley, M. Stive, L. de Vrees and S. Westmacott. 1993. *World Coast Conference Report.* Ministry of Transport, Public Works and Water Management, National Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, the Netherlands.

Bower, B. T., C. N. Ehler and D. Basta, J. 1994. *A framework for planning for integrated coastal zone management.* National Oceanographic and Atmospheric Administration (NOAA), Washington DC.

Bower, B. T. and R. K. Turner. 1998. Characterising and analysing benefits from integrated coastal management (ICM). *Ocean & Coastal Management* 38: 41-66.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. *Reefs at Risk. A Map-Based Indicator of Threats to the World's Coral Reefs.* World Resources Institute, Washington DC.

Burbridge, P. 1999. The Challenge of Demonstrating the Socio-Economic Benefits of Integrated Coastal Management. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 35-54. Berlin Heidelberg: Springer-Verlag.

Checkland, P. 1984. Rethinking a systems approach. In *Rethinking the Process of Operational Research and Systems Analysis,* eds., R. Tomlinson and I. Kiss, 43-66. London: Operational Research Society Limited & Pergamon Press.

Checkland, P. 1985. From Optimising to learning: A development of systems thinking for the 1990's. *Journal of the Operational Research Society* 36: 757-767.

Christie, P. and A. White. 2000. Introduction to Special Issue on Tropical Coastal Management. *Coastal Management* 28: 1-4.

Christie, P. and A. T. White. 1997. Trends in Development of Coastal Area Management in Tropical Countries: From Central to Community Orientation. *Coastal Management* 25: 155-181.

Chua, T.-E. 1993. Essential Elements of Integrated Coastal Zone Management. *Ocean and Coastal Management* 21: 81-108.

Chua, T.-E. 1998. Lessons Learned from Practicing Integrated Coastal Management in South East Asia. *Ambio* 27: 599-610.

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated coastal and ocean management: concepts and practices.* Washington DC and Covelo, California: Island Press.

Clark, J. R. 1992. *Integrated management of coastal zones*. Food and Agricultural Organisation of the United Nations, Rome.

Clark, K. and R. Warwick. 1994. *Change in Marine Communities: An approach to statistical analysis and interpretation*. Bournmouth, UK: Natural Environmental Resource Council. Printed Bourne Press Ltd.

Courtney, C. A. and A. T. White. 2000. Integrated Coastal Management in the Philippines: Testing New Paradigms. *Coastal Management* 28: 39-53.

Czaja, R. and J. Blair. 1995. *Designing Surveys: A guide to decisions and procedures*. California: Pine Forge Press.

Davos, C. 1998. Sustaining co-operation for coastal sustainability. *Journal of Environmental Management* 52: 379-387.

Ehler, C., N. and D. J. Basta. 1993. Integrated Management of Coastal Areas and Marine Sanctuaries. *Oceanus* 36: 6-13.

Gibson, J., M. McField and S. Wells. 1998. Coral reef management in Belize: an approach through Integrated Coastal Zone Management. *Ocean & Coastal Management* 39: 229-244.

Hackel, J. D. 1999. Community conservation and the future of Africa's wildlife. *Conservation Biology* 13: 726-734.

Hale, L. Z., M. Amaral, S. I. Abdulrahman and B. A. J. Mwandotto. 2000. Catalyzing Coastal Management in Kenya and Zanzibar: Building Capacity and Commitment. *Coastal Management* 28: 75-86.

IUCN. 1993. *Reefs at Risk*. IUCN Marine Coastal Areas Programme, Gland, Switzerland.

Jameson, S. C., J. W. McManus and M. D. Spalding. 1995. *State of the Reefs - Regional and Global Perspectives*. International Coral Reef Initiative, US Dept of State, Washington DC.

Kelleher, G. 1999. *Guidelines for Marine Protected Areas*. IUCN, Gland, Switzerland and Cambridge, UK.

Kelly, G. C. 1992. Public Participation and Perceived Relevance as Critical Factors in Marine Park Management. *7th International Coral Reef Symposium*, eds., International Society of Reef Studies, 1033-1037. Guam.

Kenchington, R. and D. Crawford. 1993. On the Meaning of Integration in Coastal Zone Management. *Ocean and Coastal Management* 21: 109-127.

Lowry, K. and H. J. M. Wickremeratne. 1988. Coastal Area Management in Sri Lanka. *Ocean Yearbook, University of Chicago.*

Makoloweka, S., M. Gorman, J. C. Horrill, H. Kalombo, C. Kawau, Z. Lugazo, K. Shurcliff, G. Uronu and T. van Ingen. 1997. Establishing Coastal Management in Tanga Region, Tanzania. An Experimental Approach. *Sharing Coastal Management Experience in the Western Indian Ocean: Integrated Coastal Area Management for Eastern Africa and the Island States*, eds., WIOMSA, Tanga, Tanzania. Western Indian Ocean Marine Science Association (WIOMSA).

Masalu, D., CP. 2000. Coastal and marine reesource use conflicts and sustainable development in Tanzania. *Ocean & Coastal Management* 43: 457-494.

McClanahan, T. R., N. A. Muthiga, A. T. Kamukuru, H. Machano and R. W. Kiambo. 1999. The effects of marine parks and fishing on corals reefs of northern Tanzania. *Biological Conservation* 89: 161-182.

Olsen, S. 2000. Sustaining ICM Initiatives in the Tropics. *Intercoast Network*.37: 3 & 34-35.

Olsen, S. and P. Christie. 2000. What are we learning from Tropical Coastal Management Experiences? *Coastal Management* 28: 5-18.

Olsen, S. B., J. Tobey and L. Z. Hale. 1998. A Learning Based Approach to Coastal Management. *Ambio* 27: 611-619.

Oppenheim, A. N. 1992. *Questionnaire design, interviewing and attitude measurement.* London and New York: Pinter Publishers.

Pernetta, J. C. and D. L. Elder. 1993. *Cross-sectoral, Integrated Coastal Area Planning (CICAP): Guidelines and Principles for Coastal Area Development. A Marine Conservation and Development Report.* IUCN, Gland, Switzerland.

Post, J. C. and C. G. Lundin. 1996. *Guidelines for integrated coastal zone management.* Washington DC: International Bank for Reconstruction and Development & The World Bank.

Rajasuriya, A., M. H. Maniku, B. Subramanian and J. Rubens 1999. Coral Reef Ecosystems in South Asia. In *Coral Reef Degradation in the Indian Ocean: Status reports and project presentations 1999.*, eds., O. Linden and N. Sporrong, 11-24. Stockholm: Sarec Marine Sciences Programme.

Rajasuriya, A., M. W. Ranjith, N. D. Silva and M. C. Ohman. 1995. Coral reefs of Sri Lanka: Human disturbance and management issues. *Ambio* 24: 428-437.

Rajasuriya, A. and A. T. White. 1995. Coral Reefs of Sri Lanka: Review of their extent, Condition and Management Status. *Coastal Management* 22: 77-90.

Rijsberman, F. 1998. *Conflict Management and Consensus Building for Integrated Coastal Management in Latin America and the Caribbean.* Washington DC, US: Sustainable Development Department, Inter-American Development Bank.

Samaranayake, R. A. D. B. 2000. Sri Lanka's Agenda for Coastal Zone Management. *Integrated Coastal Zone Management* 1: 15-19.

Sandersen, H. T. and S. Koester. 2000. Co-management of Tropical Coastal Zones: The Case of the Soufriere Marine Management Area, St. Lucia, WI. *Coastal Management* 28: 87-98.

Smith, A., C. Rogers and C. Bouchon 1998. Status of Coral reefs in the Lesser Antilles, Western Atlantic. In *Status of Coral Reefs of the World, 1998,* eds., C. Wilkinson, 135-143. Townsville: Australian Institute for Marine Science.

Sorensen, J. 1993. The International Proliferation of Integrated Coastal Zone Management Efforts. *Ocean and Coastal Management.* 21: 45-80.

Sorensen, J. 2000. *Building a Global Database of ICM Efforts.* University of Massachusetts, Boston.

Sorensen, J. C. and S. T. McCreary. 1990. *Institutional Arrangements for Managing Coastal Resources and Environments.* Washington DC: National Parks Service, US Department of Interior.

Turner, R. and W. Adger. 1996. *Coastal Zone Resource Assessment Guidelines.* LOICZ IPO, Texel, The Netherlands.

Turner, R. and B. Bower 1999. Principles and Benefits of Integrated Coastal Zone Management (ICZM). In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 13-34. Berlin Heidelberg: Springer-Verlag.

UNCED. 1992. *"Oceans and Coasts Chapter 17".* United Nations Conference on Environment and Development,

van der Weide, J. 1993. A Systems View of Integrated Coastal Management. *Ocean and Coastal Management* 21: 129-148.

Westmacott, S. 2000. Identifying the main impediments to integrated coastal management in the tropics. *Paper submitted to Ocean and Coastal Management, October 2000.*

Wilkinson, C. 1992. Coral Reefs of the World are facing widespread devastation: Can we prevent this through sustainable management practices. *7th International Coral Reef Symposium,* eds., International Society of Reef Studies, 11-21. Guam, Micronesia. University of Guam Marine Laboratory.

World Bank. 1995. *Africa: A Framework for Integrated Coastal Zone Management.* The World Bank, Washington DC.

World Commission on Environment and Development. 1987. *Our Common Future.* Oxford: Oxford University Press.

WWF and IUCN. 1998. *Creating a Sea Change: The WWF/IUCN Marine Policy.* World Wildlife Fund and the World Conservation Union, Gland, Switzerland.

3 Categorising the impediments to tropical integrated coastal management from case studies of Curaçao, Bonaire and Zanzibar

3.1 Introduction

Integrated coastal management (ICM) has been recommended as the best approach to manage the increasing use and activity found within today's coastal zones (Bijlsma et al., 1993; Post & Lundin, 1996; Cicin-Sain & Knecht, 1998). ICM involves a number of steps in a management cycle. These steps involve problem identification, the formulation of management alternatives, implementation, enforcement and monitoring and evaluation (Rijsberman & Koudstaal, 1989; Resource Analysis & Delft Hydraulics, 1993; Bower et al., 1994; Westmacott, 1995). The steps are integrated across the different sectors and stakeholder groups affected by ICM and the diverse coastal activities (see Chapter 2, Westmacott, 2000b). The need for ICM and issues tackled by ICM will differ between countries and may even differ within a country.

ICM can be defined as a continuous, dynamic, iterative, adaptive and participatory process in which a co-ordinated strategy is developed and implemented for the allocation of environmental, socio-cultural and institutional resources. This is undertaken to achieve the conservation and sustainable multiple use of the coastal zone whilst taking into account traditional cultural and historical perspectives and conflicting interests and uses (see Chapter 2, Westmacott, 2000b).

Even though the number of ICM efforts has more than doubled in the last 7 years (Sorensen, 2000), ICM continues to face problems in its implementation (see Chapter 2, Westmacott, 2000b). Identifying the impediments to ICM will enable managers and decision makers to prioritise their activities and design more effective management programmes. This study aims to answer the following questions:

- Are similar impediments to ICM found in different locations in the tropics?
- Can impediments to ICM be generalised into categories?

These questions were approached by studying in detail the ICM situation at three case study sites in the tropics. These case studies (Curaçao, Bonaire and Zanzibar) represent coastal situations where integrated coastal management (ICM) could be implemented but there is no formal ICM at present. The case studies identify the objectives ICM would have in each case study site, to identify the different stakeholders involved in ICM and their major interests and to identify the major impediments to ICM as perceived by the different stakeholders and management agencies. The results of the individual case studies are compared to assess whether similarities are seen. Any similarities are developed into categories of impediments that are later tested for their generic applicability to the tropics in a wider survey of the impediments to ICM conducted by mail and e-mail (see Chapter 4, Westmacott, 2000a). Structured interviews and practical experience are used to gather the information for the case studies.

3.2 Methods

Study sites

Curaçao and Bonaire in the Caribbean and Zanzibar in the Indian Ocean are all islands where the socio-economic setting depends on the marine environment. They are tropical islands surrounded by coral reefs. Reef based activities such as fisheries and tourism form an important part of their economies. Each site differs in terms of wealth and coastal activities. In Zanzibar, the increasing population growth put considerable pressure on the reef fisheries with little sign of alternatives. Population has grown at 3% per annum reaching 792,000 in 1995, three times the levels seen in the 1950's (Mwakanjuki, 1997). Curaçao's economy has an industrial base focused around the port activities and the oil refinery, however, tourism is increasing and the tradeoffs between environmental protection and development are topical. Tourism contributes approximately 12% of the gross domestic product of the island (Central Bureau of Statistics, 1994). The Tourism Board initiated a Dive Improvement Programme in 1995 to stimulate dive tourism on the island (Robinson, 1993). Bonaire's economy is reliant on dive tourism and the island's legislation and protection status of the reef reflects this. The number of divers has increased from 17,000 in 1991 to 27,000 in 1998 (Bonaire Marine Park unpublished data). None of these sites has an official ICM plan.

Identifying the impediments to ICM

In order to attain a generic picture of the impediments to ICM in the developing tropics three case studies were examined in detail to provide a basis on which to categorise the impediments to ICM. A review of published material was then used to substantiate the findings from the three case studies by interpreting existing reports of the successes and failures of ICM programmes.

Qualitative research methods were used to identify the impediments to implementing effective ICM at the three case study sites. Curaçao was the first site studied. The information was collected through research interviews with selected stakeholders carried out in 1995. In Bonaire, the opportunity to become involved in the management process was utilised. Participant observation in this case was focused on the management of the coral reef taking place between November 1997 and February 1999. The information in Zanzibar was collected through research interviews held with a selection of informed respondents during July 1999.

The main difference with qualitative research and quantitative research is the sampling approach. Quantitative methods typically depend on large samples selected randomly while qualitative inquiry typically focuses in depth on small samples, often selected purposefully. While the power of a statistically representative sample is generalisation, the logic and power of purposeful sampling lies in carefully selected information-rich cases. The validity, meaningfulness and insights generated from qualitative inquiry have more to do with the information-richness of the cases selected and the observational and analytical capabilities of the researcher than the sample size (Patton, 1990). Lincon and Guba (1985) recommend sample selection to the point of redundancy where sampling stops when no new information is forthcoming. The sampling strategies for Curaçao and Zanzibar were both based on purposeful sampling. Interviewees chosen in Curaçao were those involved in ICM or affected by ICM. Where a group represented individuals, such as the local dive club, the leader of this group was interviewed. Each interviewee was asked to identify other people they felt should be interviewed. This chain sampling enabled us to collect information from all persons who were likely to be a rich source of information covering the range of opinions. The interviewees selected in Zanzibar were selected as elite interviewees. Interviewees were selected for their knowledge of certain management aspects within the coastal zone. This method was selected due to the short time available in Zanzibar.

Research interviews

Research interviews were used to assess the main impediments to ICM in both Curaçao and in Zanzibar (see Appendix B). The interviews were undertaken in Curacao in 1995 and in Zanzibar in 1998. The research interview is a professional conversation whose purpose is to obtain a description of the interviewee's world with respect to the phenomenon in question (Kvale, 1996). The knowledge obtained from such interviews will be subjective and represents the experiences and perceptions of the interviewee. Although the interview is not traditionally seen as belonging to natural science methods, it is able to produce systematised knowledge, which is a core feature of scientific methods and should be recognised as being scientifically valid (Kvale, 1996). One criticism of interviewing is the inability to replicate the interview, however, the level of the information is the important factor rather than the ability to replicate (Kvale, 1996). To avoid variation in the style of interviewing, two interviewers carried out the work in Curaçao and one in Zanzibar. In Curaçao, practice interviews were carried between the two interviewers to coordinate their style of interviewing. The interview developed for this application was based on open questions that were followed up with critical probing from the interviewers.

The interviews in Curaçao were carried out as part of the development of CORAL, a coastal management model for coral reef areas (Rijsberman & Westmacott, 2000). The model, funded by the Latin America and Urban Development Division of the World Bank, was developed for Curaçao in the Netherlands Antilles and the Republic of the Maldives (Rijsberman & Westmacott, 2000; Westmacott & Rijsberman, 2000). In Curaçao, 17 different stakeholder groups involving over 22 individuals were interviewed. Interviewees were selected because they each represented an ICM stakeholder group or were significant stakeholders themselves. The interviews were carried out in person, each question being read to the interviewee and their response documented during the interview enabling cross checking of the information. In some places, prompting was required to explain the question.

The interviews elicited the stakeholders' perceptions of the major issues and problems in the coastal zone and their own objectives for the management of Curaçao's coastal zone. Each interviewee was asked to rank the importance given to different categories of management objectives. The categories were defined as: economic, environmental, social, institutional and political. Interviewees were asked to suggest actions that could be taken to manage the coastal zone. They were also asked how they felt the success of these actions should be measured. This information was used to formulate the components included in the CORAL model (see Chapter 6). In addition to this information, the interviewees were asked to identify what they saw as the main impediments to achieving integrated management.

Unlike Curaçao, the study in Zanzibar was based on elite interviewing. This uses the same interview structure but the sample of informants is carefully selected. The 'elite' informants were selected because they were considered influential, prominent and well informed. This type of interviewing has the advantage of often being able to provide an overview of a system, including the legal and financial structures, past histories and future plans (Marshall & Rossman, 1999). As with all elite interviewing, the informants were busy people and difficult to contact, relying on introductions and recommendations to make appointments. In addition, the interview needs to be adapted as the interview takes place as some informants resent following a structured interview. In total 6 people provided information for the case study. These people were all involved in the management and development of coastal resources around Unguja Island, Zanzibar.

During the interview, the interviewer needs to rapidly establish a contact that goes beyond polite conversation and idea exchange to a situation where the subject feels comfortable enough to talk about his or her experiences and feelings. This requires skill in being aware of different cultures and how they may react to certain questions. Several ethical issues need to be taken into account when collecting and analysing data through personal interaction (Kvale, 1996). The consequences of publishing certain statements need to be taken into consideration. In these interviews, confidentiality was secured and the interviewee was made completely aware of the purpose of the interview.

The interviews were recorded through text written down during the interview and backed up with tape recordings when allowed. Writing down the information during the interview allows the information to be interpreted and analysed on the spot. The information is condensed and interpreted whilst being able to cross check with the informant. Care was also taken to keep the interpretation of the information to a minimum unless it was possible to check with the interpretation with the informants either during the interview or later.

Participatory observation

The Bonaire case study is based on 15 months working for the Bonaire Marine Park from November 1997 to February 1998 where experience in day-to-day coastal management has been used to identify the impediments to successful coastal management in Bonaire. This technique of participatory observation can be used to collect information by becoming involved in the situation either as a participant or as an external observer (Marshall & Rossman, 1999). In the case of Bonaire, involvement as a full participant included daily management tasks, attending government meetings representing the Marine Park, issuing permits for marine developments, giving advice to coastal developments as well as local education initiatives. In addition, tasks included facilitation and support of the work of visiting researchers and organising an active volunteer group. This involvement enabled observations and assessments to be made regarding the issues surrounding marine conservation and management on the island.

The purpose of an observation is to describe the setting and activities taking place and interpret the meaning of what was observed from the perspective of those observing. Observers' perceptions will therefore differ as will the information gathered depending on whether the observer is external to the system or not. Understanding the system context is essential to a holistic perspective. The initial objective of the work in Bonaire was as an assistant manager to the Marine Park rather than as a researcher. The benefit of being involved as a manager meant that the reality of each situation was revealed. In the case of an external observer, certain information may be withheld. After a year of involvement, a good understanding of the impediments to effective and integrated marine and coastal management was attained.

Structure of the analysis

Analysis of the information collected through the interviews and observations has been kept as three separate case studies for Curaçao, Bonaire and Zanzibar. Although the information has been condensed and summarised it remains qualitative. The information for each case study follows the format:

- Introduction to the area
- Main issues occurring in the coastal zone
- Impediments to ICM
- Implementing ICM and overcoming the impediments

The impediments identified in the three case studies are then summarised into a set of impediment categories relating to ICM in the tropics, which are supported by a literature review. It was recognised that the three case studies were limited and although the literature review backs up many of the findings from the case studies, generalisations for the tropics cannot be confidently drawn at this stage. The three case studies were selected because they were sufficiently different to be able to cover the cross section of issues found in ICM situations. To reinforce the generalisations that were identified in the case studies, the identification of impediments to implementation of ICM was developed further through a survey designed to solicit the opinions of a broad selection of ICM practitioners throughout the tropics (see Chapter 4, Westmacott, 2000a). The survey was developed using the results and experiences gained from these case studies. Figure 1 summarises the different methods and sample selection used in studying the specific case studies and how this leads into the identification of generic ICM impediments in the tropics.

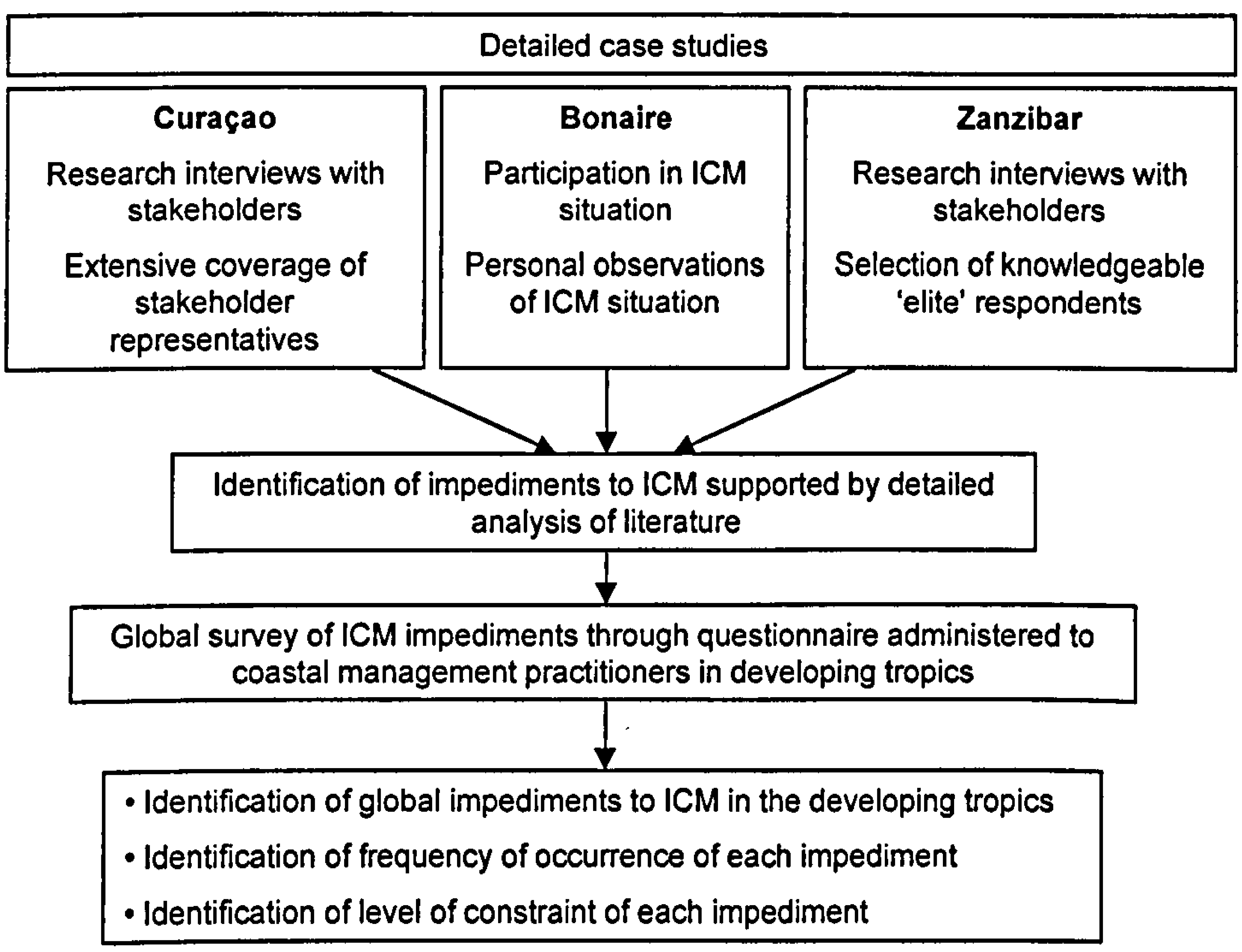

Figure 1: Schematic diagram showing the different methods used to identify impediments to ICM at the three case study sites, their input, along with the literature review into the development of a global ICM survey resulting in the identification of the nature of the different global impediments to ICM.

3.3 Results

Integrated Coastal Management on Curaçao, the Netherlands Antilles

Curaçao is one of the five islands of the Netherlands Antilles situated in the southern Caribbean (Figure 2). The island is 444 km^2 in land area is surrounded by fringing reefs and is relatively flat, the highest point only reaching just over 200m. The island is dry with no fresh water reserves. The vegetation consists of cacti and thorn scrub. The lack of land-based run off into the marine environment has enabled the coral reefs to develop close to the shore, providing sand for the beaches and a recreational playground for scuba divers and snorkellers.

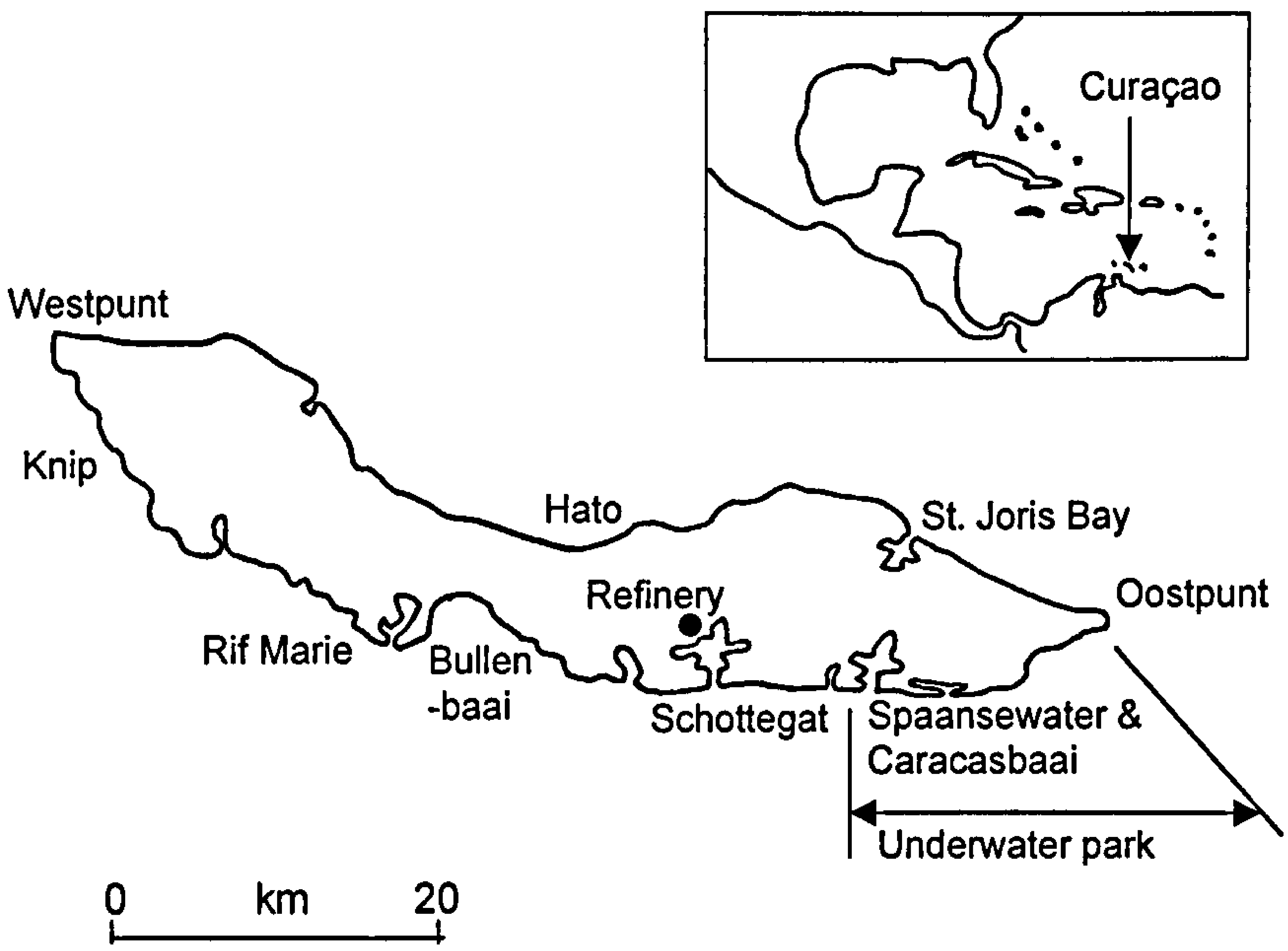

Figure 2 Map of Curaçao indicating the locations of the major coastal activities and an inset map showing Curaçao's location in the southern Caribbean

The coastal zone of Curaçao supports a wide range of activities and industries. It supports the largest natural harbour of the Caribbean, the Schottegat Harbour. Consequently, Curaçao has a large industry base of shipping and port activities. These are focused around the Schottegat, Caracasbaai, Spaansewater and Bullenbaai. The activities include the loading bays for tankers, reception facilities for oil terminals, the refinery, the dry dock and mooring facilities. The refinery creates the largest economic sector bringing a considerable income to the island as well as providing employment. Another industry vital to the island is the desalination plant, located on the Zakito lagoon just west of the entrance to the Schottegat Harbour. It is the source of drinking water for the whole island.

Tourism is a rapidly expanding business on Curaçao with dive tourism growing particularly fast. The dive tourism largely consists of shore-based diving. At present there are around 8,000 divers visiting each year out of the 209,000 tourists (Central Bureau of Statistics, 1998). New hotel complexes continue to be built, such as the resort development at Rif Marie in 1996. These are mainly concentrated along the South Coast.

Fisheries are relatively small-scale with fishermen usually going out on day trips (van't Hof et al., 1995). There are also a number of part time fisherman and recreational fisherman. Most of the fishing is pelagic and carried out with lines rather than nets, for Dolphin fish and Red Snapper. Some reef fishing occurs, also with lines and traps. The reef is also used as the source of fish bait.

The coastal zone is also an important site for local recreational activities. Local recreation in the form of swimming, boating, jetskiing and fishing is widespread around the island's coastal waters. Due to the purchase of coastal land, access to the water is becoming increasingly difficult. Many of the artificial beaches are closed off to the public or are accessible through a fee payment system. The coastal zone is also an important area for residential developments. Much of the land bordering the water is occupied with residential developments. The 1997 island population was 153 664 (Central Bureau of Statistics, 1998). The island's small area means they all live within easy reach of the coast.

Many of the pollutants and waste generated on the island are disposed of in the ocean. Sewage, some raw and some treated, is discharged into the inland waters and offshore. One major area where sewage is discharged untreated is the Punda region. Industries also discharge into the surrounding waters, a major area is that of the Schottegat bay and on the north coast at Hato.

Main issues in the Curaçao coastal zone

The issues important to ICM in Curaçao, identified through the structured interviews represent a broad cross-section of interests, opinions and concerns. The major issues have been distilled from the information gathered and are described in the following sections. The number in parenthesis following each statement indicates the percentage of stakeholders that identified the issue (total number being 17). This information was given in confidence during the interviews; consequently, it is not possible to individually reference the statements and information given. The issues have been grouped into the following categories:

- Coastal development
- Loss of public access to shoreline and public beaches
- Land based pollution
- Solid waste disposal
- Construction of artificial beaches
- Loss of mangroves
- Over fishing

Coastal development

Coastal development is seen as occurring in an uncontrolled and unplanned manner (65%). Pressure from entrepreneurs to develop has lead to ad hoc decisions (6%). This development, although recognised as being good for the island's economic growth, causes damage to both the land and water ecosystems. Runoff and erosion seen during construction as well as the dumping of construction waste affects the reefs directly (29%). Once the developments are completed, sewage is produced and disposed of into the coastal waters, again affecting the reefs (47%). Tourist developments may also use pesticides and herbicides on the gardens. These are also likely to be used on the proposed golf courses.

Loss of public access to shoreline and public beaches

One major social issue relating to the unplanned development is that of the decreasing public access to beaches (29%). The beaches are utilised by the local population for various recreational activities and as more land is bought up the points of access decrease. Land adjacent to the beaches is being bought up by developers who are then able to close access to the public.

Land based pollution

Curaçao is an island surrounded by coral reefs. These reefs are important both biologically and economically. In 1996, there were 16 dive operators registered with the Curaçao Dive Operators Association (CDOA, personal communication). It is estimated that 38% of the tourists visiting the island use the reefs for scuba diving or snorkelling (Curacao Tourism Development Board, 1996). Certain areas along the coast have seen a decline in the health of the reefs (Bak & Nieuwland, 1995). This is caused by land-based pollution (71%), the effects of artificial beach construction (47%), and physical damage caused by anchors and divers (24%). The main sources of land-based pollution are in the form of industrial wastewater, sewage and solid waste. This is generated from the industries on the island and from the residential areas (Buth & Ras, 1992).

Currently the sewage treatment capacity is insufficient (18%) and some of the sewage is disposed untreated into the inland bays, e.g,. Piscaderabaai and into the nearshore waters though outfall pipes, e.g., Punda. Where the sewerage system is absent, the houses make use of cesspools, which in small quantities may be a useful alternative although in concentration this can lead to severe pollution of the ground waters. Some of the waste from the residential areas is disposed of, directly or through the treatment plants or sewage system. This has lead to the pollution of these bays that have a high residence time with little water replacement (Buth & Ras, 1992). Discussions are held as to the benefit of opening these bays to the sea, where the waters will be flushed although this would destabilise the sediment in the bay and cause siltation and runoff damaging the reefs.

The Schottegat bay is seen as the major point of land based pollution on Curaçao (41%). The water quality is poor and flows out into the nearshore water creating a plume of discoloured water that passes along the shore with the current. Some of this waste disposed of into the Schottegat is thought to be toxic and thus harmful to the surrounding waters (Buth & Ras, 1992). Those industries specifically named as major polluters were the paint factory, the cannery Allimento Antillian, the oil refinery and the dry dock. Water from the Schottegat is also used as cooling water in the oil refinery. In the dry season this has been estimated at almost 100% (6%).

Other problems relating to liquid waste disposal that were identified were the industrial waste along the north coast (12%), and the hot water and toxins from the water desalination plant (6%). These cause bleaching of corals and stresses to the mangroves and waters of Zakito.

Solid waste disposal

One unsightly and obvious issue on Curaçao is that of garbage (29%). Officially, this is collected by Selikor and processed before being disposed of in landfills. However, the collection of waste appears insufficient, as a huge amount of garbage is illegally dumped on land and in the sea from private houses as well as industries (35%). Presently it is illegal to dump anything along the coast except dead animals and butcher's waste (6%). The landfills appear to remove the waste but they are not sealed and consequently seepage from the waste will occur into the ground (6%). At present, this is not monitored and no estimation is made as to the quantities of pollutants involved.

Construction of artificial beaches

Both beaches and reefs are a tourist attraction. On Curaçao, they are often in conflict with one another (29%). Curaçao does not have white sandy beaches, consequently artificial beaches have been constructed in front of several hotels. The design of these beaches has been far from optimal and the result is the movement of sand off the beaches onto the reefs (47%). In some places the sand actually covers the coral completely. The engineering solution to the loss of sand has been replenishment. Replenishment of sand has also occurred on the natural beaches where the sand was considered insufficient. Wave action removes much of this sand depositing it on reefs lying upto 100m off the coast (Meesters, 1995; Meesters et al., 1998).

Currently there is no monitoring of the sand lost from the beaches (6%). Partly resulting from this, no improvements are made to the beaches. Structural damage to the beaches and containing dams often occurs after storms and requires repairing afterwards. Currently the Department of Public Works is responsible for these beaches, although no funds are allocated for improvements and maintenance (6%). Most of the beaches have been constructed with funding from the Dutch Government and other aid agencies. This financing covers the construction phase only and not for the subsequent improvements and maintenance. This financial constraint is in addition to the lack of monitoring constraining any effective maintenance and improvements that may limit the sand lost from the beaches.

Loss of mangroves

The loss of mangroves is another environmental problem (18%). These have decreased by an estimated 30% over the last 10 years (6%). Deforestation also leads to increased runoff and gullies forming in the landscape (6%). This sediment rich runoff, not only contains any topsoil that may have existed on the land but reduces the water clarity, affecting fish and corals living in the receiving waters (12%). Most of the clearing of the mangroves is undertaken for development projects. The mangroves are found mainly around the inland bays. The two main areas are that of Spaansewater and St. Jorisbaai. Spaansewater is potentially threatened by a development project (12%).

Over fishing

Fisheries are an issue on Curaçao (53%). Little research is carried out on the fisheries as they are already seen as depleted (6%). Estimates made in 1980 by Dienst Landbouw Veeteelt en Visserij (LVV, Department of Agriculture, Animal Husbandry and Fisheries) found the fish catch to be in the region of 1000 metric tonnes, which was under the theoretical sustainable yield. Although overfishing of the stocks is thought to be the major reason for the decline (12%), other factors such as pollution could affect the productivity. At present, the south coast is overfished, and the north coast is now the site of much of the current fishing activity. At present, there are no regulations on who can fish and what amounts can be fished. There are also no regulations on the size of the nets and the size of the mesh used in the traps (6%). Spearfishing, although illegal, is difficult to control and is practised all around the island (6%). This selectively removes some species (*e.g.*, turtles) to dangerous levels.

Impediments to ICM on Curaçao

At present, there is no ICM plan on Curaçao. The issues and problems identified and reported in the previous section indicate that ICM may be a useful tool in dealing with this complex mix of issues. The stakeholders were asked during the interviews, to identify the impediments they perceived affecting the ability of the island to implement ICM. Table 1 shows the impediments falling into the 6 major categories identified as:

1. Lack of political capacity and will
2. Inadequate institutional capacity
3. Insufficient legislation and the legal process
4. Lack of public participation and awareness
5. Conflicts among institutions
6. Insufficient scientific support for management

The main impediment category can be seen as the lack of political capacity and will, which was identified by all of the stakeholder groups. Approximately 50% of the interviewees identified inadequate institutional capacity, insufficient legislation and lack of public participation. 30% identified weak institutional structure as an impediment and 20% the scientific support for management. This would indicate that lack of political will is perceived as the major issue that needs to be overcome if ICM is ever to be implemented on Curaçao. These categories are expanded in the following sections based on the information given in the interviews.

Table 1 Number of stakeholders in Curaçao identifying each ICM impediment

Category	Impediment	# Responses
Political attitude and participation	Lack of political will	9
	Political awareness	4
	Economic interests over environmental/ inability to say 'no' to development	3
	Lack of responsibility for decision	1
Institutional capacity	Lack of expertise	3
	Limited financial capacity	5
	Size of island makes vulnerable to external influence	1
Legislation and the legal process	Lack of legislation and capacity to make new legislation	5
	Lack of enforcement	3
Public attitude and awareness	Lack of public awareness,	5
	No value placed on nature	1
	Conflicts of interest	2
Institutional structure	Co-operation between institutions	3
	Conflicts between organisations	2
Scientific support for management	Lack of knowledge	2
	Lack of monitoring	1

Lack of political capacity and will

There was a general feeling that political awareness about integrated, comprehensive planning was lacking and that the political will to achieve this was also lacking. The interviews identified a series of doubts regarding the strength of the political system to be able to deal with ICM problems and issues. The motivation behind some of the decisions was thought not to have the vision required for long term sustainable planning. In the past decisions had been revoked, and plans altered leading to ad hoc decision making. Decisions also take a long time to be reached, during which, damage, pollution or certain undesired activities continue. This lack of political will and delayed decision making may arise due to a lack of concrete information.

The acceptance of environmental damage by decision-makers was identified as an impediment during the interviews. It was felt that decision-makers on the island do not realise the economic importance of preserving and restoring the present situation and are willing, in places, to allow further degradation.

Inadequate institutional capacity

The capacity of key ICM agencies on Curaçao is limited. The present environmental department of Central Government is small. This was seen to reflect the attitude towards environmental matters within the Government.

Curaçao, being a small island, is reliant on external financial support for many of the large development projects. In particular, the Netherlands provides support through the Cabinet for the Netherlands Antilles and Aruba (KABNAA). Typical projects receiving aid from abroad are sewage and wastewater treatment programmes and the construction of artificial beaches. Some of the smaller projects could be designed to be self-financing but would need to be implemented with awareness and information campaigns to inform the public of the reasons for charging for a previously free resource.

Insufficient legislation and the legal process

Not only is the co-ordination and co-operation between the government departments and other stakeholders lacking, but so are the laws and ability to enforce the laws lacking. It was suggested that some of these laws and regulations could be based on international environmental agreements *e.g.* migratory birds and pollution control. Currently there are no legal requirements for an environmental impact statement to be carried out before a development project starts.

Lack of public participation and awareness

It was felt that the main issues were held back and not communicated to the public. Without adequate information and education surrounding decisions, some opposition may be received. This mainly relates to the user fees where people are asked to pay for services which have been free in the past. The public backlash against conservation due to the location, size and definition of conservation areas in the Island Development Plan illustrates a public versus governmental conflict. Some of the conflicts arise because the island is small and the suitable land available for development is limited.

Several participants reported a deterioration of the education system, and an inflexibility to change and update the system to deal with issues relevant to today. Currently there is limited education focused on the marine environment and therefore a general lack of knowledge about the marine environment exists.

Conflicts among institutions

The first major institutional problem was highlighted in the definition of the coastal zone. There is split jurisdiction of this area on Curaçao. The Island Government has jurisdiction of the land and the Central (Netherlands Antilles) Government of the waters. This mixed jurisdiction over land and water leads to complications as to the whether the Island or Central Government has responsibility and which government departments are responsible for which activities. A similar situation has occurred with landowners and developers where there is a need for the appropriate definition of the rights and responsibilities so confusion and complications can be avoided in the future. In addition to the complex jurisdiction, a lack of co-operation and communication was identified between the different organisations. This was in part due to conflicting interests and management objectives. Conflicts were identified between the different users as well as between the environmental groups themselves.

Insufficient scientific support for management

The lack of knowledge and expertise in certain fields was thought to lead to unbalanced decisions. It will always be difficult to balance decisions when hard economic data is available and hard biological data is not. There is little monitoring and therefore limited data available on the impacts of certain measures. This leads to difficulties during the evaluation of plans, as no hard data is available as evidence. This has lead to projects continuing regardless of the uncertainty surrounding their impact. This is clearly seen with the construction of the artificial beaches. The lack of monitoring has halted any improvements being made to the beaches. Monitoring could also aid and assist in the enforcement of laws and regulations. Currently taking legal action against damaging developments is difficult if not impossible without the evidence that a monitoring programme may be able to produce. The lack of monitoring in most cases is due to the lack of finances to be able to undertake monitoring. Funding in the past has been secured for implementation of projects that excludes monitoring and evaluation and often ends before any monitoring and evaluation can take place.

Implementing ICM on Curaçao and overcoming the impediments

Planning and management for ICM in Curaçao involves a number of different institutions and stakeholders (Figure 3). Curaçao, as part of the Netherlands Antilles, has a two level government, Island and Central. The coastal zone of Curaçao at present falls under the jurisdiction of both the Island and the Central Government. The Island Government has control over the land and the Central Government has control over the waters. The Central Government has indicated the benefit of the Island Government being responsible for the territorial zone, extending 12 miles into the sea. The Island Government would then be responsible for the areas under the influence of the land based pollution sources. The Central Government would then have responsibility of the areas beyond the territorial zone and up to the economic exclusion zone. At present, the economic exclusion zone is 60 miles offshore.

At Central Government level, the Ministry involved in coastal management issues is the **Ministerie van Volksgezondheid en Milieu Hygiene** (VOMIL, Ministry of Public Health and Environmental Hygiene). On the island level, the **Eilandsraad** (Island Council) is the elected body of decision-makers who appoints the **Bestuurscollege** (Executive Council). This council is headed by the Lieutenant Governor and comprises nine commissioners, each with a portfolio of responsibilities that together cover all the governmental departments and those privatised companies still under governmental control. The departments are responsible for the planning and management of the islands resources. Regarding ICM, the following departments are seen as the most involved:

- **Dienst Landbouw Veeteelt en Visserij** (LVV, Department of Agriculture, Animal Husbandry and Fisheries) has responsibilities in maintenance of natural beaches, parks and the zoo. It is also charged with the management of the island's ground water resources. LVV is also responsible for **CARMABI** and **STINAPA**. CARMABI was originally the Caribbean Marine Biological Institute but since 1983 has been involved in both land and marine based biological research. STINAPA is the organisation involved in the management of the national parks, one being the Underwater Park.

- **Dienst Ruimtelijke Ordnening en Verkeer** (DROV, Department of Spatial Planning and Transport) has overall statutory responsibility for all development planning and control on the island. DROV was responsible for the preparation of the Island Development Plan.

- **Dienst Openbaar Werken** (DOW, Department of Public Works) is responsible for the provision of infrastructure for public agencies, e.g., the construction of social facilities like schools, housing and utilities, and infrastructure developments like the roads, airport, sewage systems and treatment plants. They also co-ordinate and supervise activities of development projects and capital work projects undertaken by contractors, e.g., the construction of the artificial beaches.

- **Milieudienst** (Environmental Department) is involved in the implementation of the Environment Policy Plan on the island. Their major task associated with ICM is the setting of waste disposal standards and the allocation of disposal permits. **Selikor** is the organisation responsible for the collection of garbage on the island.

- **Dienst Economische Zaken** (DEZ, Department of Economic Affairs) advises government on economic development options and policies with particular regard to the social impact of such policies. In this role, DEZ is responsible for macro economic policies, sectoral development policies, administering development aid, monitoring the social impact of economic development and monitoring price laws and housing rentals.

Some former governmental services have been privatised. Although they carry the status and structure of a private company, they are still under the guidance of the government and have an appointed Commissioner in charge. These services are:

- **Curaçao Ports Authority** (CPA) has the responsibility for facilitating efficient port operations. CPA has overall responsibility for management of St. Annabaai, the entrance to the Schottegat.

- **Curaçao Tourism Development Bureau** (CTDB) is the organisation that is responsible for overall administration of tourism in Curaçao. Its tasks are the administration and regulation of tourism in Curaçao, product development, physical tourism planning, market research, promotion of tourism investment opportunities and facilitation of tourism development projects, and human resource development.

- **Korsou Awa y Electriciteit** (KAE, Curaçao Water and Electricity Company) is responsible for the electricity generation and water production on the island.

There are several Non Governmental Organisations (NGO's) based on Curaçao. Some of these groups are specifically dealing with land issues and others with the issues relating to the reef. Many of these groups are not involved in the decision-making process even though, they may wish to be. Increasingly certain groups are called upon for advice regarding environmental matters. The environmental NGO's with an interest in ICM are **Defensa Ambiental, Amigo di Tera** and **Reef Care.**

There are a number of environmental consultancies based in Curaçao. These companies are carrying out work that spans engineering constructions to environmental assessments on recycling of wastes. CARMABI is increasingly undertaking consultancy work rather than solely the tasks from LVV. Other consultancies are **Consult Ambiental, Ecovision, DHV, Grabowski and Poort** who have done several projects for DOW as well as project developers, examples of coastal projects carried out by these consultancies are the construction and improvements of the artificial beaches and construction of sewerage systems.

Other non-governmental organisations that are concerned with management issues in the coastal zone are the **Curaçao Hotel and Tourism Association** (CHATA), **Curaçao Diving Operators Association** (CDOA) and the **University of the Netherlands Antilles** (UNA).

At present, there is no structured or formal ICM in Curaçao. However, there have been several initiatives for development plans and zoning plans. For example:

- Tourism development plan
- Reef management plan
- Island development plan
- Environmental policy plan
- Wastewater structure plan
- Solid waste plan
- Various plans for harbour development

One aspect these plans have in common is that they are primarily set up within one of the government departments rather than among several departments.

The Island Development Plan (DROV, 1992) sets out the proposed policy on urban and regional development for the coming 5 to 10 years. The plan was approved in 1995 by the Bestuurscollege

(Executive Council) and later adopted by the Eilaandsraad (Island Council) under the premise that any disagreements were dealt with. This required DROV, to prepare 450 statements in response to the letters they received. The plan is based on zoning certain areas for different activities. In total, there are 12 zones covering conservation land, residential, tourism and recreational areas, etc. This is the first initiative to zone parts of the island for conservation. Large areas of Curaçao remain in the hands of a few landowners and the plan has met with opposition when private land has been zoned for conservation.

The Tourism Master Plan (Robinson, 1993) has produced a series of reports and studies such as the Visitor Improvement Programme (VIP) and the Dive Improvement Programme (DIP). This Master Plan aims to 'identify the development principles, implementation strategies and necessary actions to achieve sustainable growth in tourism development' (Robinson, 1993). The plan aims to provide the platform for the evaluation of long-term development strategies. It is one of the first plans to look at economic development programmes and ecological conservation of the coastal zone together. The plan states that it adds to and complements the Island Development Plan. It has a separate component, the Curaçao Marine Management Zoning Plan (van't Hof et al., 1995) that deals with the conservation of the reef resources. The plan zones the entire marine area into multiple use zones.

The Environmental Policy Plan (DHV, 1990) was developed to describe the current environmental problems and propose management alternatives for mitigating these problems in the future. Those issues addressed relate to water and air pollution, solid waste disposal and nature conservation. The polluter pays principle was introduced with the accompanying awareness programmes. The mitigation of wastewater and land based pollution, is addressed in the Wastewater Structure Plan (Civil Engineering Caribbean N.V., 1991). This aims to rehabilitate the existing sewage system, and connect both the new residential areas as well as the existing unconnected areas. Once these areas are on line, the sewage will be brought to the treatment plants, also proposed for expansion. As well as this, the plan proposes to increase the reuse of water.

The Curaçao Ports Authority (CPA) has several planned harbour developments based around Schottegat, the capital and central harbour area. In addition, they have plans to develop Spaansewater, a protected lagoon in the east of the Island, for oil reception facilities. This area is currently recreational and residential area. CPA is also planning the development of a mega-cruise ship terminal at the entrance to the Schottegat harbour, to expand their existing, but limited capacity.

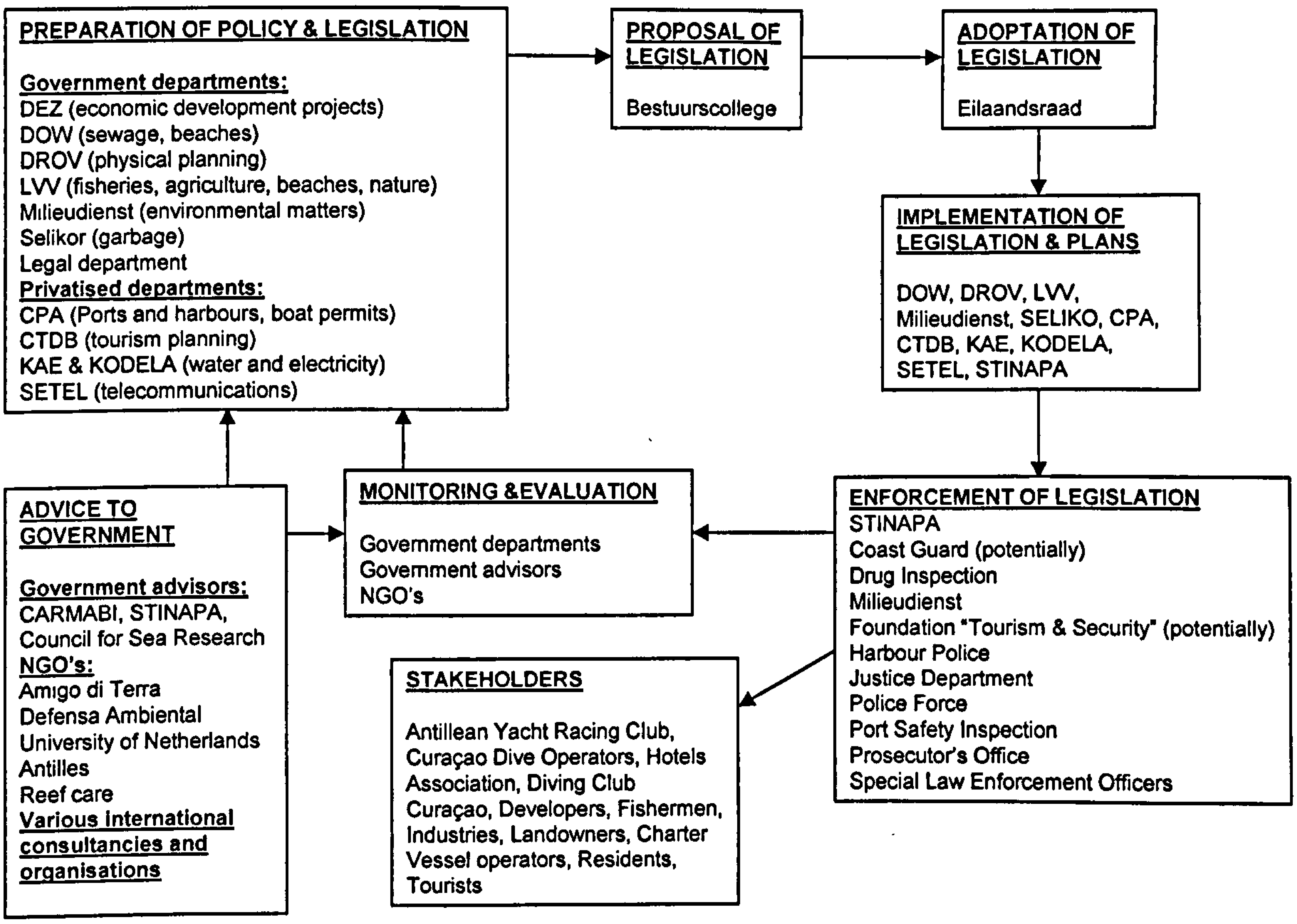

Figure 3 Flow diagram illustrating the main institutes and stakeholders involved at the different stages of the ICM decision making process on Curaçao. Arrows indicate the process starting from plan development through to implementation, enforcement, monitoring and evaluation, completing the cycle to begin again with revision of plans.

Overcoming the impediments to implementing ICM on Curaçao

Implementing ICM in Curaçao will not be an easy task. Through the interviews it was identified that ICM needs to focus on environmental conservation and protection as a primary objective. However, the importance of economic and social objectives was also identified. In order to implement any activities that may preserve the environment as a primary goal, there needs to be substantial change in the political attitudes. Lack of political will and lack of awareness of the importance of the environment and the limited ability to have a long-term vision for sustainable planning will need to be overcome before effective ICM can be implemented.

In addition, the limited resources to implement ICM are perceived as a constraint on Curaçao. These limitations relate to manpower, funds and expertise, partly due to the small size of the island. Consequently, there is limited knowledge on ICM on the island. This lack of knowledge on integrated approaches has resulted in separate plans being formulated. On the financial side, large projects such as the development of sewage systems and wastewater treatment plants are unable to be supported entirely by the Government itself. These are then dependent on foreign aid to be completed. Other developments may be constrained by the limited infrastructure currently on the island.

The legislation and legal process also needs strengthening for effective ICM to be implemented. Laws need political support to be effective and enforcement agencies need the mandate to be able to take effective action if a law is violated. The public will be more responsive to environmental conservation and protection for their long-term benefit if they understand the implications of short-term planning and environmental degradation. Raising public awareness may also be instrumental in increasing pressure on Government and as a consequence raise political will to take effective and sustainable planning decisions.

Communication between management institutions as well as between scientists and management could assist in the process to implementing ICM. Departments need to share information more effectively and communicate their activities to one another. Managers need the support from the scientists to be able to balance the decision making process. Without any support, decisions will continue to be made on economic grounds with no concern for the impacts a decision may have on the environment.

Integrated coastal management on Bonaire, the Netherlands Antilles

Bonaire, like Curaçao, is one of the five islands of the Netherlands Antilles situated in the Southern Caribbean (see Figure 4). The governmental structure is similar to that of Curaçao, with the Central Government of the Netherlands Antilles responsible for policy for the five islands and the Island Government responsible for island policy and management. The scale of activities on Bonaire are however, smaller than Curaçao. The island covers 288 km^2, has a dry climate with no surface rivers or streams and cacti and scrub vegetation. The bedrock is fossilised coral, which is porous and characterises the island with caves and caverns. The population in 1997 was 14, 539 people (Central Bureau of Statistics, 1998). The population is centred on Kralendijk, the capital. The visiting population reaches 63,000 a growth of 50% since 1990 (Central Bureau of Statistics, 1998).

The lack of run off from the land into the marine environment has enabled the reefs to develop around the whole island and develop close to the shore. The reefs start at the shoreline and gently slope to around 10 metres depth between 50 and 100 metres from the shore. The reef then drops off at an angle of 45 degrees. In the north, the reef drops steeply to over 60 metres, whereas the southern reefs are characterised by a double reef system reaching a maximum depth of 30 metres. The reefs of Bonaire have been described as some of the best remaining coral reefs in the Caribbean (Roberts & Hawkins, 1994). The coral reefs are the basis of the island's income. Tourism is based on scuba divers. In 1998, there were 28,000 scuba divers visiting Bonaire, the majority (80%) arriving from the USA (Bonaire Marine Park, unpublished data). The accessibility of the reefs has made this the major industry. Tourism is focused around Kralendijk. A high percentage of the diving, 60-80 % (Bonaire Marine Park estimation) occurs around the small satellite island of Klein Bonaire.

Other economic activities are small scale in comparison to tourism and its related activities. In the north of the island, there is an oil reception facility and the southern part of the island is characterised by flooded salt plans where the dry climate suits the evaporation required for solar salt works.

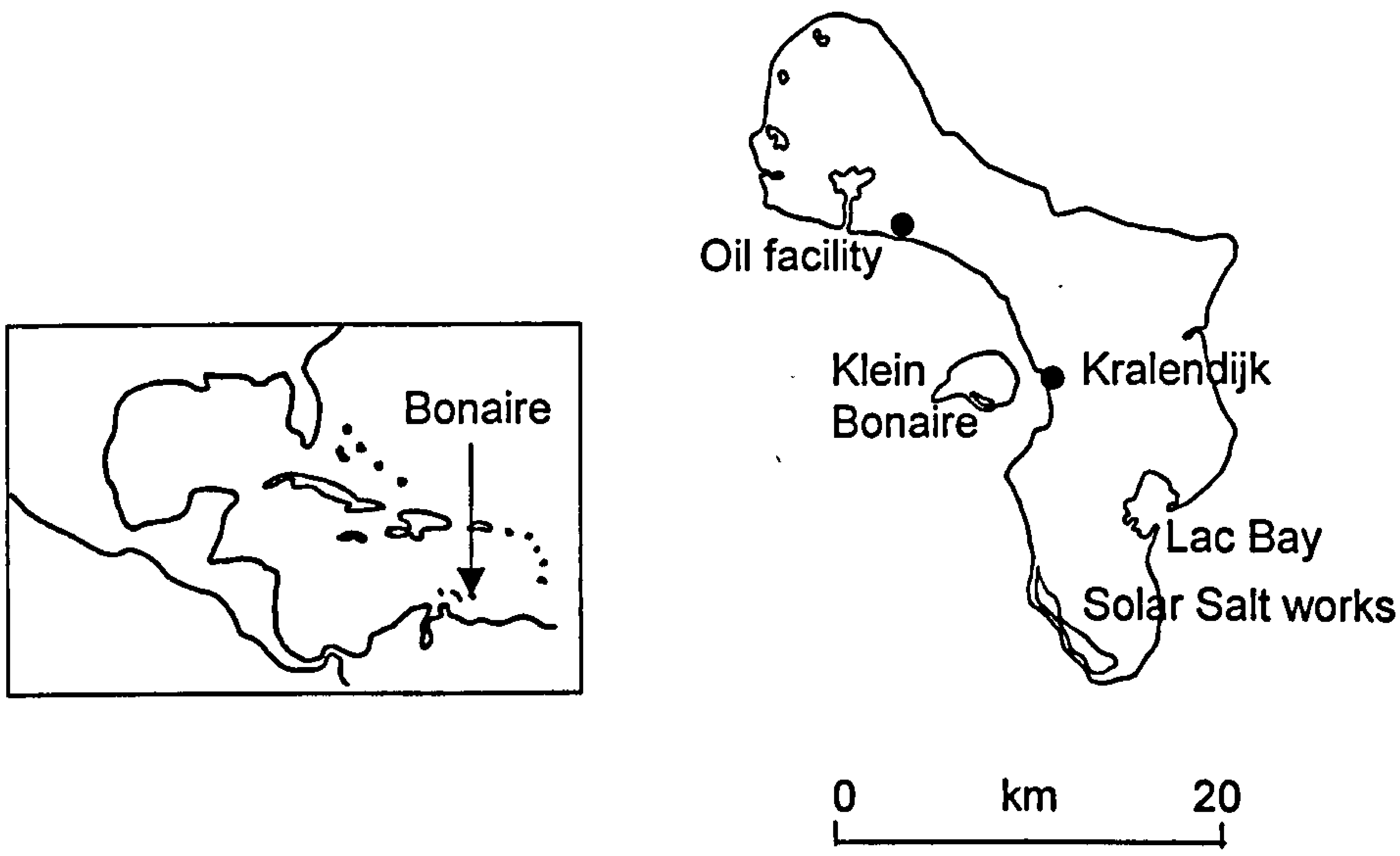

Figure 4 Map of Bonaire showing the location of the main coastal activities and inset map of its location in the Caribbean

Main issues in Bonaire's coastal zone

The main issue ICM needs to tackle on Bonaire relates to the preservation of the coral reef. The economy is dependent on tourism, which is linked to the dive tourism and therefore the reef. The main threats to the coastal zone of Bonaire come from increasing coastal development, mainly driven by the tourist community but also from residential developments and the limited infrastructure to deal with the wastewater produced. Increased levels of wastewater entering the near shore areas has led to increased nutrient enrichment encouraging the growth of algae and eventual degradation of the coral species. In addition, building regulations are limited and increased run off has led to high levels of sediment reaching the fringing coral reefs and smothering reefs.

Coastal development

Part of the attraction of Bonaire to tourists is the unspoilt nature of the island. Several tourists voiced concern over the increasing development seen on the Island. They choose Bonaire for its exclusivity. To sustain the quality of the reefs and be able to provide the adequate infrastructure, Bonaire needs to make the decision to curb tourism and provide quality rather than quantity. This will be the only way to maintain the long-term tourist industry. Lessons can be learned from some of the other Caribbean islands that elected for mass tourism without providing adequate infrastructure and have been rewarded with short-term gains followed by a gradual decline in environmental quality. Often the concentration of population that is required for the additional employment created is not carefully planned for, Montego Bay in Jamaica is one such example.

The real test of reef conservation on Bonaire will come in the next few years as the pressure is on the island for economic growth. The question at present is how much development can Bonaire sustain and whether or not the number of divers can continue to rise as they have done in the past. Bak and Nieuwland (1995) already report long-term changes on the reefs of Curaçao and Bonaire. A study into the carrying capacity of the reefs sets the number of dives per site to be around 4,500 per year per site (Dixon et al., 1993). Assuming that the dives are spread equally over the 72 public dive moorings, this would lead to a potential total of 324,000 dives per year. This is not the reality as the majority of dives are focused around the dive moorings of Klein Bonaire, which are visited daily by dive boats. In addition, shore dives can be made at any location along the coast, which means that the buffer zones between the moorings are also dived. Dixon et al. (1993) suggests a more conservative number of dives as the sustainable maximum at 180,000- 200,000 dives per year. With 27,000 divers making on average 8-10 dives per person, the number of dives made in 1998 was over 224,000, which exceeds this theoretical capacity.

The Bonaire Marine Park regulates the number of divers per site through limiting the boat size able to use the dive moorings. The maximum number of divers at a site would therefore be around 20. On average, the number of divers in a boat may be between 7 and 10. As only one boat is allowed per mooring, sites are usually dived not more than once in the morning and once in the afternoon making a lower estimate of 15 divers per day. Diving in Bonaire is year round so at the most popular sites on Klein Bonaire, the number may already reach over 5,400 per site per year. Establishing carrying capacities is therefore a useful indicator for management but how to limit and enforce the number of divers is in practice more complex. The Marine Park could limit the number of divers it allows per year by limiting the entrance tags it issues. However, this would mean that divers visiting Bonaire towards the end of the year would not be able to dive, as no entrance tags would be available. This would mean that implementation would be extremely hard if not impossible. The only way to enforce the diver numbers is with comprehensive planning that focuses on quality rather than quantity.

Wastewater treatment

As hotels and houses increased along the coast, there were no regulations in place to enforce the adequate removal and treatment of wastewater. There is no wastewater treatment plant or sewage collection system for the island. Initially the hotels disposed of sewage into soak away systems or septic tanks. However, the capacity of these was often exceeded and the leaching hole was developed which was a hole drilled into the bedrock where the excess sewage was disposed into. This system does not have any holding facilities so the untreated waste soon enters the near shore area, which is the location of the reef flat. Hotels have become more conscious of this issue, as well as being able to cut costs by utilising their wastewater for watering their gardens. However, the quantity required in the garden is often less than the quantity produced. Untreated wastewater is not only a human health hazard but the nutrients contained in the wastewater encourage algal growth that will eventually smother coral species resulting in an algal reef. As the corals are degraded, the capacity of the reef structure to grow will be diminished resulting in erosion of the reef structure. The reef structure provides shelter for many of the coral reef species of fish and invertebrates as well as providing protection to the shoreline from waves and storms.

The wastewater entering the nearshore enters as a non-point source. As a result, pinpointing the main pollutors and prioritising action is not easy. It is also not known exactly how many nutrients remain in the wastewater as it enters the marine system. These uncertainties have meant that the pollution has been allowed to continue. There is no one person who can be held responsible. It has now reached a level where there is no single, financially feasible solution, which can be implemented to solve the issue. However, there has been an increased awareness amongst developers and Government for this issue. This has been a joint effort involving the Marine Park, the environmental Non Governmental Organisations (NGO's) and the some of the Dive Operators over the last ten years. More recently, the Government has given its support to Selibon, the garbage collectors to lobby international organisations for funding to install wastewater collection and treatment facilities. However, the time involved in securing the funds and constructing the collection system and facilities it is unlikely that the project will be functional within the next 10 years. This has lead to the stakeholders to consider short-term emergency solutions. The Habitat Hotel was one of the first dive resorts established on the island by Captain Don a well-known outspoken island character, is considering trucking its wastewater to inland ponds where Captain Don now runs a garden centre and will re-cycle the wastewater and utilise the effluent for cultivation.

On an island as dry as Bonaire and reliant on desalinisation of seawater for freshwater, it would make sense to utilise this wastewater for market gardening. The implementation of such a scheme is reliant on external funding agencies. The European Union has stated its interest for several years now although the plans have never been finalised.

Impediments to ICM on Bonaire

The main impediments to ICM on Bonaire were identified through the experience of participating in ICM as assistant manager of the Bonaire Marine Park for 15 months. The impediments fall into four main categories listed as follows and detailed in the following sections:

1. Limited institutional capacity
2. Limited awareness of the value of the reef
3. Lack of political support for environmental protection
4. Lack of enforcement capacity

Limited institutional capacity

Both human capacity and financial capacity are limited on Bonaire. There is only one person specifically appointed to carry out nature conservation and environmental protected within the Government. Enforcement of the Marine Environment Ordinance is led by one manager of the Marine Park and four rangers. None of the rangers have police powers and subsequently enforcement relies on an educative and informative approach to offenders. This is not always successful and the Marine Park relies on the support of the Island's Chief Prosecutioner. Lack of personnel means that there is little or no internal monitoring of the reefs, fisheries or water quality. Monitoring is usually carried out by external personnel, which usually relies on grant funding opportunities. Some limited coral reef monitoring is undertaken by a number of non-scientist volunteers trained by the Marine Park.

Limited awareness for the value of the reef

Locally on Bonaire, there is limited awareness of the importance and vulnerability of the reef. A joint project established by the environmental NGO's and funded by World Wildlife Fund Netherlands has enabled the position of Conservation Education Officer (CEO) to be created for a three-year period. This is enabling nature conservation issues to be brought into the schools and extra-curricular activities for children and adults to be organised. Prior to this project, there was no nature education in the schools. This is slowly being introduced through the CEO. As with all externally funded projects, this has a limited time scale and expecting a change in the teaching curricula and styles within three years is ambitious. However, one successful programme that was run by the CEO was based on the 'Rare' programme from St. Lucia. This raised awareness for the protection of the endemic and endangered yellow shouldered parrot, the Lora through a mass publicity and awareness raising campaign. Questionnaires at the beginning of the campaign assessed local awareness and knowledge of the Lora. These were compared to a second questionnaire held at the end of the campaign assessing whether or not people were more aware and more sensitive to the threats to the Lora. The campaign was also able to highlight the priority areas for information and protection for the parrot. Similar campaigns could also be established for the coral reef.

A longer standing programme run by the Bonaire Marine Park and Sea Turtle Club Bonaire, Tortugnan di Boneriu (Turtles of Bonaire) holds club based activities for children relating to the marine environment. The children have been trained to snorkel with the Bonaire Marine Park first and then take part in classroom sessions and snorkel trips. Many of these children would not have the opportunity to learn to snorkel otherwise. A further activity to help local children get involved in the marine environment is through the scuba-training programme that the Marine Park has organised for the last couple of years. Scuba instruction is given by a volunteer with a holiday home on Bonaire, who trains the local children free of charge. This is arranged through the Marine Park, who covers the costs of the materials and provides the equipment and transport for the kids.

However, the CEO is a post that has finite funding and the Tortugnan di Boneiru Club has reduced its activity due to personnel constraints. Both programmes have been looking to recruit a full-time local educationalist who can be trained by the current CEO. However, there is very limited capacity within the island. Being local is an important criterion for the post. The current CEO is Dutch and made her first priority to learn the local language Papiamentu. This had definitely increased her acceptability to the children but also the teachers and other organisations with whom she must work. There is some resistance to foreigners on the island. This means that as a foreigner gaining acceptance, may take a substantial time before achieving co-operation from certain groups.

Lack of political support for environmental protection

A second type of awareness relates to prioritising government decisions. The decision-makers still see a choice between economic development and environmental protection, rather than realising these can occur at certain levels together. There is a definite need to raise awareness on the economic importance of the reef to the long-term development of the island. However, the government faces pressure to develop the economy further and increase the standard of living for local people. Businesses are becoming harder to sustain and the concern from the tourism board was raised as the number of tourists were stabilising in 1998. This can be explained by the reduction in international flights arriving on the island.

Lack of enforcement capacity

Even though there is support for controlled development and respect for the marine environment, there are still violations of the legislation. Any shoreline development requires permission from the Marine Environment Ordinance, which can involve a lengthy permit application procedure. Violations of this nature involving the construction of small platforms, piers and steps into the water creating access onto the reef are often made when the Park Rangers are off duty, during the evenings, weekends and bank holidays. No cases have resulted in a structure being removed from the water or a violator being fined for this activity. This means they continue. The enforcement procedure for such activities is weak and often those violating the ordinance are likely to have some connection to the Government and little can be done.

However, there are certain activities that have been eliminated by the provision of alternatives or public support. Anchoring has been virtually eliminated from the island by the provision of public mooring buoys. There are over seventy public dive-moorings, which can be utilised by boats of limited size for a fixed period. In addition, there are forty public yacht-moorings placed in town and there are two marinas available for visiting yachts. Fishermen have been provided with moorings by the Marine Park and residential yachts can apply for moorings. The dive operators inform the Marine Park when a mooring needs repairing if it is not seen on a regular ranger patrol. This system works effectively and the use of the moorings is respected by the local dive boats who in turn help to enforce the rules. The system is also effective because there is no need for boat owners to utilise their own anchor equipment.

Implementing ICM on Bonaire and overcoming the impediments

As with Curaçao, there is no formal structure for ICM on Bonaire. There are a number of organisations involved in ICM activities. The Management structure is similar to that on Curaçao although involves a smaller number of organisations. The preparation of policy and legislation regarding the coastal zone typically involves the Environment Department within **Dienst Ruimtelijk Ordening en Beheer** (DROB, Department of Land Use Planning and Management). For much of the work relating to the coral reefs, the **Bonaire Marine Park** (BMP) plays a major role in advising Government. The **Tourism Corporation of Bonaire** (TCB) is the quasi-government organisation responsible for the promotion of the island for tourism development as well as to tourists. Fisheries is managed by the **Dienst Landbouw, Natuur en Visserij** (LNV, Department of Agriculture, Nature and Fisheries), although they are not particularly active. Nature conservation is carried out by the Environmental Department within DROB. **Selibon** plays a much larger role on Bonaire than its sister organisation, Selikor on Curaçao. Selibon manages all aspects of waste disposal on the island and are currently securing funding for the provision of a wastewater treatment plant.

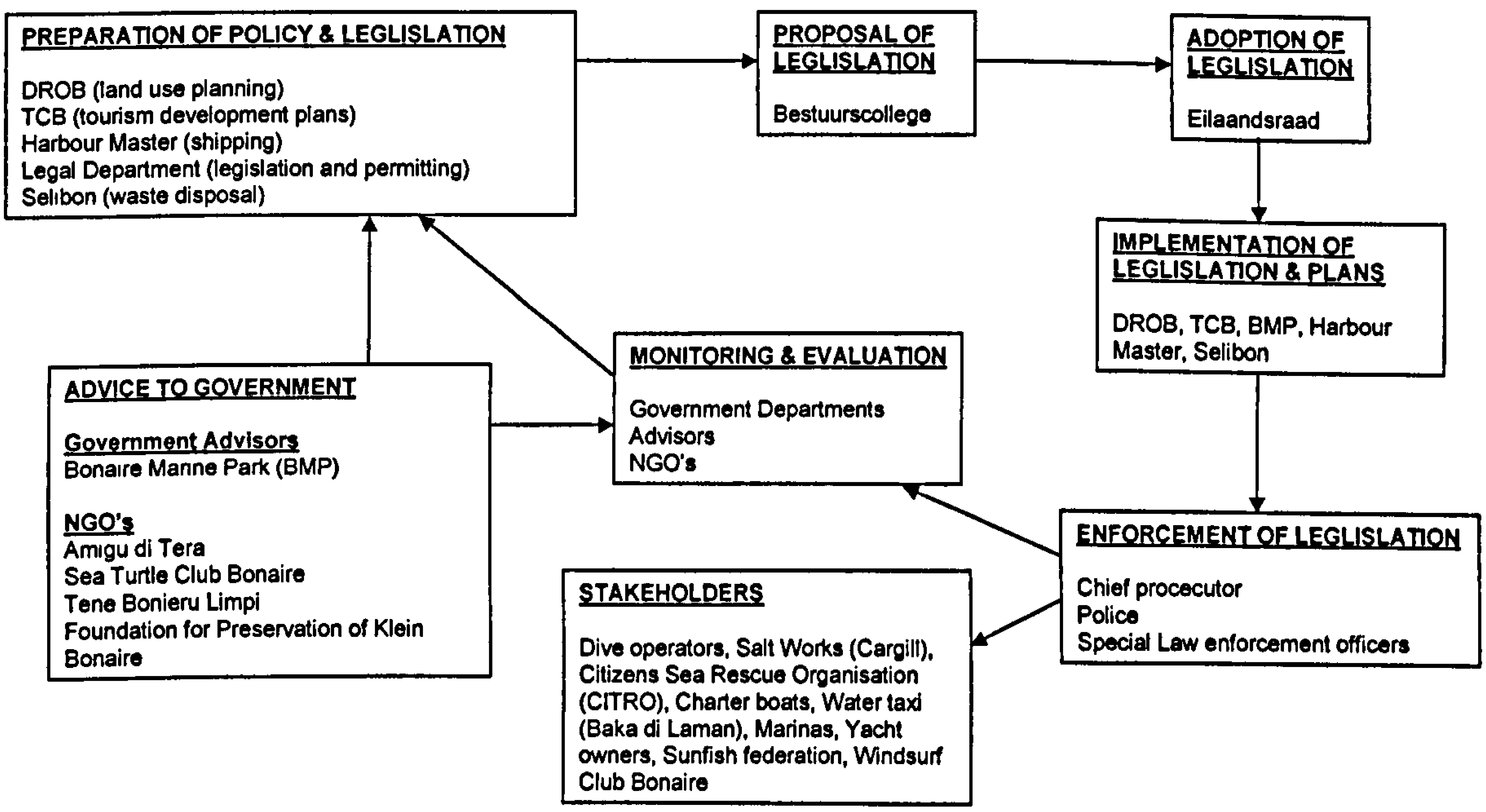

Figure 5 Flow diagram illustrating the main institutes and stakeholders involved at the different stages of the ICM decision making process on Bonaire. Arrows indicate the process starting from plan development through to implementation, enforcement, monitoring and evaluation, completing the cycle to begin again with revision of plans.

There are several environmental NGO's on Bonaire. For example, the **Sea Turtle Club Bonaire** (STCB), **Tene Boneriu Limpi** (TBL, Keep Bonaire Clean), **Amigu Di Tera** (Friends of the Earth) and the **Foundation for the Preservation of Klein Bonaire.** Along with the Bonaire Marine Park, these organisations have formed an informal alliance and have several joint projects. The dive operators also operator under an alliance called the **Commission for Underwater Resort Operators** (CURO) The hotel and tourism operators also have an alliance called the **Bonaire Hotel and Tourism Association** (BONHATA). The sustained and multiple use of the coastal zone on Bonaire, relies on the ability to preserve the coral reefs. Bonaire has been at the forefront of reef conservation for several decades now (van't Hof, 1997). In 1961, legislation was introduced to ban the collection, hunting and selling of any turtle products. This was followed in 1971 when a five-year ban on spearfishing was introduced. This ban was then extended in 1975 indefinitely. At the same time, the corals received protected status and it became illegal to break coral, take it from the water or sell it. The Bonaire Marine Park was initially established in 1979 with grant funding from Werld Natuur Fonds (WNF, World Wide Fund for Nature for the Netherlands), the Government of the Netherlands Antilles, the Island Government of Bonaire and the Government of the Netherlands. The philosophy behind the development of the park was based on a long-term vision. They realised that to enjoy long-term benefits from the reef system, it needed to be used wisely and any negative impacts should be avoided (van't Hof, 1997).

The park was well established by 1982 and legislation had been submitted to the Island Government for approval, public moorings had been installed and information leaflets had been produced. However, as the grant funding ran out so the activities were reduced. The moorings that had been installed were maintained through the dive operators. Gradual concern over the lack of management and the negative image this portrayed for the island lead to the re-vitalisation of the Bonaire Marine Park. The park was re-established in 1990 with additional funding from the Dutch Government. The funding was given on the understanding that the park would be self-financing by the end of the three-year period. By 1992, the park had become self-financing through the implementation of a diver-fee of US$10 per diver (van't Hof, 1997). This remains the same today.

The park is currently managed on the income from the diver fees, which amounts approximately to US$ 270,000 per year. This income has to cover the salaries of the staff, the maintenance of the 70 public yacht moorings, educational and research programmes and running of the 2 boats and 4 vehicles. The full time staff consists of a full time manager, a chief ranger and three rangers. There are three additional administrative staff shared with the Washington-Slagbaai Park, which is the terrestrial park on the island.

ICM on Bonaire has not been developed as a specific programme or activity; rather the management along the coastal zone has evolved into a form of ICM. The integration of institutions has been successful on Bonaire where the overall goal of conservation and sustainable use has been common to all. The groups are generally motivated by different reasons. For example, dive operators are reliant on the health of the reef for commercial gains through continuing tourism, the Marine Park's interest is conservation but for the island's sustainability. This has formed a healthy starting point for ICM where the common goal is agreed. There is, however disagreement as to what is the sustainable level of use.

The island now needs concrete data on the status of the reefs to be able to compare this with past data and make spatial assessments as to the state of the reef. This is needed to assess the reef's carrying capacities and identify if and where reef degradation is seen. This can then support the development of a comprehensive plan for the future development of the island. At this stage, the Government needs to be considering alternative options to dive tourism.

Environmental awareness amongst the public, within the schools and slowly within Government is increasing. This has been successful due to local grass-roots initiatives from the environmental NGO's. By forming an alliance together, they have secured external funds for projects that would otherwise have not been implemented. In addition, as a united group they have more power when lobbying the Government on certain issues. The Government is not able to single out an organisation or an individual but is confronted by a group of organisations which makes the position of the NGO or the individual heading the NGO more secure.

There is still the need for proof that increasing development may lead to further degradation of the coral reef, the basis of the Island's economy. This needs to be undertaken on a sensitive basis. Any evidence found should be kept at first as internal information to the island. The Government needs pressure to react and be given options to plan for the future. There have been cases when external scientists have broadcast their speculative results in the American Press, believing this publicity would pressure governments around the world to raise the priority of reef conservation. This however, had the opposite effect on Bonaire and created mistrust between the Government and the Marine Park, as well as some of the dive operators who perceived it as a way of conservation to sabotage dive tourism.

The success of Bonaire can be pinned down to a few key individuals who have been leading the main coastal management organisations and raising awareness as to the importance of the reef. It can also be attributed to the limited economic activities on the island and the fact that there does exist a common goal to sustain the coral reef in order to sustain the island's economy. The challenge will come in the next few years as the Island tries to secure funds for the treatment of its wastewater. The island Government also needs to realise and start the search for economic alternatives to the dive tourism industry to ensure no additional pressure is put on the reefs. This is particularly important as external factors such as the spread of disease and the bleaching resulting from changes in sea temperatures and other conditions is stressing the coral reefs.

Integrated Coastal Management on Unguja Island, Zanzibar, Tanzania

The coast of Tanzania stretches 800 km between Kenya and Mozambique. There are three large islands lying off the coast, Pemba, Unguja and Mafia. Pemba and Unguja form Zanzibar. The island of Unguja is often referred to as Zanzibar (Figure 6). There are also a number of smaller islands, islets and reefs within the coastal zone. About two thirds of the coastline has fringing reefs, broken by rivers such as the Rufuji River (Linden & Lundin, 1996). Tanzania has a tropical climate with temperatures averaging 26 °C. The rainfall exceeds 1 metre per year, which can lead to landslides and severe runoff from the land.

Zanzibar has a high population density and continues to grow at a rate of over 3%. The population in 1948 was 264,200 and in 2000 it is estimated that it will reach 924,000. This will result in a population density of 333 persons/km^2 (Mwakanjuki, 1997). Most of the fishing in Zanzibar is artisinal fishing from small canoes. Fish catches have declined as the number of fishermen has increased (Jiddawi & Masoud, 1994). Unguja has 118 fish landing sites and 11,965 fishermen and Pemba has 136 fish landing sites and 11,769 fishermen. Thirty percent of the population are classed as fishermen (Lyimo et al., 1997).

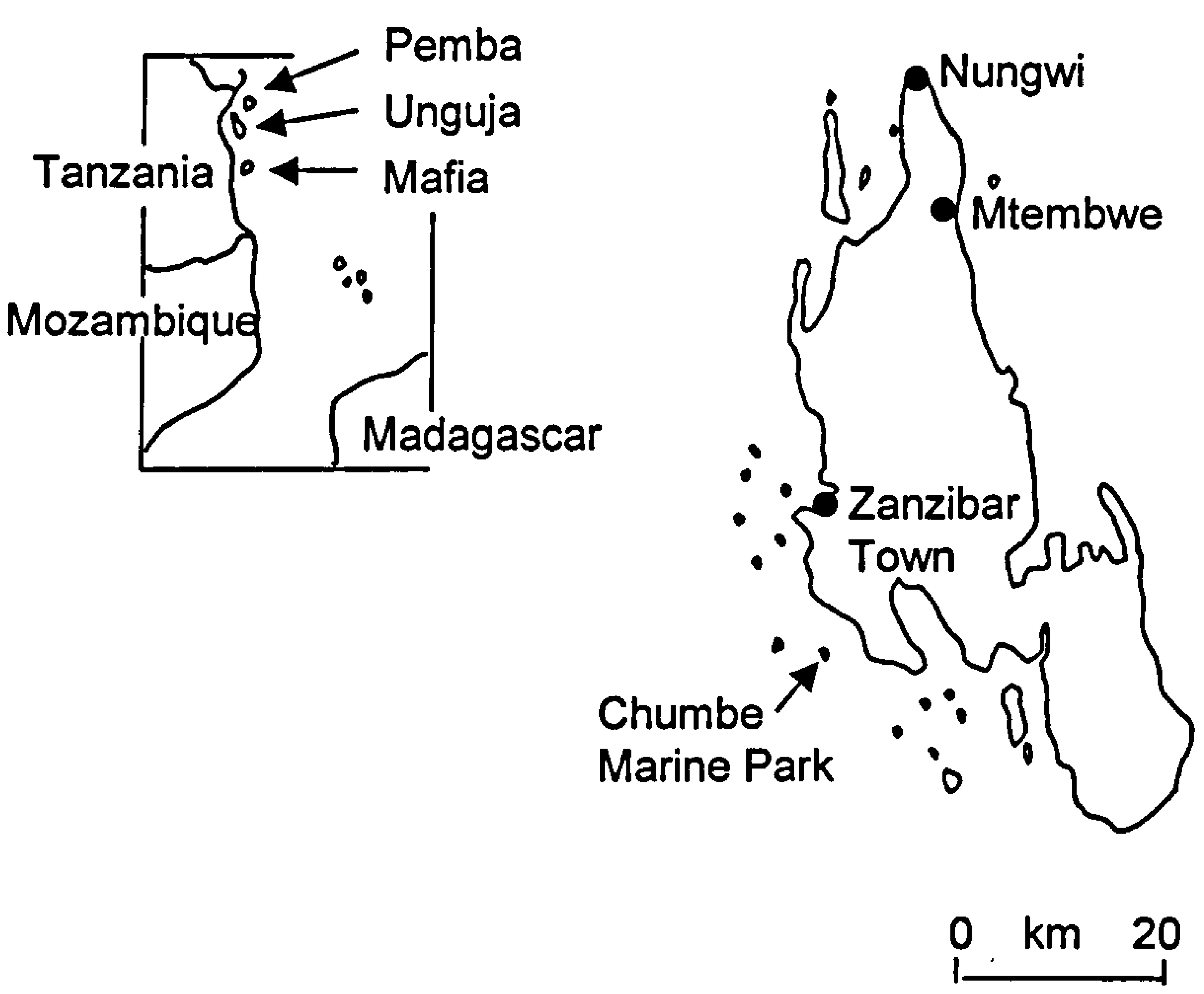

Figure 6 Map of Unguja Island, Zanzibar showing the major coastal settlements, marine parks and an inset map of its location in East Africa

Main issues in Unguja's coastal zone

Structured interviews with a select number of stakeholders from scientific organisations, NGO's, private management organisations and government departments involved in marine conservation and coastal management highlighted a series of issues occurring in the coastal zone of Unguja.

The main impact on the reef is caused by the heavy fishing pressure. Fisheries have declined in the easily accessible reefs. Protected areas have 3.5 times the fish biomass that unprotected sites have (McClanahan et al., 1999). Reefs with lower fish densities tend to be dominated by algae and the coral cover is reduced. There are local areas of suspected eutrophication, mainly around Zanzibar Town. In addition to the locally based impacts on the reef, the Indian Ocean has been affected by the warming waters and consequent coral bleaching in 1998. Sites monitored on Unguja show decline in coral cover ranging from 15-50% (Muhando, 1999).

Development is occurring at a relatively rapid scale, tourism only started in 1985 when the number of tourists was recorded at 16,268. This had increased fourfold in 10 years reaching 69,159 by 1996 (Johnstone et al., 1998). In 1993 a land use zoning plan was developed although this has not always been adhered to. In many places on the island, tourism has developed before the basic infrastructure is in place. Buildings have been constructed without adequate facilities, electricity and water, let alone waste disposal. Enforcement of building regulations is difficult once the construction phase has been carried out. Gradually some more 'eco-friendly' approaches are being developed. The bungalows developed on Chumbe Island are an example of these. They use solar power and re-cycle grey water and have composting toilets so there is no nutrient enriched water entering the shallow near shore waters and onto the reef.

Impediments to ICM on Unguja, Zanzibar

The discussions that highlighted the main issues in the coastal zone also highlighted the main impediments to implementing effective ICM. In some areas, these impediments were already hindering the organisations working effectively in a non-integrative role. Although ICM does not formally exist in Zanzibar, it was stated during one discussion that the management framework for ICM already existed. There is a current ICM project funded externally and utilising external expertise that is working at the policy level to identify the management issues through workshops and specify the scientific requirements for this. The status of this project was not entirely clear at the time of visiting. The interviews resulted in the impediments identified for the Unguja case study being categorised into the following four categories that are expanded in the following sections:

1. Lack of political will
2. Lack of integration between science and management
3. Over-extraction of free-access resources
4. Lack of local awareness

Lack of political will

The interviews stated that the largest constraint to effective management of the marine resources and ICM was political will. Political decisions are not based on data and there is a lack of scientific information built into the decision making process. It was also stated that there was little communication between the decision-makers and those implementing and being affected by the decision. Consequently, effective implementation rarely occurs. In some situations, decisions were blocking volunteer programmes that would benefit society. For instance the proposed tax on the transportation of school children on free snorkel outings and educational trips. It is thought these proposals are developed because the motivation behind a free service is not clearly understood.

Lack of integration between science and management

There is a substantial amount of scientific knowledge available on the marine environment. However, there the link between science and management is missing. The scientists stated that management does not make use of the scientific information. At the same time, the managers claimed that there was not enough information given to them from the scientists. They felt the scientists were going to their management areas and collecting data, sometimes without their knowledge. If they did receive a report on the findings, the information was rarely in a format applicable to management. There is a definitely a gap between science for science and science in support of management. Although there has been a 10 year programme building up the scientific capacity of the University of Dar es Saleem and in particular the Institute for Marine Science on Zanzibar (Moffat et al., 1998). There is now a need for capacity building in applied science and in the social sciences.

Over-extraction of free-access resources

The largest threat to the reefs was identified as the pressure on the reef fisheries. This is not a result of ignorance as to the long-term impacts on the fisheries but an inability of the fishermen to move to other activities. Fishermen rarely earn more than US$ 1 per day. Reducing pressure on the reef fisheries can only be achieved by providing these fishermen with alternatives. This may be fishing further offshore although the local fishermen do not have the capital to invest in larger boats and engines capable of this. Other options have been created in the past such as seaweed farming. This activity has been undertaken by women and it has substantially contributed to the status of these women in society. However, it has not reduced the number of fishermen on the reefs.

An example given was from Mtembwe where funding was secured to buy larger boats taking the local fishermen offshore. This worked successfully although the total number of fishermen probably stabilised rather than decreased as the population growth simply produces more fishermen.

It was suggested that management of the fisheries should be achieved through establishing locally managed fish reserves. The local fishermen would be given the responsibility to manage their own resources. They would feel ownership for that resource and therefore, have an interest in managing it for the future. This style of management has worked in a terrestrial park, the Jozani Forest, where tourists pay an entrance fee. A portion of this entrance fee goes to the local farmers in return for preserving the forest and not hunting the monkeys. Although the monkeys were a tourist attraction, they were becoming a pest to the farmers.

Lack of local awareness

Although the driving force behind the over-extraction of reef fish is poverty, there is also a lack of awareness of the marine environment. People are not aware of the link between certain fishing techniques, over-fishing and the status of the reef and availability of fish in the future. Local awareness programmes have been run along side management projects such as the Chumbe Marine Park and the expansion of the offshore fisheries in Mtembwe. The awareness programmes have been successful and consequently, implementation of the projects has been successful.

Implementing ICM in Unguja, Zanzibar

ICM will need a far-sighted approach to be implemented effectively on Unguja, Zanzibar. The poverty of the people is behind much of the resource depletion. Local small-scale employment alternatives need to be found. These then need to be introduced with educational programmes explaining the benefits of the programmes. Funding needs to be available long enough for programmes to become established and sustainable before external funding ceases.

With the limited resources available, organisations need to work closer together and to share resources. There is a local capacity that could be utilised for management of the marine environment. Some of the dive staff interviewed expressed an interest to be involved in management of certain dive sites. They have a useful knowledge of the reefs that could be utilised by management. They described the bleaching event of 1998, and the tourists reaction to it. They were able to state the water temperature, to within a degree and in relation to date and depth and relate this to when the bleaching started and the subsequent mortality. This was estimated by one dive staff member at 30%. The actual amount measured by the Institute of Marine Science (IMS) varied between 15 and 50% on Unguja (Muhando, 1999). However, these sites are on the west coast of the island whereas the dive staff were diving off the north and north-east coast.

However, the most urgent need is a curb on the population growth. Without this, it will be extremely difficult to continue to provide alternatives to fishing and the subsequent degradation of the reef.

3.4 Conclusions

The striking feature of all three case studies is that similar impediments can be found in each of the case study countries. The main impediment identified in Curaçao was the lack of political support and awareness for ICM. Bonaire, although having a strong legislative structure faced enforcement problems as political support weakened. On Unguja, the political will was so low at times it was identified as actually opposing some of the independent efforts at ICM. Bonaire and Curaçao both faced problems with lacking adequate wastewater treatment facilities and the biggest impediment to implementing these was identified as financial. In addition, on Curaçao political negotiations hindered the implementation of a funded wastewater expansion programme. The lack of public awareness was a common feature in all three case studies. This was potentially less so on Bonaire as active steps to raise awareness and education into nature conservation had been taken. Another issue raised in Curaçao and Zanzibar was the lack of management decisions actually based on scientific data. This was either due to the lack of communication between scientists and managers or the lack of interest decision makers had in using science for decision making. Overfishing was seen as a management issue in both Curaçao and Zanzibar. Impediments to overcome this, particularly in Zanzibar, are related to the poverty of the fishermen allowing them few alternatives for retraining and other employment.

Although the situations do differ, they appear to produce similar issues that could be categorised for further study (see Chapter 4). The commonalities have been drawn from the three case studies and the impediments summarised into the following six categories:

1. Weak institutional structure
2. Limited institutional capacity
3. Conflicting and weak legislation
4. Lack of political will and participation
5. Lack of public support and participation
6. Limited scientific support for management

It was recognised that these case studies covered just three areas in the tropics and may not be representative. Consequently, the results were compared to reports of impediments in a wider selection of locations identified through a literature review. These were then used to develop a survey to identify the impediments to ICM throughout the tropics (see Chapter 4, Westmacott, 2000a). The results of the three case studies and the literature review are discussed in the following sections that follow the category headings listed above.

Weak institutional structure

The case studies highlighted the fact that even where relevant ICM institutions are in place, there is often minimal communication between them. In the Bonaire situation, communication worked where motivated individuals were in charge of an organisation. This was also made easier due to the small number of people involved. The case studies undertaken as preparation to the World Coast Conference (WCC'93) identified the lack of adequate institutional arrangements as one of the major obstacles to ICM (Awosika et al., 1993; Bijlsma et al., 1993). Many ICM institutions are described as poorly integrated (Bijlsma et al., 1993; Pernetta & Elder, 1993; Baird, 1996). Chua (1998) surveyed eight ICM programmes in South East Asia and identified the lack of an institutional mechanism linking the different sector agencies as one of the main reasons why ICM plans developed were not readily implemented.

In situations where there is a lack of co-ordination between agencies, the more traditional sector-based approach will be strengthened. This can even reinforce power conflicts between the various agencies. Decisions are then taken to settle immediate, politically motivated conflicts, rather than being able to address long-term, socio-economically based conflicts as seen in the case studies prepared for the World Coast Conference in 1993 (Bijlsma et al., 1993). In order to resolve conflicts between agencies, co-ordination between the agencies that moves towards ensuring internal consistency between policies and actions, projects and programmes will be required.

A lack of integration between agencies and co-operation or co-ordination between agencies will also lead to a lack of understanding of the different ICM objectives. Difficulties can be found in achieving a consensus amongst local user groups and even within local groups. The consensus may be on objectives and perceived priorities of management or what constitutes an acceptable ecosystem state. Human adaptability and tolerance towards environmental degradation appears high and may even change with time (Baird, 1996).

In addition the links between different institutions, in some cases the structure within the institution can be a constraint to effective ICM. Government institutions may be large bureaucracies, which can be highly inefficient through overstaffing and under-funding, hampering timely problem solving and decision-making (Bijlsma et al., 1993; Baird, 1996).

Limited institutional capacity

ICM demands a variety of experiences, expertise and knowledge in both the planning and implementation phases. It requires a change in attitude towards resource management and institutional arrangements and is a relatively new concept for many developing countries where these requirements may be lacking or absent (Bijlsma et al., 1993; Pernetta & Elder, 1993; Jorge, 1997). This was also apparent in the case studies where the management mechanisms may be in place but experience of working as an integrated unit was absent. The capacity within the institutions was also a constraining factor in terms of manpower, expertise and finances.

A shortage of trained personnel and collective resources followed by inadequate financial resources, data and information ranked highly in the ICM survey carried out for the World Coast Conference (Bijlsma et al., 1993). Lack of financial capacity and personnel will lead to the institutions being unable to carry out any research or monitoring and consequently being unable to fully evaluate the impacts of developments and the ICM programme itself. This lack of resources also affects the technologies used and available equipment.

ICM institutions can also be fragmented and lack the direct authority over land-use practices affecting the coastal ecosystems. This lack of authority, mandate and the jurisdictional overlaps between agencies blocks the ability of the agencies to address problems covering ecosystems often crossing administrative boundaries that integrated management demands (Baird, 1996).

The size of the area to be managed is also an important factor when examining the resources required for effective management. Large areas, such as the Great Barrier Reef in Australia require a huge quantity of resources to be effectively managed (Craik, 1996). On the other hand small island states may have smaller areas to manage but their financial capacity and available expertise to manage such resources may be limited (Griffith & Ashe, 1993; Cornforth, 1994; Dahl, 1997).

Conflicting and weak legislation

A major constraint to effective management of coastal and marine resources lies with the legislative process (Bijlsma et al., 1993; Dawson Shepherd, 1995; Baird, 1996). Legislation relating to ICM will involve multiple agencies, highlighted in the Curaçao and Bonaire case studies. The result is often conflicting authority and jurisdiction with little or no co-ordination between levels of government and across agencies in the same government (Ehler & Basta, 1993; Craik, 1996).

Regulations may be complex and poorly understood or even misunderstood which in effect will limit the ability to enforce them. The legislative process may also be lengthy and enforcing legislation is often associated with high costs and long delays as was identified in the Curaçao case study. This will be ultimately detrimental to effective resource management and may provide outcomes too late when dealing with high impact issues.

Lack of political support and participation

The commitment and full involvement of government is essential for the initiation of ICM, the development of the required institutions and legal instruments, the implementation and the subsequent enforcement of the ICM programme. Without this political will, implementing ICM will be extremely difficult (Kenchington & Crawford, 1993; van der Weide, 1993; Chua, 1998; Olsen et al., 1998). This was most often identified as a constraint to ICM by stakeholders in Curaçao. In Bonaire, failures in effective and timely management were often due to the lack of political action and support.

A local ICM initiative in Samaná, the Dominican Republic, was successful to the extent that the local organisations had formed a combined front and agreed on a common plan. However, without national authority support for the plan, some actions are unlikely to be implemented (Jorge, 1997). Total success of the local initiative requires high-level political support. This experience shows how public participation is vital in achieving understanding of the issues, but the government needs to play a vital role in co-ordination of the effort and particularly in regulation and implementation.

Decisions are made by institutions that are swayed by various political, legal and bureaucratic influences. There is also a political expectation that coastal problems have immediate solutions (Ehler & Basta, 1993). More, realistically this is politicians personal need to stay in power and be re-elected. During a meeting regarding the establishment of a marine park in Aruba, a local Minister asked whether he would see results within four years. That was, as he described, his life span. Legal and non-governmental organisations have a substantial influence on the way scientific information is used and just possessing scientific knowledge does not mean that the decision is based on it (Baird, 1996). Decisions can be supported by experienced analysts using the latest technologies but ultimately the decision may rest with a single person who has their own agenda.

Governments have a number of priority issues they have to deal with. Often the primary concern of government is a sound economy and job creation (Baird, 1996). Governments, particularly of developing countries, may already be in debt and are reluctant to raise taxes, as it will diminish local support. Consequently, perceived low priority items are omitted from implementation. Additional funds for research, management, and enforcement are, therefore, unlikely to materialise. Economic plans are seen in competition with ecological plans, even when the economy may actually rest on the conservation of the ecological environment. This became apparent during a meeting with the Commissioner of Public Works in Curaçao who stated that it is ultimately a choice between economic development and the environment and continued to say how economic development would always prevail. This highlights the lack of awareness amongst many politicians of the value of natural resources and the dependence that sustainable economic development has on a healthy environment.

Lack of public will and participation

Ultimately it is the public's attitude that determines society's response to management decisions. The absence of public awareness and the loss of confidence in management decisions and the regulatory process can create enormous impediments to ICM (Ehler & Basta, 1993; Pernetta & Elder, 1993; van der Weide, 1993; Baird, 1996). A successful ICM programme does not necessarily have the best technical content but is one that received public approval and meets the needs of a large number of stakeholders (Chua, 1993).

Over-centralisation of institutions involved in ICM can lead to a lack of connection between those making the decisions and those experiencing the problems of the coastal zone on a daily basis (Bijlsma et al., 1993). Linked to this, are the different objectives of the national level institutions and the local resource users. In the Dominican Republic, the main objective at the national level is conservation and maintaining biodiversity while at the local resource user level the goal is well-being for themselves and their families (Jorge, 1997).

Hegarty (1997) found from a study in Bantry Bay, SW Ireland that the traditional top-down and ad hoc approach to coastal management resulted in conflicts, confusion, and lack of understanding from the coastal users. People who depended on the coastal zone are aware of its value. ICM needed to start with what people know and understand and work from there in a co-ordinated and integrated manner.

Communities and resource users may actually be unaware of the environmental impacts of their actions and the development patterns taking place around them. Even if they are aware, there may be a perceived absence of alternatives to their current and unsustainable resource use patterns (Jorge, 1997). This is highlighted in Unguja, Zanzibar where 30% of the population continue to rely on a diminishing fisheries resource through lack of alternatives.

Coastal zones are also home to several resources, such as fish and mangroves that are viewed as common property. Growing numbers of users and increasing conflicts between them leads to over extraction of resources often called the tragedy of the commons (Berkes, 1985; Ehler & Basta, 1993; Laroche & Ramananarivo, 1995; Amar et al., 1996; Poulsen, 1996). This common property view of coastal resources is mainly held by "western" societies. This is a widespread problem throughout the Caribbean. In the South Pacific, traditional use has enabled non-government bodies to manage and restrict access to their resources. In the absence of this traditional form of management, government intervention is required to prevent such user conflicts (Jorge, 1997).

Limited scientific support for management

The lack of information and limited understanding of coastal and marine resources, processes and opportunities can act as an impediment to ICM (Bijlsma et al., 1993; Pernetta & Elder, 1993; Baird, 1996; Lauck et al., 1998). The lack of information was identified as a constraint for effective ICM in Curaçao, whereas the lack of communication between management and science was identified as a constraint in Zanzibar.

There is a substantial amount of scientific research being undertaken throughout the coastal zone. The lack of data and information may be more related to inadequate communication between scientists, managers and stakeholders (Ehler & Basta, 1993; Done & Reichelt, 1998). Organisations creating scientific knowledge may not be disseminating it rapidly enough or in an understandable form to ensure timely science-based management decisions (Baird, 1996). Likewise, managers may not be defining what their needs are to the scientific community (Chua, 1997). Perhaps one of the major constraints is that scientific philosophy is based on the search for generality and solutions to universal problems. By contrast, the ICM process typically requires answers to local questions rather than generalities. Agencies supporting 'fundamental' research will not fund research with only local benefits and local agencies may not have sufficient funds to support the necessary research.

A recent survey of marine park managers in the Caribbean identified all 16 respondents wanting to carry out more monitoring than they were currently. Clearly, monitoring of local ecological resources provides input to the ICM process being used to assess the effectiveness of management measures. Monitoring programmes are often started by external or regional scientific institutions using methods that require scientific expertise in both the collection and processing of the data (Smith & van't Hof, 1991). Limited personnel and financial resources are likely to preclude the continuance of these types of programmes. Often monitoring programmes are not designed to provide data for management and the monitoring is carried out for scientific research. McCorry (1996) surveyed 49 monitoring programmes from various organisations and areas and found 50% collected data for 'science' and fundamental research while only 16% collected data for 'management' purposes, for example, providing an assessment of the state of resources.

McCorry (1996) states that financial and labour costs were the two most constraining factors in monitoring. This is supported by the results of the recent Caribbean-wide survey where 64% of the responses of the follow-up survey stated that lack of finance and personnel was the main constraining factor to their desired monitoring programmes. Lack of equipment and equipment failure was mentioned by 21% of the respondents as was lack of expertise and having no suitable methods to collect the data. 14% of the respondents stated that lack of time was also a constraining factor.

So, why is science failing to support management? In some cases, reports are left with the receiving agencies. However, data collected by scientists may only be available to the manager when it has been published in peer- reviewed journals, often a year or more later. Pressure on scientists to publish their work in high-ranking journals will impede rapid information transfer (Baird, 1996). With increasing pressure on coastal environments such as coral reefs, there is little room for managers to wait for years before acting on scientific data and recommendations. These reports and papers may be lengthy and technically written which also affects the availability of the information to the busy manager or decision maker and non-specialist.

References

Amar, E. C., R. M. T. Cheong and M. V. T. Cheong. 1996. Small-scale fisheries of coral reefs and the need for community-based resource management in Malalison Island, Philippines. *Fisheries Research* 25: 265-277.

Awosika, L. S., S. Boromthanarat, R. Cornforth, M. Hendry, R. Koudstaal, M. Ridgley, J. Sorenson, L. de Vrees and S. Westmacott. 1993. *Management Arrangements for the development and implementation of coastal zone management programmes*. World Coast Conference Organising Committee, Noordwijk, the Netherlands.

Baird, R. C. 1996. Toward New Paradigms in Coastal Resource-Management - Linkages and Institutional Effectiveness. *Estuaries* 19: 320-335.

Bak, R. P. M. and G. Nieuwland. 1995. Long-term changes in coral communities along depth gradients over leeward reefs in the Netherlands Antilles. *Bulletin of Marine Science* 56: 609-619.

Berkes, F. 1985. Fishermen and the Tragedy of the Commons. *Environmental Conservation* 12: 199-206.

Bijlsma, L., M. Crawford, C. Ehler, F. Hoozemans, V. Jones, R. Klein, B. Miermet, N. Mimura, R. Misdorp, R. Nicholls, K. Ries, J. Spradley, M. Stive, L. de Vrees and S. Westmacott. 1993. *World Coast Conference Report.* Ministry of Transport, Public Works and Water Management, National

Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, the Netherlands.

Bower, B. T., C. N. Ehler and D. Basta, J. 1994. *A framework for planning for integrated coastal zone management.* National Oceanographic and Atmospheric Administration (NOAA), Washington DC.

Buth, L. and T. Ras. 1992. *Inventory of the land-based sources of marine pollution, Netherlands Antilles.* Prepared for CERPOL Programme, IOC - UNEP CAR/RCU by the Council for Sea Research and Sea Activities, Willemstad.

Central Bureau of Statistics. 1994. *Statistical yearbook of the Netherlands Antilles 1994.* Central Bureau of Statistics, Willemstad.

Central Bureau of Statistics. 1998. *The Netherlands Antilles Statistical Orientation, 1998.* Central Bureau of Statistics, Willemstad.

Chua, T.-E. 1993. Essential Elements of Integrated Coastal Zone Management. *Ocean and Coastal Management* 21: 81-108.

Chua, T.-E. 1997. The essential elements of science and management in coastal environmental managements. *Hydrobiologia* 352: 159-166.

Chua, T.-E. 1998. Lessons Learned from Practicing Integrated Coastal Management in South East Asia. *Ambio* 27: 599-610.

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated coastal and ocean management: concepts and practices.* Washington DC and Covelo, California: Island Press.

Civil Engineering Caribbean N.V. 1991. *Eilandgebied Curaçao. Afvalwaterstructuurplan (in dutch).* Prepared for the Department of Public Works, Curacao, Willemstad.

Cornforth, R. 1994. Integrated Coastal Zone Management - the Pacific Way. *Marine Pollution Bulletin* 29: 1-3.

Craik, W. 1996. The Great Barrier Reef Marine Park, Australia: A model for regional management. *Natural Areas Journal* 16: 344-353.

Curacao Tourism Development Board. 1996. *Tourism Exit Survey 1995.* Curacao Tourism Development Board, Willemstad.

Dahl, C. 1997. Integrated coastal resources management and community participation in a small island setting. *Ocean & Coastal Management* 36: 1-3.

Dawson Shepherd, A. 1995. Maldives: A Framework for Marine Environmental Management. *Newsletter for Coastal Management in Tropical Asia* March: 1-2.

DHV. 1990. *Milieubeleidsplan Curaçao (in Dutch).* Report prepared for the Environmental Service of Curacao, Willemstad.

Dixon, J. A., L. Fallon Scura and H. van't, Tom. 1993. Meeting Ecological and Economic Goals: Marine Parks in the Caribbean. *Ambio* 22: 117-125.

Done, T. J. and R. E. Reichelt. 1998. Integrated coastal zone and fisheries ecosystem management: Generic goals and performance indices. *Ecological Applications* 8: S110-S118.

DROV. 1992. *Preliminary islandwide development plan Curaçao (EOP): A summary.* Prepared by the Department of Urban and Regional Development, Planning and Housing (DROV) for the Executive Council of Curaçao, Willemstad, Curaçao.

Ehler, C., N. and D. J. Basta. 1993. Integrated Management of Coastal Areas and Marine Sanctuaries. *Oceanus* 36: 6-13.

Griffith, M. D. and J. Ashe. 1993. Sustainable Development of Coastal and Marine Areas in Small Island Developing States: A Basis for Integrated Coastal Management. *Ocean and Coastal Management* 21: 269-284.

Hegarty, A. 1997. Start with what the people know: a community based approach to integrated coastal zone management. *Ocean & Coastal Management* 36: 1-3.

Jiddawi, N. S. and A. Masoud. 1994. *Status of Marine Fisheries of Zanzibar.* Workshop on the Management for Sustainable Fisheries, Windhoek, Namibia.

Johnstone, R. W., C. Muhando, A. and J. Francis. 1998. The Status of the Coral Reefs of Zanzibar: One Example of a Regional Predicament. *Ambio* 27: 700-707.

Jorge, M. A. 1997. Developing capacity for coastal management in the absence of the government: a case study in the Dominican Republic. *Ocean & Coastal Management* 36: 47-72.

Kenchington, R. and D. Crawford. 1993. On the Meaning of Integration in Coastal Zone Management. *Ocean and Coastal Management* 21: 109-127.

Kvale, S. 1996. *Interviews.* Newbury Park, CA: SAGE.

Laroche, J. and N. Ramananarivo. 1995. A preliminary survey of the artisanal fishery on coral reefs of the Tulear region (southwest Madagascar). *Coral Reefs* 14: 193-200.

Lauck, T., C. W. Clark, M. Mangel and G. R. Munro. 1998. Implementing the precautionary principle in fisheries management through marine reserves. *Ecological Applications* 8: S72-S78.

Linden, O. and C. G. Lundin. 1996. *Integrated Coastal Zone Management in Tanzania.* The World Bank, Land Water and Habitats Division and SIDA, Marine Science Program, Washington DC and Stockholm.

Lyimo, E., B. A. Juma, I. O. Bhai and A. H. Juma. 1997. *Smallholder support project - Zanzibar. Fisheries Sector component: Report of the fisheries frame survey conducted in Unguja and Pemba.* Fisheries Sub-Commission, Zanzibar, Tanzania.

Marshall, C. and G. B. Rossman. 1999. *Designing Qualitative Research.* Thousand Oaks, CA: SAGE.

McClanahan, T. R., N. A. Muthiga, A. T. Kamukuru, H. Machano and R. W. Kiambo. 1999. The effects of marine parks and fishing on corals reefs of northern Tanzania. *Biological Conservation* 89: 161-182.

McCorry, D. 1996. *the Worldwide Status of Coral Reef Monitoring Programmes, 1994.* MSc dissertation. Newcastle Upon Tyne: University of Newcastle upon Tyne.

Meesters, E. H. 1995. *Coral Reef Data Collection and Analysis. Phase 2 report of the project Cost-effectiveness analysis of coral reef management and protection: A case study of Curaçao.* Prepared for the Latin American and Caribbean Environment and Urban Development Division of the World Bank. Resource Analysis, Delft, the Netherlands.

Meesters, E. H., R. P. M. Bak, S. Westmacott, M. Ridgley and S. Dollar. 1998. A Fuzzy Logic Model to Predict Coral Reef Development under Nutrient and Sediment Stress. *Conservation Biology* 12: 957-965.

Moffat, D., M. Ngoile, O. Linden and J. Francis. 1998. The Reality of the Stomach: Coastal Management at the Local Level in Eastern Africa. *Ambio* 27: 590-598.

Muhando, C. A. 1999. The 1998 coral bleaching and mortality event in Tanzania: Implications for coral reef research and management. *Conference on Advances in Marine Sciences in Tanzania*, eds., J. Francis and C. Muhando, Zanzibar, Tanzania.

Mwakanjuki, A. 1997. Population growth and its implications in the coral reef environment. *Coral Reefs: Values, Threats, & Solutions*, eds., R. W. Johnstone, J. Francis and C. Muhando, A, Zanzibar, Tanzania. Institute for Marine Sciences, Zanzibar.

Olsen, S. B., J. Tobey and L. Z. Hale. 1998. A Learning Based Approach to Coastal Management. *Ambio* 27: 611-619.

Patton, M. Q. 1990. *Qualitative evaluation and research methods.* Newbury Park, CA: SAGE.

Pernetta, J. C. and D. L. Elder. 1993. *Cross-sectoral, Integrated Coastal Area Planning (CICAP): Guidelines and Principles for Coastal Area Development. A Marine Conservation and Development Report.* IUCN, Gland, Switzerland.

Post, J. C. and C. G. Lundin. 1996. *Guidelines for integrated coastal zone management.* Washington DC: International Bank for Reconstruction and Development & The World Bank.

Poulsen, A. L. 1996. Coral reef gastropods: A sustainable resource? *Pacific Conservation Biology* 2: 142-145.

Resource Analysis and Delft Hydraulics. 1993. *How to Account for the Impacts of Climate Change in Integrated Coastal Zone Management: Concepts and Tools for Approach and Analysis. Version 2.0.* World Coast Conference (WCC'93) Organising Committee, Ministry of Transport Public Works and Water Management, The Hague, the Netherlands.

Rijsberman, F. and S. Westmacott 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of Curacao. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 49-66. Washington, DC: The World Bank.

Rijsberman, F. R. and R. Koudstaal. 1989. Development and Application of a Framework for Analysis for Integrated Coastal Resources Management in an International Context. *Coastal Zone 1989,* eds., O. T. Magoon, 58-71. ASCE, New York.

Roberts, C. M. and J. P. Hawkins. 1994. *Report on the Status of Bonaire's Coral Reefs.* Eastern Caribbean Centre, University of the Virgin Islands, St. Thomas, U.S. Virgin Islands, 00802, USA,

Robinson, J. 1993. *A Master Plan for Tourism Development.* Curaçao Tourism Development Bureau., Willemstad.

Smith, A. H. and T. van't Hof. 1991. *Coral reef monitoring for management of marine parks: cases from the insular Caribbean. Paper presented at the IDRC workshop on Common Property Resources, Winnipeg, Canada, September 1991.* CANARI, St. Lucia.

Sorensen, J. 2000. *Building a Global Database of ICM Efforts.* University of Massachusetts, Boston.

van der Weide, J. 1993. A Systems View of Integrated Coastal Management. *Ocean and Coastal Management* 21: 129-148.

van't Hof, T. 1997. *New Guide to the Bonaire Marine Park.* Harbour Village Beach Resort Bonaire, Netherlands Antilles.

van't Hof, T., A. O. Debrot and I. A. Nagelkerken. 1995. *Curacao Marine Management Zone: A plan for sustainable use of Curaçao's reef resources.* Report prepared for the Curacao Tourism Development Board and Stinapa by CARMABI, Willemstad.

Westmacott, S. 1995. *Decision Support in Coastal Zone Management.* MSc thesis. Delft, the Netherlands: International Institute for Hydraulic and Environmental Engineering (IHE) & Resource Analysis.

Westmacott, S. 2000a. Identifying the main impediments to integrated coastal management in the tropics. *Paper submitted to Ocean and Coastal Management, October 2000.*

Westmacott, S. 2000b. Where should the focus be in tropical integrated coastal management? *Paper submitted to Coastal Management, September 2000. Resubmitted for acceptance after reviewer's comments April 2001*

Westmacott, S. and F. Rijsberman 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of the Republic of the Maldives. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 67-82. Washington, DC: The World Bank.

4 Identifying the main impediments to integrated coastal management in the tropics

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4.1 Introduction

The concept of integrated coastal management (ICM) has been identified as the way to cope with the multiple objectives, interests and uses of the coastal zone (Bijlsma et al., 1993; Post & Lundin, 1996; Cicin-Sain & Knecht, 1998). In practice ICM is a complex process that involves reconciling the interests of a number of different and often opposing stakeholder groups (Clark, 1997). ICM aims to get these groups to develop a coordinated strategy that requires their cooperation and ability to understand and respect each other's needs and desires (Sorensen & McCreary, 1990; Clark, 1997). An ICM strategy will ultimately be the result of compromise between the different groups. In addition, identifying the main issues and developing the ICM plan requires management personnel to be able to analyse multiple user impacts on a variety of different socio-economic and environmental issues (Turner & Adger, 1996; Huber & Jameson, 2000). Implementation requires support and acceptance by the local community whose activities may have been or will be affected by the implementation of the management plan (Kelly, 1992; Davos, 1998). Implementation will also require adequate financial resources. ICM needs to be able to facilitate a common goal and devise a multi-faceted management plan that covers as many interests as possible and allows a variety of different activities to continue in the coastal zone. It is the process where rational decisions are made concerning the conservation and sustainable use of coastal and ocean resources and space (Cicin-Sain & Knecht, 1998).

Despite wide acceptance of the concept of ICM, many countries are having difficulties implementing effective ICM (Bijlsma et al., 1993; Chua, 1998). Only 12% of tropical coastal locations are actually monitoring and evaluating their integrated management plans while 50% of tropical coastal locations either have no form of management or their issues are only recognised by management (see Chapter 2; Westmacott, 2000). Many tropical coastal and marine ecosystems are deteriorating under heavy pressure from human and economic activity (Huber & Jameson, 2000). There is evidence that reefs and human populations do not always exist well together and as a result there is clear evidence of worldwide reef decline (Ginsburg, 1994; Wilkinson & Salvat, 1997). If the state of the environment is one criterion against which to measure the success of ICM, then it appears we are a long way from achieving it.

The ICM concept has been known for several years now with the 1982 Law of the Sea Convention and Chapter 17 of UNCED's Agenda 21 containing most of the necessary prescriptions for ICM (Cicin-Sain & Knecht, 1998). Since this time legal instruments, conferences and meetings and international conventions have continued to help define it. It has been estimated that ICM takes 8-12 years to implement (Olsen et al., 1998), in which case we should hope to see more than 12% of tropical locations implementing, monitoring and evaluating their ICM programmes (see Chapter 2; Westmacott, 2000). Even in areas where ICM programmes have been initiated, there are few reports of the sustainable use or recovery of the over-used environment. In Sri Lanka the opposite has been reported (Rajasuriya & White, 1995; Rajasuriya et al., 1999). ICM efforts began in the Philippines over 20 years ago and ICM is still seen as only *potentially* able to reverse the trends in ecosystem degradation (Courtney & White, 2000).

If ICM is not a new concept, what exactly is impeding its success? Is it a shortage of funds or a lack of trained or qualified personnel? Countries, which in the past were perhaps short of trained personnel, now have ever-increasing local capacity through the abundance of internationally funded programmes (Linden & Granlund, 1998). Funding has been available to establish ICM programmes around the world, for example, Tanga in Tanzania funded through Ireland Aid (Makoloweka & Shurcliff, 1997), Hikadduwa, Sri Lanka funded through the US Agency for International Development (USAID) (Olsen et al., 1998) and the Coastal Resources Management Project in the Philippines also funded through USAID (Courtney & White, 2000).

The questions this study attempts to answer are:

- What are the main reasons for this inability to implement ICM *successfully* and are we seeing similar problems impeding successful implementation of ICM around the world?
- To what extent do these impediments affect the ability to implement ICM and where should we focus our ICM efforts?

If we are able to identify the common impediments to ICM in the tropics, we may be better informed in which direction to guide our ICM efforts in the future. Efforts can then be focused on overcoming these barriers to integrated management enabling the ultimate goal of sustainable use of the coastal zone's resources.

4.2 Methods

To gain a global understanding of potential or existing ICM efforts in the tropics, a survey was designed with the widest coverage possible (see Appendix A). A critical aspect was to define the criteria to measure the impediments to ICM. Through questionnaire surveys, respondents involved in the ICM process were asked to evaluate the level of these impediments at their location and to give an estimate of how important they felt they were to the ICM process. In order to achieve this, a combination of methods was used (Figure 1). Initially, three detailed case studies of coastal management situations were examined through research interview techniques and personal experience (see Chapter 3). These case studies identified the impediments to ICM in these locations. This information was supported by a detailed literature survey. Together the three case studies and the literature were used to develop general categories of impediments. From these categories, criteria that were measurable indicators of the impediments were developed along with a scale with which to assess the impact these criteria had on ICM. The criteria formed the basis of the ICM survey that was used to identify global ICM impediments and their impact on ICM. The whole process can be seen schematically in Figure 1.

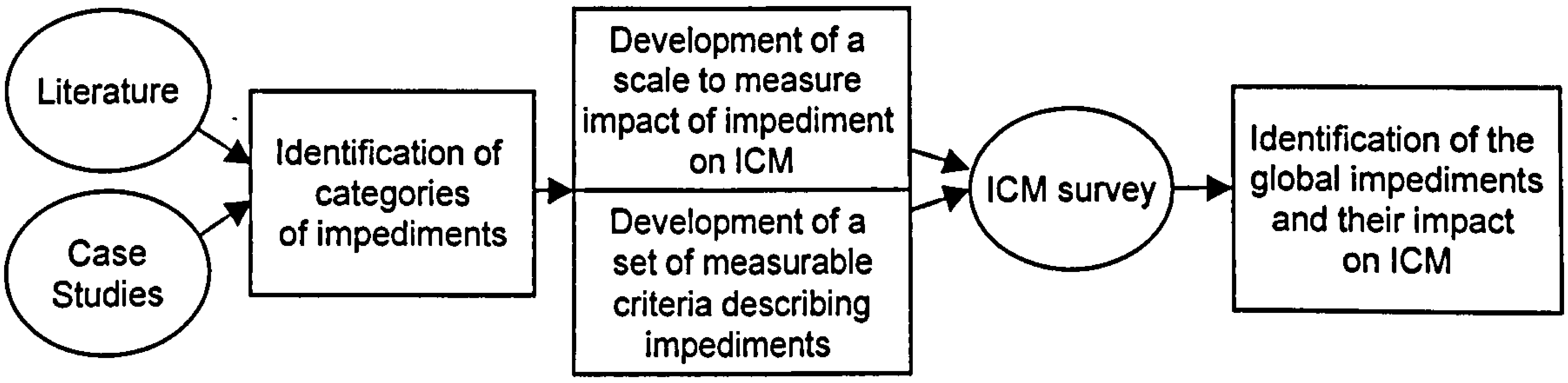

Figure 1 ICM case studies and a literature survey were used to develop categories of impediments to management that lead to the development of an ICM survey and the identification of the global impediments to ICM and their impact on implementing ICM

The three case studies that were used were from Curacao and Bonaire in the Netherlands Antilles and Zanzibar in East Africa. It was recognised that these were limited in both number and type of location they represented. This was the reason to explore the literature further and to continue with the development of the broader survey. The aim of the research was not to select areas where specific ICM projects had been undertaken but rather to explore a selection of management situations in different coastal areas. Areas where specific ICM efforts have been undertaken were also included, such as Sri Lanka and Tanga in Tanzania.

The survey allowed information to be gathered from a wide range of locations and was sent via mail and e-mail or distributed by hand to the respondents. A remote (mailed) survey can result in a poor response rate; one assumption being that the respondent understands what is expected of him. It is difficult to ensure that the person to whom the survey was sent actually completes it and answers the questions in the order they are intended (Oppenheim, 1992). These were all considered in the design of the survey and were addressed in a covering letter accompanying the survey that also gave details for the respondent to e-mail any queries and receive assistance before completing the survey. The surveys were followed up by e-mails to attempt to increase the response rate, a covering letter was included with the survey to explain its aims and give some explanatory definitions of terms used.

The questionnaire was divided into two sections. The first section contained framing questions so the respondent had already identified the coastal activities and management institutions involved in ICM in the area selected. The section aimed to start the respondent thinking of the wider picture of ICM and avoid a sector-based analysis. While this is not leading the respondent, it ensured the answers were given about similar situations. The second section contained 21 questions. Each question contained two parts. The first part of each question required the respondent to indicate the extent to which each impediment criterion was present. For each category of impediment, 3-4 questions (criteria) were designed to probe this issue further (Table 1). The order with which the measurement scale was presented in the questionnaire (e.g., high to low) differed for each question to keep the attention of the respondent.

Table 1 Impediments criteria and qualitative measurement scale

Category	Criteria	Measurement scale
Weak institutional structure	How much active communication is there between the ICM institutions?	None; 6 monthly -Yearly; monthly – 6 monthly; Weekly - monthly; Daily – weekly
	How often do official committees with representatives of more than one ICM institution meet?	There are no committees; 6 monthly - Yearly; monthly – 6 monthly; Weekly - monthly; Daily – weekly
	How are the management plans of the different ICM institutes integrated?	All are formally; All are informally; Some are formally; Some are informally; No integration
	How do the ICM institutions function internally?	Non-functioning; Inefficient; Slow but they function; Moderately efficient; Efficient
Limited institutional capacity	Is there local experience in ICM in the relevant institutions?	In all institutions; In most institutions; In some institutions; In a few institutions; No local experience
	What level of education do personnel available for ICM have?	No training; Secondary school; College; University; Post-graduates
	Are there adequate finances to implement the necessary measures to achieve ICM?	Yes; Yes, for infrastructure but <u>not</u> personnel; Yes, for personnel but <u>not</u> infrastructure; Small funds; Inadequate funds
	Do institutions have sufficient authority to be effective?	None do; One does; A few do; Most do; All do
Conflicting and weak legislation	Do the different institution's jurisdictions conflict?	Never; One situation; A few situations; Most situations; Always
	Is there sufficient legislation for effective ICM?	Yes; No
	Is the legislation ever found confusing?	Yes; No
Lack of political attitude and participation	Is the Government committed to environmental protection?	Actively; Verbally; Supports independent efforts; Not committed; No, against
	Is the Government actively involved in sustainable development initiatives?	Yes; No
	Are decisions a balance between environmental protection and economic development?	Yes; No
	Do decisions have a long-term focus as opposed to short term?	Regularly; Sometimes; Never;

Category	Criteria	Measurement scale
Lack of public attitude and participation	Are the public aware of the importance of the environment?	None are; A few are; Some are; Most are; All are
	Are the public involved in decision making?	Regularly; Often; Sometimes; Rarely; Never
	Would you describe the decision making as top down rather than bottom up?	Yes; No
Limited scientific support for management	Is there verbal communication between scientists and the managers?	Regularly; Often; Sometimes; Rarely; Never
	Is there dissemination of information (reports, papers, etc.) from scientists to managers?	Regularly; Often; Sometimes; Rarely; Never
	Is science used as the basis of management decisions?	Regularly; Often; Sometimes; Rarely; Never

The second part of each question related to how the respondent perceived these as impediments to the system. They were ranked by the respondent selecting one of five response categories, in answer to the following question: *How does or would this, affect the ability to implement ICM?*

The respondent is then given a choice of five answers:

- Very negatively
- Negatively
- No effect
- Positively
- Very positively

Care was taken in designing the questions so as not to lead the respondent to an answer they think is *correct*. At the beginning of the questionnaire, it was stressed that no answer is the correct answer and they should be answered as truthfully as possible. Consequently, each questionnaire remains anonymous and individual results will not be published.

Avoiding designing 'leading' questions was particularly difficult in the second section where the response categories were used. Although response categories can be subjective and one person's 'good' may be another's 'fair', they are a useful way to structure the responses (Bradburn et al., 1979; Czaja & Blair, 1995). Ordering the categories relative to each other was chosen to limit the effect of scaling bias. The same response categories were used for each question and limited to five categories of responses, so that respondents would be drawn to the extremes. The questions varied in that some would have been expected to have a positive influence on ICM and others a negative. This meant that the respondent had to carefully consider each response rather than answer automatically.

Processing the results

Analysis of the results followed the following steps:

1) Analysis of the similarities between the impediments found at the different locations
2) Explanation of the similarities by environmental variables
3) Analysis of the frequency of impediments as individual criteria and as categories
4) Analysis of the impact each impediment criteria has on the ability to implement ICM

Analysis of similarities between the respondents' stated impediments to ICM was carried out using PRIMER (Plymouth Routines in Multivariate Ecological Research), which was originally developed for the analysis of biological data (Clarke & Warwick, 1994). Non-metric multidimensional scaling (MDS) analysis was carried out on a matrix of dissimilarity coefficients (Euclidean distance) between respondents. Non-metric MDS was chosen over principal component analysis (PCA) or factor analysis because of the fewer assumptions about the nature and quality of the data. One problem was how to deal with missing data. In this analysis, it was decided to replace missing data with the null value that would imply that a particular impediment has no effect on ICM implementation. Use of a zero value for missing data would imply a low (extreme) effect. Realising that this was not the perfect solution, analyses were carried out on the two datasets, first replacing missing values with a zero and then with the null value. Using the RELATE option in PRIMER that tests for evidence of similarity in multivariate pattern for 2 sets of samples, it was shown that there was no significant difference between the two approaches (Spearman rank $R = 0.791$, $p = <0.001$). The data presented were therefore those using the null-value for missing data.

The results of the multi-dimensional scaling (MDS) analysis were displayed as 2-D plots for ease of interpretation. In all cases the stress values were below 0.23 indicating that a 2-D representation of the higher-dimensional similarities were adequate. The analysis was separated into three parts, first the analysis and visualisation (MDS ordination) of the level of impediments, and secondly the analysis of the perceived impact the impediments had on implementing ICM in each location. The third step in the analysis was to try to find some explanation for the similarities seen. It was hypothesised that patterns could be explained by:

- Survey location – which could indicate cultural differences
- Poverty and wealth indices – which could relate to the prioritisation of ICM below basic provision of health, water and sanitation facilities as well as ability to finance ICM
- Institutional structure – the number of institutions involved could make basic agreement on ICM objectives harder to achieve
- Importance of tourism – which could raise the priority for environmental protection

- Loss of biodiversity – if this is perceived as a priority issue it could raise the level ICM
- Level of reliable communications – which could indicate the ease at which institutions could communicate together

The analysis of the relative effect of these 'environmental variables' was carried out in PRIMER under the BIO-ENV routine, that identifies the environmental variables that 'best explain' the multivariate pattern seen in the MDS. Again, two analyses were carried out, first on level of impediments seen in each location and secondly on the impact these have on ICM.

The survey results were then analysed to identify the most common impediment criteria using mean values for the level of each impediment identified by each respondent. This required the measuring scale for the criteria to be allocated a numeric value. For simplicity, this was allocated as one to five, from best case (low level of impediment) to worst (high level of impediment). This also enabled mean values for the criteria within each category to be assessed enabling the most common category of impediments to be identified.

The final part of the analysis looked at how each criterion was perceived to affect ICM implementation from negatively to positively. This was undertaken through Spearman Rank correlation analysis that calculated the correlation between the level of impediment identified and the respondent's perception on how this affects ICM.

4.3 Results

The three detailed case studies and the literature review identified similar impediments to the implementation of ICM (see Chapter 3). These were summarised into the following six general categories of impediments:

1. Weak institutional structure
2. Limited institutional capacity
3. Conflicting and weak legislation
4. Lack of political support and participation
5. Lack of public support and participation
6. Limited scientific support for management

The results from the case studies provided a basis to develop a generic overview of impediments to ICM. However, they provided just three examples, two being from similar sites. The literature supported the results of the case studies but the ICM survey, which was distributed across the tropics, was needed to support these findings and really provide a generic overview of impediments. Of the 74 surveys sent via mail, e-mail and by hand, 42 were completed and returned. Some surveys missed individual questions and two of the surveys completely missed the second section and were omitted from this analysis. This highlights the disadvantage of mailing the surveys, as they could not be checked before being returned.

Similarities of impediments found at survey locations

The multidimensional scaling (MSD) plot of similarities between the levels of impediments found in each survey location showed that the criteria developed as indicators of impediments were useful in describing the issues impeding ICM. The plot (Figure 2) shows those locations where ICM is implemented, monitored and evaluated (represented by the larger circles) on the lower left side of the plot moving across to those where ICM is not implemented (small circles) on the upper right side. A few locations do not follow the same pattern. The larger circle on the top right of the plot represents the Solomon Islands; this apparent deviation from the general pattern could be due to the existence of traditional forms of resource management in this location (Veitayaki, 1997). Traditional management may be able to overcome some impediments such as limited training capacity or even financial capacity. The two overlapping circles at the bottom of the plot represent two locations in Tanzania. The plot indicates similarities in impediments although different levels of achievement of ICM. The larger circle represents Tanga in Tanzania where a specific ICM project is apparently overcoming the impediments and a certain level of ICM is being achieved. This compares to the smaller circle representing Zanzibar where similar impediments are seen but without any specific ICM projects there is no ICM at present.

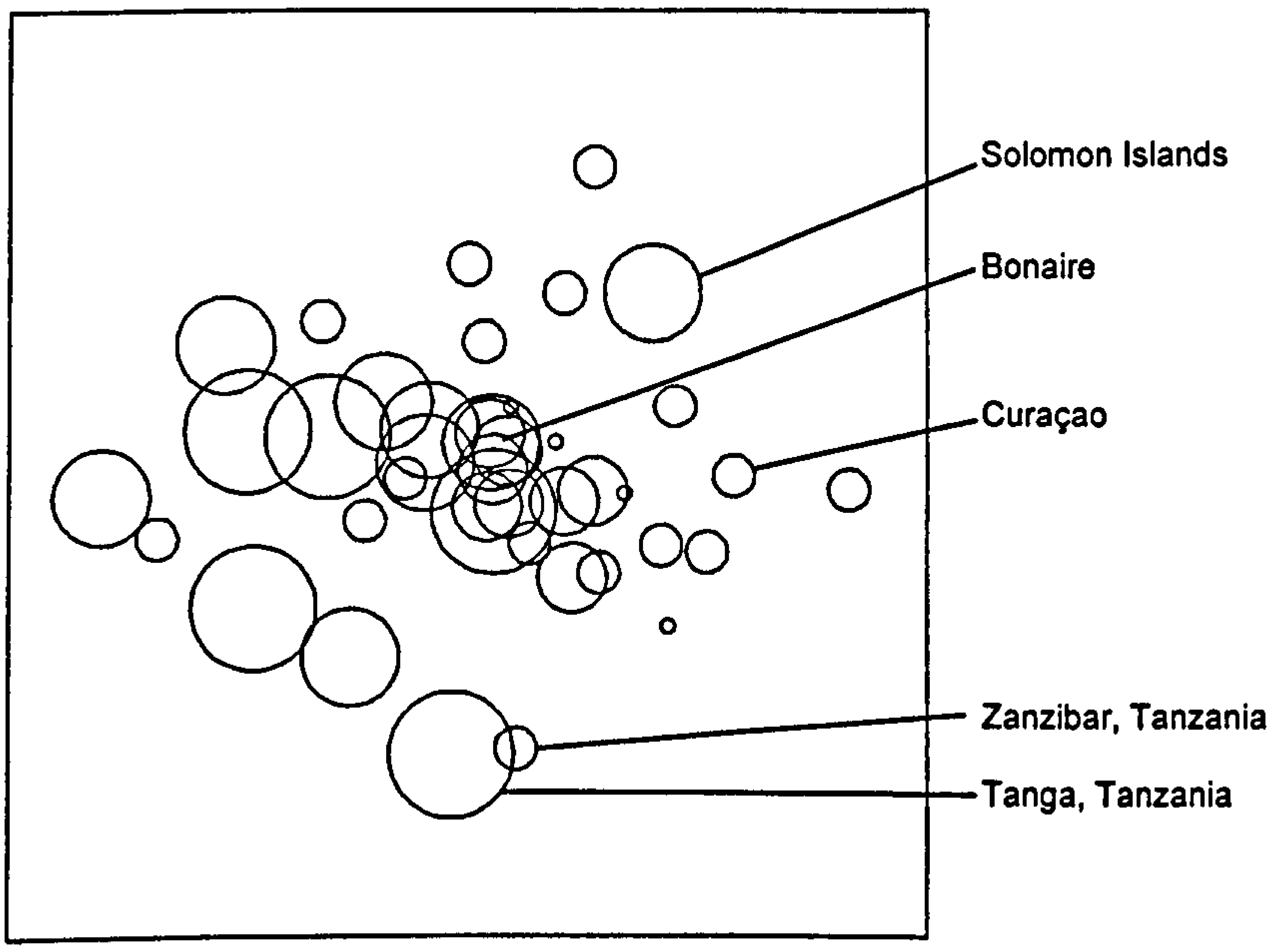

Figure 2 Multi-dimensional scaling (MDS) plot of similarities (Euclidean distance) in levels of impediments affecting ICM between respondents. The proximity of the circles indicates their similarity; the size of the circle indicates the extent to which ICM is being achieved from no management (small) to full implementation (large) on a 5-point scale. Stress = 0.23 which indicates that this 2-D representation is a good representation of the higher-dimensional similarities between samples (respondents). The labels represent the three case study sites and the locations mentioned in the text.

Explanation of similarities by environmental variables

The BIO-ENV routine identified the following three factors as having the greatest significance (spearman rank correlation coefficient, r=0.209) in explaining the factors affecting the similarities between the levels of impediments found in each location:

- Level of priority population growth has as a management issue
- The location (defined as Caribbean, Eastern Africa & Red Sea, Asia and the Pacific)
- Level of priority unemployment has as a management issue

This indicates that impediments to ICM and, therefore the ability to implement ICM, is affected by other priority management issues such as rapid population growth rate, putting pressure on stretched resources, and unemployment, potentially indicating a lack of alternative employment for those over-exploiting coastal resources. The effect of location on the level of impediments could be explained by cultural differences between the regions.

The BIO-ENV routine carried out to identify the factors best explaining the impact the impediments had on ICM in each location identified the following 4 factors as most significant (spearman rank correlation coefficient, r=0.158):

- Level of priority unemployment has as a management issue
- Number of tourists visiting the area
- Level of reliable communications
- Contribution of travel and tourism to the GDP

As with the level of impediments, the lack of alternative employment opportunities could exacerbate the impact the various impediments have on ICM by limiting the options for alternative employment. The number of tourists and the contribution of tourism to the GDP could lessen the impact the impediments have on ICM by increasing the reliance of economic development on environmental quality and therefore raising the profile of environmental protection. The level of reliable communications can be seen as directly affecting the ability of different stakeholder organisations and groups to cooperate and interact.

Frequency of impediment criteria and categories

The results show that the impediments differed considerably in their occurrence (Figure 3). The lack of both clear and sufficient legislation was apparent in over 65% of the cases. However, it should be noted these were both measured on a yes-no scale. Classed in the same category, *conflicting and weak legislation* was the issue of *overlapping jurisdiction*, which in 85% of the cases was not overlapping. These criteria are apparently not related and in a follow up survey could be split into two separate categories.

Bottom up decision-making is not a frequent occurrence, 75% of the locations said it never occurred indicating that the public have little influence on the decision making process. However, they were reported to sometimes be involved in decision-making. *Public awareness* was variable, the majority of responses stated that some to most of the public were aware of the importance of the environment. A greater awareness by the public could lead to a greater push to become involved in ICM.

The institutional structure available to ICM brought out by the survey shows that there is little or no formal integration of institutions and plans. Integration occurs on an informal and sporadic basis, likewise with official ICM meetings. This in itself may not be an issue if decision makers see the need for cooperation between institutes and take the initiative to facilitate this. The *level of active communication* is evenly spread through the responses from *none* to *active* levels. The majority, 68%, meets more frequently than six monthly. Ideally, communication between ICM institutions becomes a normal process but this could be affected by the level of development of telecommunications in each location, which was assessed in terms of reliable, unreliable and non-existent for phone, e-mail and Internet connections (see Table 2). Most survey locations had a reliable level of telecommunications available to them. Internet and e-mail is increasingly common but has not yet reached all locations, however where the phone communications were reliable, e-mail and Internet was also available. Over a third of the survey locations may be hampered by the lack of reliable communications.

Table 2 The percentage of survey locations with reliable, unreliable and non-existent phone, e-mail and Internet communications

Communication	Reliable	Unreliable	Does not exist
Phone	63	25	12
E-mail	60	19	21
Internet	56	23	21

The most common issue related to institutional capacity is the *lack of adequate finances* within the ICM institutes, found in 58% of the locations, compared to the 10% who state they do have adequate finances. Lack of finance is often stated as one of the main impediments to ICM although the survey shows it is just one of a number of impediments. Surprisingly for the few places actually implementing ICM, only 8% stated there was no ICM experience within the ICM institutions. This is promising for the future development of ICM as is the fact that capacity in terms of trained personnel was also not identified as a major issue. *Adequate education* facilities were apparently available with 50% of the location's ICM personnel having access to colleges of higher education or universities. Interestingly 64% of the locations also had a marine research institute. *Sufficient authority* within the ICM institutions was not widespread although in most cases, some institutions did have sufficient authority. This may however, indicate an imbalance with the more development orientated institutions have greater authority than those involved in environmental conservation and protection.

The results show that science is not regularly used in management. This could be due to the limited level of communication between scientists and managers. However, a reasonable level (often to regular) of verbal communication between scientists and managers was found in 48% of the locations. Dissemination of reports from scientists was often on an infrequent basis. Managers often need summary reports written in a less technical language than are often delivered.

Decisions are seldom a balance between economic development and environmental protection. However, 60% of Governments are apparently involved in sustainable development initiatives. Active involvement in environmental protection was 28%, which would indicate that many of the ICM initiatives are spearheaded and pushed by outside aid projects or by local NGO's. However, no Government was reported to be actually against environmental protection and only 15% were not committed. Although it was not comprehensive as a method of planning, the majority (80%) of respondents stated that there was sometimes a long-term focus to planning.

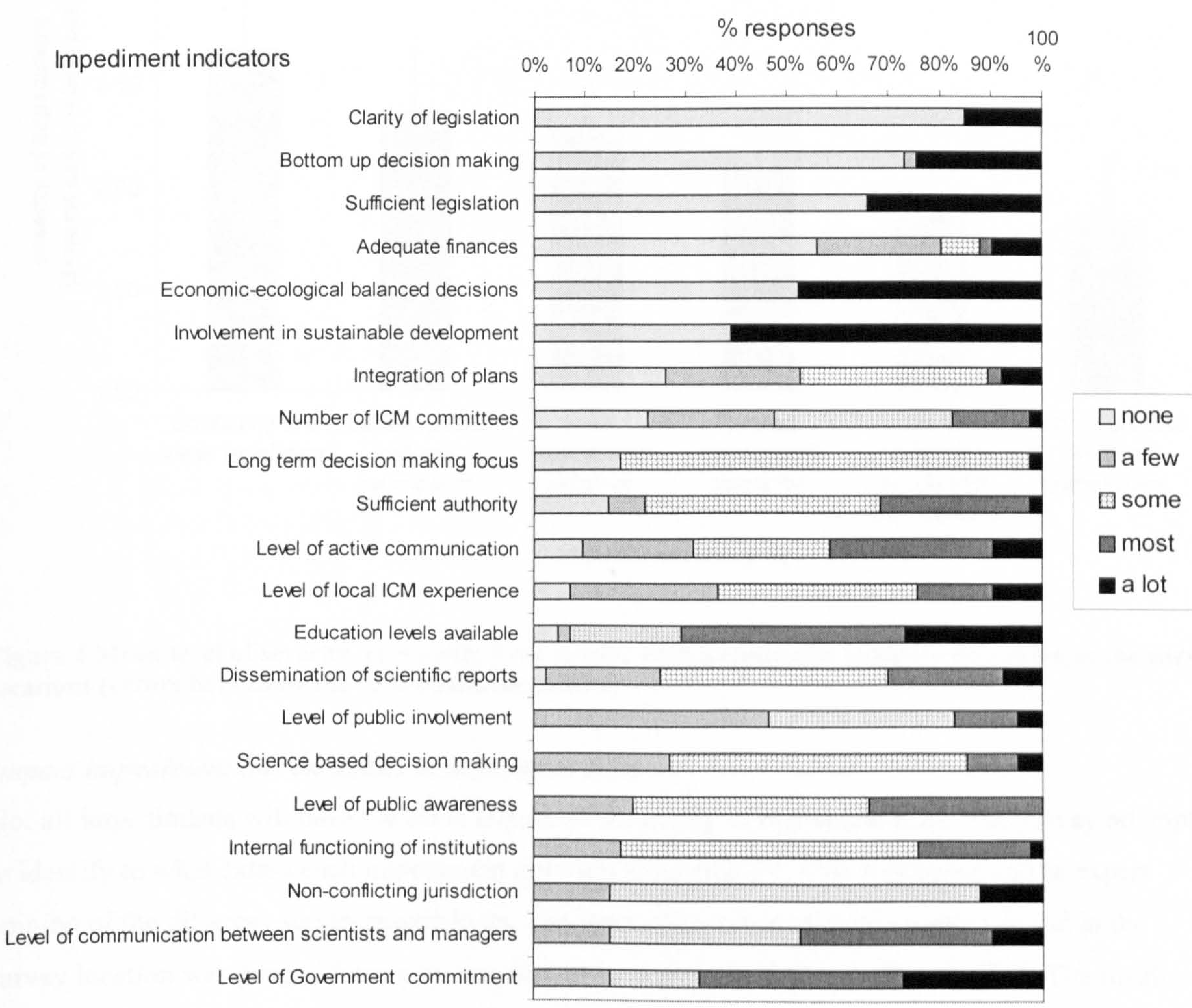

Figure 3 Frequency of different levels of ICM impediments reported by respondents seen in the survey locations

The most common group of impediments falls into the category of *conflicting and weak legislation* (Figure 4). This is followed by *lack of public attitude and participation* and *weak institutional structure*. The *lack of political awareness* was the least severe and the individual criteria show that *sustainable development initiatives* and *balanced economic-ecological decisions* were reported in some decisions. Although in most categories the criteria followed similar patterns, there were a few situations where this was not the case. However, to provide an overview and broad summary, the results were averaged for each category. For future evaluations of ICM potential, a more limited number and manageable number of criteria could be selected.

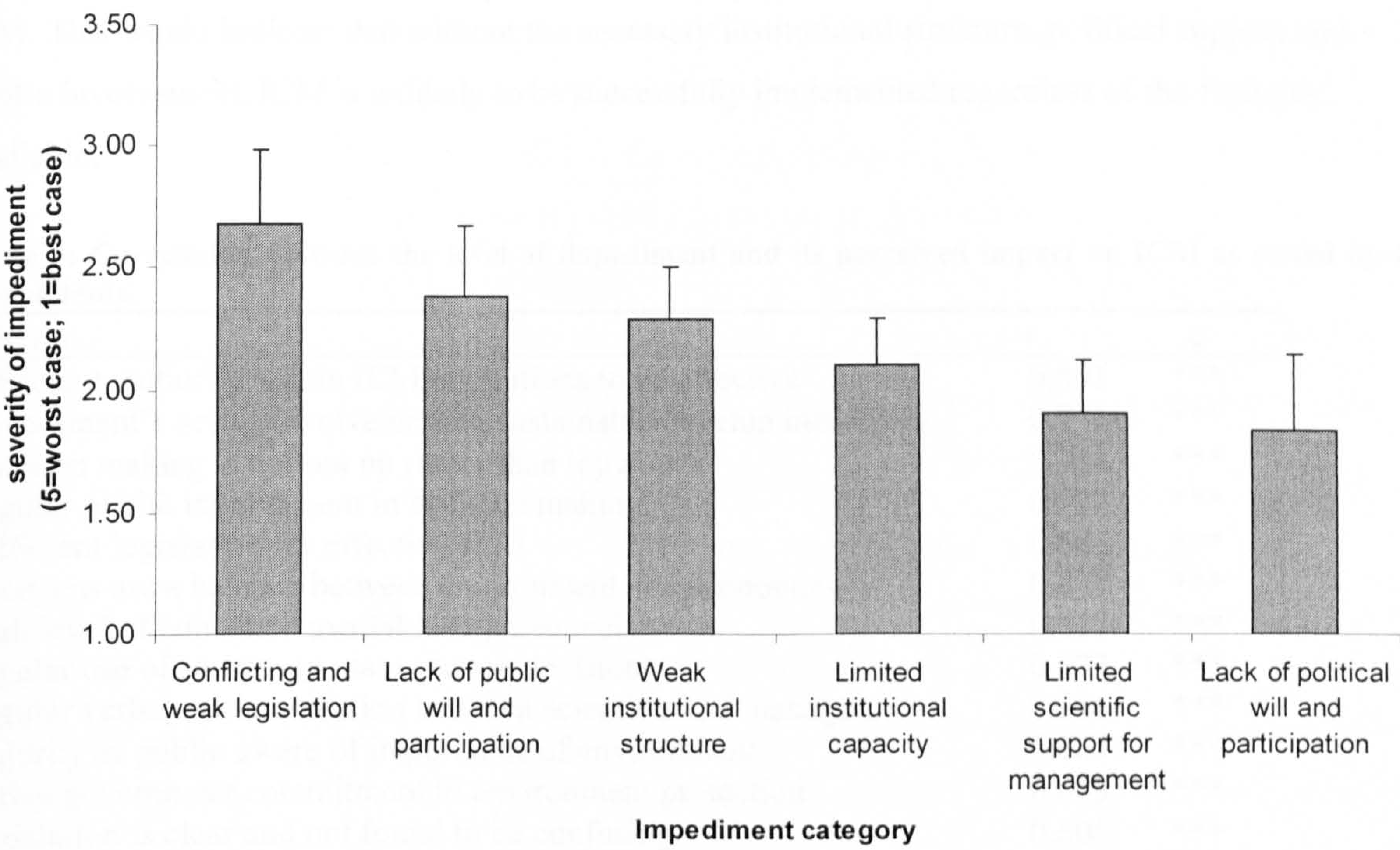

Figure 4 Mean level of severity (1 = none; 5 = a lot) for each impediment category occurring in the survey locations (errors bars show the 95% confidence limits)

Impact impediment has on ability to implement ICM

Not all impediments will have the same impact on the ability to implement ICM. The survey attempted to identify to what extent each impediment criterion affected ICM. This was based on the expert opinion of the different survey respondents. The level of each impediment criterion found in the survey location was gauged from very negative to very positive as to its effect on ICM. The results were then correlated to the level of impediments found in each location to try to establish consensus between the experts as to how each criterion affects ICM. The correlation was carried out on ranked data, which also included the yes: no categories for continuity. This was the reason to attempt to select impartial respondents who did not have a stake in over- or under-stating the level of impediment and its impact on ICM. This, however, is not always possible and they remain expert perceptions.

The results of the correlation (Table 3) show that the criteria are good indicators of the potential of a location to implement ICM with all but three of the criteria showing a significant correlation between the level of impediment and the ability to implement ICM. The results also indicate that for ICM to have a chance of implementation, ICM institutions need to have sufficient authority. In addition, factors having the greatest effect on the ability to implement ICM relate to the level of Government support and public involvement in the decision making process. Additional important factors are the capacity of the institutions in terms of education and support from science. Interestingly the level of adequate finances was not seen as having a significant impact on the ability of an area to implement ICM. This would indicate that without the necessary institutional structure, political support and public involvement, ICM is unlikely to be successfully implemented regardless of the finances available.

Table 3: Correlation between the level of impediment and its perceived impact on ICM as stated by the respondents.

Criteria	r	p
Sufficient authority within ICM institutions to be effective	0.801	***
Government's active involvement in sustainable develop initiatives	0.776	***
Decision making is bottom up rather than top down	0.758	***
Regular public involvement in decision making	0.727	***
Sufficient legislation for effective ICM	0.685	***
Decisions are a balance between environment and economics	0.679	***
High level of education available to personnel	0.677	***
Regular use of science in management decisions	0.673	***
Regular verbal communication between scientists and managers	0.666	***
Majority of public aware of importance of environment	0.664	***
Active government commitment to environment protection	0.613	***
Legislation is clear and not found to be confusing	0.606	***
Regular official ICM committee meetings	0.590	***
Institutional jurisdictions are rarely in conflict	0.561	***
Regular dissemination of information from scientists to managers	0.504	**
High level of local experience in ICM	0.478	*
Efficient functioning of ICM institutions	0.467	*
High level of integration of management plans	0.467	*
Regular long-term focus on decision making	0.454	n/s
Regular active communication between ICM institutions	0.444	n/s
Adequate finances available for implementation of ICM plans	0.438	n/s

The results of the correlation are ranked in the order of their significance. At the 95% significance level, all of the correlations would appear to be significant. However, taking a more conservative approach based on Bonferroni significance levels, after 21 correlations, the significance level should be reduced to 0.002. Using this level of significance, there is no significant common consensus of the impact the long term focus for decision making, the level of active communication between ICM institutions and the level of adequate financing available to ICM have on the ability to implement effective ICM. Significance levels are denoted by '***' $p<=0.001$, '**' $p<0.002$ and '*' $p=0.002$.

The results of the correlation (Table 3) were aggregated into the impediment categories. The highest correlation between impediment category and its perceived impact on the management process was in lack of public will and participation ($r = 0.72$; $p<0.001$). There is a strong consensus that the lack of public awareness and participation plays a major role in preventing the implementation of ICM. The lack of political will and participation, conflicting and weak legislation, limited scientific support for management and limited institutional capacity were all ranked similarly, averaging $r=0.64$, 0.63, 0.62 and 0.61 respectively ($p<0.001$ in all cases). The only category with a comparatively lower consensus on its impact on implementing ICM was weak institutional structure with an average of $r=0.49$ ($p=0.002$).

4.4 Conclusions

There is a substantial amount of literature on the theory behind ICM (Lowry & Wickremeratne, 1988; Bijlsma et al., 1993; Chua, 1993; Cicin-Sain, 1993; Turner & Adger, 1996; Cicin-Sain & Knecht, 1998; Salomons & Turner, 1999) but far less on identifying and overcoming the impediments to ICM. Evaluations have focused on which components of the programme are being implemented (Chua, 1998), rather than the level of success each component has attained. The lack of evaluation of ICM programmes means that there is little or no feedback into the programme itself as well as other programmes, which might have been able to learn from the experiences of a more mature ICM effort. In the case of donor-funded projects, objective evaluation of the programme or projects is often omitted (Sorensen, 1993). If an evaluation is completed, it is often buried in the institution's system and is not readily available for others to benefit from it (Sorensen, 1993).

In the past, generalisations have been made stating that decision-makers may face a number of problems at the ICM implementation stage (Bijlsma et al., 1993; Cicin-Sain & Knecht, 1998). The results of this study have enabled these problems to be specifically measured by both defining criteria with which to measure these impediments and a qualitative scale with which to gauge their severity. These criteria were related to the level of ICM seen in different locations and can therefore be useful indicators of the ability of an area to implement ICM.

The ICM impediments were found throughout the tropics at differing intensities. Similarities between the locations and the level of impediments found were linked to environmental factors of rapid population growth, unemployment and the regional location. This highlights the need to take into account other management priorities and certain cultural issues when embarking on ICM.

The World Coast Conference in 1993 identified the obstacles to ICM as falling into two main categories: *institutional strengthening* and *technology and skills* (Bijlsma et al., 1993). This study shows that these are two of a number of categories of impediments that affect the ability to implement ICM. This study identified six main categories of impediments. Specifying public and political support as two separate categories emphasises the need for attention to these areas. The lack of public and political support was perceived as having the greatest impact on the ability to implement ICM. The level of public support is clearly an issue in ICM as the lack of bottom up (grass roots) involvement in decision making was identified as one of the most common impediments. In addition, "institutional strengthening" was separated into two categories, one relating to institutional capacity and one to institutional structure. Institutional capacity included financial capacity, which was identified as one of the most common impediments. A further additional category was that of conflicting and weak legislation, again the lack of clear and sufficient legislation was identified as the most common impediments in the survey areas.

The impact the impediments had on ICM was linked to certain environmental factors. The priority of unemployment as a management issue, the level of tourism in the area and the level of reliable communications provided the best explanation from the BIO-ENV analysis. These factors may well indicate the lack of employment opportunities as alternatives to activities that are resulting in over-extraction of resources, the level of awareness of economic dependence on the environment and the ease of communications between different agencies and also the scientific community.

The individual impediments that were perceived to have the greatest effect on the ability to implement ICM again emphasised the need for public and political support and involvement in any ICM activities. Public participation has been identified as vital to ICM (Kelly, 1992; Hegarty, 1997; Davos, 1998; Masalu, 2000). This study not only shows the impact that lack of public involvement has on ICM implementation, but also that there is still a widespread lack of public participation in coastal management throughout the tropics. It may be that future ICM programmes need to pay greater attention to involving and educating the public before they are able to move forward with ICM. This may in turn require a longer-term focus for ICM programmes, starting with the more time consuming issues of raising awareness rather than theoretical plan development that may not have the support of the local community. Education and participation is a time consuming process and adequate time needs to be made available for this. However, even if the conditions are such that public participation is possible, Cicin Sain and Knecht (1998) point out that coastal stakeholders do need to invest their own time and energy into the effort.

Likewise with public participation, political involvement was also identified as playing a major role in affecting the success of ICM programmes. When carrying out ICM, the lack of political will can actually block well-meaning ICM efforts (Jorge, 1997). Gaining political support may be a difficult process but it appears unlikely that we can proceed in ICM without it. Future ICM efforts need to tackle any lack of public or political support before management efforts begin in earnest. Once again, this may require a revision in programme time scales.

Although the lack of adequate finances was a common issue, there was no clear consensus as to its impact on ICM. This would suggests that factors such as public and political support have a far greater impact on the ability to implement ICM. The impact that re-focusing coastal decision makers' attitudes and approach to planning and management has on ICM may be greater than increasing finances available to these organisations. However, without adequate funding there will be certain parts of the ICM process, for example monitoring and evaluation, which are not possible.

The results show that ICM efforts should initially be focused on raising public and political support. Implementation and enforcement, in particular, requires sufficient authority within the ICM agencies to be successful. These issues, although not always the most common are likely to be the most crippling to any ICM effort and should be given priority when embarking on any ICM programme.

References

Bijlsma, L., M. Crawford, C. Ehler, F. Hoozemans, V. Jones, R. Klein, B. Miermet, N. Mimura, R. Misdorp, R. Nicholls, K. Ries, J. Spradley, M. Stive, L. de Vrees and S. Westmacott. 1993. *World Coast Conference Report*. Ministry of Transport, Public Works and Water Management, National Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, the Netherlands.

Bradburn, N. M., S. Sudman and Associates. 1979. *Improving Interview Method and Questionnaire Design*. San Francisco: Jossey-Bass.

Chua, T.-E. 1993. Essential Elements of Integrated Coastal Zone Management. *Ocean and Coastal Management* 21: 81-108.

Chua, T.-E. 1998. Lessons Learned from Practicing Integrated Coastal Management in South East Asia. *Ambio* 27: 599-610.

Cicin-Sain, B. 1993. Sustainable Development and integrated coastal management. *Ocean and coastal management* 21: 11-43.

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated coastal and ocean management: concepts and practices*. Washington DC and Covelo, California: Island Press.

Clark, J. R. 1997. Coastal zone management for the new century. *Ocean & Coastal Management* 37: 191-216.

Clarke, K. and R. Warwick. 1994. *Change in Marine Communities: An approach to statistical analysis and interpretation*. Bournmouth, UK: Natural Environmental Resource Council. Printed Bourne Press Ltd.

Courtney, C. A. and A. T. White. 2000. Integrated Coastal Management in the Philippines: Testing New Paradigms. *Coastal Management* 28: 39-53.

Czaja, R. and J. Blair. 1995. *Designing Surveys: A guide to decisions and procedures*. California: Pine Forge Press.

Davos, C. 1998. Sustaining co-operation for coastal sustainability. *Journal of Environmental Management* 52: 379-387.

Ginsburg, R. N. 1994. *Proceedings of the Colloquium on Global Aspects of Coral Reefs: Health, Hazards and History, 1993*. Rosentiel School of Marine and Atmospheric Science, University of Miami.

Hegarty, A. 1997. Start with what the people know: a community based approach to integrated coastal zone management. *Ocean & Coastal Management* 36: 1-3.

Huber, R. M. and S. C. Jameson 2000. Integrated Coastal Zone Management in the Tropical Americas and the Role of Decision Support Models. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.*, eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 3-13. Washington, DC: The World Bank.

Jorge, M. A. 1997. Developing capacity for coastal management in the absence of the government: a case study in the Dominican Republic. *Ocean & Coastal Management* 36: 47-72.

Kelly, G. C. 1992. Public Participation and Perceived Relevance as Critical Factors in Marine Park Management. *7th International Coral Reef Symposium*, eds., International Society of Reef Studies, 1033-1037. Guam.

Linden, O. and A. Granlund. 1998. Building Capacity for Coastal Management. *Ambio* 27: 589.

Lowry, K. and H. J. M. Wickremeratne. 1988. Coastal Area Management in Sri Lanka. *Ocean Yearbook, University of Chicago.*

Makoloweka, S. and K. Shurcliff. 1997. Coastal management in Tanga, Tanzania: a decentralized community - based approach. *Ocean & Coastal Management* 37: 349-357.

Masalu, D., CP. 2000. Coastal and marine reesource use conflicts and sustainable development in Tanzania. *Ocean & Coastal Management* 43: 457-494.

Olsen, S. B., J. Tobey and L. Z. Hale. 1998. A Learning Based Approach to Coastal Management. *Ambio* 27: 611-619.

Oppenheim, A. N. 1992. *Questionnaire design, interviewing and attitude measurement.* London and New York: Pinter Publishers.

Post, J. C. and C. G. Lundin. 1996. *Guidelines for integrated coastal zone management.* Washington DC: International Bank for Reconstruction and Development & The World Bank.

Rajasuriya, A., M. H. Maniku, B. Subramanian and J. Rubens 1999. Coral Reef Ecosystems in South Asia. In *Coral Reef Degradation in the Indian Ocean: Status reports and project presentations 1999.*, eds., O. Linden and N. Sporrong, 11-24. Stockholm: Sarec Marine Sciences Programme.

Rajasuriya, A. and A. T. White. 1995. Coral Reefs of Sri Lanka: Review of their extent, Condition and Management Status. *Coastal Management* 22: 77-90.

Salomons, W. and R. K. Turner. 1999. *Perspectives on Integrated Coastal Zone Management.* Berlin Heidelberg: Springer-Verlag.

Sorensen, J. 1993. The International Proliferation of Integrated Coastal Zone Management Efforts. *Ocean and Coastal Management.* 21: 45-80.

Sorensen, J. C. and S. T. McCreary. 1990. *Institutional Arrangements for Managing Coastal Resources and Environments.* Washington DC: National Parks Service, US Department of Interior.

Turner, R. and W. Adger. 1996. *Coastal Zone Resource Assessment Guidelines.* LOICZ IPO, Texel, The Netherlands.

Veitayaki, J. 1997. Traditional marine resource management practices used in the Pacific Islands: an agenda for change. *Ocean and Coastal Management* 37: 123-136.

Westmacott, S. 2000. Where should the focus be in tropical integrated coastal management? *Paper submitted to Coastal Management, September 2000. Resubmitted for acceptance after reviewer's comments April 2001*

Wilkinson, C. and B. Salvat 1997. The Global Coral Reef Monitoring Network: Reversing the Decline of the World's Reefs. In *Coral Reefs: Challenges and Opportunities for Sustainable Management: proceedings of an associated event of the fifth annual World Bank Conference on Environmentally and Socially Sustainable Development,* eds., M. E. Hatziolos, A. Hooten, J and M. Fodor, 16-19. Washington DC: World Bank & International Centre for Living and Aquatic Resources Management (ICLARM).

PART II

ASSESSING MANAGEMENT TOOLS

PART II: Introduction

There are a number of tools available to the coastal manager. These range from computer based decision support systems (Gustavson et al., 2000), economic-ecological modelling techniques (Turner et al., 1998), multi-criteria analysis (Saaty, 1991; Beinat et al., 1994; Nijkamp & van den Burgh, 1997), conflict resolution (Rijsberman, 1998), database management (Fedra, 1995), remote sensing (Green et al., 1996) and geographical information systems (GIS) (Mumby et al., 1995). Less 'formal' tools also exist, for example communication techniques, methods to present scientific data in a manner that is easily understood by non-specialists. These are also important management tools. Any one of these tools can be seen to be just one components of the manager's *toolbox*. Armed with this toolbox, the manager is then able to apply a single or combination of tools to tackle the various problems encountered in the process of integrated coastal management.

The following three chapters address two specific ICM management tools.

- Chapter 5 is a broad overview of computer based decision support systems and their applicability to integrated coastal management.
- Chapter 6 assesses the CORAL model as a case study of one specific computer based decision support system.
- Chapter 7 assesses several different economic valuation techniques and their application to integrated coastal management.

Computer based decision support systems are continually being developed for use in ICM (Engelen et al., 1995; Westmacott & Rijsberman, 1995; Fabbri, 1998; Turner et al., 1998; Hogarth, 1999; van der Weide & De Vrees, 1999; Gustavson et al., 2000). Each system or approach aims at supporting the ICM decision making capacity by providing a means to compare the impacts of different management strategies. However, their acceptance and use is dependant on a number of factors and the complex decision making environment challenges the developer's ability to provide a useful and useable system. In many cases, they simply inform debate rather than perform the role for which they were originally intended. By critically assessing these systems, it was felt that future development could be guided and assisted by the findings, benefiting coastal managers around the world.

One of the main issues in integrated coastal management is the inability to convince politicians and senior managers responsible for sectoral agencies that there are significant advantages to be gained by investing time, effort and funds in developing coastal management (Burbridge, 1999). Much of the continued degradation of coastal resources has been linked to the failure to appreciate the full value of the beneficial functions provided by such systems (Crooks & Turner, 1999). Economic valuation is being increasingly used and is seen as a potentially powerful tool for managers. It was felt that this was a timely and needed look at the potential to fully utilise economic valuation in integrated coastal management and for this reason it has been specifically selected for evaluation.

References

Beinat, E., P. Nijkamp and P. Rietveld. 1994. Value Functions for Environmental Pollutants: A technique for enhancing the assessment of expert judgements. *Environmental Monitoring and Assessment* 30: 9-23.

Burbridge, P. 1999. The Challenge of Demonstrating the Socio-Economic Benefits of Integrated Coastal Management. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 35-54. Berlin Heidelberg: Springer-Verlag.

Crooks, S. and R. Turner. 1999. Integrated Coastal Management: Sustaining Estuarine Natural Resources. *Advances in Ecological Research* 29: 241-289.

Engelen, G., R. White, I. Uljee and P. Drazan. 1995. Using Cellular Automata for Integrated Modelling of Socio-environmental Systems. *Environmental Monitoring and Assessment* 34: 203-214.

Fabbri, K. P. 1998. A methodology for supporting decision making in integrated coastal zone management. *Ocean & Coastal Management* 39: 51-62.

Fedra, K. 1995. Decision-Support For Natural-Resources Management - Models, GIS, and Expert-Systems. *AI Applications* 9: 3-19.

Green, E. P., P. J. Mumby, A. J. Edwards and C. D. Clark. 1996. A Review of Remote-Sensing For the Assessment and Management of Tropical Coastal Resources. *Coastal Management* 24: 1-40.

Gustavson, K., R. M. Huber and J. Ruitenbeek. 2000. *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.* Washington, DC: The World Bank.

Hogarth, A. N. 1999. SIMCOAST. *CoastNET.*4: 6.

Mumby, P. J., P. S. Raines, D. A. Gray and J. P. Gibson. 1995. Geographic Information-Systems - a Tool For Integrated Coastal Zone Management in Belize. *Coastal Management* 23: 111-121.

Nijkamp, P. and J. C. van den Burgh. 1997. New advances in economic modelling and evaluation of environmental issues. *European Journal of Operational Research* 99: 180-196.

Rijsberman, F. 1998. *Conflict Management and Consensus Building for Integrated Coastal Management in Latin America and the Caribbean.* Washington DC, US: Sustainable Development Department, Inter-American Development Bank.

Saaty, T. L. 1991. *Multicriteria Decision Making: The Analytic Hierarchy Process.* Pittsburgh, USA: RWS Publications.

Turner, R., W. Adger and I. Lorenzoni. 1998. *Towards Integrated Modelling and Analysis in Coastal Zones: Principles and Practices.* LOICZ IPO, Texel, The Netherlands.

van der Weide, J. and L. De Vrees 1999. Methods and Tools to Support CZM. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 69-88. Berlin Heidelberg: Springer-Verlag.

Westmacott, S. and F. R. Rijsberman. 1995. CORAL, Coastal Management Model for the Sustainable Development of Coral Reef Areas. *Physics and Chemistry of the Earth* 20: 245-250.

5 Developing decision support systems for integrated coastal management in the tropics: Is the ICM decision making environment too complex for the development of a useable and useful DSS?

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5.1 Introduction

Integrated coastal management

Integrated coastal management (ICM) involves the management of the marine, estuarine, wetland and coastal systems (Sorensen & McCreary, 1990; Clark, 1992). The tropics are characterised by ecosystems that include vulnerable ecosystems such as coral reefs, mangroves and seagrass beds. The human system utilises and influences the ecosystems through fishing, tourism, recreation, residential, and industrial activities. Decision makers are faced with the issues of rapid population growth, increasing pressure to develop areas for tourism, depletion of the fish stocks through over-capacity and over-exploitation of the resource, and often a lack of personnel and financial capacity to manage the resources (Wilkinson, 1992; IUCN, 1993; Jameson et al., 1995; Bryant et al., 1998; Cicin-Sain & Knecht, 1998). Decision makers need to understand a wide array of issues, such as pollution and its effects on the environment, social issues and human behaviour, over exploitation and fishery dynamics and other local issues.

Decision making in the coastal zone involves multiple decision makers and multiple disciplines to be able to understand and cope with the complexity of the issues faced (Sorensen & McCreary, 1990; Bijlsma et al., 1993; Bower et al., 1994; Cicin-Sain & Knecht, 1998). ICM decision makers are required to understand issues beyond their own area of responsibility. In an ICM decision making environment, decision makers need to be able to broaden their view to understand and incorporate the impacts of their decisions on other stakeholder groups and socio-economic sectors. Pressing time constraints demanded by day-to-day management tasks often allow little opportunity for this. There is a gap for some form of information system or decision support tool in order to broaden views and increase a wider understanding of the issues.

Decision support systems

Decision support systems (DSS) are developed under the belief that these systems are able to improve our understanding of the inter-relationships between natural and socio-economic variables and hence result in improved decision making (Te'eni & Ginzberg, 1991; Fabbri, 1998). An ICM-DSS can be defined as a computerised system capable of supporting and assisting decision making in ICM.

While the name "Decision Support System" suggests a system capable of improving decision making, there is a danger that misapplication of models and tools can lead to unrealistic and misleading outputs (Parker et al., 1995). Much of this can be overcome through careful design of the system and ensuring the appropriate information is given to the decision makers about the model and its limitations with system checks to avoid misuse. It is true that as models become more complex, the results are not always more reliable. Developing the all-inclusive model may not be the answer to the complexity of the problem faced. Comprehensiveness and complexity do not necessarily lead to increased accuracy (Loucks, 1987). However, Parker (1995) warns against taking extreme positions on the use of models emphasising that while they may not provide all the answers, they are also not a waste of time. He continues to point out that model results and predictions should be accompanied with some indication of the level of confidence that can be placed on the outcome, avoiding the results being either under or over-valued, or discounted entirely.

Developing DSS for ICM

Traditionally models have been developed for just one section of the ICM decision making environment, for example, a component of the ecology or the economic system, but rarely for the combined economic-ecological system. The complex nature of the ICM decision making environment requires the development of an ICM-DSS to tackle the following issues:

- *Involvement of multiple decision makers*
- *Multiple issues and hence multiple disciplines involved*

This leaves the question as to whether or not the ICM decision making environment is too complex to develop a useful DSS.

Considering both the economic and ecological system is essential for ICM. Examining the two systems in isolation can create problems because they are inherently tied together with one system influencing the other (Staley, 1987; Nijkamp & van den Burgh, 1997). The ecosystem provides goods and services that sustain a certain level of economic activity. This in turn leads to continuing utilisation of the ecosystem through extractive and non-extractive uses leading to a new ecosystem state potentially able to provide a different level of goods and services supporting a new level of economic activity.

Analysing the economic system without accounting for the ecological system could lead to unsustainable resource use, by maximising economic goals without accounting for any degradation to the environment that may occur as a result of these economic activities. In the long term, this degradation could have a negative feedback on various components of the economic system. The ICM analysis must account for the 'costs' of the resource degradation, which is only possible when both the socio-economic and ecological components of the system are included. Likewise, isolating the ecological analysis from the economic system can lead to unrealistic policy recommendations that ignore the main economic reasons leading to resource degradation (Dixon, 1993). The first attempts to combine the ecology and the economy in modelling were probably in the 1960's with the development of water quality management models which combined water quality prediction models with models that incorporated management alternatives and their costs, enabling the most cost-effective solutions to be sought (Loucks, 1987). More recently ecological-economic approaches are being addressed and a new era of integrated DSSs are being developed, e.g. spatial DSS integrating socio-economic and biophysical parameters in context of ICM (Fabbri, 1998) and environmental management (Zhu et al., 1998).

The use of computerised modelling techniques as management tools has increased as computers have become more user-friendly and accessible (Parker et al., 1995). The development of these computerised decision support tools in coastal management is increasing, and being led by some of the major international organisations. Examples include:

- COSMO a coastal zone simulation model and CORONA, the role play version of COSMO, developed for the World Coast Conference in 1993 (Bijlsma et al., 1993) by the Netherlands' Government (Resource Analysis & Delft Hydraulics, 1993);
- ISLAND-model, developed for the United National Environment Programme, Caribbean Unit and presented during the ICM Conference on Small Island Developing States in Barbados, 1994 (Engelen et al., 1993);
- COMA, a coastal model for Africa, developed as part of the World Bank's post-UNCED strategy towards environmentally sustainable development in Sub-Saharan Africa (Westmacott, 1995; World Bank, 1995);
- The CORAL models developed for Montego Bay in Jamaica, Curaçao in the Netherlands Antilles and North and South Male Atoll in the Republic of the Maldives. CORAL is a model for coral reef management and protection incorporating a cost-effectiveness methodology developed by the World Bank (Westmacott & Rijsberman, 1995; Huber & Jameson, 1998; Gustavson et al., 2000);
- SIMCOAST, an expert system for world-wide coastal zones initiated in 1995 and jointly funded by ASEAN and the EU (Hogarth, 1999);
- Reef Base, the global data base for coral reefs developed by the International Centre for Living Aquatic Resources Management (ICLARM) and supported by Reef Check and the Global Coral Reef Monitoring Network (GCRMN) (McManus et al., 1999);

The renewed International Coral Reef Initiative Call for Action (ICRI, 1998) states that managers and communities are not getting the information and tools they need to make sound management decisions. As a result, they see the need to create a network of knowledge-based systems through networks of people, ideas and information to promote science-based management and public participation in that process. This emphasises the need and support for the development of systems that are able to transfer expertise and knowledge from scientists and experts to the decision makers. The task to develop useful decision support tools is, however, not as easy as it may first appear.

This paper aims to answer the question as to whether or not the ICM decision making environment in the tropics is too complex for the development of useable and useful DSSs. It achieves this through first examining the complexity of the ICM decision making environment, looking at the features of a DSS and the various modelling techniques available. A further section explores the usability of a DSS and reports on how this can be improved through the development process. The final section analyses some of the different DSSs developed for ICM.

5.2 The decision making environment

An ICM DSS is designed to support decision making within the ICM decision making environment. In order to be able to design or evaluate an ICM-DSS we need to understand what the ICM decision making environment entails. ICM decision makers have to be able to evaluate complex problems involving the understanding of a multitude of fields and disciplines. Like any decision makers, they have to evaluate alternative strategies and select the most appropriate for their situation. After implementation, they must be able to evaluate the success of the chosen strategy through monitoring, leading to eventual re-design and adaptation of the strategy. The ability to undertake these management tasks is influenced by a variety of factors. For example: the available knowledge and expertise, the understanding and communication between the different decision makers and stakeholders, the willingness of the decision makers to co-operate, the financial resources available and the acceptability of the strategies to those affected. All these factors form part of the decision making environment, shown schematically in Figure 1, and affect the capacity to make balanced decisions.

The ICM decision making environment is highly complex and variable. The factors influencing different decision makers may result in different behaviour patterns. The human way of thinking is not normative or rational but conditional, meaning that that humans use their whole life experience to reach a decision (Kainuma et al., 1991). Attempting to mimic human decision making in a computer system is therefore unlikely to be achievable and DSS should be seen as *support systems* not *decision makers*. This is supported by Cohen (1978), who states that models and systems analysis cannot perform all the activities that are critical for effective planning. Models have a role in planning but they cannot replace the planning process. DSSs should be designed in such a way as to support the components within the decision making environment (Figure 1) by providing additional information, analytical tools and management tools that would not otherwise be available.

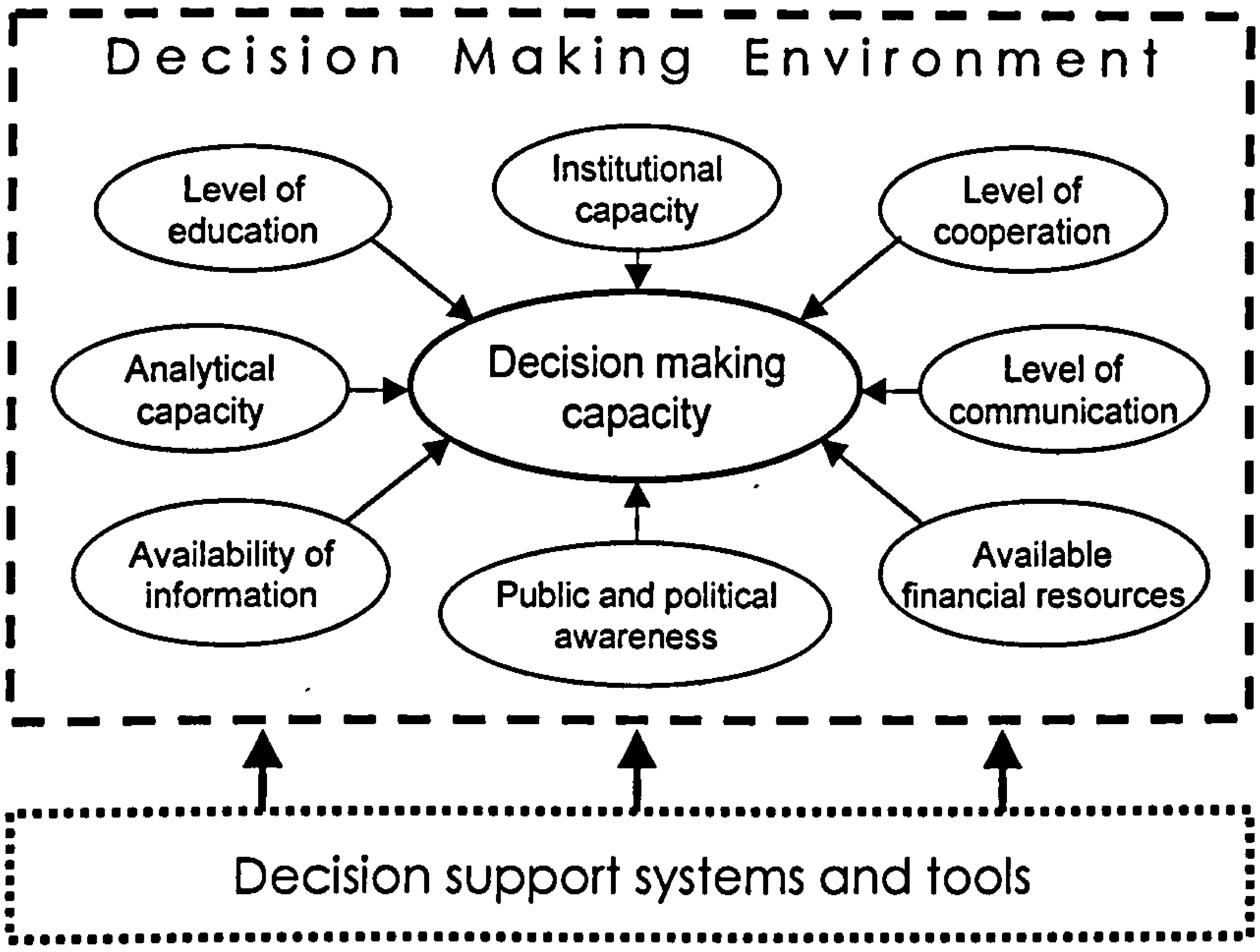

Figure 1 Decision making environment

5.3 Decision support systems

A DSS aims to strengthen the decision making capacity. This capacity is affected by various factors within the decision making environment (see Figure 1). Kainuma (1991) states that the purpose of their DSS is to assist in systematic thinking and to deepen mutual understanding. As integrated coastal management becomes increasingly complex, it becomes more of a social problem. These complex issues are difficult to understand by one discipline and a combination of expertise is required to both evaluate alternative strategies and analyse the consequences of the management (Kainuma et al., 1991). Not only are multiple experts required, but ICM also involves a number of decision makers. The type of decision-maker that is being dealt with or the DSS is being designed for will have an important influence on the type of DSS developed through the selection of appropriate tools (Te'eni & Ginzberg, 1991).

In developing a DSS it is important to know its ultimate purpose. A DSS can be developed as a screening tool to assess the environmental impacts of individual projects (Geraghty, 1993) or it can be developed as a planning tool for developing and analysing alternative management strategies (Westmacott & Rijsberman, 1995; Gustavson et al., 2000). The systems can be developed for use by analysts or for use by decision makers. The specific purpose will determine the contents and design of the DSS. Each DSS has several main components, typically consisting of a user interface, a knowledge base or database and a series of models (Geraghty, 1993; Zhu et al., 1998). These components are shown in Figure 2.

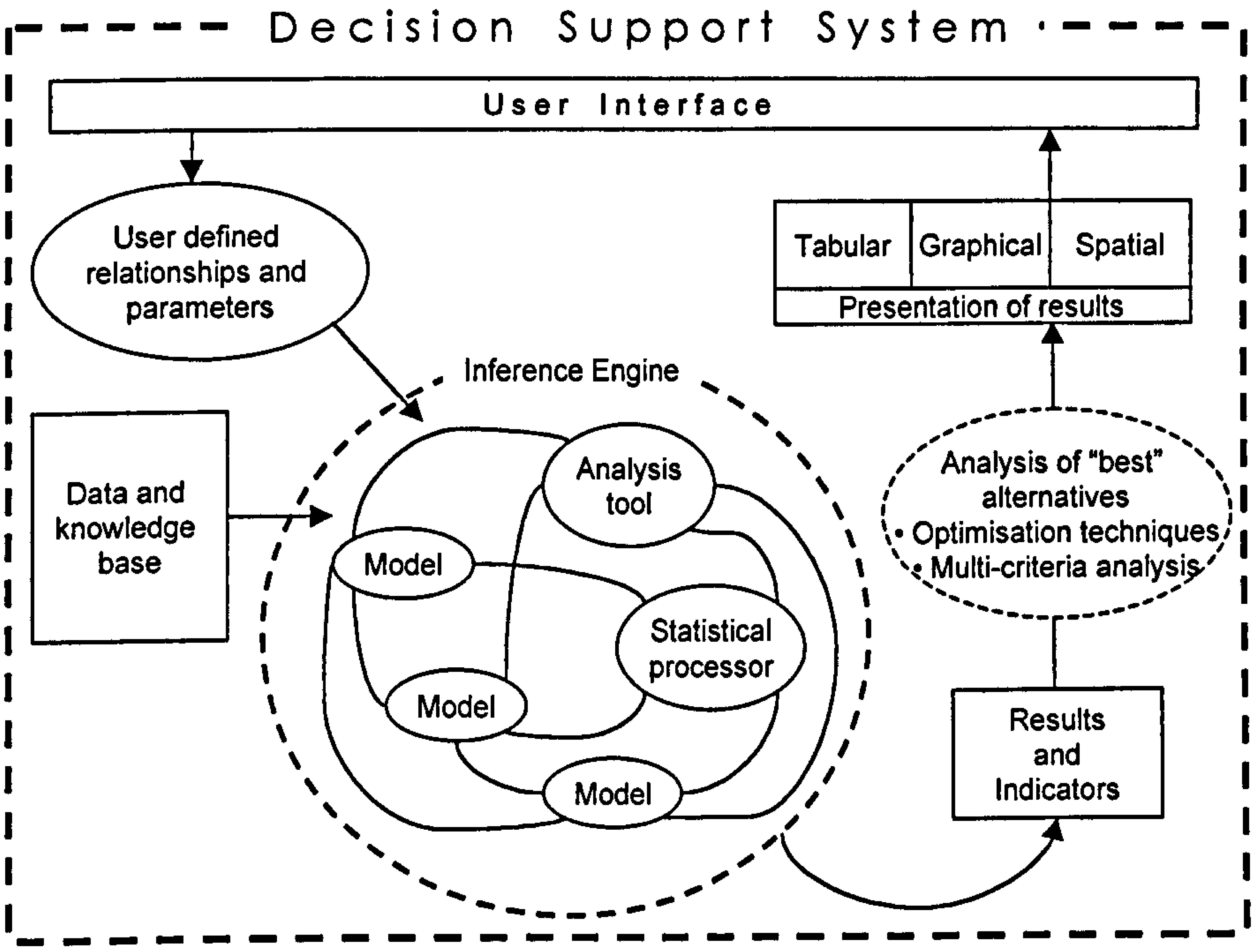

Figure 2 Components of a decision support system

The user interface

The user interface is the only part of the decision support system that the user will ultimately come into contact with. As a result it plays an important part in the usability of the system. Designed carefully, the user interface can be instrumental in guiding the user through the various steps of the analytical procedure (Kloditz et al., 2000). The user is required in most cases to input various parameters and definitions, for example setting different economic growth rates as scenarios and defining various management plans whose impacts will be analysed by the inference engines.

A DSS may be designed as a 'shell', meaning there are rules and models forming the inference engine and a user interface but no knowledge base containing information relating to the specific location. It is a system empty of its domain-specific knowledge which is required as input by the user for application to a variety of locations (Geraghty, 1993). An example of this is SIMCOAST (Hogarth, 1999).

The data and knowledge base

The data and knowledge base contains all the required data and information to drive the models within the inference engine. It may also contain framing and background information that may assist the user in designing strategies and scenarios to evaluate. In the case of a generic DSS shell, this part of the DSS is empty and the experts in that particular location are involved during the model development in formulating the rules and judgements forming this part of the DSS.

The inference engine

The inference engine is the model or set of models that drive the analytical capabilities of the DSS. These can be simple structural models or complex 3-dimensional models. The different modelling techniques available are discussed in more detail in the following section. The models' results are likely to be a series of criteria describing the economic and ecological system. For example, a DSS developed for a coral reef location may produce the following criteria:

- Coral reef health (% hard coral cover, coral diversity, fish diversity)
- Economic growth (number of jobs created, income per capita)
- Social welfare (access to coastline line, number of public beaches)

It is then the task of the decision maker to compare and evaluate the resulting levels of these criteria for each management strategy analysed.

Analysis of the "best" alternative

Several techniques are available to assist the decision-maker in the selection of alternatives, collectively termed multi-criteria analysis (MCA) techniques (Beinat et al., 1994b; Beinat et al., 1994a). The techniques enable comparisons of alternatives, measured by different criteria, to be made. The criteria are weighted or valued by the user to enable them to be compared against each other. This can introduce a certain degree of subjectivity that can be minimised through group involvement in the process. MCA is applied once the alternatives have been developed. It presumes the existence of adequate, reliable, quantitative environmental-economic models (Nijkamp & van den Burgh, 1997). The strength of multi-criteria techniques is that they are able to address problems marked by various conflicting interests. Optimisation on the other hand approaches the problem much more rigidly by trade-offs; a loss in one criterion will mean a gain in another (Nijkamp & van den Burgh, 1997). Like all decision support tools, MCA technqiues are not able to replace the human decision-maker and their main aim should be to provide help and guidance to the decision-maker in discovering their most desired alternative (Stewart, 1992).

Presentation of results

The development of computing capacity and availability of geographical information systems (GIS) and other graphical techniques are enabling results of models to be presented in a visual form rather than simply as tables and graphs. GIS can be used to display geographical data and develop spatial models. These spatial models are increasingly being developed and a methodology combining GIS and MCA is currently being used to develop a spatial ICM-DSS (Fabbri, 1998).

5.4 Modelling techniques

When selecting the type of models required or the modelling approach to take, it is important to know the level of accuracy required and the resources available. If all that is required is a "back of the envelope" calculation then there is no need for complex modelling approaches (Bewers et al., 1992). There is a huge variety of modelling techniques from the highly complex, data intensive hydrodynamic models to system diagrams indicating graphically different impacts and relationships. For ICM, some combination of economic and ecological model is required. Combining economic and ecological models is likely to result in a degree of uncertainty leading to a trade-off between generality, precision and realism (Dixon, 1993), (Costanza et al., 1993). Validation of these multi-disciplinary models becomes increasingly difficult to achieve, as such comprehensive data is rarely available (Bewers et al., 1992). However, if a DSS is to be developed for ICM, the multidisciplinary approach must be tackled.

Data availability

Data availability is also an important factor in selection of the model or modelling technique. An alternative approach is needed when dealing with modelling in social and management sciences as opposed to natural sciences. Social science is more vague and may require a softer approach (Checkland, 1984; Checkland, 1985). Different techniques are required for qualitative as opposed to quantitative information. Modelling with limited data or vague concepts can be overcome through the development of a linguistic model based on fuzzy sets requiring no numerical data, as long as suitable knowledge is obtained (Kainuma et al., 1991).

Modelling scale

The scale on which the DSS is to be used is also an important factor in model selection. Economic information is often available at the macro level (e.g. income per capita for the whole country) while ecological information is available at the micro level (e.g. % hard coral cover at a specific monitoring site).

Structural models

One of the simplest forms of modelling can be seen in the form of structural models. These may be the early conceptual stages of a programmed model, or they may serve a useful purpose in themselves. Structural models have been defined as 'any model that represents a complex system as a set of elements with relations – nearly always in pairs – linking some or all of them and places the emphasis on the geometry or structure rather than on quantitative aspects of the relationships' (Kainuma et al., 1991). The structure of the system being modelled is fundamental to understanding what is happening. The structural model can give the decision-maker as well as the modeller, new insights into the system. It is a useful tool for dealing with complex environmental and social issues (Kainuma et al., 1991). An example of a structural model can be seen in Figure 3 for the coast of Curaçao where the linkages between the coastal activities are visualised but not quantified (Rijsberman & Westmacott, 1996).

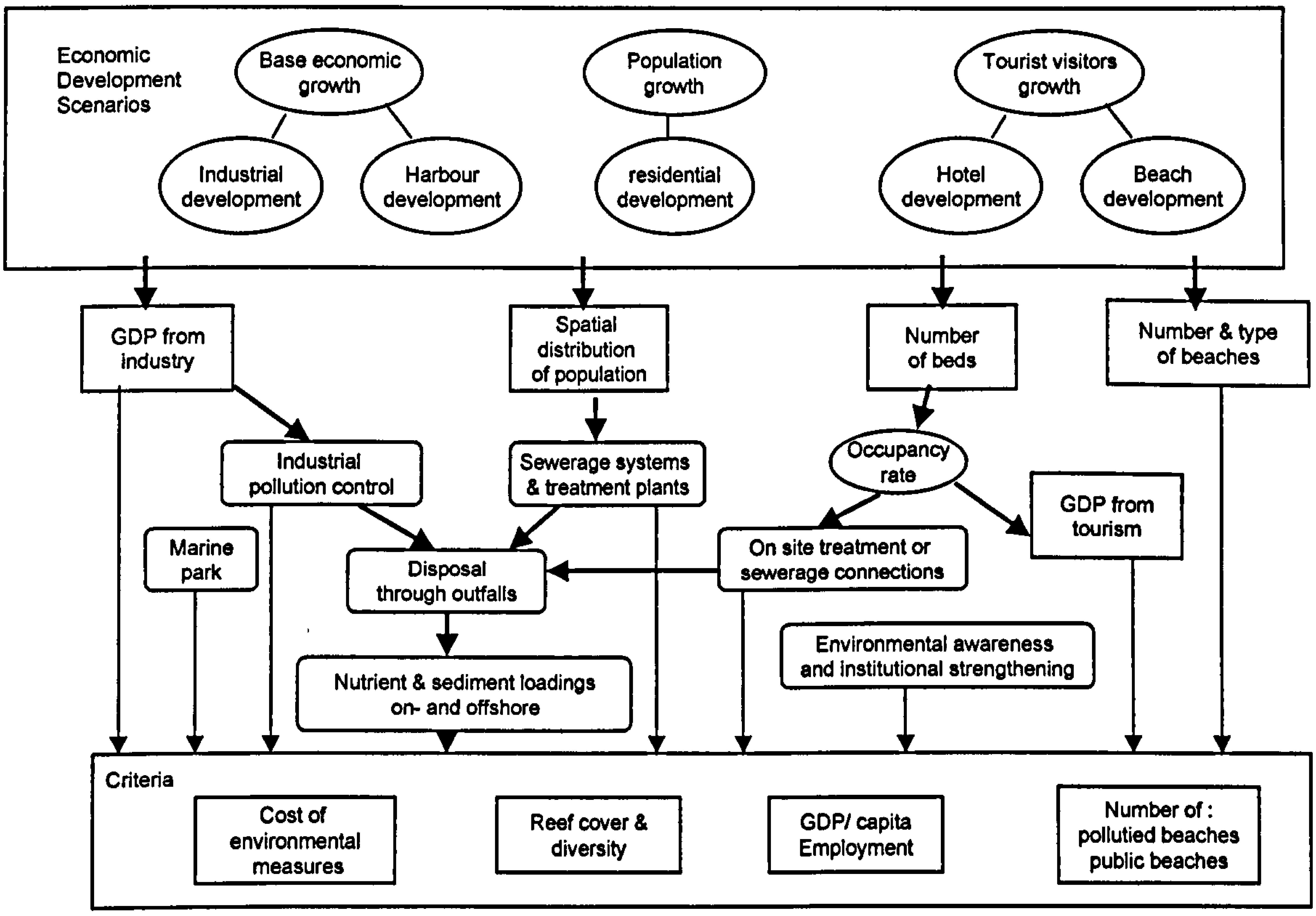

Figure 3 A structural model for the coastal system of Curaçao (after Rijsberman and Westmacott, 1996)

Structural matrices

Structural matrices show in qualitative terms (e.g., high to low), the levels of influence or impact an activity may have on a system. Coiacetto (1996) defined a simple-to-understand matrix that captures the essential features of a wetland to be managed (see Figure 4). A structural matrix will enable managers to identify the first order impacts of human activities, structures and land-use changes on a series of carefully selected environmental attributes and allow participants to co-operate within a framework of reference which is understandable and accessible to all. The approach provides a rough, but broad state of the system which can be used to identify those areas where further investigation and study is required (Coiacetto, 1996).

			ENVIRONMENTAL ATTRIBUTES	Clearing and infilling	Catchment clearing	Land cultivation	Grazing	Floodgates	Drains and canals	Levees	Bridge	Breakwater	Urban development	Sewage treatment works	Water craft sports
				ACTIVITIES/ LAND USES											
HYDROLOGICAL	Ground water	1	Level		●	○			○	∘					
		2	Stability		○	∘									
		3	Quality												
	Marine	4	Tidal range								○				
		5	Tidal exchange								○	●			
		6	Tidal velocity								•	●			
		7	Tial Obstructions					●							
		8	Wave energy								○	•			
	Fluvial – Stream-flow	9	Volume		●								●		
		10	Stability		●			∘	∘				○		
		11	Velocity						•				●		
		12	Obstructions					•	•						
	Fluvial – Wetland Inundation	13	Depth		•						●		●		
		14	Duration								●		●		
		15	Frequency		•				●	○			●		
	Other	16	Water Temperature												
		17	Turbidity	●											
MATERIAL INPUTS	Sediments	18	Fluvial (Quantity)		⬤	●	•			∘			●		
		19	Fluvial (stability)		○	○	•			∘			∘		
		20	Marine (Quantity)								•	⬤			
		21	Marine (Stability)												
	Nutrients	22	Nutrients (Quantity)		●	●	•	∘		○			●	●	
		23	Nutrients (Stability)		○	○	•	∘		○			○	●	
	Other inputs	24	Toxins			●							●	•	•
		25	Pathogens				•							•	
		26	Noxious Flora	●		●	•	•	•				•		
		27	Noxious Flauna	•					•				●		
OTHER ATTRIBUTES		28	Area of wetlands	◯			•				∘				
		29	Wetland vegetation				◯								
		30	Rare Species	*			*		*						*
		31	Fauna	○											○

Key

• ∘ Minor Increase: Decrease in Environmental attribute

● ○ Intermediate Increase: Decrease in Environmental attribute

⬤ ◯ Major Increase: Decrease in Environmental attribute

* Indeterminate or complex impact

Figure 4 Hypothetical coastal wetlands environmental interactions matrix (after Coiacetto (1996))

Hydrodynamic modelling

Hydrodynamic modelling is generally thought of as complex two and three dimensional numerical models formulated by the major hydrological laboratories. However, modelling water circulation can be simple, making assumptions that the body of water under consideration is a well-mixed 'box' and using average circulation and current patterns derived from observations (Bewers et al., 1992). Again the selection of the method will depend on the final use of the model and the other components within the modelling system. There is little point in having a complex 3 dimensional hydrological model when the economic model resulting in the levels of pollution is a simple cause-effect relationship.

Simulation modelling

Simulation modelling is a form of modelling based on specific equations that are calibrated and verified with field data. Many examples can be found in the natural sciences. The ecological model of reef fisheries developed by McClanahan (1995), models the coral-ecosystem in order to show impacts of different fishing intensities and catch selection. The model is able to identify potential management strategies producing the most stable fishery yields. The fisheries model developed by Saila (1993), shows the effects of destructive fishing practices on coral reefs. The results of the model show the effects of management practices on recovery times. This type of modelling requires the ability to quantify relationships and parameters, both during model definition and calibration which requires substantial amounts of field data.

Spatial modelling

With the advance of geographical information systems (GIS) and computing capacity, spatial modelling is becoming more and more accessible. Spatial modelling can be both large and small scale depending on the data available. Remotely sensed images are now able to provide us with high-resolution images of land use and even information on marine ecosystems. The Island-model is one example of a spatial model this utilises cellular automata (Engelen et al., 1995). It models the economic and environmental system and tracks changes in land use simulated over time. Perez-Trejo (1993) utilised spatial dynamic modelling to model land use changes on the island of Crete. The spatial component of the model identifies the suitability of land for different uses.

Expert systems and fuzzy modelling

Expert systems attempt to simulate the means by which a human expert tackles real-world problems using a set of rules, heuristics and inferences programmed into a computer system. These systems interpret information and reason toward a conclusion with the aim of obtaining the same results that the human expert would arrive at if presented with a comparable task (Geraghty, 1993). Expert systems and fuzzy reasoning based on fuzzy sets (Zadeh, 1965) are able to convert qualitative reasoning into quantitative mathematics (Kainuma et al., 1991). The power of expert systems is that they are potentially capable of providing expertise where the expert is not available and as a result are able to build capacity (Geraghty, 1993).

Fuzzy modelling, first introduced by Zadeh (1965), is based on the concept that things are not true or false, black or white but rather shades of grey (Kosko, 1994). It utilises qualitative, linguistic relationships based on expert knowledge and judgement to link a set of inputs to a set of outputs. This type of modelling can be implemented where sufficient numerical data to build up a statistical model using traditional methods may be missing (Kainuma et al., 1991; Nijkamp & van den Burgh, 1997).

Fuzzy logic has been applied to many different applications relating to ICM. Examples include modelling the anthropogenic impacts on coral reefs (Meesters et al., 1998), modelling the impact of recreation on the environment in the Western Scheldt (van der Werff & Goosens, 1997), selecting alternative projects when environmental evaluation is vague or little understood (Smith, 1994), classifying vegetation classes from remotely sensed images (Foody, 1996) and even modelling the hydrological cycle (Bardossy, 1996). Fuzzy logic provides a means of incorporating those traditionally non-quantifiable goals into the decision making process.

5.5 Utilisation of decision support systems

There are drawbacks to modelling and the development of a DSS. Most models end up buried and forgotten in academic reports after, perhaps, serving as the focus of a few spirited debates (Pearse & Walters, 1987). Model conclusions, qualitative or otherwise, seldom become the basis for a strategic policy guideline or basic decision. Detailed prescriptions resulting from models are rarely adopted comprehensively. To many modellers, having their models "actually applied" has come to mean little more than "presented for discussion" (Pearse & Walters, 1987). Keil (1995) presented two concepts of 'perceived usefulness' and 'ease of use' as important factors in determining acceptance and use of these types of information systems. He defined 'perceived usefulness' as the degree to which a person believes that using a particular system would enhance his job or her job performance and 'ease of use' as the degree to which a person believes that using a particular system would be free from effort. The 'ease of use' of a system is seen as broader than simply interface design. Usability is not whether the user can manipulate the tool but whether the tool will enhance the user's ability to execute tasks and perform his or her job (Keil et al., 1995)

The level of usefulness of a DSS and its ease of use will define the type of tool it becomes. Figure 5 illustrates the different definitions of the type of DSS depending on its perceived usefulness and ease of use (Keil et al., 1995).

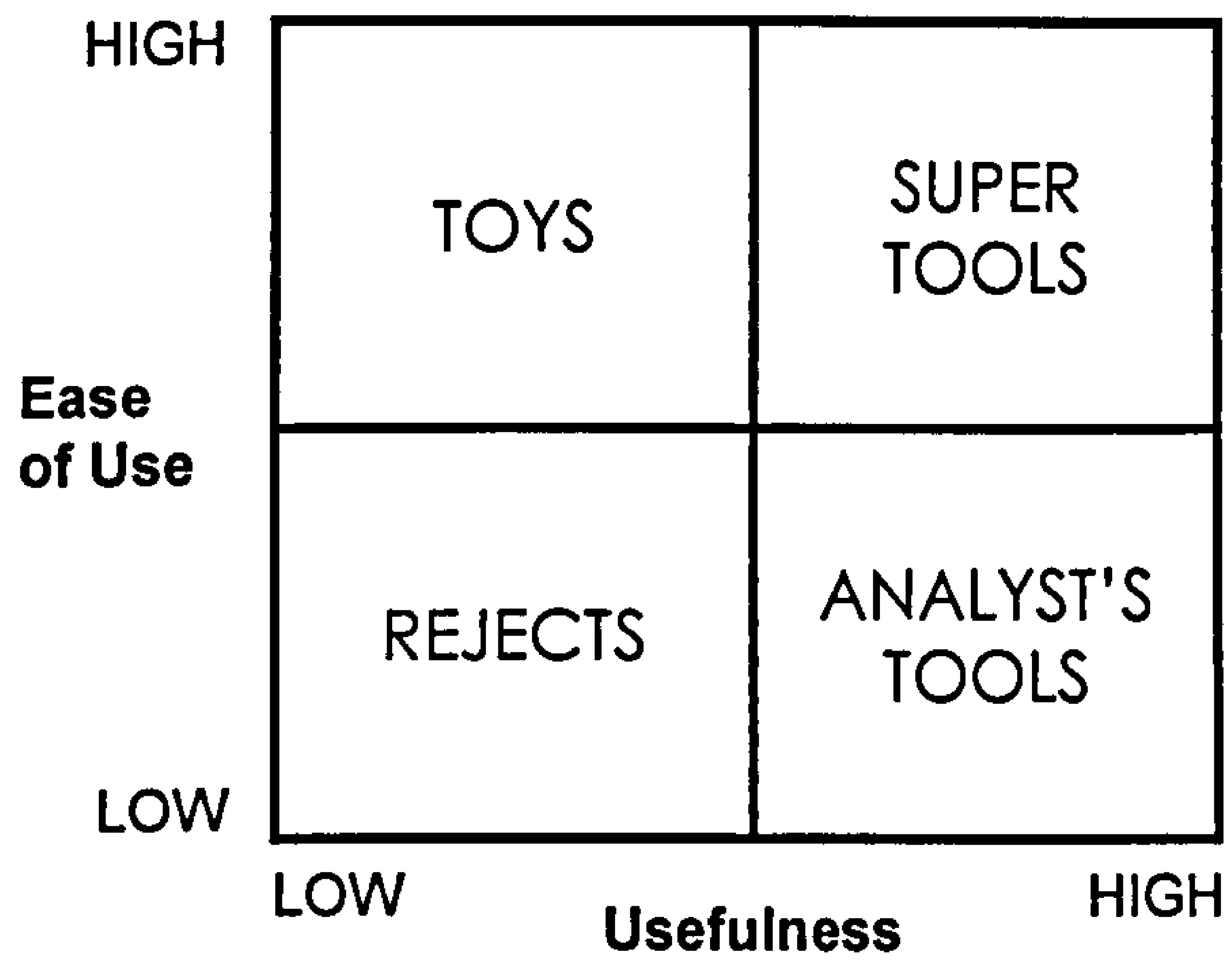

Figure 5 Grid defining the type of decision support system developed depending on its perceived usefulness and ease of use (adapted from Keil, 1995)

Figure 5 suggests those systems that are neither useful, nor easy to use hold little appeal and will generally be rejected. Those systems that are easy to use, although have little inherent usefulness will be classed as toys (Keil et al., 1995). Their limited capacity holds them back from being useful as decision making tools, however, they may have an important use for educational purposes. Analyst's tools are tools that are powerful enough to be useful but the complexity of use or learning required to operate the systems is too great to be undertaken by many. A few analyst's who believe the functionality outweighs the low ease of use will utilise these systems. Super tools refer to powerful systems that are both functional and easy to use. These tools stand the greatest chance of being utilised and accepted.

Model-builders need to be sensitive to the concerns of the local decision makers and stakeholders. A model dropped into a complex policy making setting will threaten many of the people involved (Pearse & Walters, 1987). Models will never be able to incorporate everyone's concerns and will always remain approximations of reality. However, if they are built interactively with the subject experts, the decision makers and the analysts, the decision makers will learn during the process as well as being able to input their interests and concerns into the system (Guariso & Werthner, 1989; Kainuma et al., 1991). If model builders want their systems to be used they must fully involve stakeholders and potential users and develop a working partnership between model developers and model users (Argent et al., 1999; Ewing et al., 2000).

Many of the obstacles to the acceptance of models can be overcome by effective communication (Pearse & Walters, 1987), these obstacles include:

- resistance and apprehension towards to new technology,
- opposition to change that a model is usually designed to assist in making,
- opposition to compromise of conflicting interests optimised by the model,
- suspicion about objectivity of the model development,

- commitment to existing non-threatening concepts and difficulty in understanding new concepts,
- truncated perceptions aggregating results beyond the scale of the individual
- different interests in distribution effects of who will gain and who will suffer from new policies versus efficiency gains measured in economists or ecologists terms
- apparent irrelevance due to failure to identify what questions are of primary interest
- blurred decision making authority as opposed to the single decision maker

In addition to these obstacles, Geraghty (1993) lists three main drawbacks in the development of decision support systems:

1. The long development time involved (5-10 person years)
2. The knowledge acquisition bottleneck or difficulty in transferring knowledge from the expert to the computer. Expertise is often intuitive and requires a series of lengthy interviews to extract.
3. Unlike the expert, the DSS does not know when it has reached its limits of its expertise. The expert will say when he cannot solve the problem with his knowledge, a computer system may provide misleading results.

However, Geraghty (1993) does state that expert systems provide a promising approach to limited expertise available in environmental assessment and recognises their potential in education and training. Some argue that the most valuable aspect of a complex model is its capacity for educating those involved in management (Osbourne et al., 1986). The educational role covers the identification of the variables subject to management control, the nature of interactions among these variables and the assessment of the relative impacts of alternative management initiatives.

5.6 Decision support systems in integrated coastal management

A DSS developed specifically for ICM is a system that attempts to improve our understanding of the inter-relations between natural and socio-economic variables in the coastal zone and hence result in improved decision making in the coastal zone. This requires the DSS to deal with the complexity of the ICM decision making environment. The list below summarises some of the requirements within the decision making environment (see Figure 1) in many coastal areas:

- Educational level: a broad understanding of multiple subjects
- Analytical capacity: ability to analyse economic-ecological interactions
- Institutional capacity: experts, negotiators and managers from all stakeholder groups to help towards developing a balanced management plan
- Cooperation: cooperation between multiple stakeholder groups with differing views and objectives
- Communication: active communication between multiple stakeholder groups

- Financial resources: adequate finances for both development as well as conservation; financial resources for development of alternative activities
- Awareness: awareness of the impacts human activities have on the environment and the impact environmental degradation has on human welfare and the economy
- Information: available data on both the economy, ecology and their impacts on one another

In many coastal areas, some or all of these requirements are missing.

An ICM-DSS therefore needs to:

- Incorporate multiple objectives and views
- Cover a multi-disciplinary subject area
- Deal with limited data and information

Specific to ICM is the need to take into account the multiple objectives and views found between the different stakeholders. The DSS can therefore play several roles. In the first instance, it is able to collate data and information from the different groups that may otherwise not share their information. Secondly, it can provide a facilitative role between the various stakeholder groups enabling discussion on both the variables to take into account and the various interactions between these variables. Thirdly it can play an educational role for other observers highlighting the interactions and impacts between different coastal activities and environments. Finally, it can support and assist ICM decision making.

Incorporating multiple objectives and views

Many models fail to produce outputs relevant to the economic or political context of the problem being modelled (Staley, 1987). An example of a model's misleading results can be seen from the analysis of the ecological impact of the oil industry in the Canadian Arctic (Staley, 1987). This analysis was carried out in isolation from the socio-economic situation. Models were developed to identify the impacts that expanding the oil industry would have on wildlife. However, it was identified later that the major environmental impact would come from the unregulated human response and economic behaviour of the native people to their increased wealth. They would now have the means to employ others to carry out their fishing and with their increased wealth, would be able to mechanise the previously subsistence fishery and over-exploit the resource. Using this example, Staley (1987) emphasises the need to develop models through an open process involving all the important actors and expertise. This minimises the risk of missing important interactions, such as a change in the behaviour of the socio-economic system as a response to a change in the ecological system.

Covering multi-disciplinary subject area

An ICM-DSS needs to cover a wide multi-disciplinary subject area that includes both socio-economic fields as well as environmental and ecological fields. Dixon (1993) examined three attempts to link economic analysis to ecological analysis. The first example illustrated the impacts of forestry on soil erosion and subsequently on coral reefs. The model outputs provided scenarios which were input into an economic analysis which was a simple present value calculation of the gross revenues of two scenarios - logging and not logging. The second example (Ruitenbeek, 1994), created linking scenarios between mangrove conversion and other parts of the ecosystem, e.g. offshore fishery production, traditional use of the mangrove and the benefits of erosion control and biodiversity maintenance. The third example, from Bonaire, was used to identify at what levels SCUBA diving within a marine park was compatible with the twin goals of resource conservation and revenue generation. Data were collected to identify the linkages between diving intensity and coral cover and coral diversity. This information was then linked to the economic analysis of the generation of revenues by diving tourism.

Dealing with limited data and information

As already stated, an ICM-DSS needs to cover both the economic and ecological analysis. This poses an issue of modelling scales and data requirements. Economic areas of importance within ICM will usually be regulated by administrative boundaries drawn on a map, while ecological boundaries are likely to follow watersheds and ecosystems that change with seasons and environmental conditions. Impacts can also be transported across boundaries by water and air. Data will occur at different scales. Economic data may be collected for the administrative unit, while ecological data covers a small part of the ecosystem.

In many cases, some economic data may exist while ecological data is lacking which could compromise the ability to reach balanced decisions. An ICM-DSS needs to be able to deal with uncertainty. This uncertainty could result from insufficient or unavailable accurate data, or external developments and cross-boundary issues, or the fact that human behaviour is unpredictable.

5.7 Critical analysis of three ICM-DSS

There is an implicit judgement that the extent to which a model is used to influence policy decisions is a measure of its success. However, as discussed in the previous section an ICM-DSS may have a number of roles from collation of data to assisting with policy decisions. It may be difficult to assess how much impact a model application has had because of the complex interplay among interest groups and policy making authorities during the model development as well as the fact that model recommendations are never followed precisely and will always be adapted in some way (Pearse & Walters, 1987).

A good ICM-DSS may tackle the problem comprehensively so it can be better understood and analysed. However, this does not guarantee that it will be used in making policy decisions. Model developers must pay attention to the social side of DSS development as well as just the technical side (Argent et al., 1999) ensuring that the end users have been adequately involved in its development. A DSS may also be rejected because it is developed before its time in which case it may be a valuable building block for future modelling approaches (Pearse & Walters, 1987).

This section examines three examples of DSS developed for coastal situations in the tropics. These are described individually in the following sections and summarised in the final section where they are analysed in terms of their design and the role the play. The following issues are addressed.

Design of the DSS:

- Does the DSS incorporate multiple objectives and views?
- Does the DSS cover a multi-disciplinary subject area?
- Does the DSS deal adequately with limited data and information?

Role of the DSS:

- Does the DSS collate ICM data and information?
- Does the DSS facilitate discussion?
- Does the DSS play an educational role?
- Does the DSS support decision making?

The three examples have been selected for their different structures and approaches to the development of the DSS. They all aim to support planning on a local scale as opposed to a regional system such as COMA (Westmacott, 1995), which covers the region of West Africa and COSMO (Resource Analysis & Delft Hydraulics, 1993), which was developed as a regional educational tool. Descriptions are given of the modelling approach taken and the user requirements as well as their usefulness, ease of use, adaptability and ability to deal with uncertainties in data quality.

- SimLucia focuses on the spatial modelling approach and tracks changes in land use patterns through the use of cellular automata.
- CORAL is a model developed for Curaçao, Maldives and Jamaica. The Curaçao and Maldives models were developed into ICM-DSS tools aimed at improving ICM planning combining economic and ecological models for ICM.
- SimCoast^{TM} is an example of a generic DSS formulated as a shell where expert judgement is used to develop the model.

SimLucia

SimLucia has been developed as part of a vulnerability assessment of low-lying coastal areas and small islands to climate change and sea level rise (Engelen et al., 1993). SimLucia was developed during the second phase of the project featuring the application of the generic modelling and decision support framework to the island of St. Lucia, West Indies.

The model has two scales of operation, the macro and micro-scale. The macro-scale model (see Figure 6) simulates the natural, economic, social and land-use environments. The natural sub-system focuses on climate change and its influence on sea level rise and hence changes in land use. The economic sub-system simulates demands in agriculture, industry and quarries, trade and services, tourism, rural and urban residential areas. The social sub-system tracks population dynamics and wealth. The land use sub-system tracks changes in the demand for different land use types. The land-use sub-system is linked to the micro-model where actual land use changes are predicted using cellular automata transition rules (Engelen et al., 1995). The transition rules define the behaviour of each cell, which are 500m by 500m. The rules can be defined in both qualitative and quantitative terms and can be adapted by the user. Change to a cell's land-use depends on the original state of the cell and of its neighbours. There is a set of rules that define the influence one type of land-use has on another. These rules, along with the suitability of a cell for a particular land use, can be edited by the user.

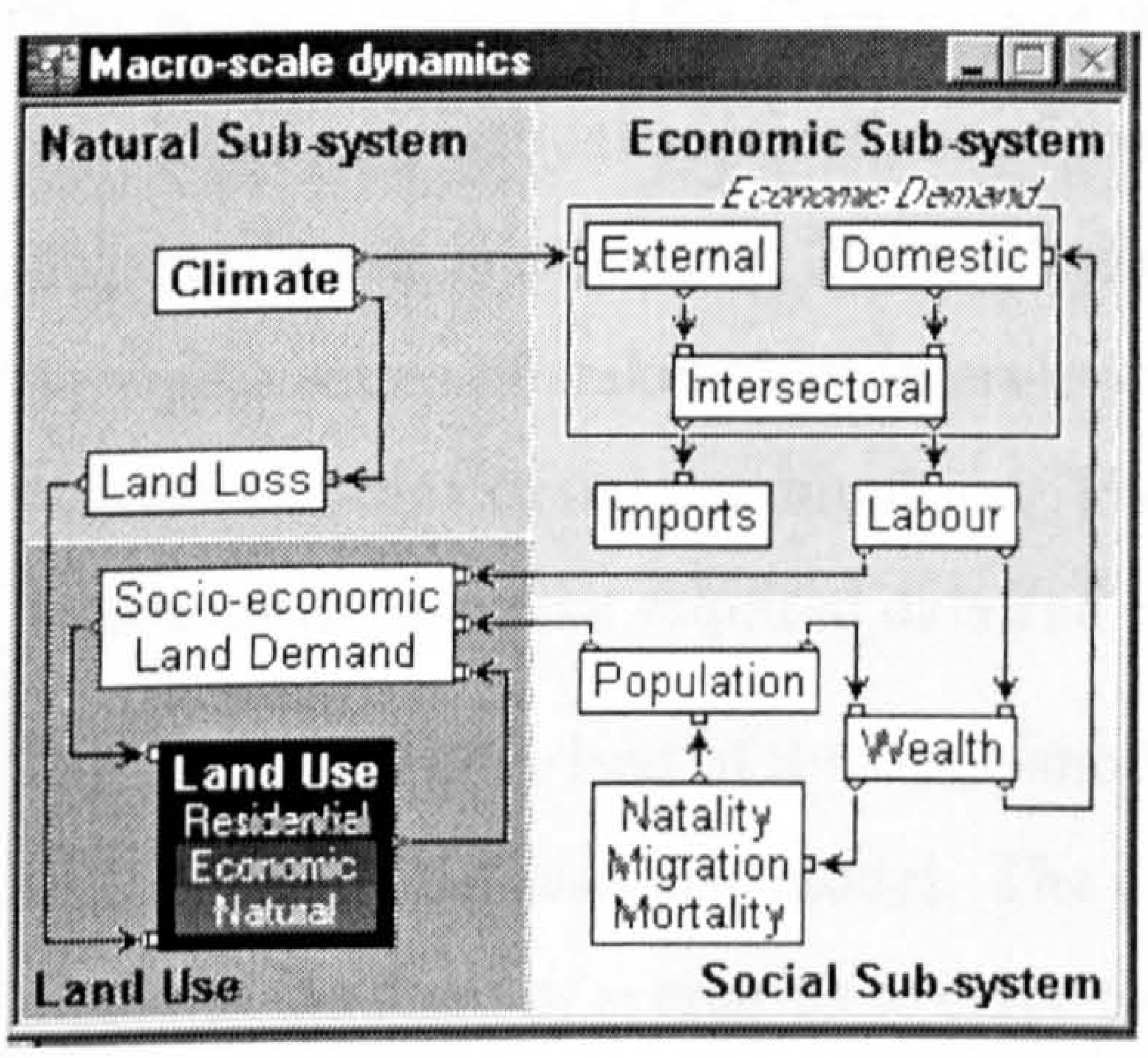

Figure 6 Macro-scale model of SimLucia

The model simulates the situation over 40 years, which can be paused for shorter periods. The results are displayed in the new land-use map of the area as well as by clicking on the components of the macro-model. The model is not objective driven and focuses on one indicator (criteria) that is the change in land use patterns. Other indicators can be found by clicking on the specific components of the macro model (see Figure 6).

The modelling approach combines the use of hard quantitative economic modelling techniques with a qualitative rule base where quantitative relationships are harder to define. The process of defining the qualitative rules on land suitability and the influence of different land use patterns on one another could be used to facilitate discussion between stakeholders. The educational value of the tool is limited due to the limited number of criteria and capacity to compare scenarios. Changes in the land use are often small and comparisons between situations through memory are difficult. This has been partially overcome through the add-on analysis component that enables two maps to be compared. The result shows for the selected land-use type, those cells that have changed between the two situations.

The advantages of this type of modelling can be clearly seen in the graphical output in the form of land use changes, for example loss of natural habitats. If the scenarios are already in place, the model is easy to use and can simply be run. As an ICM-DSS, the model is disadvantaged by focusing only on changes to land-use patterns as well as its low ease of adaptation of the scenarios and examination of the results. SimLucia can be described as an analysts tool (see Figure 5).

CORAL

CORAL has been developed and applied in Curaçao, Jamaica and the Republic of the Maldives to assist in coral reef management (Huber & Jameson, 1998). The model uses a mixture of simulation modelling, multi-variate statistical procedures and fuzzy logic. Costs are incorporated into the model to help decision makers select the least-cost solution.

The models developed for Curaçao and the Maldives were developed in the wider context of ICM and developed as practical applications of the CORAL model developed for Montego Bay, Jamaica (Rijsberman & Westmacott, 2000; Westmacott & Rijsberman, 2000). The models were developed through a series of stakeholder interviews and consultations to attempt to reflect within the model the concerns of the coastal communities. The models were then developed in isolation from the coastal communities once the required data and information had been assembled.

The model is comprised of three sub-models (see Figure 7): an economic model, a water quality model and an ecological response model. The economic model is a simulation model requiring user-defined inputs in the form of scenarios to drive the model for the coming 10 years. This model generates pollution loadings, which enter the nearshore waters where the reefs are situated. A simple water quality model was developed based on well-mixed sections of water adjacent to the coast. This predicts average water quality concentrations, which are linked to the ecological response model. The ecological model was developed with fuzzy logic utilising expert judgement (Meesters et al., 1998). The user defines different management strategies. These strategies encompass economic, social, institutional and ecological concerns, e.g., tourism developments, maintaining public access to beaches, raising public awareness and wastewater treatment options. The results of the model are displayed in terms of ICM indicators (descriptors of the coastal system e.g., income per capita, % hard coral cover) that can be selected by the user. These indicators are presented as quantitative values in a comparison table for each strategy that has been defined. As an additional analysis tool, the cost-effectiveness of the different environmental options is evaluated. This shows the costs of the environmental options in relation to the improvements made in reef health, measured in coral diversity and coral cover. The model is accessed through a user-friendly interface that guides the user from scenario definition, through to strategy definition and onto the analysis of the different alternatives. The interface enables the user to return to previous steps to define a further strategy or to adjust one previously defined.

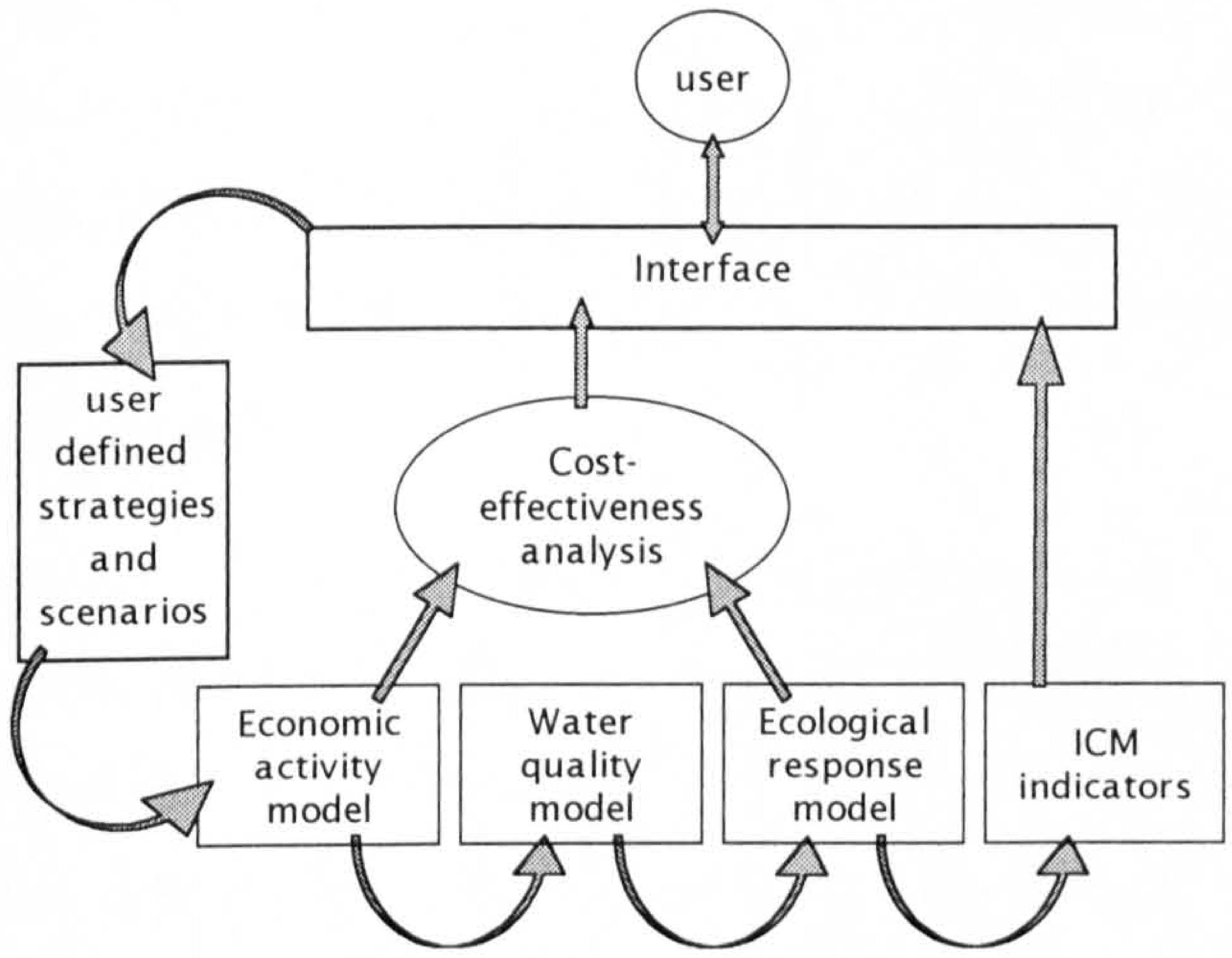

Figure 7 Components of the coral model and the linkages between them (after Rijsberman and Westmacott, 2000)

CORAL is a multi-objective tool that through the stakeholder interviews during its design phase should reflect the concerns and interests of the various stakeholder groups. It deals with limited data in the ecological component of the model by the use of fuzzy logic and utilises expert judgement in this field. The economic activity model and the water quality model rely heavily on the use of quantitative data. In many cases, these data were interpreted from existing data sources and reports that were not specifically carried out for this purpose bringing in some degree of inaccuracy and assumptions.

The model contains a database of all the data and information that was collected during the development of the tool. This is mainly textual information that also presents the data used in the model. This is available to the user via an interactive display within the interface. This collation of information into a single system enabled learning and discussion to take place among the previously disparate groups. The model created a forum for discussion both in its establishment and after development. This involvement could have been increased by the model being developed at the coastal site and involving more of the islanders in the model development and review process. However, time and resources precluded this.

It has been used in ICM courses where stakeholders attended and discussed the interactions within the coastal zone as well as in schools where the interactive information provides the students material for discussion.

The model displays a structured approach to ICM decision making, leading the user through a step wise analysis of the planning process. The disadvantage of the system is its rigid structure and the inability to change certain parameters e.g., locations of developments. These are pre-programmed and based on the current planned developments. The user is, however, able to define different growth scenarios (economic growth rate, tourism demand) and management plans (economic developments and environmental protection options) and compare the differences between the various alternatives. CORAL falls beyond being a toy and short of being a super tool (see Figure 5), its usefulness being as a facilitator and educator rather than decision making.

SIMCOAST™

SimCoast™ is a fuzzy logic rule-based expert system designed to enable researchers, managers and decision makers to create and evaluate different policy scenarios for coastal zone management (Bottrell, 1999). The system is designed as a DSS shell where experts for each specific situation design the parameters, data and rules. This enables the system to be generic. Typically the model is developed within a workshop setting.

To start the process of model development, a series of definitions are required detailing the institutions and individuals involved. These are linked to the definitions made later. The model is based on a 2-dimensional transect of the coastal area. Each project may be an area comprising of multiple transects, although these are not linked together in the model. This transect is divided into zones, from upland down to the open sea. For each model, 'targets' are defined along with their corresponding 'effects'. The targets are the goals to be attained through management activities and the effects are indicators enabling the targets to be measured. For each transect, the user defines the main features of each zone and the extent to which they play a role in each zone. This is defined either in terms of a 'crisp' number (percentage) or as a fuzzy qualitative value e.g., large. Similarly, the activities occurring in each zone are defined. The third stage of model development is the rule definitions (see Figure 8). For each combination of features and activities, the impact on the target is defined. For example: for a user-defined size of FEATURE and a user-defined level of ACTIVITY, there is a user-defined size of IMPACT (measured in qualitative terms from large negative to large positive) in a selected ZONE on a selected EFFECT (indicator) measured in corresponding UNITS for the corresponding TARGET. In addition, the user defines an associated certainty factor for each rule.

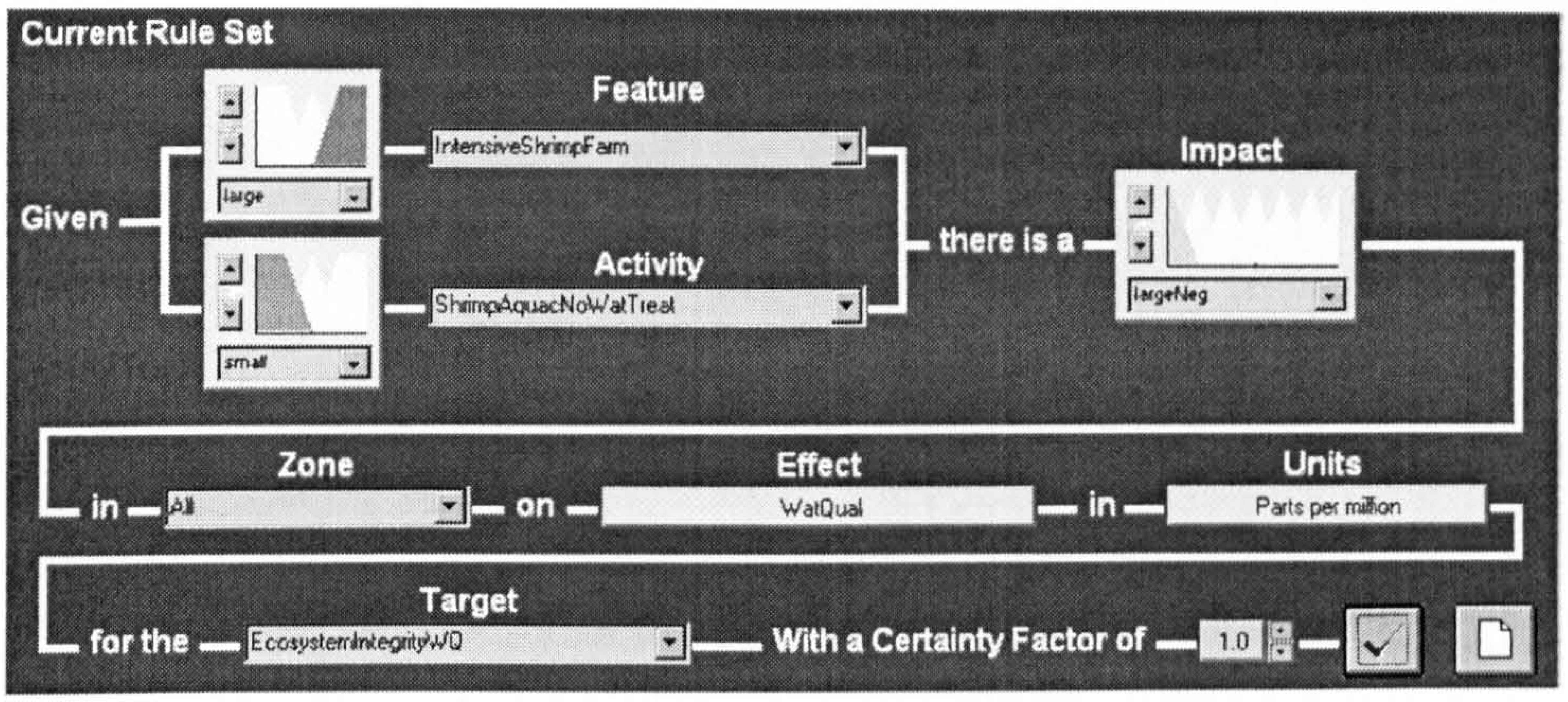

Figure 8 Rule definition procedure in SimCoast™

After the definition of the model, the user can review the definitions of the features and activities. The expert system is then initiated where the rules are fired. These can be scrutinised either individually or as summaries. The output of each rule is a level of influence from –1 to +1. The final results are presented in a grid where for each target a matrix of the influence of activities (from –1 to +1) on the different zones can be seen. The last step is a series of influence diagrams where the activities with the greatest effect on the specific targets can be seen.

There are several advantages of the SimCoast™ methodology. The first is the flexibility in that it is a shell that can be utilised to develop models for any coastal zone. The model development is usually undertaken within a workshop setting, which has the advantage that multiple interest groups and experts can be involved in its development. Incorporating fuzzy logic into the modelling system enables the use of qualitative judgement and non-specific data. A level of confidence is associated with each rule and parameter definition. The disadvantages are that it requires time to develop each application and several experts are required to develop the model. An analyst will probably be required to use the software and explain the results. Navigation around the software is not immediately obvious and it is often difficult to return to previous situations. However, the software is ultimately designed to be used by the analysts so this may not be an issue. The model is limited to 2-dimensional transects which are not interconnected and therefore the system is not able to account for trans-boundary issues. The rules are also defined as relationships between one factor and one activity. If defined within the context of the total rule base this may be overcome. However, it is more likely that the rules are defined in isolation, which is not realistic in the typical coastal zones we are attempting to deal with. It also opens the model to misuse as one rule may be edited without altering other dependant rules.

Expanding the definition of the rules to take into account the linkages between levels of various activities and effects on the zone's features, as well as enabling the different transects to be linked together in a similar manner as the zones could overcome these disadvantages. SimCoast™ can be described as more than simply an analysts tool but somewhere under a super tool.

5.8 Achievement of the models to fulfil the role of an ICM-DSS

The three models, SimLucia, CORAL and SimCoast™, have different strengths and weaknesses. Each model has been developed using a different approach. Involvement of the stakeholder community for CORAL was undertaken at the design process while SimCoast™ depends on this involvement during the model development stage. SimLucia utilises graphical displays and makes use of GIS techniques whereas CORAL is more static and makes use of tabular displays. Table 1 summarises the different abilities of the three models to fulfil the role of an ICM-DSS. The assessment is based on personal experience in using and working with the models.

Table 1 Qualitative assessment of the achievement of three coastal management models to fulfil the role of an ICM-DSS. Key: • to some extent; •• reasonably; ••• definitely

		SIMLUCIA	CORAL	SIMCOAST
DESIGN OF THE DSS	Does the DSS incorporate multiple objectives and views?	•	•••	•••
	Does the DSS cover a multi-disciplinary subject area?	•••	•••	•••
	Does the DSS deal adequately with limited data and information?	••	••	•••
ROLE OF THE DSS	Does the DSS collate ICM data and information?	•	•••	•
	Does the DSS facilitate discussion?	•	••	•••
	Does the DSS play an educational role?	•	•••	••
	Does the DSS support decision making?	•	•	•

Following from this analysis, Figure 9 shows the position of each DSS in the useful versus useable grid presented earlier in Figure 5. CORAL has a less useful function in actual decision making as it is rigid in its structure, however it is easy to use and has a potential for the different users to broaden their field of knowledge exploring other disciplines. SimCoast™ on the other hand is flexible, adaptable and involves people in the development of the models but it is difficult to use without the experts operating the system. SimLucia is relatively difficult to use and has been developed for a specific purpose in land use planning, however it does highlight the potential for spatial modelling techniques.

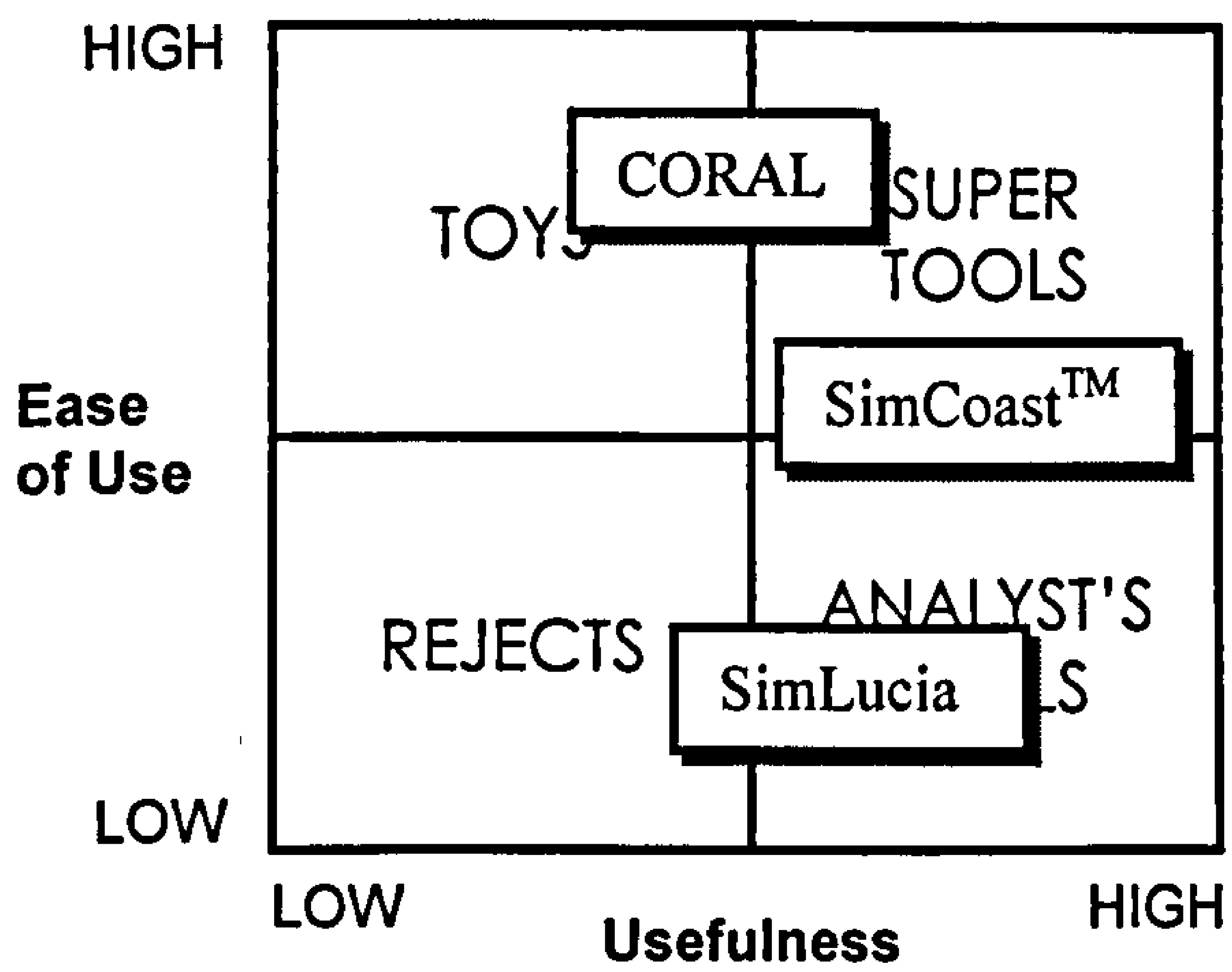

Figure 9 Position of the three coastal models within the grid defining a DSS in terms of perceived usefulness and ease of use (see Figure 5; adapted from Keil, 1995)

5.9 Conclusions

ICM differs from some environmental management applications, where DSSs have already been successfully applied, because of its multi-disciplinary and multi-objective decision making environment, the complexity of issues facing the decision makers and typically the lack of adequate, reliable data.

The three examples illustrated three different approaches to developing an ICM-DSS, each achieving the requirements of an ICM-DSS to differing degrees. They all demonstrated the ability to model the multi-disciplinary system by combining economic and ecological modelling techniques. They also utilised rule-based modelling techniques, e.g. fuzzy logic, to overcome the areas where data were lacking but expert judgement was available. The multi-objective environment was incorporated by generating a broad spectrum of criteria or indicators that describe various aspects of the coastal system. Where the stakeholders are involved in either the design or development of the system, these criteria can be selected to reflect their concerns and interests.

The roles of the DSSs also varied. The possibility to develop an information tool, with an educational role was seen in the CORAL model. SimCoast™ utilises a workshop environment in the development of each model and hence involves various experts and stakeholders in the model development. This, by default, will facilitate and assist the decision making process by acting as a forum for discussion. Likewise, through presentation workshops and stakeholder interviews, the development of the CORAL model facilitated the ICM process by acting as a focal point for discussion between the different stakeholders. This facilitation role also acts as an educator, informing the stakeholders of activities and impacts beyond their own field of expertise and interest. There are clearly several different ways in which a DSS can assist in decision making and these should be recognised by the developers when selecting the techniques to use.

The key points influencing the success of a DSS can be summarised as:

- Involvement of the end-users in the development of the DSS
- Designing the DSS for the end-users needs rather than the needs perceived by the developer
- Easy to use interface requiring limited time investment to learn how to use the system
- Flexible, adaptable and updateable system
- Visual display of results

The models, as successful as they were, did not fully achieve the objectives of a DSS to really assist with ICM decision making. Developing the all encompassing, flexible, reliable, useable, up to date DSS may not actually be feasible. The financial resources and time required to collect the required data and develop the model may mean such systems are always outdated. However, these current systems should not be overlooked. The importance of a tool that facilitates discussion and brings together stakeholders with different objectives cannot be emphasised enough. Lack of communication and cooperation are often the greatest bottlenecks to ICM decision making (see Chapters 3 and 4). The analysis of the economic-ecological interactions in the coastal zone is often an academic issue and the real need for management support is in overcoming the issue of communication and cooperation. So, although these systems may not be able to fully support the preparation of ICM management plans, they can play a vital role in facilitating both communication and cooperation between stakeholder groups.

References

Argent, R., R. Grayson and S. Ewing. 1999. Integrated Models for Environmetnal Management: Issues of Process and Design. *Environment International* 25: 693-699.

Bardossy, A. 1996. The use of fuzzy rules for the description of elements in the hydrological cycle. *Ecological Modelling* 85: 3-12.

Beinat, E., P. Nijkamp and P. Rietveld. 1994a. Indices of Soil Quality: A multicriteria value functions approach. *Journal of Environmental Systems* 23: 1-20.

Beinat, E., P. Nijkamp and P. Rietveld. 1994b. Value Functions for Environmental Pollutants: A technique for enhancing the assessment of expert judgements. *Environmental Monitoring and Assessment* 30: 9-23.

Bewers, J., J. Blanton, A. Davies, P. Gurbutt, E. Hofmann, B. Jamart, D. Lam, M. Takahashi and G. Verboom. 1992. A Conceptual Model of Contaminant Transport in Coastal Marine Systems. *AMBIO* 21: 166-169.

Bijlsma, L., M. Crawford, C. Ehler, F. Hoozemans, V. Jones, R. Klein, B. Miermet, N. Mimura, R. Misdorp, R. Nicholls, K. Ries, J. Spradley, M. Stive, L. de Vrees and S. Westmacott. 1993. *World Coast Conference Report.* Ministry of Transport, Public Works and Water Management, National Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, the Netherlands.

Bottrell, H. 1999. *SimCoast™ Fuzzy Logic Expert System for Integrated Coastal Zone Management: User Manual*. Centre for Coastal and Marine Sciences, Plymouth, UK.

Bower, B. T., C. N. Ehler and D. Basta, J. 1994. *A framework for planning for integrated coastal zone management*. National Oceanographic and Atmospheric Administration (NOAA), Washington DC.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. *Reefs at Risk. A Map-Based Indicator of Threats to the World's Coral Reefs*. World Resources Institute, Washington DC.

Checkland, P. 1984. Rethinking a systems approach. In *Rethinking the Process of Operational Research and Systems Analysis,* eds., R. Tomlinson and I. Kiss, 43-66. London: Operational Research Society Limited & Pergamon Press.

Checkland, P. 1985. From Optimising to learning: A development of systems thinking for the 1990's. *Journal of the Operational Research Society* 36: 757-767.

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated coastal and ocean management: concepts and practices*. Washington DC and Covelo, California: Island Press.

Clark, J. R. 1992. *Integrated management of coastal zones*. Food and Agricultural Organisation of the United Nations, Rome.

Cohen, J. L. 1978. *Multiobjective Programming and Planning*. Cambridge, UK: Academic Press.

Coiacetto, E. 1996. A model for use in the management of coastal wetlands. *Landscape and Urban Planning* 36: 27-40.

Costanza, R., L. Wainger, C. Folke and K. Maler. 1993. Modelling complex ecological economic systems. *BioScience* 43: 545-555.

Dixon, J. A. 1993. Economic Analysis of Coastal Zone Development Options: Linking Economic and Ecological Models. *Workshop on Integrated Quantitative Analysis and Tropical CZM,* eds., 12. San Jose, Costa Rica.

Engelen, G., R. White, I. Uljee and P. Drazan. 1995. Using Cellular Automata for Integrated Modelling of Socio-environmental Systems. *Environmental Monitoring and Assessment* 34: 203-214.

Engelen, G., R. White, I. Uljee and S. Wargnies. 1993. *Vulnerability Assessment of Low-lying Coastal Areas and Small Islands to Climate Change and Sea Level Rise*. Research Institute Knowledge Systems (RIKS), Maastrict.

Ewing, S. A., R. B. Grayson and R. M. Argent. 2000. Science, Citizens and Catchments: Decision Support for Catchment Planning in Australia. *Society and Natural Resources* 13: 443-459.

Fabbri, K. P. 1998. A methodology for supporting decision making in integrated coastal zone management. *Ocean & Coastal Management* 39: 51-62.

Foody, G. 1996. Fuzzy modelling of vegetation from remotely sensed imagery. *Ecological Modelling* 85: 3-12.

Geraghty, P. J. 1993. Environmental Assessment and the Application of Expert Systems: an Overview. *Journal of Environmental Management* 39: 27-38.

Guariso, G. and H. Werthner. 1989. *Environmental Decision Support Systems*. New York: Ellis Horword Limited.

Gustavson, K., R. M. Huber and J. Ruitenbeek. 2000. *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.* Washington, DC: The World Bank.

Hogarth, A. N. 1999. SIMCOAST. *CoastNET.*4: 6.

Huber, R. M. and S. C. Jameson 1998. CORAL: A Least-Cost Management Decision Support Model for Coral Reef Ecosystems. *Intercoast Network.* Fall: 20-21.

ICRI. 1998. *Renewed call for Action: International Coral Reef Initative 1998*. Great Barrier Reef Marine Park Authority, Townsville, Australia.

IUCN. 1993. *Reefs at Risk.* IUCN Marine Coastal Areas Programme, Gland, Switzerland.

Jameson, S. C., J. W. McManus and M. D. Spalding. 1995. *State of the Reefs - Regional and Global Perspectives.* International Coral Reef Initiative, US Dept of State, Washington DC.

Kainuma, M., Y. Nakamori and T. Morita. 1991. *Development of an Intellegent Decision Support System for Environmental Modeling and Planning.* National Institute for Environmental Studies, Japan.

Keil, M., P. M. Beranek and B. R. Konsynski. 1995. Usefulness and ease of use: field study evidence regarding task considerations. *Decision Support Systems* 13: 75-91.

Kloditz, C., F. Rijsberman, S. Werners and S. Westmacott 2000. Development of the User Interface - Coral-Curacao, Coral-Maldives and COCOMO. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 153-158. Washington, DC: The World Bank.

Kosko, B. 1994. *Fuzzy Thinking.* London: HarperCollins Publishers.

Loucks, D. P. 1987. Water Quality - Economic Modeling. In *Economic-Ecological Modeling,* eds., L. C. Bratt and W. F. J. van Lierop, 135-148. Amsterdam: North-Holland.

McClanahan, T. R. 1995. A coral reef ecosystem-fisheries model: Impacts of fishing intensity and catch selection on reef structure and processes. *Ecological Modelling* 80: 1-19.

McManus, J., S. Vergara and K. Reyes 1999. ReefBase 3.0. *InterCoast Network.* Spring: 19-21.

Meesters, E. H., R. P. M. Bak, S. Westmacott, M. Ridgley and S. Dollar. 1998. A Fuzzy Logic Model to Predict Coral Reef Development under Nutrient and Sediment Stress. *Conservation Biology* 12: 957-965.

Nijkamp, P. and J. C. van den Burgh. 1997. New advances in economic modelling and evaluation of environmental issues. *European Journal of Operational Research* 99: 180-196.

Osbourne, C. T., J. E. Schefter and L. Shabmon. 1986. The Accuracy of Water Use Forecasts: Evaluation and Implications. *Water Resources Bulletin* 22: 101-109.

Parker, M., J. G. Thompson, R. R. Reynolds and M. D. Smith. 1995. Use and Misuse of Complex-Models - Examples From Water Demand Management. *Water Resources Bulletin* 31: 257-263.

Pearse, P. H. and C. J. Walters 1987. Perspectives on the Application of Economic-Ecological Models. In *Economic-Ecological Modeling,* eds., L. C. Bratt and W. F. J. van Lierop, 269-281. Amsterdam: North-Holland.

Perez-Trejo, F., N. Clark and P. Allen. 1993. An Exploration of Dynamical Systems Modelling as a Decision Tool for Environmental Policy. *Journal of Environmental Management* 39: 305-319.

Resource Analysis and Delft Hydraulics. 1993. *How to Account for the Impacts of Climate Change in Integrated Coastal Zone Management: Concepts and Tools for Approach and Analysis. Version 2.0.* World Coast Conference (WCC'93) Organising Committee, Ministry of Transport Public Works and Water Management, The Hague, the Netherlands.

Rijsberman, F. and S. Westmacott. 1996. *Cost-effectiveness analysis of coral reef management and protection: A case study of Curaçao. Final Report - CORAL, a decision support system for coral reef management in Curaçao.* Prepared for the Latin American and Caribbean Environment and Urban Development Division of the World Bank by Resource Analysis, Delft, the Netherlands.

Rijsberman, F. and S. Westmacott 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of Curacao. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 49-66. Washington, DC: The World Bank.

Ruitenbeek, H. J. 1994. Modeling Economy Ecology Linkages in Mangroves - Economic Evidence For Promoting Conservation in Bintuni Bay, Indonesia. *Ecological Economics* 10: 233-247.

Saila, S. B., V. L. Kocic and J. W. McManus. 1993. Modelling the effects of destructive fishing practices on tropical coral reefs. *Marine Ecology Progress Series* 94: 51-60.

Smith, P. 1994. Applications of Fuzzy Sets in the Environmental Evaluation of Projects. *Journal of Environmental Management* 1994: 365-388.

Sorensen, J. C. and S. T. McCreary. 1990. *Institutional Arrangements for Managing Coastal Resources and Environments.* Washington DC: National Parks Service, US Department of Interior.

Staley, M. 1987. The Practice of Resource Modeling. In *Economic-Ecological Modeling,* eds., L. C. Bratt and W. F. J. van Lierop, 257-268. Amsterdam: North-Holland.

Stewart, T. 1992. A Critical Survey on the Status of Multiple Criteria Decision Making Theory and Practice. *Omega International Journal of Management Science* 20: 569-586.

Te'eni, D. and M. J. Ginzberg. 1991. Human-computer decision systems: The multiple roles of DSS. *European Journal of Operational Research* 50: 127-139.

van der Werff, J. and H. Goosens. 1997. *A fuzzy model for recreation in the Western Scheldt: Applying fuzzy logic to perform qualitative modelling using expert knowledge.* Resource Analysis and Delft Hydraulics, Delft, the Netherlands.

Westmacott, S. 1995. *Decision Support in Coastal Zone Management.* MSc thesis. Delft, the Netherlands: International Institute for Hydraulic and Environmental Engineering (IHE) & Resource Analysis.

Westmacott, S. and F. Rijsberman 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of the Republic of the Maldives. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 67-82. Washington, DC: The World Bank.

Westmacott, S. and F. R. Rijsberman. 1995. CORAL, Coastal Management Model for the Sustainable Development of Coral Reef Areas. *Physics and Chemistry of the Earth* 20: 245-250.

Wilkinson, C. 1992. Coral Reefs of the World are facing widespread devastation: Can we prevent this through sustainable management practices. *7th International Coral Reef Symposium*, eds., International Society of Reef Studies, 11-21. Guam, Micronesia. University of Guam Marine Laboratory.

World Bank. 1995. *Africa: A Framework for Integrated Coastal Zone Management.* The World Bank, Washington DC.

Zadeh, L. A. 1965. Fuzzy Sets. *Information and Control* 8: 338-353.

Zhu, X., R. Healey, G. and R. J. Aspinall. 1998. A Knowledge-Based Systems Approach to Design of Spatial Decision Support Systems for Environmental Management. *Environmental Management* 22: 35-48.

6 Developing a decision support system as a tool for integrated coral reef management: Lessons learned from CORAL

Descriptions of the CORAL model have been published in Westmacott and Rijsberman (1995); Westmacott and Rijsberman (2000); Rijsberman and Westmacott (2000) and Kloditz et al. (2000).

6.1 Introduction

Decision support systems (DSS) are developed as a means to improve our understanding of the inter-relationships between natural and socio-economic variables and consequently result in improved decision making (Te'eni & Ginzberg, 1991; Fabbri, 1998). In the coastal zone, there is a complex mix of activities surrounding both the marine and terrestrial ecosystems. Integrated management is called for to tackle this complex mix of activities requiring an inter-disciplinary analytical approach. CORAL is a DSS that has been developed to include this inter-disciplinary approach. It aims to assist with integrated coastal management in Curaçao (Westmacott & Rijsberman, 1995; Rijsberman & Westmacott, 2000) and the Republic of the Maldives (Westmacott & Rijsberman, 2000). The computerised system is able to show the impacts of coastal developments and environmental protection measures on the economy, environmental and social situation in the two case study countries. Involvement in the development and implementation of CORAL in Curaçao has enabled this study to look beyond the completion of the product and into the usefulness of such a tool for management providing a number of valuable lessons to be learned.

The development of the CORAL DSS was part of a larger project that aimed to develop a least-cost model to evaluate the cost-effectiveness of alternative coral reef management interventions (Ruitenbeek et al., 2000). In order to assess the cost-effectiveness of coral reef management strategies, three sub-models were developed that linked together forming a single integrated model. The sub-models were an economic activity model, a water quality and an ecological response model. To allow the models to be utilised by different users and not solely by the developers, a user interface was developed (Kloditz et al., 2000). The aim was that anyone with access to a PC could operate the DSS through this interface. The initial modelling approach produced outputs that were additional to the cost-effectiveness and of importance to integrated coastal management (ICM). As CORAL was developed, some of the models were expanded to broaden its applicability, covering a range of ICM indicators rather than simply cost-effectiveness. The focus of the model then changed to become an ICM planning tool. The aim was to achieve a user-friendly management model where users would input their ideas and plans for ICM in Curaçao and the Republic of the Maldives and could analyse the impacts of the different plans in economic and environmental terms. Once finalised, both systems were presented to the ICM user groups in their respective countries. A continuation of the project in Curaçao allowed a more complete evaluation of the DSS and involved a number of stakeholders in its evaluation.

The aim of this study is to evaluate to what extent CORAL is a useful decision support system for integrated coastal management in Curaçao and the Maldives, whether this could have been improved and how the lessons learned from the development could assist in the development of other decision support systems.

6.2 Description of the CORAL model

Development of CORAL

Development of the model started with a preliminary visit to Curaçao in April 1995 (Rijsberman et al., 1995). Key contact persons were established during this preliminary visit, which was followed by the data collection carried out in July and August of 1995 (Meesters, 1995; Westmacott et al., 1995). The data collection in Maldives was carried out in November and December of the same year (Westmacott, 1996). A return visit to Curaçao was made in April 1996 to present the status of the DSS at an ICM Seminar (Rijsberman & Westmacott, 1996a). At this time, the interface had been developed and the model was being refined and tested. It was installed on the computers of all those who had assisted in the definition of the DSS and the data collection. The first version of the model was finalised at the end of 1996 (Rijsberman & Westmacott, 1996b; Rijsberman & Westmacott, 2000). A short visit to present the model in the Maldives took place in December 1996. In January 1997, continuation of the project in Curaçao enabled the previous version of CORAL to be updated. During this period from January through to July CORAL was used in an ICM course, integrated into a school curriculum and was tested with the organisations involved in the initial development as well as any others interested.

Structure of CORAL

CORAL was developed as a coastal zone management decision support system focusing on the analysis of environmental protection options for coral reef management. CORAL was developed initially for Curaçao and then later new models were developed and linked for the Maldives. The user is able to evaluate different management strategies, both economic developments and environmental protection options through a series of criteria. The criteria were selected as indicators of the socio-economic and environmental system, for example, income gained from tourism and live coral cover. CORAL is a computerised model that comprises of the following four main components:

- A user interface,
- An economic activity model,
- A water quality model, and
- An ecological response model

The structure is shown in Figure 1 and described in more detail in the following sections. The general pattern is that the user provides inputs concerning economic development scenarios and environmental management strategies through the user interface. The economic activity model translates these assumptions and choices into pollutant loadings in the various sections along the coast and keeps track of a number of economic parameters (in terms of GDP per capita, employment, and environmental costs and investments). The base year for CORAL is 1995 and projections are made for the year 2005.

A full description of the different components of CORAL for both Curaçao and Maldives is given in Rijsberman & Westmacott (2000) and Westmacott & Rijsberman (2000).

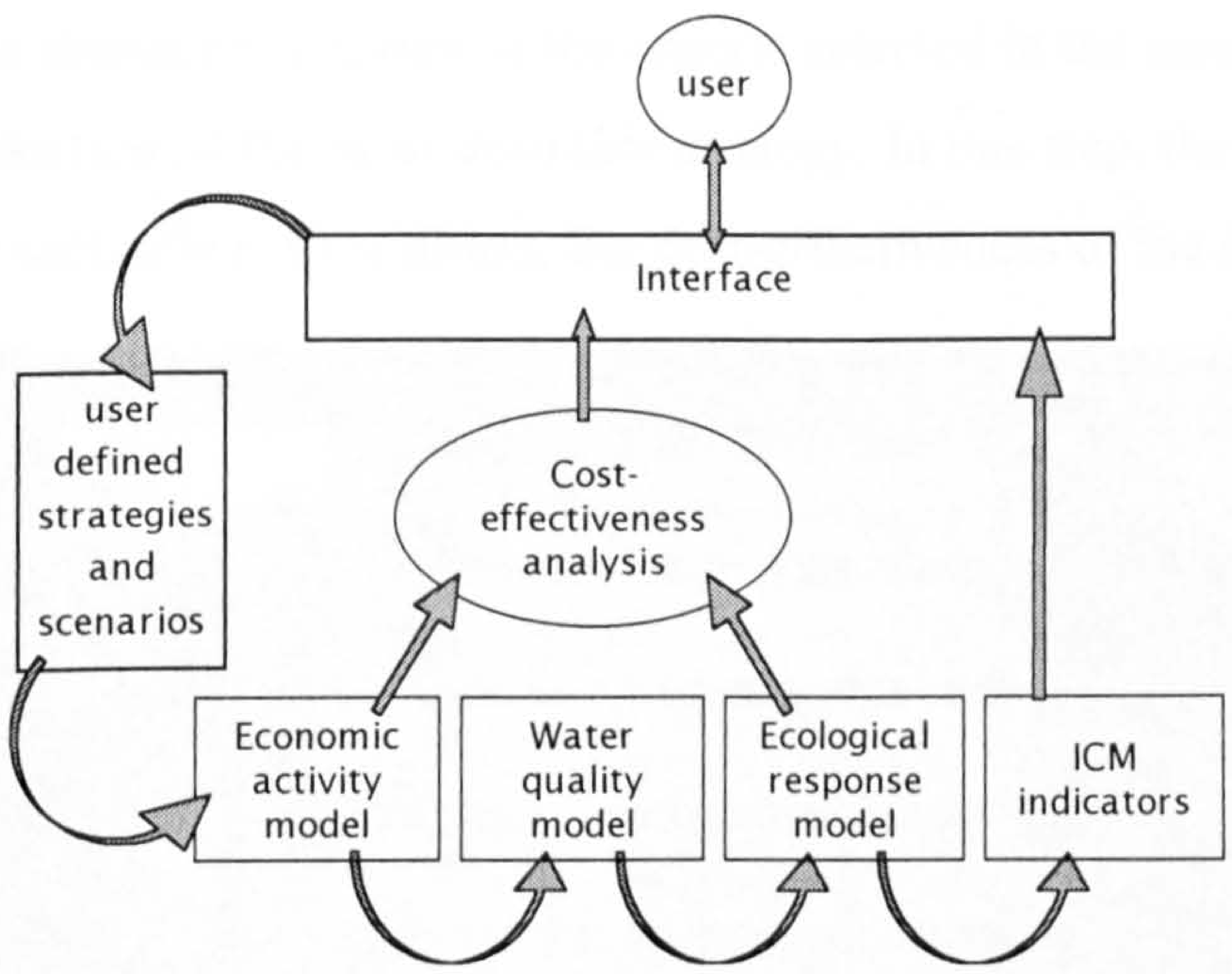

Figure 1. Diagram showing the structure of the CORAL DSS

User Interface in CORAL

One of the components of a decision support system is the user interface. The design of this will be instrumental in guiding the user through the decision. The user interface of CORAL is described in detail in Kloditz et al. (2000). The design uses a step-wise approach leading the user logically from problem definition to evaluation of alternatives. This step-wise approach is based on a generic framework for analysis that has been developed over the last 10-15 years (Rijsberman & Koudstaal, 1989; Delft Hydraulics, 1993; Bower et al., 1994; Westmacott, 1995). Practical applications of this approach to ICM issues are given by, for instance, (Baarse & Rijsberman, 1987; Ridgley & Rijsberman, 1992). Following this framework, the main steps in an integrated coastal management analysis within CORAL can be seen in the main screen of the interface (Figure 2).

The analysis begins with background information on the issues and problems found in the area. The user is able to browse through this section, which contains text, data and graphics to help assess the situation. The second step is the definition of objectives and criteria as yardsticks to measure fulfilment of objectives. The user must define the main objectives and select the criteria that are going to be used in the analysis. The third step requires the user to have some knowledge of the socio-economic system, as they are required to define the growth scenarios. These are the uncertain, exogenous developments such as tourism demand and economic growth rates. These become the driving force behind the economic model. The fourth step is the definition of the management strategies in terms of their component measures. The user defines management measures in three categories: economic development, environmental protection and institutional and administrative measures. The economic developments include the development of tourist resorts and residential housing as well as harbour developments. The environmental protection options in CORAL focus on wastewater treatment. The institutional and administrative options involve the development of marine parks and implementation of educational programmes. The fifth step is the analysis of the impacts of the strategies in terms of the criteria selected in the second step and the final step is the evaluation and selection of the most desirable strategy. In this step, the various alternative strategies can be compared to each other. In addition, the cost-effectiveness of the different strategies can also be evaluated.

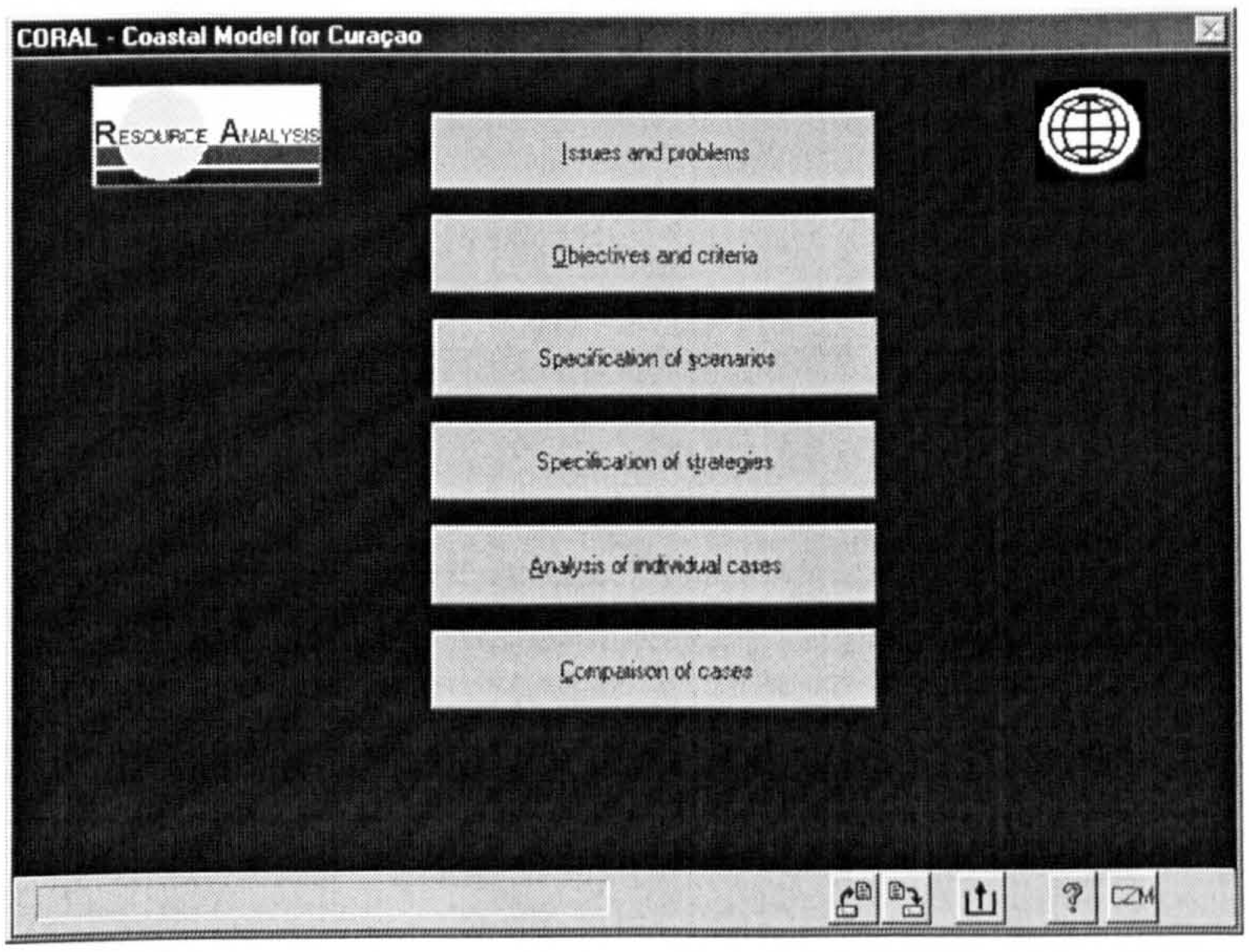

Figure 2 Main menu of the CORAL DSS for Curaçao showing the step-wise structure to the analysis

Economic activity model

The main purpose of the economic activity model (see Figure 3) is to determine pollutant loadings resulting from assumptions about economic development combined with environmental strategies. In addition, the CORAL model specifically calculates the costs of the environmental measures taken to reduce these pollutant loadings.

The economic development scenarios are on two levels. First are the economic and population growth and the tourism demand and at the more detailed level, the specific industrial and harbour developments, the residential developments and the tourism and beach developments. These developments lead to specific spatial distribution of activities along the coast. Their impact on the marine environment can be minimised through specific environmental protection options. These will influence the final nutrient and sediment loads on and offshore. These parameters are then linked into the water quality model. The costs of the environmental options are calculated and used with the results of the reef health model in the computation of the cost-effectiveness of the coral reef management strategies. Other economic criteria are shown directly to the user as ICM indicators.

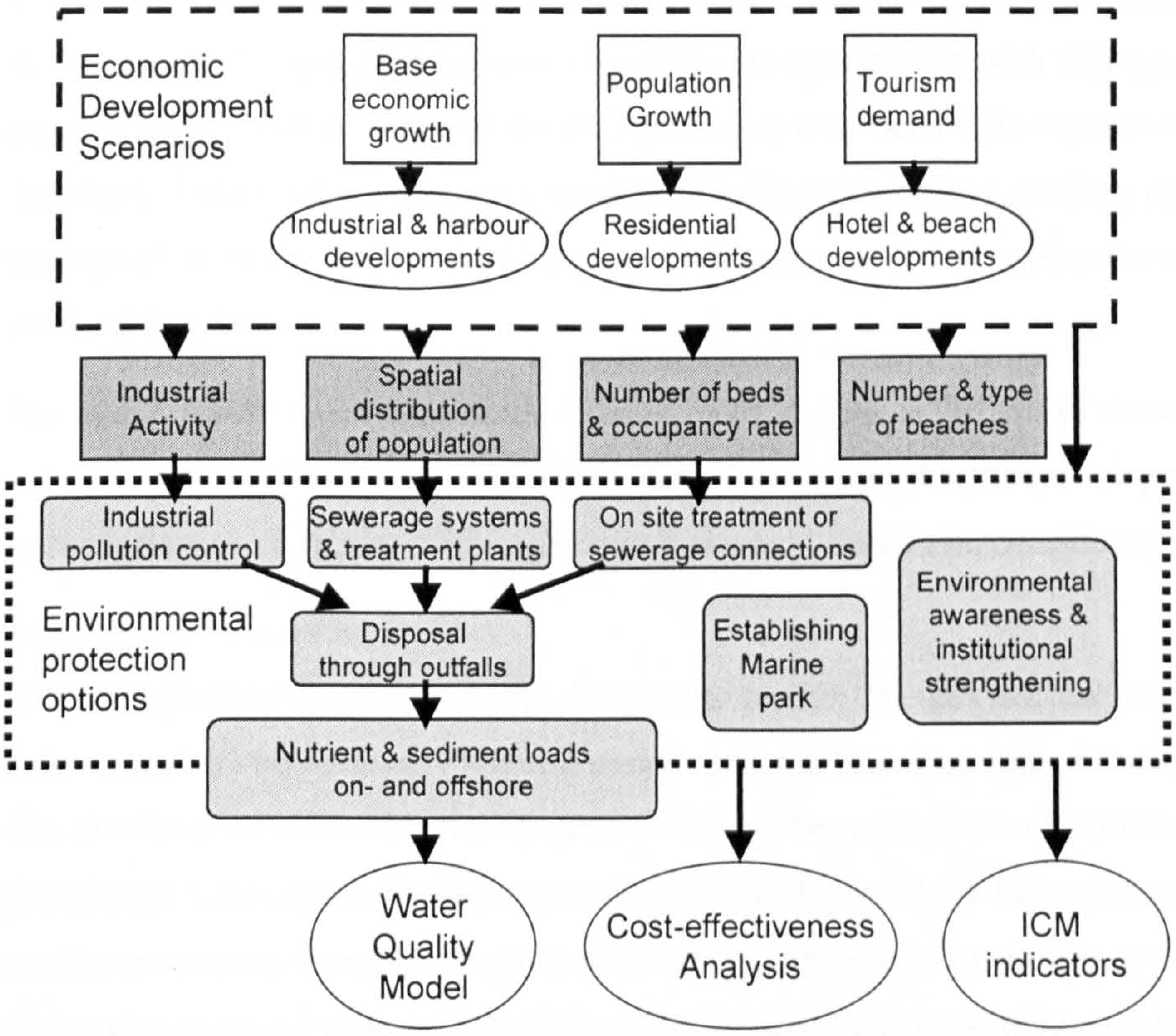

Figure 3 Structure of the economic activity model in the coral reef management decision support system, CORAL

Water quality model

The water quality model picks up loadings of nitrogen, phosphorous, suspended particulate matter and *E. Coli* from the economic activity model. The pollutants (apart from *E. coli)* were selected as they were thought to be the most damaging to the coral reef (Meesters, 1995; Meesters et al., 1998). *E. Coli* was added as an indicator of sewage pollution and a public health risk. The model provides approximate indications of the water quality, concentrations of the pollutants, under average conditions, in six sections along the coast (Rijsberman & Westmacott, 1996b).

The description of water quality for the dissolved constituents was modelled with a transport model that includes decay and exchange with the open sea. Suspended particulate matter behaves in a different manner and must be modelled accordingly, separately accounting for the effects of non-cohesive particles and cohesive particles. It is assumed that the non-cohesive particles are related to the impact from the artificial beaches. This is modelled in terms of a length of reef that is impacted which is equal to the length of the beach plus some 'influence length' downstream. The cohesive particles are modelled in a transport model.

The model is driven by the average east-west current parallel to the coastline and takes into account the effects of tidal mixing (diffusion) perpendicular to the coastline, as well as decay of the pollutant materials within each of the six sections. This type of simple model approximates the coast for a straight line with high lateral velocities compared to the tidal velocities. Precise water quality determination for specified times and locations are not possible with this type of model. Taking into account the level of accuracy of the ecological response model this was not considered a major drawback. Estimates of sediment concentrations (in terms of low, medium and high, as required by the ecological response model) were based on the location and composition (in terms of grain-size) of artificial beaches.

The water quality model covers the areas of reef flat. This is the part of the reef that is taken into account in the reef health model. If the model were to consider the reef slope then other aspects such as the influence of mixing with ocean currents would need to be considered in more depth.

Ecological response model

The ecological response model was designed to predict changes in coral cover and diversity under anthropogenic stress, namely nutrient enrichment and increased sedimentation (Meesters et al., 1998). The challenge of modelling reef systems is the number of unknown factors and imprecise data and knowledge. Consequently, the model utilised fuzzy logic, which had previously been applied to highly nonlinear systems in engineering (Kosko, 1994). This type of modelling approach utilises a single expert or a group of experts' knowledge of the system. The experts are used to define a qualitative rule base of interactions between the coral reef and the human environment. In order to achieve this, a number of parameters describing the state or health of the coral reef had to be selected. Likewise parameters describing the human impacts on the coral reef had to be selected. Together, these formed the input variables. In the model for Curaçao, the reef variables were coral cover, coral diversity, maximum colony size and substratum available for colonisation. The impact variables were dissolved inorganic nitrogen, phosphate and suspended particulate matter. The output of the model was the state of the reef in 10 years time under set conditions. Two variables, coral cover and coral diversity, were used as the descriptors of reef health in 10 years time. 10 years was chosen as a compromise between the need for answers into pressing management problems and the normal time frame for coral reef processes, which can be substantially longer (Meesters et al., 1998).

Each variable was defined in terms of its maximum and minimum value. For example, in Curaçao coral cover was defined as between 0 and 35% and coral diversity between 0 and 100%. These ranges were then divided into classes of high, medium and low. The expert uses these classes to define the rule base in qualitative terms using 'high', 'medium' and 'low' instead of numerical values. A typical rule was as follows:

If nitrogen, phosphate and suspended particulate matter are low and colony size, available substrate coral cover and diversity are high then coral cover will be high in 10 years.

The experts defined the outputs for every combination of input variables in terms of low, medium and high levels. This resulted in 2187 combinations of input variables, where rules were defined describing the coral cover and diversity in each situation after 10 years. The model has been critiqued for being described as a predictive model rather than an expert system that organises knowledge about reef development under stress (O'Connor, 2000). However, the strength of the system lies in its ability to allow others to access expert knowledge and judgement and to provide estimations of coral reef health even when hard scientific data are lacking (Meesters et al., 1998; O'Connor, 2000).

The results of the ecological response model were linked to the cost data of the environmental protection options to compute the cost-effectiveness of coral reef management strategies as well as being available to the user as ICM indicators.

The analysis within the DSS

The user is able to carry out the analysis in CORAL at two levels. The first level allows the user to examine the computed ICM indicators for individual management strategies (see Figure 4). The table shows three columns. The first is the base strategy, which is the situation without any specific economic development options or environmental protection measures in place. The second column shows the impacts of only the economic development options and the final column shows the complete selected strategy. This enables comparison of the impacts of developments on the socio-economic and ecological system with and without the implementation of different environmental management strategies. The user is also able to examine reef health and beach water quality in more detail for the six sections along the coast as well as details on the division of the GDP between economic sectors and the employment created (Figure 4). Comparisons are made in these more detailed analyses between the selected strategy and the base strategy.

The second level of the analysis allows comparisons of multiple management strategies. This enables the user to evaluate which is the most effective in terms of the objectives defined at the start of the analysis. The results are presented in a table format similar to that shown in Figure 4. The user is also able to go a step further and analyse which of the strategies is the most cost-effective in terms of cost versus change in reef health along the coast. These results are presented in graphical format for both coral cover and coral diversity (Figure 5). The x-axis represents different environmental protection options and the y-axis represents the cost-effectiveness of these options in terms of costs per unit gain in reef health. In this part of the analysis, the user needs to be aware of what is being compared as both economic development scenarios and environmental protection options can be altered. This may lead to a comparison of the effectiveness of different environmental protection options under different development scenarios leading to a potentially meaningless comparison.

Examples of the analyses can be found in detail in (Rijsberman & Westmacott, 2000; Westmacott & Rijsberman, 2000).

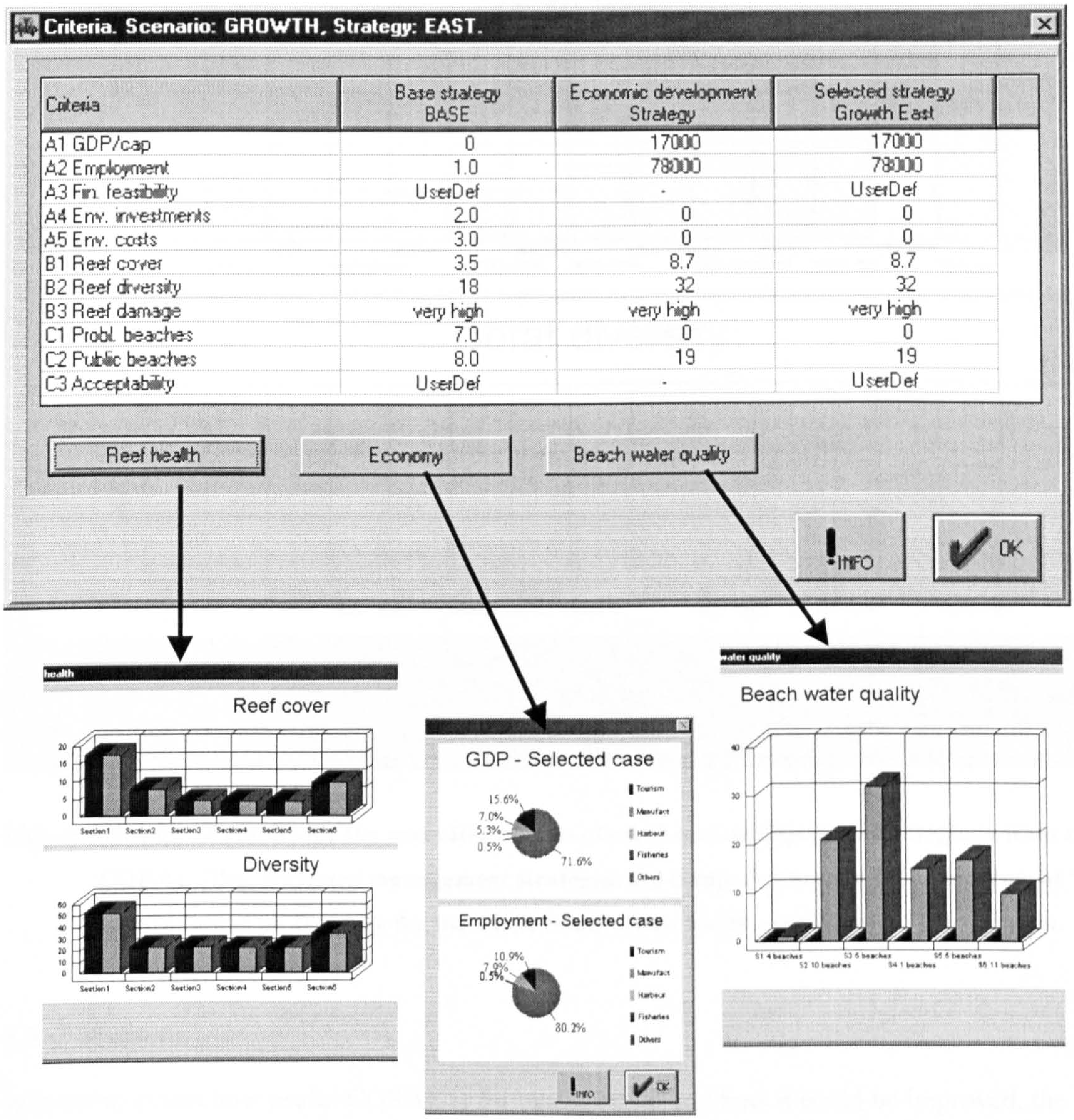

Figure 4 Display of the results for the analysis of individual management strategies within the CORAL DSS. The results for the selected criteria are presented in tabular form where the selected strategy can be compared to base levels of growth. More detailed results can be found in graphs and charts, as shown for reef health, economic activity and beach water quality.

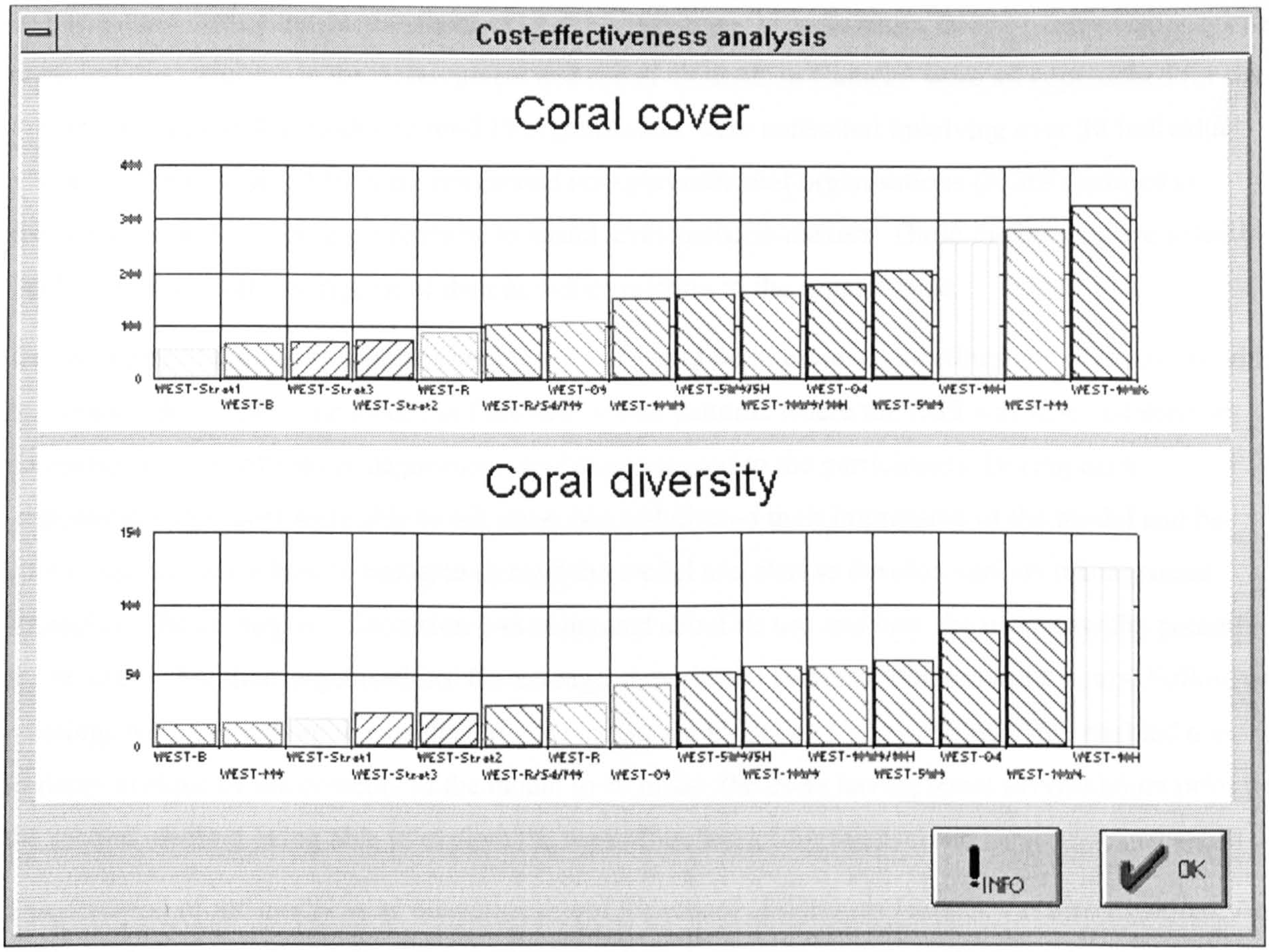

Figure 5 Display of results for the cost-effectiveness of coral reef management strategies within the CORAL DSS. Different management strategies are compared to each other in terms of % change in coral cover or diversity for the whole South Coast Reefs per million US$ investment.

6.3 Methods

In order to assess how useful CORAL is for management and how it could be improved, the opinions of different ICM stakeholders were gathered. After the development of the models and interface, the DSSs were presented to the potential users and those people involved in its formulation. This process was limited in the Maldives due to the end of the project. The model was presented to these stakeholders in the Maldives during a 7-day visit in December 1996. Evaluation and further discussion on the model was then continued with one Government Department. The establishment of a second phase of the project in Curaçao allowed a more in-depth evaluation, which was undertaken during the period January – July 1997.

The stakeholders involved in the evaluations were those who had been involved in the formulation of the DSS. These stakeholders represented those living and working in activities depending on or affected by the coral reef. If any additional stakeholders were identified in the second phase of the project, they were also included in the evaluation. In Curaçao a broad selection of ICM stakeholders, totalling 17 different groups and over 22 individuals had been used. In Maldives, similar consultations had been held during the development of CORAL involving 27 individuals from 11 organisations. The organisations involved in the development and use of CORAL in Curaçao were all approached for the evaluation phase of the model. In total 19 organisations were consulted involving over 30 individuals. These institutions varied from environmental non-governmental organisations (NGO's) aimed at conservation and lobbying government to island level decision-makers. These institutions are listed in Table 1 with a short description of their activities relating to the coastal zone.

The structure of the evaluation was qualitative and based on interviews, meetings and discussions with the stakeholders. All of the meetings followed similar patterns where the DSS was first installed on computers in their offices or departments and demonstrated to the participants. During each presentation, the users were able to ask questions and discuss their impression of the model and be able to use and learn how to navigate through the model and start to develop various management strategies. The subsequent discussion was structured about its use and how the users saw the potential for its use within their organisations. On average, these initial sessions took around 2 hours. Follow up meetings were carried out to establish to what extent the model had been utilised. This enabled a more in-depth critique of the contents of the model to be made, the users having spent several hours prior to the second meeting being able to explore the uses of the model for themselves.

The potential of the model as an educational tool for school children and adults was also explored. An ICM evening course for adults was established to introduce the concepts of ICM and develop management strategies with help from the CORAL DSS. This enabled continued training for those institutions and individuals already involved in the CORAL evaluation. During the evaluation meetings, the participants were told about the course and personally invited along to it.

The results of the evaluation are mainly descriptive and look at the usage of the DSS, the potential applications of the DSS and the needs of the stakeholder organisations. Due to the limited potential to fully evaluate the model in the Maldives, the results focus on the evaluation in Curaçao. From this information, conclusions can be drawn on the usefulness of the DSS to ICM and the lessons that can be learned from its development.

Table 1 Institutions involved in the development and use of CORAL in Curaçao

Organisation	Description
Amigu di Tera	NGO. Local Friends of the Earth environmental group. Running small environmental projects and lobbying government.
Bonaire Marine Park	NGO. Neighbouring island of Bonaire. Management body of the Marine Park. Facing many similar issues as found on Curaçao.
Carmabi	Government supported NGO. Foundation responsible for the management of the marine environment on Curaçao and the marine research centre.
Commissioner CTDB	Political decision maker at Island Government level with responsibility for tourism.

Organisation	Description
Commissioner DROB/ DOW	Political decision maker at Island Government level with responsibility for land use planning and public works .
Curaçao Ports Authority	Private company managing the Ports and Harbours of Curaçao
Curaçao Tourism Development Board	Privatised arm of Government responsible for the development and marketing of tourism on the island
Defense Ambiental	NGO. Political environmental lobby group.
Department of Economic Affairs (DEZ)	Island government department responsible for economic development of the island
Department of Public Works (DOW)	Island government department responsible for public works, e.g., wastewater treatment and sewerage
Department for land use planning and transport (DROV)	Island government (Curaçao) department responsible for the land use planning, recently produced zoning plan for the island identifying areas for development and conservation.
Department for land use planning and management (DROB)	Island government (Bonaire) department responsible for the land use planning.
Department for agriculture, animal husbandry and fisheries (LVV)	Island government department responsible for fisheries and agriculture. Limited monitoring in fisheries sector due to limited capacity.
Environment Department (Milieudienst)	Island government department responsible for environmental issues such as pollution permits.
Radulphus school	Local school where CORAL DSS Was used as educational tool for final year students.
Reef Care	NGO. Local environmental action group involved in conservation of coral reefs. Main activities are monitoring and awareness raising for the reefs.
Curaçao Oil refinery (Refineria di Korsou)	Privatised arm of Government responsible for the management of the oil refinery
Chair for Environmental and Development at the University (SLMEO)	NGO. Foundation formed within the University of the Netherlands Antilles (UNA) to develop environmental education within UNA but also available to the general public within the Antilles.
Ministry of Public Health and Environment (VOMIL)	National government responsible for the development of environmental policy throughout the Netherlands Antilles.

6.4 Results

In Curaçao, a total of 36 evaluation meetings were held. This does not include the sessions and discussions that resulted from the ICM course. Of the 19 institutions involved in the development of CORAL, 8 sent employees to the course. In many cases, more than one participant attended the course, which allowed a broader evaluation of CORAL to be undertaken. The number of participants that attended the course from each institution is detailed in Table 2. CORAL was installed in 15 of the institutions listed in Table 1. In some organisations, the computers did not have sufficient capacity to run the model. This highlights the importance of developing such systems with the local computer hardware capacity in mind.

Table 2 Participants in ICM training course in Curaçao

Institution	Participants
Public Works (DOW)	8
Land Use Planning, Curaçao (DROV)	3
Land Use planning, Bonaire (DROB)	1
Island Council	1
Amigu di Tera	1
University of Netherlands Antilles	2
Refinery	1
Environmental Department (Milieudienst)	1
Other participants	6

DSS usage

Of the 15 institutions where the CORAL model was installed, none independently used the model. This meant that the time people spent on learning the possibilities of the model was limited to the presentations or the time they were allocated in the courses they attended. Some of the course participants installed the model at home and used the model to answer the questions set in the course.

This limited use could be for several reasons. The most common reason given was the inability of the model to answer the questions they really wanted to ask it. The inflexibility of the model restricted the use so much that they appeared unenthusiastic to continue to use the model. However, this also put them off utilising the model as a source of data. During the course when participants were given more time to explore the model, they discovered new facts and data. In developing the model, data was gathered from a wide variety of sources, namely the various Government departments. Although the data from one department could be made available to other departments, it became clear during the development of the model this was not typically the case. As a result, many departments were not aware of reports and plans of the other departments.

A second reason for the model's limited use was the time that it took the users to really be able to operate the model and find out where they could find the information. They were first confronted with the definition of the different growth scenarios, which required them to have some knowledge of the socio-economic growth of the island and future projections. In hindsight, the model should have already evaluated high, medium and low growth levels for overall economic growth rate, population growth rate and growth in the number of tourists. These could be based on projections made by the Central Bureau of Statistics and the Curaçao Tourism Development Board. Developing management strategies was seen as time-consuming. In CORAL, defining management strategies is completed for different locations along the coast. The user has the option to define economic developments in 15 different coastal locations and environmental protection options in 10 locations.

Training time to use the model varies depending on the level of understanding required. Generally, the participants could become acquainted with the user interface, how they should be operating the model and where they could find the data and information contained in the model's database after the 5 hours training provided through the ICM course. However, this was not enough time for the participants to fully test different ICM strategies and evaluate the model results based on their own experiences. More time would have also been needed for participants to gain a full working knowledge of the model, the assumptions and the data used. Without this they were only able to examine the results provided by the model rather than fully understand how they were derived.

The multi-disciplinary nature of the DSS means that in order to understand the various modelling approaches, different expertise is required. A full understanding of the different components would take the average user quite some time, estimated to be around a week, with time after to test and work with the model. For most of the potential users, this was too large an investment with no guarantee that the model would be useful to their daily work. The ICM course did provide the opportunity for the different user groups to superficially evaluate the model's potential.

Stakeholder needs and objectives for a DSS

During the fieldwork in Curaçao in 1997, it became clear that the different user groups involved in the development of CORAL all had their own priorities and interests for the use of an ICM decision support system or certain aspects of an ICM decision support system. The different priorities can be categorised depending on the desired use of such a system. The categories were defined as

- an educational or awareness raising tool,
- a data management system,
- a DSS on an island level,
- a DSS for a single economic sector (e.g., tourism, public works), or
- a DSS on a project evaluation level.

These priorities were identified during the interviews and discussions that took place during this period (see Table 3).

Table 3 Number of institutions from the group of CORAL-DSS users stating their preference for a particular category of use of a decision support system.

CORAL-DSS User groups	Education/ awareness tool	Data management system	Island level DSS	DSS for one economic sector	Project evaluation tool
Non governmental organisations	5	2			
Island and national government agencies		3	5	1	
Privatised government department/ company managing national resource		1			2

The NGOs' interest was mainly in the educational and awareness raising use of CORAL. The two institutions focusing on the data management and storage function were the Marine Parks on Curaçao and Bonaire. These two institutions are defined as non-governmental even though they are managing a national resource on behalf of the Government.

The Government institutions were more focused on the use of CORAL as a decision support system for island planning. The three departments focusing on the data management and storage function were those with island wide responsibilities, such as land-use planning. These departments questioned the ability to keep the model updated with the latest data and information. They also questioned the number of assumptions that needed to be made to model such a system and the realism of these. As a result, they preferred to keep the emphasis on developing and improving the system to increase data availability for their own analysis.

The privatised companies were small in number but the project nature of their work and the more commercial approach to their work, meant they leant towards the development of an analytical tool that is able to deal with one project at a time rather than an overall planning tool.

The different purposes of the DSS can be seen on three different levels:

1. Utilising the model as a database;
2. As a presentation tool, and;
3. As an analytical ICM tool.

These are sequential steps in the DSS use. In order to be able to use the model for presentation purposes, an analyst needs to prepare the cases to be presented. These can be two separate people, the analyst and the presenter. Utilising the model as a database can be achieved with a few hours training. Once the user is familiar with the interface, utilising the model as a presentation tool can also be mastered in a few hours. Actually using and understanding the analytical modelling capabilities of such a model will take a greater time investment, probably in the region of a few weeks to become comfortable with the results and assumptions used in the model. This time investment could be beneficial if the model effectively assisted the analysis for decision making.

In the Maldives, the limited time to present the model resulted in its limited use. Several pieces of information contained in the model's information screens were considered sensitive and the Department of Environment who were acting as the focal point consequently did not want the model widely distributed at that time. The visit was used to troubleshoot the model and list all necessary changes. As a result, it was updated and sent back to the Department of Environment but was never distributed to those others involved in its development.

6.5 Conclusions

The question then remains as to whether or not CORAL was a useful decision support system for coral reef management in Curaçao and the Maldives and identifying what lessons can be learned from the project. Being able to look back over its development it is likely that improvements could have be made. Most importantly, there are lessons that could be learnt from the development and these could assist in the development of other decision support systems.

Use of CORAL

Although CORAL has not been utilised since the finalisation of the project and departure of the project consultants, it is not to say that the system was not useful in supporting coral reef management. It is widely recognised that many models end up buried or forgotten but may have served as the focus of spirited debates (Pearse & Walters, 1987). If model builders want their systems to be used, they must fully involve stakeholders and potential users and develop a working partnership between model developers and model users (Ewing, *et al.,* 2000; Argent, *et al.,* 1999). However, even though there was a thorough consultation process at the outset of the model development that enabled the developers to account for the needs and concerns of the local decision makers and stakeholders, the model was still not embraced and utilised. It may be that the development process was not interactive enough as the model was not developed locally, rather it was designed with stakeholder input, developed remotely and then presented back to those concerned. Several people on Curaçao expressed an interest in maintaining CORAL. However, the primary project goals were to test the cost-effective methodology developed for coral reef management in Jamaica (Ruitenbeek et al., 2000) rather than develop a working DSS in Curaçao and the Maldives. Developing a working DSS was seen as an important feature by the developers (Rijsberman & Westmacott, 2000; Westmacott & Rijsberman, 2000) and could have been developed further with potentially greater long-term success.

Useful to management?

The fact that CORAL was not utilised by the managers means it was not perceived to be useful to management. Keil et al., (1995) presented 'perceived usefulness' and 'ease of use' as two important factors in determining the acceptability and subsequent use of such information systems. They defined 'perceived usefulness' as whether or not the systems enhanced the user's job. Even though CORAL is relatively easy to use, taking only a few hours to become familiar with its interface and options, it was not extensively used. The options within it are static, there are certain fixed assumptions that users may wish to adapt but are unable to and the data used will become quickly outdated. Consequently, few people felt it would really assist them in making long-term planning decisions.

However, CORAL may be able to help overcome some of the impediments to ICM. Some of the main impediments (see Chapters 2-4,Westmacott, 2000a; Westmacott, 2000c) relate to the lack of public and political support for integrated management decisions. Part of the lack of support can be explained by a lack of involvement and understanding of the issues. CORAL and similar tools can play an important role is raising awareness and understanding of the issues involved. It is a powerful means of visualising change over time and potential degradation to an ecosystem and its social and economic implications without actually having to degrade an ecosystem.

During the development of the project, CORAL acted as a forum for discussion in both locations. Discussing the design of the DSS was a reason to bring the various different stakeholders involved in ICM together. Discussions on the main issues to include, the model objectives and outputs made the various groups start thinking about ICM as an integrated process and how their various interests and activities affect one another. An assessment of three ICM-DSSs (see Chapter 5, Westmacott, 2000b) describes how the design of CORAL incorporates multiple objectives and views and covers a multi-disciplinary subject area. This in itself is a valuable tool to illustrate the integration of activities and interests in the coastal zone. A steering committee was established in the Maldives, which could have later developed into an ICM committee, but this was only functional when the external consultant was there.

Another useful aspect of CORAL was its capacity as an educational tool. It was used in Curaçao for an adult education course, during meetings with high-level policy makers as well as in schools. However, for this purpose the full modelling capabilities are surplus to requirement. The system could have been developed as a shell where the different scenarios are worked out together with the coastal experts and then input into the shell (interface) for presentation.

In addition, the information function of the DSS enables people to access a wide spectrum of data and information that was otherwise stored in grey literature within the individual departments. However, in its present form, the database is static and can only be accessed and updated by the program developers. Ideally, the system could enable the addition of new reports and act as a central storage of grey literature and information on the coastal zone.

Lessons learned from the development of CORAL

The development of CORAL has provided a series of useful insights and lessons that may well increase the usability of other similar systems. These are as follows:

- Regardless of the final outcome of the modelling effort, consultations during development can provide a forum for discussion on the main issues and management options within an integrated setting, moving towards thinking about ICM
- Consultations alone are not sufficient for model acceptance and use. Locally based counterparts need to be identified who are used in consultations, data collection as well as model development. These counterparts will ultimately maintain and promote the use of the model. This may require adaptation to the design of the interface, model components and database so that the data and information can be constantly accessed by the maintainer. However, a counterpart should be seen by the ICM stakeholders as neutral to the ICM process, which is often hard to identify. Likewise, such a counterpart would be able to maintain the initiatives established such as the Steering Committees.
- Flexibility, adaptability and update-ability are paramount if the system is to be used. This does not however guarantee success.
- A DSS can play an important educational and awareness role for schools, stakeholders and decision makers. However, this may not require the development of complex models, rather the development of an interface with the ability to save various scenarios. The scenarios can be developed during consultations with the experts in the various aspects of coral reef management.
- Developing a system with the computer hardware and software capacity of the end users in mind is paramount. Ideally, a 'stand-alone' system is developed that is able to run without requiring additional software.
- Pre-defined scenarios, for example, a high rate of development or a medium rate of development are crucial to aid the usability of a DSS and build the confidence of the DSS users in situations where users may not have expertise in all required fields.
- Users need to believe in the underlying modelling assumptions, which should be listed clearly and concisely so they can be easily evaluated. The model should not remain a black box to the users.
- Potential DSS users will have different priorities and objectives. The aims and objectives of a DSS should be carefully considered and focused on during development.

References

Baarse, G. and F. Rijsberman 1987. A Policy Analysis Approach to the problem of sea level rise. In *Impacts of Sea Level Rise on Society,* eds., H. Q. Wind, pp. 21-76. Rotterdam, the Netherlands: Balkema Publishers.

Bower, B. T., C. N. Ehler and D. Basta, J. 1994. *A framework for planning for integrated coastal zone management.* National Oceanographic and Atmospheric Administration (NOAA), Washington DC.

Delft Hydraulics. 1993. *A Global Vulnerability Analysis, vulnerability assessment for population, coastal wetlands and rice production on a global scale.* Tidal Water Disvision, Rijkswaterstaat, Ministry of Transport, Public Works and Water Management, the Netherlands.,

Fabbri, K. P. 1998. A methodology for supporting decision making in integrated coastal zone management. *Ocean & Coastal Management* 39: 51-62.

Keil, M., P. M. Beranek and B. R. Konsynski. 1995. Usefulness and ease of use: field study evidence regarding task considerations. *Decision Support Systems* 13: 75-91.

Kloditz, C., F. Rijsberman, S. Werners and S. Westmacott 2000. Development of the User Interface - Coral-Curacao, Coral-Maldives and COCOMO. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 153-158. Washington, DC: The World Bank.

Kosko, B. 1994. *Fuzzy Thinking.* London: HarperCollins Publishers.

Meesters, E. H. 1995. *Coral Reef Data Collection and Analysis. Phase 2 report of the project Cost-effectiveness analysis of coral reef management and protection: A case study of Curaçao.* Prepared for the Latin American and Caribbean Environment and Urban Development Division of the World Bank. Resource Analysis, Delft, the Netherlands.

Meesters, E. H., R. P. M. Bak, S. Westmacott, M. Ridgley and S. Dollar. 1998. A Fuzzy Logic Model to Predict Coral Reef Development under Nutrient and Sediment Stress. *Conservation Biology* 12: 957-965.

O'Connor, R. J. 2000. Expert Systems, Fuzzy Logic and Coral Reef Development under Environmental Stress. *Conservation Biology* 14: 904-906.

Pearse, P. H. and C. J. Walters 1987. Perspectives on the Application of Economic-Ecological Models. In *Economic-Ecological Modeling,* eds., L. C. Bratt and W. F. J. van Lierop, 269-281. Amsterdam: North-Holland.

Ridgley, M. and F. R. Rijsberman. 1992. Multicriteria Evaluation in a Policy Analysis of a Rhine Estuary. *Water Resources Bulletin* 28: 1095-1109.

Rijsberman, F. and S. Westmacott. 1996a. CORAL, a decision support system for coral reef management in Curacao. *Integrated Coastal Zone Management Seminar,* eds., I. Curiel, I. Korstjens and R. Libier, 48-58. Curacao. Leerstoel voor Milieu en Ontwikkeling.

Rijsberman, F. and S. Westmacott. 1996b. *Cost-effectiveness analysis of coral reef management and protection: A case study of Curaçao. Final Report - CORAL, a decision support system for coral reef management in Curaçao.* Prepared for the Latin American and Caribbean Environment and Urban Development Division of the World Bank by Resource Analysis, Delft, the Netherlands.

Rijsberman, F. and S. Westmacott 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of Curacao. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 49-66. Washington, DC: The World Bank.

Rijsberman, F., S. Westmacott and D. Hirsch. 1995. *Cost-effectiveness analysis of coral reef management and protection: A case study of Curaçao. Phase one report, CORAL project.* Prepared for the Latin American and Caribbean Environment and Urban Development Division of the World Bank. Resource Analysis,, Delft, the Netherlands.

Rijsberman, F. R. and R. Koudstaal. 1989. Development and Application of a Framework for Analysis for Integrated Coastal Resources Management in an International Context. *Coastal Zone 1989*, eds., O. T. Magoon, 58-71. ASCE, New York.

Ruitenbeek, J., M. Ridgley, S. Dollar and R. M. Huber 2000. Interventions for Coral Reef Conservation - A Least Cost Model. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.*, eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 129-136. Washington, DC: The World Bank.

Te'eni, D. and M. J. Ginzberg. 1991. Human-computer decision systems: The multiple roles of DSS. *European Journal of Operational Research* 50: 127-139.

Westmacott, S. 1995. *Decision Support in Coastal Zone Management.* MSc thesis. Delft, the Netherlands: International Institute for Hydraulic and Environmental Engineering (IHE) & Resource Analysis.

Westmacott, S. 1996. *Cost-effectiveness analysis of coral reef management and protection: A case study of the Republic of the Maldives. Phase 2 report: Model definition and data collection.* Resource Analysis. Report prepared for the Latin America and Caribbean Environment and Urban Development Division (LA3EU) of the World Bank), Delft.

Westmacott, S. 2000a. Are we tackling the main issues constraining Integrated Coastal Management in coral reef areas? *Paper presented at the ISRS 9th International Coral Reef Symposium, Bali, October 2000. Reviewed and forwarded for acceptance for Proceedings*

Westmacott, S. 2000b. Developing decision support systems for integrated coastal management in the tropics. Is the ICM decision making environment too complex for the development of a useable and useful DSS? *Environmental Management, in press.*

Westmacott, S. 2000c. Identifying the main impediments to integrated coastal management in the tropics. *Paper submitted to Ocean and Coastal Management, October 2000.*

Westmacott, S., P. Klinckhamers, L. Fernandes and F. Rijsberman. 1995. *Cost-effectiveness analysis of coral reef management and protection: A case study of Curaçao. Phase 2 Field Visit project report.* Prepared for the Latin American and Caribbean Environment and Urban Development Division of the World Bank. Resource Analysis, Delft, the Netherlands.

Westmacott, S. and F. Rijsberman 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of the Republic of the Maldives. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 67-82. Washington, DC: The World Bank.

Westmacott, S. and F. R. Rijsberman. 1995. CORAL, Coastal Management Model for the Sustainable Development of Coral Reef Areas. *Physics and Chemistry of the Earth* 20: 245-250.

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7 Assessing economic valuation as a tool for integrated coastal management in coral reef areas

The case studies in this work have contributed to the following publications: Spash (2000), Spash, et al., (2000), Westmacott, et al., (2000a; 2000b; 2000d).

7.1 Introduction

Coral reefs are highly productive ecosystems that support a range of goods and services (Spurgeon, 1992; Moberg & Folke, 1999; Cesar, 2000a). These ecosystems are currently threatened by global environmental change and human impacts (Jameson et al., 1995; Bryant et al., 1998; Wilkinson, 2000). Integrated coastal management (ICM) aims to maintain the sustained multiple use of the coastal zone through a continuous, dynamic, iterative, adaptive and participatory process (see Chapter 2; Sorensen & McCreary, 1990; Bijlsma et al., 1993; Bower et al., 1994; Turner & Adger, 1996; Cicin-Sain & Knecht, 1998; Westmacott, 2000b). This process involves the development of an integrated strategy, which is implemented for the allocation of environmental, socio-cultural and institutional resources. ICM also accounts for traditional cultural and historical perspectives and conflicting interests and uses.

The benefits of ICM are numerous although not easily measured and quantified. Economic valuation is being increasingly applied to tropical coastal ecosystems to assess these benefits in monetary terms and to show that improved management and conservation is economically justified. A number of valuation studies specific to coral reefs have been carried out recently (see Table 1) and are summarised in Cesar (2000b).

Table 1 Summary of economic valuation studies related to coral reefs

Type of Reef valuation	Literature
Total Economic Value	Spurgeon (1992), Riopelle (1995), Costanza, et al. (1997), White and Cruz-Trinidad (1998), Cesar (2000a)
Marine Protected Areas	Dixon and Sherman (1991), Dixon (1993), Dixon, et al., (1993; 2000), Pendleton (1995), Cesar, et al., (2000b), White, et al., (2000)
Over-exploitation and Destructive practices	Hodgson and Dixon (1988), Cesar, et al., (1997), Berg, et al., (1998), Pet-Soede, et al., (1999) Ohman and Cesar (2000)
Rehabilitation	Spurgeon (1998), Spurgeon and Lindahl (2000)
Biodiversity	De Groot (1992), Spash (2000), Spash, et al., (2000)
Recreation	Pendleton (1995), Davis and Tisdell (1996), Andersson (1997)

Much of the loss and degradation of coastal resources has been due to a failure to fully appreciate and account for the goods and services that they provide (Dixon, 1998; Crooks & Turner, 1999). This is mainly because many of the goods and services provided by coral reefs are not traded in the commercial market and as a result are viewed as *free* resources. For example, the coastal protection function of coral reefs does not carry costs to the local community who are protected by it. This function can, however, be impaired by storm damage, coral mining and blast fishing possibly resulting in flooding and damage to property. This will impose costs on the local population and the government, either in damage or in provision of alternative forms of protection. Both can be seen to represent *values* previously provided by the coral reef.

Economic valuation can highlight the importance of the goods and services supported by coral reefs by placing a monetary value on the goods and services provided. However, economic valuation of ecological systems involves a number of controversial issues, from methodological to ethical issues (Bingham et al., 1995; Costanza, 1998; Dixon, 1998; Bateman & Willis, 1999a). With this in mind, the question is whether economic valuation can play a role in the management of these coastal resources. More specifically, the question is here whether economic valuation can help in overcoming some of the main impediments affecting the ability to implement integrated coastal management. These include lack of political will and public support (see Chapter 4; Westmacott, 2000a).

This study presents three case studies carried out for the valuation of various coral reef goods and services in order to assess the potential of economic valuation as a management tool. First, however, the concept of economic valuation as well as valuation techniques will be briefly discussed. For a detailed discussion on this, the reader is referred to the relevant literature cited in the text.

7.2 Economic Valuation of coral reefs and valuation techniques

Economic valuation

The economic value of an ecosystem, in this case coral reefs, is generally defined as the total value of its component parts, e.g. the goods and ecological services that the ecosystem provides. This has been termed the *Total Economic Value* (TEV) (Turner, 1993; Turner et al., 1994). The values of some of these components are easy to identify, while others are more difficult or even either unknown or intangible (Dixon, 1998). The term TEV, although generally accepted by most economists, remains controversial (Turner, 1999). In its simplest form, TEV is comprised of use values (direct and indirect) as well as non-use values (see Figure 1). The latter are values associated with the existence of the resource (existence values) and the value of retaining options and opportunities for one's own use (option values) and one's children (bequest value). Each of these will be briefly discussed below. For a detailed discussion, specifically applied to coral reefs, see Barton (1994).

Total Economic Value

Use Values		Non-use Values		
Direct Use Values	**Indirect Use Values**	**Option Values**	**Existence Values**	**Bequest Values**
Consumptive uses • Coral mining • Shell collection • Fishing Non-consumptive uses • Scuba diving • Recreation	• Storm surge protection • Fish nursery area • Food chain	• Viewing • Recreational use	• Biodiversity • Recreational amenities	• Biodiversity • Recreational amenities
Valuation methods	**Valuation methods**	**Valuation methods**	**Valuation methods**	
• Market Analysis • Other non-market valuation methods (TCM, CVM, HP, IOC, IS)	• Damage costs avoided • Preventive expenditures • Value of change in productivity • Relocations costs • Replacement costs	• CVM	• CVM	

Notes: **Market Analysis**: based on market prices; **HP** = hedonic pricing, based on land/ property value data; **CVM** = contingent valuation method based on social surveys designed to elicit willingness to pay values; **TCM** = travel cost method, based on recreational expenditure data; **IOC** = indirect opportunity cost approach, based on options foregone; **IS** = indirect substitute approach.

Figure 1 Total Economic Value of coral reef ecosystems (after Dixon, 1998) and valuation methods (after Bower & Turner, 1998)

The direct uses of the coral reef can be consumptive or non-consumptive. Consumptive direct uses generally relate to harvesting and production activities such as fishing or mining. Non-consumptive direct uses exist when the resource is used for recreation, education and research among others. The direct use values tend to be based on the marketed products (e.g. fish) and are more easily valued through prices and values identified by the commercial market. Indirect uses are harder to value, as these are not directly traded in the market place. Examples are coastal protection and the habitat provision, for example, as a nursery area for fish.

Non-use values range from option values to existence values. The option value is the value that people attribute to the ability to use the area in the future. They may be motivated by the desire to leave their future generations the chance to enjoy and use the area. This is known as the bequest value. The third type of non-use value relates to the desire to preserve nature regardless of human use, this is known as the existence value.

Valuation Techniques

A number of different methods have been developed to assess the values of the different goods and services (see Figure 1). Measuring the direct use values traded in commercial markets is relatively straightforward: prices are known and demand curves can be estimated. For many of the ecological services provided by coral reefs, however, there is no established market value and complex techniques are used to arrive at an economic value of these services (Barton, 1994). Three general categories of valuation techniques applicable to tropical coastal resources can be identified (Barton, 1994):

(i) Direct techniques that obtain information about the established market value of the affected goods and services or of direct expenditures, e.g., change in levels of production

(ii) Potentially applicable techniques, which use the market indirectly to obtain information about values and expenditures, e.g., replacement costs of coastal protection structures or cost of property at threat from flooding if mangrove or reef is removed

(iii) Survey based methods, which use hypothetical markets and situations through, for instance, questionnaire surveys such as the contingent valuations method (CVM) where people's willingness to pay (WTP) for a benefit or willingness to accept compensation (WTA) for a loss is ascertained.

Here, two methods are briefly described which will be important in the case studies below. For other techniques mentioned in Figure 1 such as hedonic pricing, travel costs, preventive expenditures, see Barton (1994). The best known, technique for identifying direct use values is referred to as the Effect on Production (EoP) method. This technique, also referred to as the 'change in productivity' method, looks at differences in output (production) as the basis of valuing reef services (Barton, 1994). The technique is often used in valuation of fisheries and tourism (producer surplus) to estimate the difference in value of productive output before and after the impact of a threat or a management intervention (Cesar, 2000a).

Reef degradation may also lead to fewer dive tourists and therefore lower tourism revenues. Hence, the change in number of tourists can be estimated, valued and subsequently used as a proxy for the loss in tourism value. For fisheries, the technique can be used to estimate the loss in the fisheries value from a specific threat, such as coral mining (Berg et al., 1998; Ohman & Cesar, 2000) or the gain in the fisheries value from a management intervention, such as the introduction of a marine reserve (Alcala, 1988). Below, net revenues in fisheries are estimated as part of the Curaçao case study on the TEV of reefs. In order to value the management benefits of these resources, a quantitative ecological analysis that can link management to ecosystem and production changes would be required (Cartier & Ruitenbeek, 2000). An ecological response model was developed as part of the cost-effectiveness analysis project carried out in Curaçao (Rijsberman & Westmacott, 2000) that linked the changes in water quality resulting from various management measures to changes in reef health, measured in coral cover and coral diversity (Meesters et al., 1998).

It should be noted that that both the revenue estimates and the EoP estimates focus on the production side. Hence, this approach does not give changes in overall economic value of fisheries, as it leaves out changes in welfare to consumers. In the case studies presented below, possible market distortions and their impact on prices are omitted for simplicity, so the estimates provide financial costs rather than economic costs. Yet, it is often used as a conservative lower-bound proxy for the fisheries value of reefs (Berg et al., 1998; Pet-Soede et al., 1999). The terms *financial costs* and *welfare costs* will be used extensively in the case studies below.

The most well known survey-based method is the Contingent Valuation Method (CVM). CVM elicits information of respondents for a specific environmental resource or a change in ecosystem conditions. CVM requires that individuals express their preferences by answering questions about hypothetical choices (Bateman & Turner, 1993). Typically, respondents are asked how much they would be willing to pay (WTP) to ensure a welfare gain from a change in provision of a non-marketed environmental commodity; or how much they would be willing to accept (WTA) compensation to endure a welfare loss from a reduced level of provision. It is argued that WTP is more appropriate for welfare gains and WTA for welfare losses (Bateman & Turner, 1993).

There are a number of potential biases associated with CVM. Careful use of CVM is therefore necessary. The NOAA-panel (Arrow et al., 1993) has given explicit recommendations on the correct performance of CVM-surveys. One important point is identifying the effects of embedding (part-whole bias). Embedding occurs when a respondent is unable to place a value on the good in question but specifies a value for a larger good (Bateman & Turner, 1993). Another important point is the choice of the payment vehicle. This is again controversial and remains largely unresolved as to which is the preferable method (Hanley, 2000). Bidding games may suffer from a starting point bias, payment cards from anchoring effects and open-ended designs may be difficult for respondents to answer (Bateman et al., 1995; Hanley, 2000). Whichever method is selected, these issues need to be accounted for. These issues are particularly important in the comparison of values from different studies. These points will be explicitly discussed for the case studies.

From the management perspective, economic valuation can be used to highlight the benefits of management through comparing the value of the goods and services provided without management to the value of the enhanced goods and services provided with management [Pendleton, 1995; (Bower & Turner, 1998). It also enables the total economic value of the resource to be ascertained to increase the awareness of what reefs are worth. Although survey-based estimates are preferred to arrive at the TEV from a theoretical point of view, the use of market-based valuations has the advantage of carrying more credibility than valuations based on hypothetical markets. In certain cases, the total economic value may not be required and a partial valuation based on market prices is enough to demonstrate the benefits of protection and management (Cesar et al., 1997). However, it seems that regardless of the drawbacks and unresolved issues, both can play an important role in supporting integrated coastal management (ICM).

7.3 Methods

Three valuation studies are presented here. Two were undertaken in Curaçao in 1997 (Figure 2) as part of the development of the cost-effectiveness methodology for coral reef management project, funded by the World Bank (Rijsberman & Westmacott, 2000). As a second phase of the project, a valuation study was carried out to assess the potential for carrying out full cost-benefit analysis for resources such as coral reefs and maintenance of biodiversity. Part of this valuation involved the utilisation of CVM to value the benefits of maintaining and improving coral reef biodiversity along the island's south coast (Spash, 2000; Spash et al., 2000).

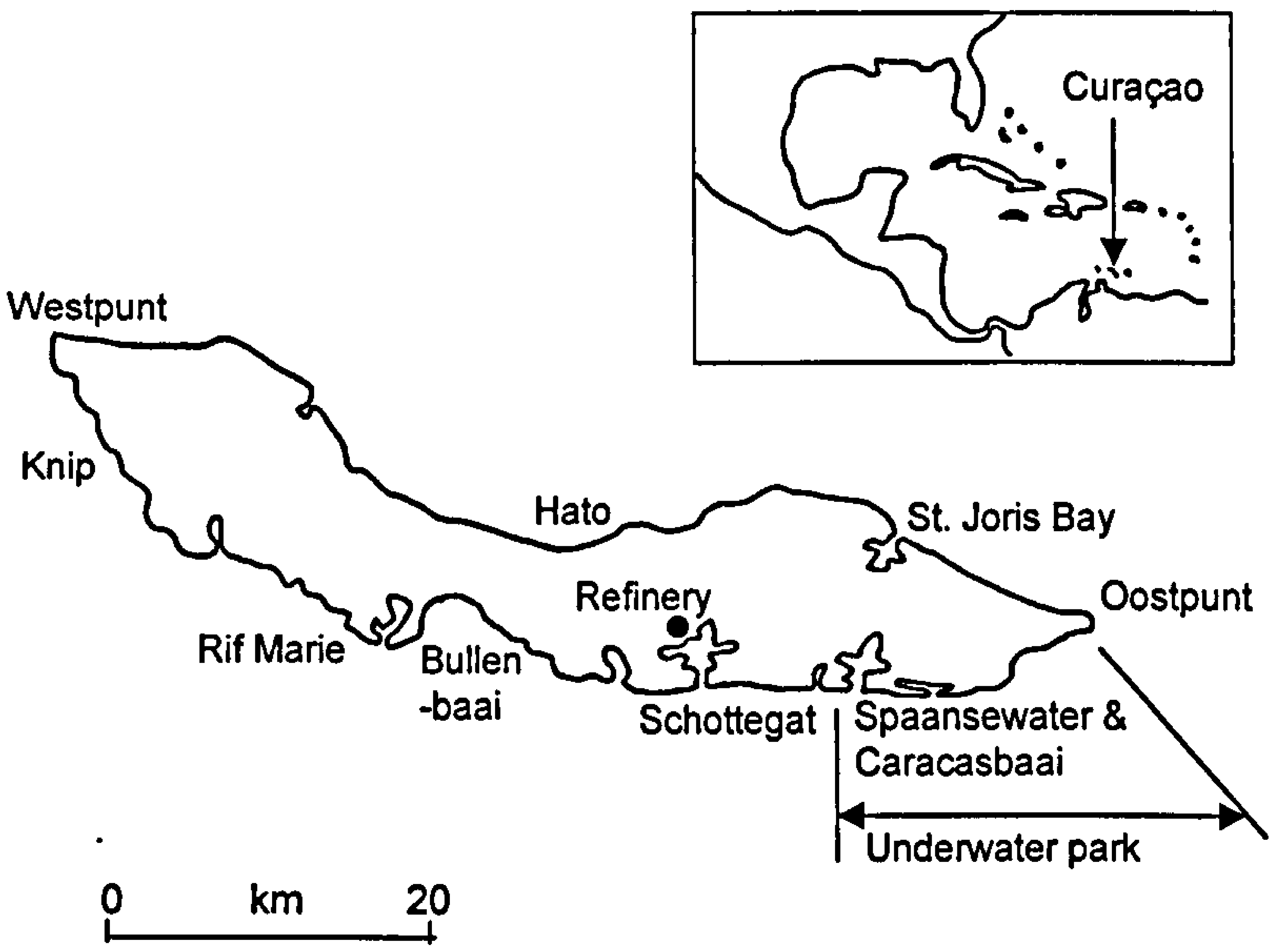


Figure 2 Map of Curaçao showing the locations of the main centres of activity and its location in the Southern Caribbean (inset)

The study asked both local residents and foreign tourists for their WTP to improve coral reef biodiversity. Respondents were asked what they would be willing to hypothetically contribute towards a trust fund, which would be managed by the Marine Park in order to increase marine biodiversity within the park boundaries. The respondents were told the following:

> *The current marine biodiversity of the proposed park is around 50% of its full potential and if we 'do nothing' this will soon fall to 35%, being two thirds degraded. Management strategies could maintain the biodiversity at 50% but if contributions are adequate, a trust fund would be established for use by a new South Coast Marine Park for exclusive use on projects to increase biodiversity within the Park to 75% of its potential.*

They were then asked for their WTP to a trust fund as an open-ended question where they could state any amount they desired. This type of questioning has the advantage that the respondents do not have a value suggested to them as a starting point. The method with which the respondent has to pay does result in changes in the mean WTP (Bateman et al., 1995). The mean WTP is calculated along with the 5% trimmed mean so as to test for the effects of outliers.

The second valuation, also carried out in Curaçao (Figure 2), aimed at valuing the direct uses of the reefs. This required data to be collected on tourism, fishing, education and scientific uses. The fisheries part of the valuation is examined in detail here as an example of direct use valuation based on production levels and market prices. The complete direct use valuation can be found in Rijsberman and Westmacott (1998). The data were mainly collected from existing sources and surveys. They relate to total numbers of fishers involved, expenditures, production, revenues generated and the costs. Some of the cost data were gathered from interviewing fishermen and divers. These data were used to obtain estimates of the net revenues of the fisheries sector.

For both valuations carried out in Curaçao, most of the data were collected in local currency. The values have been converted into US$ from the local currency, which is the Netherlands Antilles Guilder (NAf). This is officially set at a fixed rate of 1.78 NAf to the US$, therefore, eliminating any concern regarding exchange rate issues.

The third valuation used in this analysis was undertaken as part of an international programme called the Coral Reef Degradation in the Indian Ocean (CORDIO) programme (Linden & Sporrong, 1999; Souter et al., 2000). A series of socio-economic projects were carried out to examine the impacts of the 1998 coral bleaching in the Indian Ocean (Westmacott et al., 2000a; Westmacott et al., 2000b). Coral bleaching can be caused by high sea surface temperatures and high levels of sunlight (UV), which affects the physiology of the coral and causes a whitening effect, or *bleaching* of the coral tissues. This loss of colour is due to the loss or degradation of symbiotic algae (zooxanthellae) upon which the coral polyps depend for much of their nourishment. Prolonged bleaching conditions (for over 10 weeks) can eventually lead to mortality of the coral polyps (Goreau & Hayes, 1994). Sustained high water temperatures (1-2 °C anomalies) during 1998 caused the most geographically extensive bleaching event ever recorded. The Indian Ocean was one of the worst affected regions, with coral death as high as 90% in the Maldives, the Chagos archipelago and in parts of East Africa (Linden & Sporrong, 1999; Wilkinson et al., 1999; Goreau et al., 2000; Souter et al., 2000).

The study reported here was carried out in the period August and November 1999 in Zanzibar (Tanzania) and Mombasa (Kenya) (see Figure 3). It aimed to assess the economic impacts of coral bleaching on the diving and recreation industry. A broad-based survey was carried out to obtain economic data as well as background information about:

(i) The main reasons for divers and snorkellers to visit the region;

(ii) The importance of diving and snorkelling in relation to other attractions offered by the destination;

(iii) Tourists' awareness of coral bleaching and whether the knowledge of the occurrence of coral bleaching would affect their decision to visit or dive;

(iv) The attributes that divers find most important about their underwater experience.

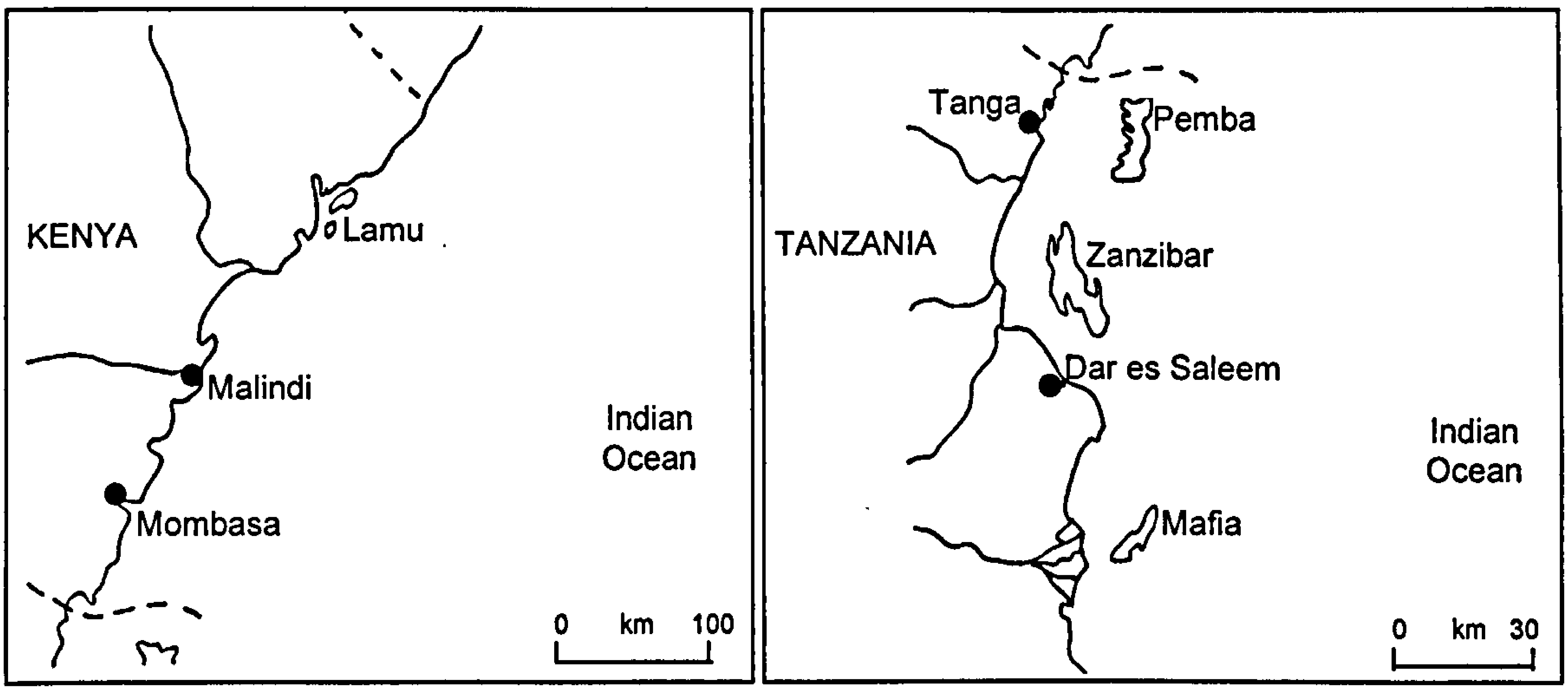


Figure 3 Map of Kenya and Tanzania showing the main coastal towns and islands, including Mombasa and Zanzibar

In order to estimate the financial costs and the welfare costs of coral bleaching to the tourism function of coral reefs, survey information and background data from before and after the bleaching event were compared. Data from before the bleaching event were collected in 1996/1997 by a Swedish researcher (Andersson, 1997). Her survey identified the recreational value of reefs at that time. The survey described in this chapter adapted her questionnaire to include specific bleaching related questions. This enabled the comparison of divers' and snorkellers' valuation of the reef resources before and after the coral bleaching event of 1998.

The survey solicited information on tourist expenditures to estimate financial costs of coral bleaching to the local economy, represented by the loss in net revenues from tourists either not visiting or not diving. It utilised a CVM question to estimate the economic welfare cost to tourists. The study in Zanzibar and Mombasa used both WTP and WTA to identify tourists' welfare losses. The two main questions were:

- *Considering your experience so far on this trip, and the total cost of this trip, how much more expensive would the trip have to be before you decide not come?*
- *If the reefs on the coast were completely degraded, how much cheaper would your trip have to be for you to still come?*

The analysis is used to estimate the welfare loss of two groups of people. First, the tourists stating they would not visit the area and secondly, tourists who would still visit but would no longer dive. The welfare loss of tourists that would continue to dive but with potentially a lower level of diver satisfaction has not been included.

A further question was asked in the survey to try to elicit the WTP for reef conservation. This represents the non-use value that divers place on knowing that the reef will be conserved in the same state. This consists of the bequest value and the existence value (see discussion above in Section 7.2). A similar method was used to the CVM in Curaçao where a hypothetical trust fund was used as the payment vehicle for contributions made towards reef conservation. The question (used in Mombasa) was as follows:

> *The coral reefs in Kenya are threatened because of pollution, destructive fishing methods, poor sewage treatment and coral harvesting. Imagine that a fund was set up by a non-governmental organisation to ensure that the conditions of the reefs were kept in their current condition and that all of the money collected would be used for this purpose. If you knew that the lack of such support would lead to the destruction of the reefs, which of the following amounts best describe the maximum amount you are willing to pay per visit (in addition to your total personal cost) to such a fund that ensures the current state of the reefs. Please check one:*
> *0___1___5___10__15__20__25___50___100__200 ____USD/visit*

This study differs from the Curaçao study in that it utilised a payment card rather than an open-ended question to elicit the WTP value. This approach may give slightly higher values than the open-ended question but it may remove some of the uncertainty induced by open-ended questions (Turner et al., 1998b).

7.4 Results

Valuation of coral reef biodiversity in Curaçao

The CVM survey in Curaçao was initially pre-tested on around 100 respondents to ensure that they understood the questions and to check that the survey, originally developed for Jamaica was applicable to Curaçao. This procedure resulted in presentational changes concerning the information, which was made less technical. Shows cards were also developed to help respondents in answering certain questions. In general, the quantity of information was reduced so the revised survey took around 20 minutes rather than the initial 35 minutes to administer (Spash et al., 2000). The revised survey was carried out on 1152 people, 656 were locals and 496 were tourists. The results of interest to management are as follows:

- Identification of user benefits and assessment of WTP indicating support for conservation and potential to raise funds through user fees

- Identification of non-use values indicating the potential to establish fund raising 'friends of' organisations
- Assessment of the willingness to volunteer time, indicating the potential to increase personnel capacity

Identification of user benefits and willingness to pay for conservation

By asking the respondents to identify their activities along the south coast, the survey is able to provide managers with an idea of the benefits both local residents and foreign tourists gained from the south coast. The most common activities were swimming both for the tourists and for locals followed by diving and snorkelling (Table 2). Swimming, diving and enjoyment of the beaches all rely on a healthy marine ecosystem. These benefits accrue to tourists and local residents and their conservation and management is likely to be of concern to the general public and decision makers.

Table 2 Direct personal benefits gained by locals and tourists visiting the south coast of Curaçao (n=1152)

Benefit	Locals (%)	Tourists (%)
Swimming	32	30
Diving and snorkelling	11	21
Using beaches and sunbathing	11	15
Eating seafood from the reefs	10	5
Just visiting and enjoying the scenery	9	7
Fishing	8	3
Earning tourist related income	5	4
Boating and sailing	3	5
Others	1	2
No benefits	9	9

With their personal benefits in mind, as well as the fact that other important political issues that may require funding such as health services and education, the respondents were asked for their willingness to pay for increased coral reef biodiversity along the South Coast. The respondents replied in terms of *yes* and *no*. Those who stated *no* were asked the reason for this, those stating *yes* were asked what amount they would be prepared to give.

In the beginning, it was hypothesized that tourists would give higher amounts than locals because of their substantially higher incomes. However, this was not the case and the mean willingness to pay did not vary significantly between tourists and locals (see Table 3). This information is important in establishing user fees and would indicate that the yearly fee could be the same for tourists and locals and would be best based on a yearly license or tax as opposed to a per use fee which may penalise local more frequent users. In establishing user fees, it is important to recognise that not all people are willing to pay. The Curaçao survey identified that only 50% of the population would be willing to pay (Table 3). Some of those refusing to pay are reef users who are either unable or unwilling to pay. Out of the 1152 respondents, 88% indicated that they would use the south coast reefs in the coming 5 years. Half of these, 44% of the surveyed population state that they do not want to pay for the conservation of the resource but still want to use it in the coming 5 years. In estimating user fees, managers need to select a level of payment that would be acceptable to the majority of users. The number of zero bids identified by this survey indicates that there could be a political problem in establishing user fees. However, this may be more related to the complexity of the survey design than a real refusal to pay. Hanley (2000) states that surveys revealing more than 40% zero bids are likely to be too complex. This survey identified 50% zero bids, of which 38% were protest bids. However, during the data collection, it was felt that the survey was complex and hard for the respondents to understand. The pre-test and subsequent revision led to simplification of the final survey but this may not have been sufficient. This does highlight, however, the complexity of this technique in producing reliable data.

Table 3. Statistical summary for willingness to pay for improved reef biodiversity as stated by tourists and locals surveyed in Curaçao

	Mean ($)	Median ($)	5% trimmed mean ($)	Standard deviation ($)	Max. WTP ($)	Positive bids	Zero bids	Total
Locals	25.3	0.0	11.2	79.9	674	313	343	656
Tourists	25.1	1.1	12.7	80.6	1124	262	234	496
Total	25.2	0.0	14.9	80.1	1124	574	577	1152

It is important to note that the 'mean' WTP is not necessarily the best user fee level, especially if the aim is to encourage people to visit the area. Figure 4 shows that the mean WTP, of US$25, will only be acceptable to 15% of the population. A more acceptable amount will be much lower and therefore the realisable value may be substantially less than the mean value. If CVM was to be used to identify potential user fees for Curaçao, a simpler more direct survey should be developed and used.

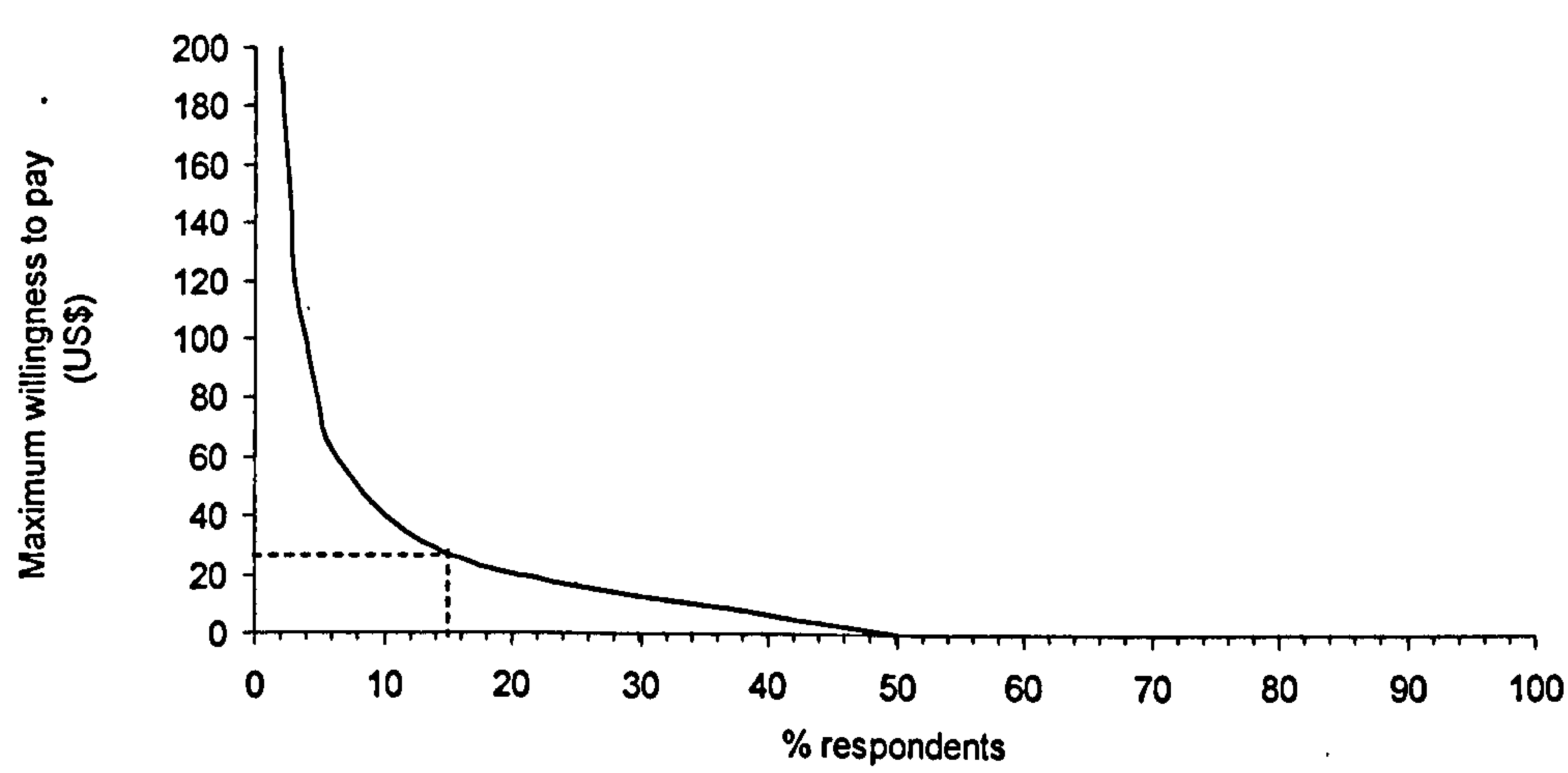


Figure 4 Frequency distribution showing the percentage of survey respondents' willing to pay for improved reef biodiversity in Curaçao in US$ (n=1152). The mean WTP of US$ 25 is indicated by the dotted line.

Checks were carried out in the survey to identify those zero bids that could be classed as protest bids. This was achieved through further questioning as to the motivation behind the respondent's zero bid. Protest bids are those bids where the respondent refuses to give a value even through they may be concerned with the resource issue in question (Hanley, 2000). The importance of identifying these protest bids is that they will create a bias in the results reducing the WTP. In Curaçao, 38% of the zero bids fell into this category (Spash et al., 2000). Removal of these protest bids leads to an increase of the mean WTP to US$30.

An additional issue to be taken into account in CVM studies is that of 'embedding', which is a check as to whether the respondent is bidding for just the good in question or a wider range of goods that they were unable to separate (Bateman and Turner, 1993). The Curaçao survey identified those unable to separate the South Coast reefs, from all the reefs, which would result in an overstated bid when only considering the South Coast. This can be seen to affect 35% of the positive bids from the tourists and 37% of the positive bids from the locals (see Table 4). However, an additional question in the survey would be needed to identify the percentage these respondents would allocate to south coast reefs in order to revise their original bids. This was not carried out.

Table 4 Table showing the level embedding affecting the willingness to pay responses for the south coast reefs as opposed to all the reefs of Curaçao

	Tourists (%)	Locals (%)
Increase payment for other reefs of Curaçao	47	58
No increase because no value placed on other reefs of Curaçao	18	5
No increase because payment covers all Curaçao's reefs	35	37

Identification of non-use values

The CVM survey asked those giving positive bids whether they would continue paying to the trust fund if they left the island and never returned. This enables an estimation of the non-use value (option, bequest and existence values) to be made. Almost 50% of the tourists and 35% of the local residents would be prepared to continue paying the initial amount specified each year even though they would not return (Figure 5). The other results fell into the 50% category or between 0 and 30%. Such trust funds, often called 'Friend's of' organisations are just one way of raising money for conservation programmes. The results give a mean value of US$16 per year that could be raised from those donors originally giving a positive bid.. However, there will be certain administrative expenses coming from the establishment of such a system as well as the need to maintain the donor's interest through newsletters, etc. These types of costs need to be weighed against this potential net income before such an organisation is established. Although the mean value can be used to estimate the feasibility of establishing a trust fund, like the user fees, the mean WTP will be a overestimation of the realisable value, particularly if a fixed membership fee is set.

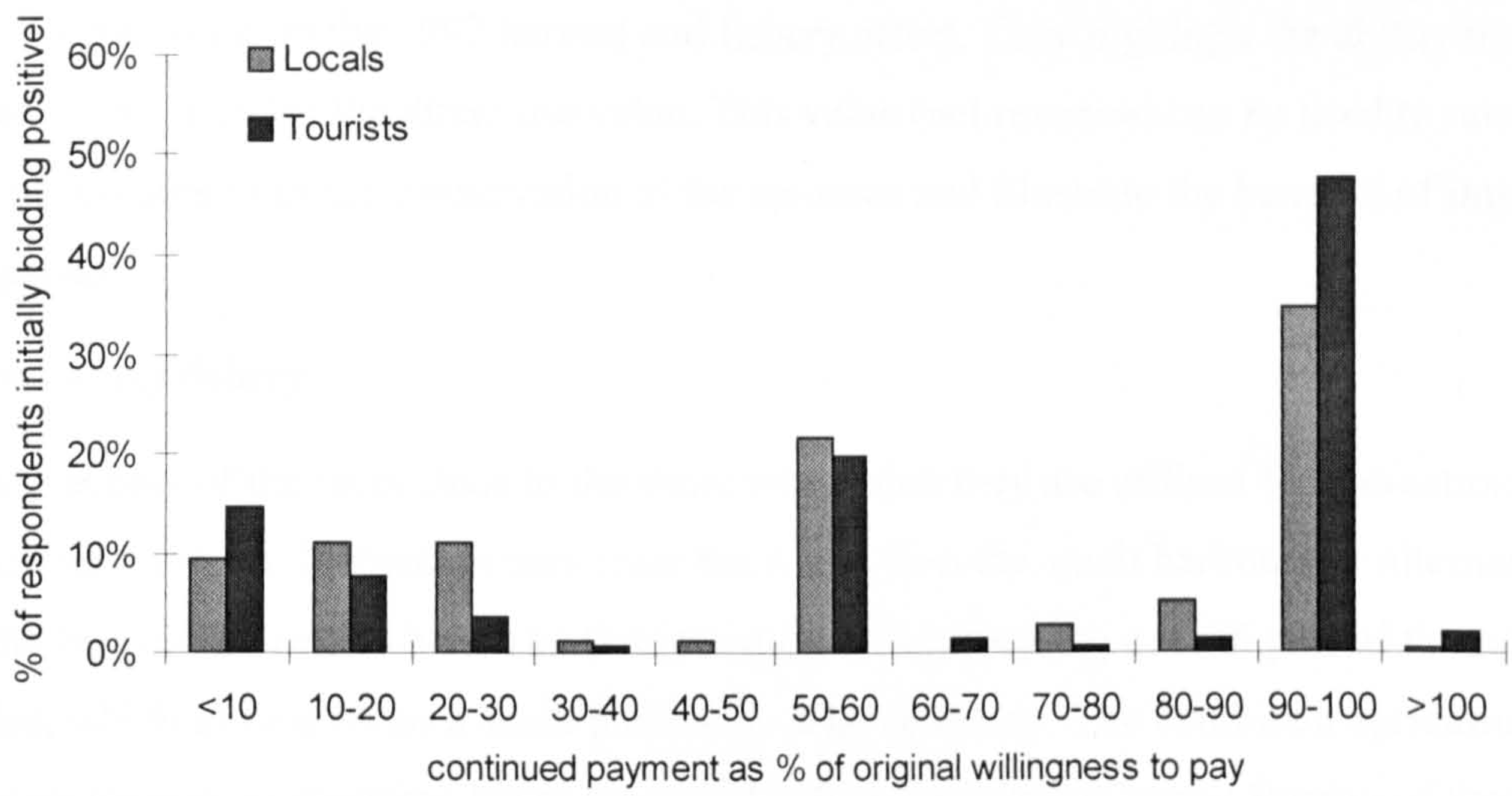


Figure 5 Frequency distribution illustrating the percentage of the survey respondent's original willingness to pay that they would continue paying to the trust fund after leaving Curaçao and never returning. Positive bidders only, locals n= 169, tourists n=142.

Identification of willingness to volunteer time

Respondents were given an alternative to monetary payment to the trust fund. This may be important in developing countries where the non-monetary sector is important (Spash, 2000). Respondents were asked if they would volunteer time to help with work in the Park. However, it was discussed and hypothesised on Curaçao that the concept of voluntary work was not widely accepted and this figure is likely to be low. In comparison to the same data gathered from Jamaica, this hypothesis was apparently correct (Spash, 2000; Spash et al., 2000). The results for Curaçao showed that on average, local residents and foreign tourists alike offered to volunteer on average 1 day per person. This is a substantial part of the tourists' vacation, as they only have on average 9 days on the island (Curacao Tourism Development Board, 1996). It also accumulated to a substantial number of person-days from the local population. Reef Care Curaçao is an existing volunteer organisation that utilises the goodwill of local residents, mainly expatriates living on the island to collect data for their projects (van Veghel & De Meyer, 1993; van Veghel et al., 1995). Although this may seem initially like a substantial number of man-days, training is often required which would require more than one volunteer day to be worthwhile.

Valuation of the reef fisheries in Curaçao

Direct use valuations can be based on net revenues from market identified prices and costs and the levels of production. These types of valuations may be more politically acceptable as they are more tangible than those values identified through hypothetical questions. Consequently, they could play an important role as a management tool even though they do not give the full economic value (see Section 7.2). The direct use valuation of Curaçao's reef resources included the fisheries, tourism and recreational, educational and scientific values of the reef. The results presented here focus on the fishery sector based on the 1997 harvest and fishery effort. They highlight the ability to use net revenues as a proxy for the direct use value. This value (net revenue) can be used to raise attention to levels of investment in the conservation of the resource and illustrate the benefits of improved management.

Curaçao's reef fishery

The easy access of the reefs close to the shore means that they are utilised for recreational as well as commercial fisheries. Fishermen may enter the water from the small harbours or alternatively directly from the beach. The reef fisheries on Curaçao are limited, forming a small part of the total island fisheries, which in turn forms a small part of the total economy. The combined agriculture, fishing and mining sector only contributes 1% to the total GDP of the island (Central Bureau of Statistics, 1998a). The major economic sectors are tourism, manufacturing and shipping. The fisheries sector is managed by the Department Landbouw, Veeteelt en Visserij (LVV; Agriculture, Animal Husbandry and Fisheries). Due to the small size of the industry, little has been done to closely monitor the catch. However, the reef fisheries are known to be over-fished (Gerard van Buurt, pers com., 1997). In many locations in the world, fishing co-operatives exist forming a useful basis for monitoring data. In the case of Curaçao, there is no such co-operative and fishermen act on an individual basis. There are also very few registered fishermen. Many fishermen work on a part time basis or without registering to avoid taxes. The total number of fishing boats is thought to be in the region of 1000 (van't Hof et al., 1995). The boats are in general small and are used on a daily basis by the local fishermen. They are generally around 5 meters long, the larger being distinguished by having a deck, which the smaller ones do not have. The larger boats are used for offshore pelagic catches as well as reef fish.

Revenues generated from reef fisheries

Estimates from 1988 indicate that the total fish landings for Curaçao were in the region of 900,000 – 1,200,000 kg. Of this, approximately 10-15% were reef fish, although it is thought that the percentage of reef fish could well be lower now (Gerard van Buurt, pers com). This would lead to a yield of reef fish between 90,000 and 180,000 kg yr^{-1}. More recent estimates indicate that the total catch from reef fisheries is 102,200 kg yr^{-1} (van't Hof et al., 1995). The price of fish in Curaçao varies depending on where the sales outlet is. Fish is sold in the supermarkets, the cafés (tokos) and directly from the fishing boats in the Capital, Willemstad. A survey from the Dienst Economische Zaken (DEZ; Department of Economic Affairs) gives a price range of 3.4 US\$ kg^{-1} for Mas-bangu (reef fish used as bait in the pelagic fishery) to 9.0 US\$ kg^{-1} for Mero (popular pelagic fish) (EXTRA, 1997). The latter was the price from a local supermarket where the price tends to be 30% higher than that from the fisherman direct. An estimated average value of 5.6 US\$ kg^{-1} was used for reef fish in this valuation. Combined with the annual catch of 102,200 kg this brings the revenue generated from reef fish caught at an estimated 572,300 US\$ yr^{-1} (see Table 5).

Yearly Costs

Like any direct use valuation, the fisheries valuation needs to account for the costs of catching the fish as well as the revenues generated from the fishery. The costs include the direct management costs as well as the opportunity costs (Emerton, 1999; Rodwell & Roberts, 2000). The opportunity costs include, for example, the loss of potential earnings from other activities. The opportunity costs in this study are based on the assumption that a fisherman in Curaçao is able to earn the minimum yearly salary of US$ 4,500 (Central Bureau of Statistics, 1998b) as an unskilled labourer elsewhere. However, those in the industry for some time may be reluctant to leave and will be prepared to earn less than the minimum wage. There are an estimated 120 full time fishers and 280 part-time fishers working on the larger boats (van't Hof et al., 1995). From this, it is calculated that 1-2 fishermen operate these larger boats, and 1 person operates the smaller boats. This means the opportunity cost of labour is calculated at one full time and one half time fisherman for the larger boats and one full time fisherman for the smaller boats. The shore based fishermen work on a part-time and recreational basis. It is assumed that they spent on average 20% of their potential paid working time fishing, approximately 1 day per week, although exact figures are not known.

There was no readily available data on the investment and operational costs of the fisherman in Curaçao; consequently, the cost of a boat and equipment, which is paid off over 10 years, was attained from asking several fishermen (see Table 5). Operational and maintenance costs were estimated during discussions at around 10% of the investment. The most recent survey of fishing effort carried out by the research institute, CARMABI (van't Hof et al., 1995) estimated the total number of fishing days for each form of fishing on the reef on an annual basis. The total number of boats over 5 m was estimated at 200 and less than 5m at around 500 (van't Hof et al., 1995), this means they spend on average 10-12% of their time on the reef. This is in line with LVV estimates that approximately 10% of the total fish catch comes from the reef, consequently this value was used to apportion that part of the total costs relating to the reef fish catch (see Table 5). The total cost of fishing is the sum of the investment payoff, the operational and maintenance costs and the opportunity costs of labour multiplied by the number of operations. This is then adjusted for the proportion attributable to reef fishing. The total cost of reef fishing is estimated at US$ 766,900 (see Table 5).

Net revenues from reef fisheries

The direct use valuation shows reef fisheries to have a current (1997) yearly net worth of US$ -194,700 based on the 1995 level of production (see Table 5). The negative value indicates that the costs exceed the gross revenues. The investment, operational and maintenance costs are less than the gross revenues indicating that Curaçao fishermen are prepared to earn less than the minimum wage and continue fishing. These results back up the information from LVV that the reefs are currently being overfished. These results indicate that current fishing effort on the reefs of Curaçao exceed the point of optimal economic yield. If fishing pressure increases further, fish stock levels may not be able to be sustained and will eventually collapse. Fishing at these levels not only leads to low income for fishermen but may also have a negative effect on the tourism industry, where a healthy fish population is one of the main underwater attractions (Polunin et al., 2000; Westmacott et al., 2000c).

If effective ICM were able to increase stocks, the income to the fishermen and the profitability of the fishing industry would increase. Without effective ICM, it is likely that the net revenues from fishing will decline even further unless fishing effort is reduced.

Table 5. Net value of the reef fishery for each fishing type calculated from yearly reef fishing revenues and costs per fisherman in Curaçao in US$

Revenues	Boat >5m with deck	Boat <5m w/o deck	Shore fishermen	Shore collectors	TOTAL
Reef fish catch, kg yr^{-1}	43,800	46,500	10,300	1,600	102,200
Price of fish, US$ kg^{-1}	5.6	5.6	5.6	5.6	
Yearly revenues, US$	245,100	260,400	57,600	9,200	572,300
Yearly costs					
Investment payoff per operation, US$	2,500	1,200	60	60	
Operation & maintenance, US$	2,200	1,100	10	10	
Opportunity costs of labour	6,700	4,500	900	900	
Total costs per operation, US$	11,500	6,900	1000	1000	
% Attributable reef fishing	10%	12%	100%	100%	
Yearly cost of reef fishing, US$	230,400	405,400	99,300	31,800	766,900
Net value of reef fishery, US$	14,700	-145,000	-41,800	-22,610	-194,700

Investment in conservation of reef resources

Fisheries is just one of the benefits the reef in Curaçao supports. The total tourism expenditure was estimated at around US$ 220 million in 1995 (Curacao Tourism Development Board, 1996). An estimated 38% of the tourists visiting Curaçao visit the reef for scuba diving or snorkelling (Curacao Tourism Development Board, 1996). If this figure were to include the non-diving family members accompanying the divers then the percentage of tourists visiting Curaçao for reasons that are specifically related to the coral reefs would increase. These direct use values of the reef resources can be compared to the amount invested in its management and conservation. The organisation currently in charge of the management of the Underwater Park and enforcing the Island's Reef Protection Ordinance is currently subsidised by the Government. In 1997, it received US$ 70,000 for these activities. This is less than 1% of the gross reef related revenues generated by tourism, which depend on these resources for their survival. This represents a small investment in the conservation and protection of a revenue generating resource. These figures could be used to raise awareness of the revenues the resource supports and may provide sufficient justification for greater investment in its management and protection.

Financial and economic impact of the coral bleaching on divers in Mombasa and Zanzibar

In total 304 tourists were interviewed, 100 in Mombasa and 204 in Zanzibar split evenly between Nungwi in the North and the capital Stone Town in the South. These tourists were all divers and snorkellers and they were asked to complete the survey at the dive shop. They represent the portion of tourists who are actually using the reef. Several aspects of this study are of interest to management, namely:

- Identification of the main tourist attractions and dive site characteristics in order to prioritise management actions promoting tourism
- Assessment of the extent diver behaviour is affected by coral bleaching and what are the financial and economic consequences to local operators
- Assessment of the impact of reef degradation on divers' willingness to pay

Main tourist attractions and importance of dive site characteristics

The respondents were asked for their reasons to come to the area based on seven categories of attractions, which they ranked in order of importance. For both locations, *relaxing* and *general pleasure were* the main attraction and reason for coming to the area (see Figure 6). In Zanzibar, *snorkelling, diving* and *beaches* followed in importance while in Mombasa, *beaches* was ranked higher than both *diving* and *snorkelling.* In both locations, it seems that the reef plays an important role in choosing these destinations.

Various features of a dive site will make them more or less attractive to divers and snorkellers. The respondents were asked to grade the importance of different characteristics of a dive or snorkel site based on six characteristics. Divers in both areas identified the *variety of fish life* as the most important characteristic of a dive or snorkel site (see Figure 7). There is little variation in the ranking of *variety of corals, visibility* and *overall condition of the reefs*. The items *wilderness feeling* and *adventure* were of lowest importance at both locations. This information shows the importance of maintaining fish abundance and diversity on reefs with tourism potential.

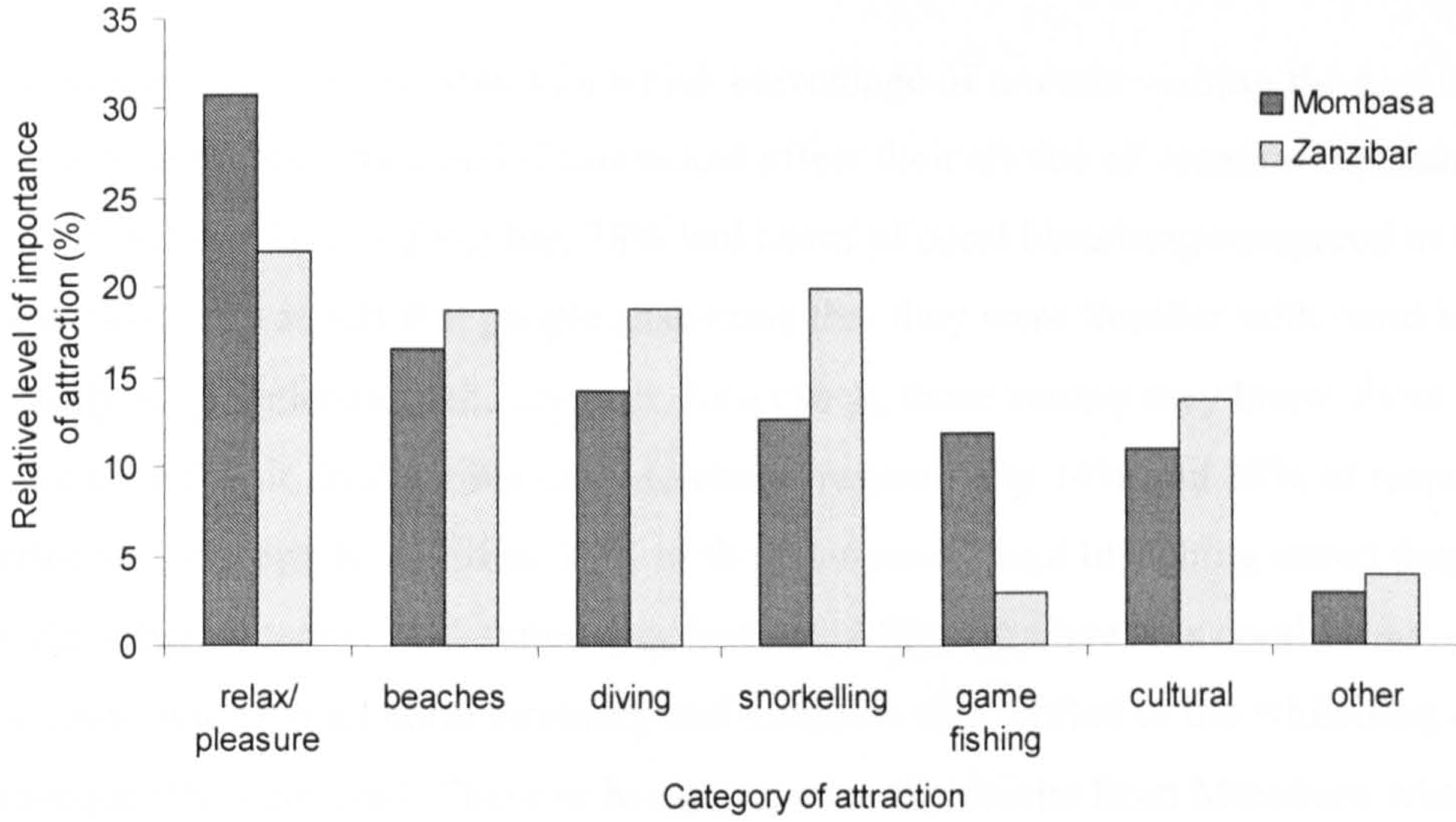


Figure 6 The relative importance of the various attractions for divers and snorkellers surveyed in Zanzibar and Mombasa, measured by the importance ranking used as a weighting factor combined with the frequency of responses for each category (Mombasa n=99; Zanzibar, n=205)

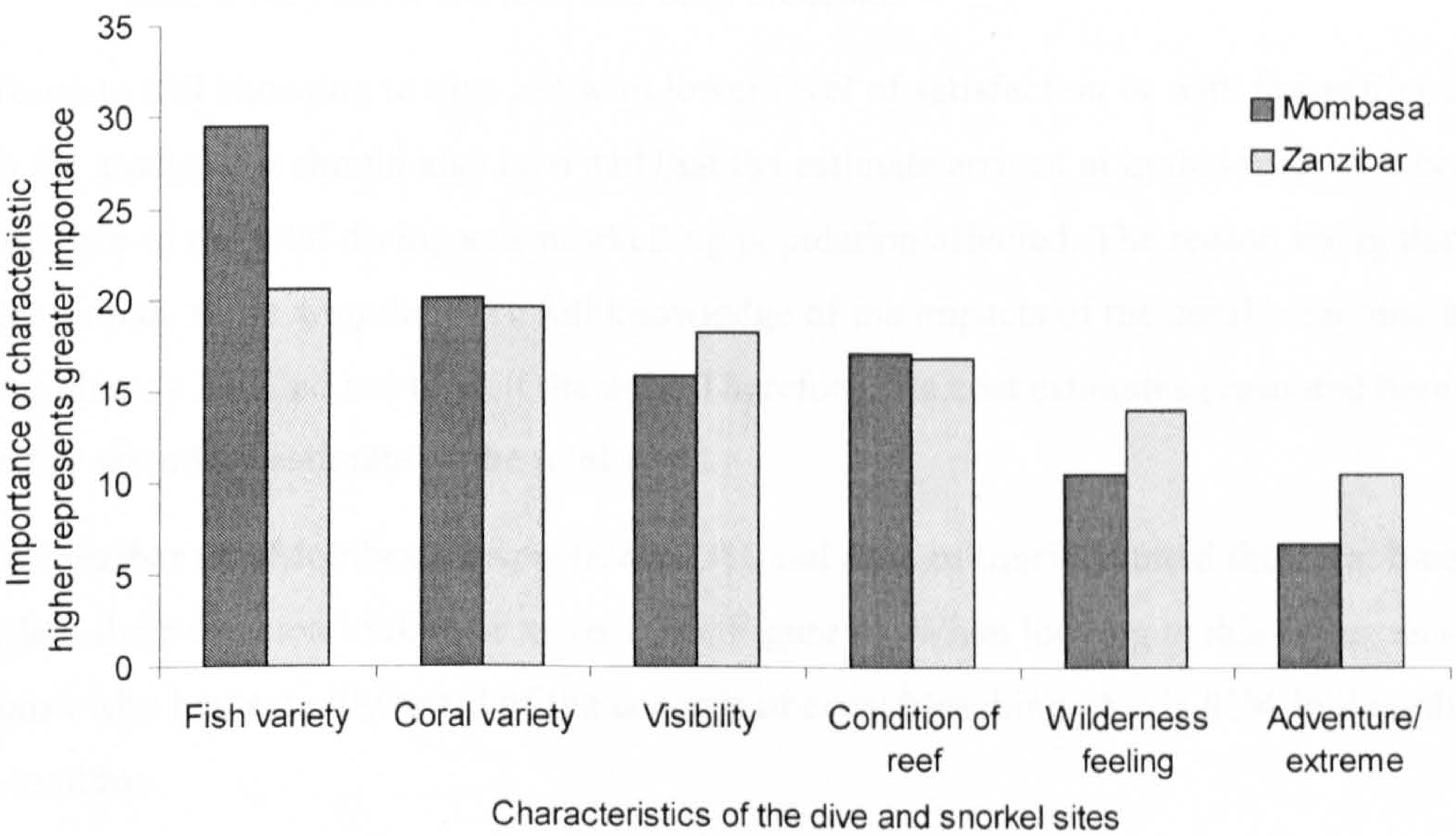


Figure 7 The relative importance of the dive site characteristics surveyed in Zanzibar and Mombasa, measured by the importance ranking used as a weighting factor combined with the frequency of responses for each category (Mombasa n=99; Zanzibar, n=205)

Effect of coral bleaching on diver behaviour and financial and economic consequences

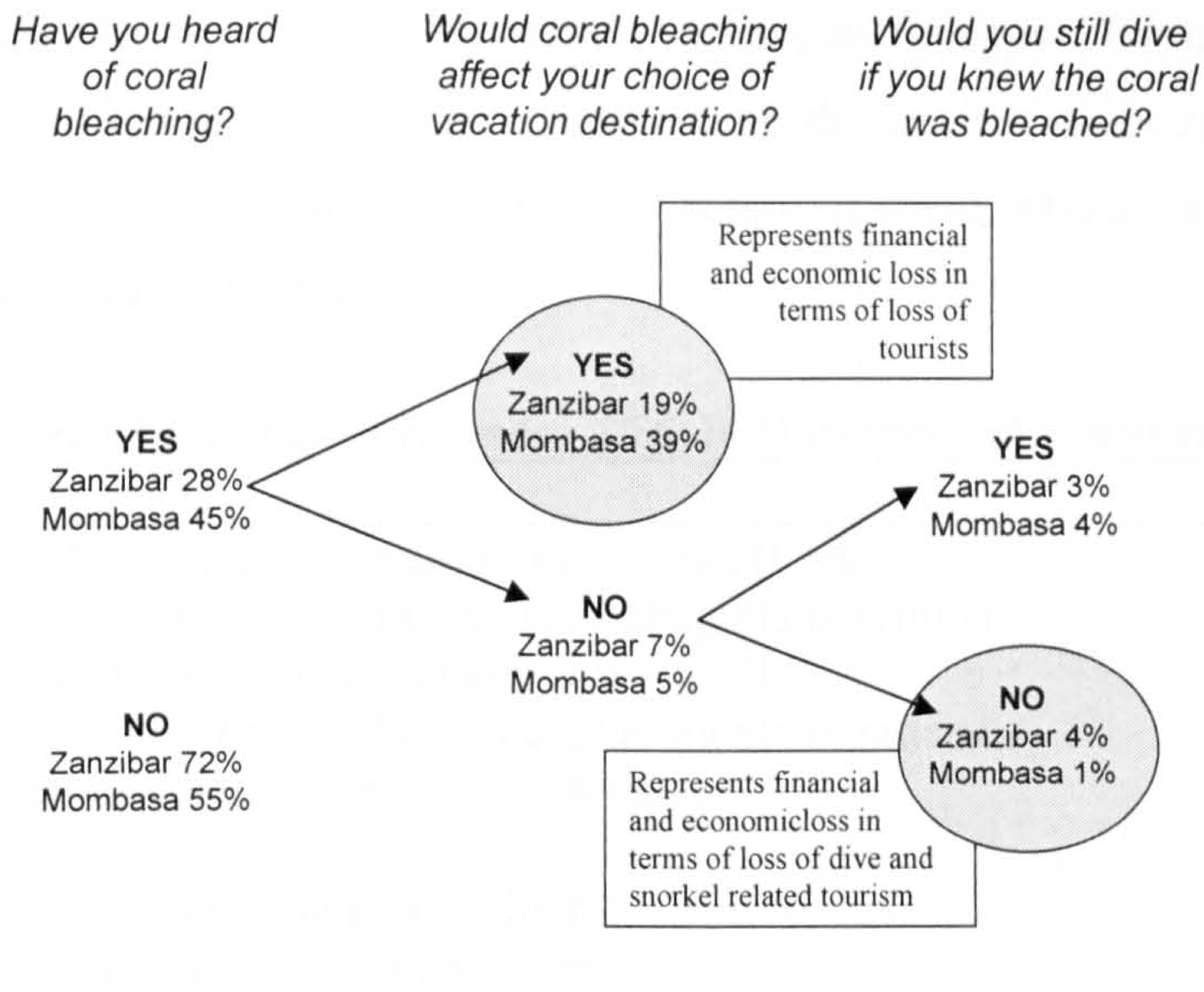
The survey attempted to ascertain which percentage of tourists visiting the two locations were actually aware of coral bleaching and if this would affect their choice of vacation destination and their decision to dive and snorkel. In Zanzibar, 28% had heard of coral bleaching compared to 45% in Mombasa. In some cases, it was felt that people answering that they were familiar with coral bleaching did not actually fully understand the concept. As a check, those stating they knew about coral bleaching were asked to define it. In Zanzibar and Mombasa, respectively 14% and 38% of respondents could not define the concept. In addition, 19% of those aware of coral bleaching stated they had seen the impacts on Zanzibar, whereas 52% stated they had not. Although there was coral bleaching on Zanzibar, it did not cause widespread coral mortality and its effect was limited to the whitening of the corals, which subsequently recovered. This can be compared to the results from Mombasa where the bleaching had a greater effect causing substantial coral mortality. Of those who had knowledge of coral bleaching, 53% said they had seen the impacts of it compared to 30% who said they had not. Around 17% did not answer the question. It appears that the knowledge and understanding of the concept of coral bleaching was limited in both cases.

The resulting costs of coral bleaching is analysed for the following groups:

1. Tourists familiar with coral bleaching who would decide not to visit the area if they knew that the area had been bleached
2. Tourists familiar with coral bleaching who would still visit the area although they would not dive if they knew the area had been bleached.

Tourists still choosing to dive but with lower level of satisfaction or with fewer dives are not included in the analysis. It should also be noted that the estimate arrived at in this study is a conservative estimate of the total diving and snorkelling population affected. The reason being that the sample does not include those who did have full knowledge of the impacts of the coral bleaching and consequently, had already decided not to visit the area. Therefore, the cost estimates presented here represent the lower boundary estimate of the total costs.

In Zanzibar and Mombasa, respectively 23% and 40% of tourists stated the coral bleaching would affect their decision to dive or to visit (see Figure 8). When looking at this figure as a proportion of those who had actually heard of the concept of coral bleaching, this is 82% in Zanzibar and 89% in Mombasa.



Note: All percentages are of the total sample of divers and snorkellers

Figure 8 Flow diagram illustrating the responses to questions regarding knowledge of coral bleaching and its effect on choice of destination and decision to dive

This means that full knowledge of coral bleaching is likely to affect tourists' decisions to visit an area and to dive, showing the importance of the type of information divers receive regarding the state of the coral reef and the damage caused by events such as the bleaching. The costs of coral bleaching can be seen as financial costs in terms of locally lost revenues and welfare costs to the tourists in terms of loss of utility. The former is of interest to the local manager who may have to deal with the consequences in terms of loss in profit and employment. The cost in terms of lost revenues was calculated based on survey questions about their expenditure data for the whole trip and for the diving related activities (see Table 6). Based on these sample data, the total loss of revenue resulting from coral bleaching was calculated. To achieve this, the total number of tourists visiting the areas in 1998 was used as well as the percentage of these tourists participating in diving and snorkelling (see Table 6). Data on the percentage of tourists diving and snorkelling were not available. However, it was estimated at between 20 and 30%. The corresponding range in results is given, similar to the approach used by Carter (1995). In the Maldives, which is considered a diving destination, 45% of the tourists are recorded as divers (Cesar et al., 2000a). The costs are presented here as loss in gross revenue. No data were available on variable costs and profit margins of tourist operators.

The total loss of gross revenues from coral bleaching was estimated at between US$ 13.9 million and 20.8 million in Mombasa and between US$ 3.0 million and 4.4 million in Zanzibar (see Table 6). To put this loss in perspective, it is as high as the average yearly income for 8700-13000 Kenyans and 5500-8000 Tanzanians based on the GDP per capita for 1999 measured in US$ based on purchasing power parity (Central Intelligence Agency, 1999). This highlights the importance of identifying feasible, large scale, alternative revenue generating and livelihood programmes. The loss in revenues identified in this study only accounts for the tourism sector and not the fisheries sector. The latter has lower costs but higher numbers of people affected, who are also poorer and less able to find alternatives for themselves.

Table 6 Loss of gross revenues (US$) in Mombasa and Zanzibar due to coral bleaching

	Mombasa	Zanzibar
Total vacation expenditure in the area (US$)		
5% trimmed mean excluding blank returns	1,288	868
Expenditure on dive related activities (US$)		
5% trimmed mean excluding blank returns	234	166
Total number of tourists (1998 data)	137,402	86,455
% Tourists taking part in diving	20-30	20-30
% Divers not visiting anymore	39	19
% Divers not diving but visiting	1	4
Number of tourists not visiting	10,700-16,000	3,300-4,900
Loss of gross revenues (million US$)	13.8-20.7	2.9-4.3
Number of tourists not diving	280-410	690-1000
Loss of gross revenues (million US$)	0.6-1.0	0.1-0.2
TOTAL LOSS OF GROSS REVENUES (million US$)	13.9-20.8	3.0-4.4

The welfare cost of coral bleaching is represented by the loss to tourists deciding not to visit the area and the welfare loss to the divers and snorkellers for not having access to healthy reefs. In order to calculate this, we utilise the additional amount respondents would be willing to pay for their vacation for the divers deciding not to visit at all and the willingness to accept compensation for not having access to the reefs for those visiting the area but choosing not to dive. The economic welfare cost for these two groups of people can be seen to be between US$6.8 million and 10.2 million for Mombasa and US$ 1.9 million and 2.8 million for Zanzibar (see Table 7). The results show that the value divers place on having access to the reefs is equivalent to around 35% of their total costs, indicating the importance of the reef as part of their vacation. What is neglected in this analysis is the probability that dive tourists will visit another area and also derive welfare from that experience. This type of substitution may decrease the welfare cost to tourism for loss of access to healthy reefs in Zanzibar and Mombasa.

Table 7 Welfare loss in US$ to tourists in Mombasa and Zanzibar due to the coral bleaching

	Mombasa	Zanzibar
Consumer surplus (US$)		
5% trimmed mean, excluding blank returns	625	507
WTA compensation for non access (US$)		
5% trimmed mean, excluding blank returns	460	307
Total number of tourists (1998 data)	137,402	86,455
% Tourists taking part in diving (range 20-30%)	20-30	20-30
% Divers not visiting anymore	39	19
% Divers not diving but visiting	1	4

Number of tourists not visiting	10,700-16,000	3,300-4,900
Welfare cost (million US$)	6.7-10.0	1.7-2.5
Number of tourists not diving	280-410	690-1000
Welfare cost (million US$)	0.1-0.2	0.2-0.3
TOTAL WELFARE COST (million US$)	6.8-10.2	1.9-2.8

Impact of reef degradation on divers' willingness to pay

The conservation value of the reef in this survey was established by eliciting the willingness to pay (WTP) of divers to maintain the reef in its current condition. This WTP for reef conservation can be related directly to the state of the reef because the WTP question is specifically in terms of the *current condition* of the reef. Having data prior to the bleaching event enabled any change in value to be identified, which could well reflect a change in the quality of the reef. The previous survey established a WTP for reef conservation of US$ 30 per diver (Andersson, 1997). This survey carried out 3 years later, identified an average US$ 20 per diver in answer to the same question. This indicates a decrease of 33%, which aggregates to a loss of US$ 0.2 - 0.3 million for Zanzibar. However, it would be too simplistic to assume that this drop in value can be associated solely to a decline in reef quality. Rather, it may well reflect, for example, a change in the experience of divers, their income or their interest in the marine environment. For these reasons a comparison of the socio-economic characteristics of the divers in 1996 and 1999 in Zanzibar was carried out (Table 8).

The only change in socio-economic variables between 1996 and 1999 was the level of diver experience (see Table 8). This may be a direct result of a decline in reef conditions where the more experienced divers are aware of reef conditions through reports of reef degradation from dive magazines or other sources and have visited other more pristine sites. Less experienced divers may be less willing to pay for reef conservation resulting in the observed decrease, although this was not established in this study. However, the change in WTP could be simply related to the change in reef quality; a 20% decrease in hard coral cover was reported at various monitoring sites (Muhando, 1999). It would be very difficult to specify exactly which part of the decrease in conservation value was due to coral bleaching and which part was the result of a change in socio-economic variables.

Table 8 Change in socio-economic variables between 1996 and 1997

Socio-economic variable	Observed change from 1996-1999
Income	No significant change in average income
Country of origin	No significant differences
Reasons for visiting	Slight increase in ranking of importance of diving
Best features of the dive	No change in grading of diver experience
Dive certification level	No significant change
Dive experience level	Less experienced divers visiting
Dive expenditure	13 % decrease in dive related expenditure

However, the decrease in willingness to pay for the conservation of the reefs may also be related to the level of visible management. To gain support from visitors for reef conservation, efforts need to be visible, e.g., through public information, brochures and reef rangers in the field providing visitors with information. Reef degradation is also not the only issue affecting tourism. Tourism around Mombasa decreased sharply due to perceived safety issues resulting from a few incidents reported in foreign newspapers. This is a clear illustration of the power of the media in altering public opinion. Clearly there are a multitude of factors affecting tourism demand and satisfaction, all of which have an influence on the WTP and revenue generating potential.

7.5 Discussion and Conclusions

The continued decline of valuable coastal resources has been specifically related to the inability of policy and decision makers to realise their full value (Dixon, 1998; Crooks & Turner, 1999). The three case studies presented in this Chapter have shown how different valuation techniques can be used to value environmental resources. They identify the potential to place monetary values on previously unidentified values and highlight several issues to be taken into account when designing a valuation study. This study has also shown how these different economic valuation techniques can be used to assist management in several ways, namely:

- Identifying the benefits of improved management
- Identifying the costs of inaction and ineffective management
- Identifying revenue generating potential
- Raising political and public awareness
- Understanding user behaviour

The case studies also show how different techniques identify the values of different stakeholder groups. Identifying who benefits and who loses may be vital to management to control potential conflicts and enable equitable and sustainable allocation of resources, in terms of both economics and ecology.

Identifying the benefits of improved management

Information from discussions with LVV indicated that the reef in Curaçao is already being overfished. The direct use valuation has confirmed this. Management of the whole coast, covering all the reefs could well increase their productivity. Although no studies have been carried out to estimate the productivity of the reef in Curaçao, there is a growing number of studies showing the effects of fisheries management and in particular fisheries reserves on reef productivity. Data and information from other studies around the Caribbean and more tenuously around the World could be used to make approximations of the benefits of improved coral reef and fisheries management on Curaçao. Closure of reefs to fishing has been seen to build up both abundance and biomass in 3-5 years (Polunin & Roberts, 1993; Roberts, 1995; Bohnsack, 1996; Russ & Alcala, 1996; Wantiez et al., 1997; Rodwell & Roberts, 2000). A meta-analysis of marine reserves states that overall abundance within the reserves is 3.7 times higher than outside the reserves (Mosquera et al., 2000). This build-up can also benefit the areas adjacent to the reserve due to larval dispersal and adult fish migration (Hastings & Botsford, 1999; Sladek Nowlis & Roberts, 1999; Rodwell & Roberts, 2000). Studies carried out in Saba and Belize show two-fold increases in fish biomass just 4 years after establishing fishing reserves (Polunin & Roberts, 1993). The fishing reserves established in Anse Chastenet, St Lucia saw a doubling in the biomass of the fish after just two years of the reserve being established (Roberts & Hawkins, 1997). The Marine Reserve in Barbados has higher total density and size of fishes than the non-reserve areas (Chapman & Kramer, 1999).

In Curaçao, the current protected area of reef is small and adjacent to a privately owned stretch of coast. Although the reef is currently protected under the Island Reef Ordinance, ideally, the whole coast would come under active protection and management by means of a zoning scheme (van't Hof et al., 1995). Funding is already scarce for the Underwater Park, which relies on a subsidy from the Government. The new zoning scheme will depend on funding to be generated from the reef users. A similar scheme is already in use on Bonaire, the neighbouring island also part of the Netherlands Antilles (Dixon et al., 1993; Dixon et al., 2000). The costs of implementing and managing such a scheme is likely to be outweighed by the benefits of improved management. Assuming the costs of improving the management of the coral reef on Curaçao are comparable to running the Marine Park on the neighbouring island of Bonaire, the costs could be around US$ 300,000 yr^{-1} (Bonaire Marine Park, unpublished data). If improved management were to increase the fisheries productivity by just half of the current levels, a conservative estimate, the increase in net revenues from fishing alone would already exceed the costs of the improved management. This type of information could be invaluable justification for implementing improved management of the coastal resources.

Identifying the costs of inaction and ineffective management

Economic valuation is able to highlight the costs of 'inaction', i.e. the long-term costs of not addressing current issues (Cesar et al., 2000b). It can be used to demonstrate to decision makers the benefits of ICM in a situation by looking at the resource benefits with ICM and without ICM (Bower & Turner, 1998). The net benefits of ICM being the difference between the total benefits minus the costs associated with ICM and the losses, for example lost productivity, resulting from resource degradation. It may also show the intermediate and long-term costs of unsustainable resource use, such as destructive fishing, that may only bring short-term profits to a limited number of stakeholders (Pet-Soede et al., 1999).

Ineffective management in coral reef areas can benefit from identifying the long-term costs of unsustainable resource use. A good example where economic valuation techniques have persuaded management to follow sustainable resource use options is the cost-benefit study in El Nido, the Philippines (Hodgson & Dixon, 2000). The study showed how continued logging of the upland areas would produce gross revenues far less than the predicted revenues from fisheries and tourism that would be foregone because of resource degradation. Consequently logging was banned and a resurvey of El Nido 10 years on showed that the predictions were if anything an underestimation of the actual revenues generated.

In the case when a valuation is being carried out to highlight the benefits of management, a total economic valuation (TEV) may not be necessary and a partial valuation is sufficient. Carrying out a partial valuation, for example, just covering the market based direct use valuation provides sufficient justification to continue or adapt a particular project under review. Carrying out the lengthy process of survey-based techniques may not be required. In addition, the use of so-called benefits transfer may be applicable in certain situations (Cesar, 2000a). This refers to using a value established for one area in another area with similar characteristics. However, this is a controversial technique and care should be applying benefit transfers (Turner et al., 1998a).

Identifying revenue generating potential

There are several ways in which valuation studies can provide management with information that they can directly use in management strategies to raise revenues. They are listed below:

Establishing user fees

Managers of coastal resources, for example, coral reefs are often looking for ways to raise additional revenues. The survey-based techniques such as the contingent valuation methodology can be used to identify amounts people would be willing to pay for access to the reefs. The structure of the survey, the willingness to pay question and the description of the payment vehicle can all be used to identify the most appropriate method and level of payment that would be acceptable to the local and visiting community. These types of surveys were used in setting the user fees on Bonaire (Dixon et al., 1993; Dixon et al., 2000). The Zanzibar and Mombasa data showed that tourists were willing to pay approximately 2-3% of the total vacation expenditure towards reef conservation. This allows management to develop these additional sources of income and enable them to budget their management plans and actions accordingly.

Establishing trust funds and 'friends of' organisations

Like user fees, information gathered from CVM surveys can be used to identify the potential to establish trust funds and 'friends of' organisations through the identification of the non-use value. The manager can use the information identified in the survey to evaluate the feasibility of establishing such a system. Examples are numerous: The Friends of Galapagos, an international network of trusts and societies, such as the Galapagos Conservation Trust, collects revenues from supporters of the

Galapagos Islands (www.gct.org). Belize has established a National Protected Areas Conservation Trust (PACT) which raises funds and receive gifts and donations from Belizean and foreign individuals, corporations, and foundations, as well as from bilateral and multilateral organisations, earmarked for activities support conservation and promoting environmentally sound management of Belize's natural and cultural resources to foster sustainable development (www.pactbelize.org). The Centre for Ecosystem Survival is a non-profit tax-exempt organisation in the US that enables people to adopt a reef to enable conservation projects to be undertaken (www.savenature.org). With the increased use of the Internet and email, sending information in the form of newsletters and updates need not be prohibitively expensive.

Increasing personnel capacity through the voluntary sector

The Curaçao survey identified the willingness to volunteer time as a proxy for a monetary value. Managers struggling with a shortage of personnel capacity may be able to tap into these resources and utilise them in conservation work. Assessing the time people are willing to volunteer will enable the manager to develop suitable and effective projects and activities.

Raising political and public awareness and support

Two of the main impediments restricting progress in ICM have been identified as the absence of political will and support and the lack of public awareness (see Chapter 4; Westmacott, 2000a). The case study of the direct use valuation of reef fisheries in Curaçao and its comparison to current Government subsidies for the management of the reef is a direct example of where economic valuation could be used to raise political awareness and justify further funding for the management and protection of the reefs. However, to raise awareness the work needs to be presented to the decision-making community in an easily accessible format. The work carried out by Costanza et al. (1997) valuing the worlds ecosystem goods and services proved controversial, however it stimulated discussion, resulting in a Special Issue of Ecological Economics dedicated to discussion of the paper and was read widely by both policy makers and scientists (Costanza, 1998). Whether the values are correct or not, may be immaterial. It brought attention to the huge previously unvalued natural resources of the world. Economic valuations could play a major role in raising awareness and justification for the management and protection of coastal and marine resources in the tropics. However, for valuation studies to reach the public and political arena, they need to be written in a style accessible to non-scientists.

Understanding user behaviour

In the Zanzibar and Mombasa surveys, awareness of coral bleaching would apparently affect their use of the resource and may well result in loss of revenue to the area. From a management perspective, this has implications for the type of information that the tourists are receiving on the state of the reefs.

If sensationalist news reports are painting an unrealistic picture of total degradation, then there needs to be clear information given as to the actual condition of the reef. In the case where the reefs are degraded, it may be better to allow the reefs to recover before encouraging the tourists to visit and be subsequently disappointed. Providing alternatives to reef related activities may keep the tourist's interest in the destination. Planning for a change in tourism activity may need to take place sooner rather than later in these situations.

Whose values?

The Zanzibar and Mombasa study identified the costs of the coral bleaching in terms of loss of gross revenues, a part of which will be lost by the local community and the welfare losses to the tourism community. This welfare loss may actually turn out to be insignificant as the tourist may be initially be disappointed but then goes elsewhere to a place where similar goods and services are offered at a similar cost. The financial loss to the local community may also be offset by alternative sources of income. Large investors in tourism projects may just invest elsewhere. Those who will ultimately suffer the most are those least able to do anything about it. These poor communities have few alternatives available to them. To understand these effects, valuations need to account for the benefits and losses to different stakeholder groups.

Direct use valuations, or financial valuations identify revenues to the local community. These will be directly relevant in management analysis where degradation of an ecosystem threatens local peoples' livelihood. Contingent valuation (CV) on the other hand identifies a number of values, some of which are welfare values to the non-resident community and some may be to the local community. In addition, the contingent valuation method (CVM) elicits virtual values in that there are no monetary transactions taking place (Cesar, 2000a). From the management and decision making perspective it is important to identify to whom the values accrue and likewise who may be losing. Management interests will be the benefits and losses to the local community, which may be more realistically represented in terms of changes in revenues represented by the direct use techniques. Changes in welfare values identified through CV may carry less weighting in a political debate because they identify values through hypothetical questions and often focus on welfare benefits to a number of non-resident as well as resident communities.

However, this is not to say CV does not have its uses. It has been used in a number of influential studies; one of the most notable was the grounding of the oil tanker, Exxon Valdez. The non-use value elicited through a CV identified the damages at US$ 3.8 billion (Bateman & Willis, 1999b). The Exxon Company commissioned an enquiry into the validation of the methodology, which eventually resulted in an out of court settlement of US$ 1.1 billion (Bateman & Willis, 1999b). CV is a controversial method of valuation and has many supporters as well as critics (Bateman & Willis, 1999a).

References

Alcala, A. C. 1988. Effects of Marine Reserves on Coral Fish Abundances and Yields of Philippine Coral Reefs. *Ambio* 17: 194-199.

Andersson, J. 1997. The Value of Coral Reef for the Current and Potential Tourism Industry on Unguja Island, Zanzibar. *Coral Reefs: Values, Threats, & Solutions.*, eds., R. W. Johnstone, J. Francis and C. Muhando, A., 82-90. Zanzibar, Tanzania. Institute for Marine Sciences, Zanzibar.

Arrow, K., R. Solow, P. Portney, E. Leamer, R. Radner and E. Shuman. 1993. *Report of the NOAA Panel on Contingent Valuation.* General Council of NOAA, Resources for the Future, Washington DC.

Barton, D. 1994. *Economic Factors and Valuation of Tropical Coastal Resources.* SMR, Bergen, Norway.

Bateman, I., J and K. Willis, G. 1999a. *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU and Developing Countries.* Oxford, UK: Oxford University Press.

Bateman, I. J., I. H. Langford, R. K. Turner, K. G. Willis and G. D. Garrod. 1995. Elicitation and truncation effects in contingent valuation studies. *Ecological Economics* 12: 161-179.

Bateman, I. J. and R. K. Turner 1993. Valuation of the Environment, Methods and Techniques: The Contingent Valuation Method. In *Sustainable Environmetnal Economics and Management: principles and practice,* eds., R. K. Turner, 120-191. London and New York: Belhaven Press.

Bateman, I. J. and K. Willis, G 1999b. Introduction and Overview. In *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU and Developing Countries,* eds., I. Bateman, J and K. Willis, G, 1-16. Oxford, UK: Oxford University Press.

Berg, H., M. C. Ohman, S. Troeng and O. Linden. 1998. Environmental Economics of Coral Reef Destruction in Sri Lanka. *Ambio* 27: 627-634.

Bijlsma, L., M. Crawford, C. Ehler, F. Hoozemans, V. Jones, R. Klein, B. Miermet, N. Mimura, R. Misdorp, R. Nicholls, K. Ries, J. Spradley, M. Stive, L. de Vrees and S. Westmacott. 1993. *World Coast Conference Report.* Ministry of Transport, Public Works and Water Management, National Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, the Netherlands.

Bingham, G., R. Bishop, M. Brody, D. Bromley, E. T. Clark, W. Cooper, R. Costanza, T. Hale, G. Hayden, S. Kellert, R. Norgaard, B. Norton, J. Payne, C. Russell and G. Suter. 1995. Issues in ecosystem valuation: improving information for decision making. *Ecological Economics* 14: 73-90.

Bohnsack, J. 1996. Maintenance and recovery of reef fishery productivity. In *Reef Fisheries,* eds., N. Polunin and C. Roberts, 283-313. London: Chapman & Hall.

Bower, B. T., C. N. Ehler and D. Basta, J. 1994. *A framework for planning for integrated coastal zone management.* National Oceanographic and Atmospheric Administration (NOAA), Washington DC.

Bower, B. T. and R. K. Turner. 1998. Characterising and analysing benefits from integrated coastal management (ICM). *Ocean & Coastal Management* 38: 41-66.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. *Reefs at Risk. A Map-Based Indicator of Threats to the World's Coral Reefs.* World Resources Institute, Washington DC.

Carter, C. 1995. *Dive Tourism in Zanzibar: New Depths.* B.Sc. Thesis. Bristol: University of Bristol.

Cartier, C. and J. Ruitenbeek 2000. Review of the Empirical Biodiversity Literature. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 207-239. Washington, DC: The World Bank.

Central Bureau of Statistics. 1998a. *The Netherlands Antilles Statistical Orientation, 1998.* Central Bureau of Statistics, Willemstad.

Central Bureau of Statistics. 1998b. *Statistical yearbook of the Netherlands Antilles 1998.* Central Bureau of Statistics, Willemstad.

Central Intelligence Agency (1999). *CIA Factbook.*

Cesar, H. 2000a. Coral Reefs: Their Functions, Threats and Economic Value. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 14-39. Stockholm, Sweden: Sida Press.

Cesar, H. 2000b. Introduction. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 9-13. Stockholm, Sweden: Sida Press.

Cesar, H., C. G. Lundin, S. Bettencourt and J. Dixon. 1997. Indonesian coral reefs - An economic analysis of a precious but threatened resource. *Ambio* 26: 345-350.

Cesar, H., A. Waheed, M. Saleem and D. Wilhelminson 2000a. Assessing the impacts of the 1998 coral reef bleaching on tourism in Sri Lanka and Maldives. In *Assessment of the socio-economic impacts of the 1998 coral reef bleaching in the Indian Ocean: report prepared for the CORDIO programme, African Environmental Department of the World Bank,* eds., S. Westmacott, H. Cesar and L. Pet Soede, 101-113. Delft and Amsterdam: Resource Analysis and Institute for Environmental Studies.

Cesar, H., S. Westmacott, L. Emerton and S. Wells. 2000b. *Economic Benefits of Marine Protected Areas in the Western Indian Ocean Region.* Coastal Zone Management Centre, The Hague, Netherlands.

Chapman, M. and D. Kramer. 1999. Gradients in coral reef fish denfisty and size across the Barbados Marine Reserve boundary: effects of reserve protection and habitat characteristics. *Marine Ecology Progress Series* 181: 81-96.

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated coastal and ocean management: concepts and practices.* Washington DC and Covelo, California: Island Press.

Costanza, R., R. D'Arge, R. de Groot, S. Farber, M. Grasse, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton and M. ven den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Costanza, R. e. 1998. Special Section: Forum on Valuation of Ecosystem Services. *Ecological Economics* 25: 1-136.

Crooks, S. and R. Turner. 1999. Integrated Coastal Management: Sustaining Estuarine Natural Resources. *Advances in Ecological Research* 29: 241-289.

Curacao Tourism Development Board. 1996. *Tourism Exit Survey 1995.* Curacao Tourism Development Board, Willemstad.

Davis, D. and C. Tisdell. 1996. Economic management of recreational scuba diving and the environment. *Journal of Environmental Management* 48: 229-248.

DeGroot, R. 1992. *Functions of Nature: Evaluation of Nature in Environmental PLanning, Management and Decision Making.* Groningen: Wolters-Noordhoff.

Dixon, J. A. 1993. Economic Benefits of Marine Protected Areas. *Oceanus* 36: 35-40.

Dixon, J. A. 1998. Economic Values of Coral Reefs: What are the Issues? In *Coral Reefs: chalenges and opportunities for sustainable management,* eds., M. Hatziolos, 157-162. Washington: World Bank.

Dixon, J. A., L. Fallon Scura and H. van't, Tom. 1993. Meeting Ecological and Economic Goals: Marine Parks in the Caribbean. *Ambio* 22: 117-125.

Dixon, J. A., L. F. Scura and T. van't Hof 2000. An Economic and Ecological Analysis of the Bonaire Marine Park. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 158-165. Stockholm, Sweden: Sida Press.

Dixon, J. A. and P. B. Sherman. 1991. Economics of Protected Areas. *Ambio* 20: 68-74.

Emerton, L. 1999. *Economic Tools for the Management of Marine Protected Areas in Eastern Africa.* IUCN Eastern African Programme, Nairobi, Kenya.

EXTRA. 1997. *Current price of fish.* 3 March 1997. Willemstad, Curacao.

Goreau, T., T. McClanahan, R. Hayes and A. Strong. 2000. Conservation of Coral Reefs after the 1998 Global Bleaching Event. *Conservation Biology* 14: 5-15.

Goreau, T. J. and R. L. Hayes. 1994. Coral Bleaching and Ocean "Hot Spots". *Ambio* 23: 176-180.

Hanley, N. 2000. Contingent Valuation as a Means of valuing the Conservation of Coral Reefs: An Assessment of the Method. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 241-246. Washington, DC: The World Bank.

Hastings, A. and L. W. Botsford. 1999. Equivalence in Yield from Marine Reserves and Tradational Fisheries Management. *Science* 284: 1537-1538.

Hodgson, G. and J. Dixon. 1988. *Logging Versus Fisheries and Tourism in Palawan: An Environmental and Economic Analysis.* Environmental and Policy Institute, East-West Centre, Honolulu.

Hodgson, G. and J. A. Dixon 2000. El Nido Revisited: Ecotourism, Logging and Fisheries. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 55-68. Stockholm, Sweden: Sida Press.

Jameson, S. C., J. W. McManus and M. D. Spalding. 1995. *State of the Reefs - Regional and Global Perspectives.* International Coral Reef Initiative, US Dept of State, Washington DC.

Linden, O. and N. Sporrong. 1999. *Coral reef degradation in the Indian Ocean: Status reports and project presentations, 1999.* Stockholm: CORDIO, SAREC Marine Science Program.

Meesters, E. H., R. P. M. Bak, S. Westmacott, M. Ridgley and S. Dollar. 1998. A Fuzzy Logic Model to Predict Coral Reef Development under Nutrient and Sediment Stress. *Conservation Biology* 12: 957-965.

Moberg, F. and C. Folke. 1999. Ecological goods and services of coral reef ecosystems. *Ecological Economics* 29: 215-233.

Mosquera, I., I. Cote, S. Jennings and J. Reynolds. 2000. Conservation benefits of marine reserves for fish populations. *Animal Conservation* 3: 321-332.

Muhando, C. A. 1999. The 1998 coral bleaching and mortality event in Tanzania: Implications for coral reef research and management. *Conference on Advances in Marine Sciences in Tanzania,* eds., J. Francis and C. Muhando, Zanzibar, Tanzania.

Ohman, M. C. and H. Cesar 2000. Costs and Benefits of Coral Mining. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 85-93. Stockholm, Sweden: Sida Press.

Pendleton, L. H. 1995. Valuing coral reef protection. *Ocean & Coastal Management* 26: 119-131.

Pet-Soede, C., H. S. J. Cesar and J. S. Pet. 1999. An economic analysis of blast fishing on Indonesian coral reefs. *Environmental Conservation* 26: 83-93.

Polunin, N., I. Williams, J. Carrier and L. Robertson. 2000. *Ecological and social impacts in planning Caribbean marine reserves.* University of Newcastle & Department for International Development, Newcastle & London, UK.

Polunin, N. V. C. and C. M. Roberts. 1993. Greater biomass and value of target coral-reef fishes in two small Caribbean marine reserves. *Marine Ecology Progress Series* 100: 167-176.

Rijsberman, F. and S. Westmacott. 1998. *Direct Use Valuation of the coral reef resources of Curaçao.* Resource Analysis & World Bank, Delft, the Netherlands.

Rijsberman, F. and S. Westmacott 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of Curacao. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.*, eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 49-66. Washington, DC: The World Bank.

Riopelle, J. 1995. *The Economic Valuation of Coral Reefs: A case study of West Lombok, Indonesia..* Halifax, NS: Dalhousie University.

Roberts, C. 1995. Rapid build up of fish biomass in a Caribbean Marine Reserve. *Conservation Biology* 9: 815-826.

Roberts, C. M. and J. P. Hawkins. 1997. How small can a marine reserve be and still be effective? *Coral Reefs* 16: 150.

Rodwell, L. D. and C. M. Roberts 2000. Economic Implications of Fully-Protected Marine Reserves for Coral Reef Fisheries. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 107-124. Stockholm, Sweden: Sida Press.

Russ, G. R. and A. C. Alcala. 1996. Marine reserves: Rates and patterns of recovery and decline of large predatory fish. *Ecological Applications* 6: 947-961.

Sladek Nowlis, J. and C. M. Roberts. 1999. Fisheries benefits and optimal design of marine reserves. *Fisheries Bulletin* 97: 604-616.

Sorensen, J. C. and S. T. McCreary. 1990. *Institutional Arrangements for Managing Coastal Resources and Environments.* Washington DC: National Parks Service, US Department of Interior.

Souter, D., D. Obura and O. Linden. 2000. *Coral Reef Degradation in the Indian Ocean: Status Report 2000.* CORDIO/SAREC Marine Science, Sweden CORDIO Programme.

Spash, C. 2000. Assessing the Benefits of Improving Coral Reef Biodiversity: The Contingent Valuation Method. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 40-54. Stockholm, Sweden: Sida Press.

Spash, C. L., J. van den Werff ten Bosch, S. Westmacott and J. Ruitenbeek 2000. Lexicographic Preferences and the Contingent Valuation of the Coral Reef Biodiversity in Curaçao and Jamaica. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.*, eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 97-118. Washington, DC: The World Bank.

Spurgeon, J. 1998. The Socio-Economic Costs and Benefits of Coastal Habitat Rehabilitation and Creation. *Marine Pollution Bulletion* 37: 373-382.

Spurgeon, J. P. and U. Lindahl 2000. Economics of Coral Reef Restoration. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 125-136. Stockholm, Sweden: Sida Press.

Spurgeon, J. P. G. 1992. The Economic Valuation of Coral Reefs. *Marine Pollution Bulletin* 24: 529-536.

Turner, K., D. Pearce and I. Bateman. 1994. *Environmental Economics: an elementary introduction.* Hemel Hempstead: Harvester Wheatsheaf.

Turner, R. 1999. The Place of Economic Values in Environmental Valuation. In *Valuing Environmental Preferences: Theory and Practice of the COntingent Valuation Method in the US, EU and Developing Countries,* eds., I. Bateman, J and K. Willis, G, 17-41. Oxford, UK: Oxford University Press.

Turner, R. and W. Adger. 1996. *Coastal Zone Resource Assessment Guidelines.* LOICZ IPO, Texel, The Netherlands.

Turner, R., W. Adger and R. Brouwer. 1998a. Ecosystem services value, research needs and policy relevance: a commentary. *Ecological Economics* 25: 61-65.

Turner, R., W. Adger and I. Lorenzoni. 1998b. *Towards Integrated Modelling and Analysis in Coastal Zones: Principles and Practices.* LOICZ IPO, Texel, The Netherlands.

Turner, R. K. 1993. *Sustainable Environmental Economics and Management: Principles and Practice.* London: Belhaven Press.

van Veghel, M. L. J. and K. De Meyer. 1993. *Abundance and Temporal Dynamics of the Tropical Compound Ascidian Trididemnum solidum along the coast of Bonaire.* Reef Care, Curacao and the Bonaire Marine Park,

van Veghel, M. L. J., D. Lambrechts, Y.M. and M. Joenje. 1995. *Reef Care's Coral Research for Volunteers on Curacao.* ISRS European Regional Meeting, Luxembourg.

van't Hof, T., A. O. Debrot and I. A. Nagelkerken. 1995. *Curacao Marine Management Zone: A plan for sustainable use of Curaçao's reef resources.* Report prepared for the Curacao Tourism Development Board and Stinapa by CARMABI, Willemstad.

Wantiez, L., P. Thollot and Kulbicki. 1997. Effects of marine reserves on coral reef fish communities from five islands in New Calidonia. *Coral Reefs* 16: 215-224.

Westmacott, S. 2000a. Identifying the main impediments to integrated coastal management in the tropics. *Paper submitted to Ocean and Coastal Management, October 2000.*

Westmacott, S. 2000b. Where should the focus be in tropical integrated coastal management? *Paper submitted to Coastal Management, September 2000. Resubmitted for acceptance after reviewer's comments April 2001*

Westmacott, S., H. Cesar and L. Pet Soede 2000a. Socio-economic assessment of the impacts of the 1998 coral reef bleaching in the Indian Ocean: a summary. In *Coral Reef Degradation in the Indian Ocean: Status Report 2000,* eds., D. Souter, D. Obura and O. Linden, 143-159. CORDIO/SAREC Marine Science, Sweden CORDIO Programme.

Westmacott, S., H. Cesar, L. Pet-Soede and O. Linden 2000b. Coral Bleaching in the Indian Ocean: Socio-Economic Assessment of Effects. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 94-106. Stockholm, Sweden: Sida Press.

Westmacott, S., I. Ngugi and J. Andersson 2000c. Assessing the impacts of the 1998 coral reef bleaching on tourism in Tanzania and Kenya. In *Assessment of the socio-economic impacts of the 1998 coral reef bleaching in the Indian Ocean: report prepared for the CORDIO programme, African Environmental Department of the World Bank,* eds., S. Westmacott, H. Cesar and L. Pet Soede, 115-137. Delft and Amsterdam: Resource Analysis and Institute for Environmental Studies.

Westmacott, S., K. Teleki, S. Wells and J. West. 2000d. *Management of bleached and severely damaged coral reefs.* Gland Switzerland and Cambridge, UK: IUCN.

White, A. and A. Cruz-Trinidad. 1998. *The Values of Coastal Resources: Why Protection and Management are Critical.* Coastal Resource Management Project, Cebu City, Philippines.

White, A., M. Ross and M. Flores 2000. Benefits And Costs Of Coral Reef And Wetland Management, Olango Island, Philippines. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 215-227. Stockholm, Sweden: Sida Press.

Wilkinson, C. 2000. *Status of Coral Reefs of the World: 2000.* Cape Ferguson, Queensland, Dampier, Western Australia: Australian Institute of Marine Science.

Wilkinson, C., O. Linden, H. Cesar, G. Hodgson, G. Rubens, J. Rubens and A. E. Strong. 1999. Ecological and Socioeconomic Impacts of 1998 Coral Mortality in the Indian Ocean: An ENSO Impact and a Warning of Future Change? *AMBIO* 28: 188-196.

PART II: Discussion

The management tools discussed have a number of different uses from assisting in problem analysis to education and awareness raising roles. They are just a few examples of the types of tools available to management. Analysts and researchers need to continue to develop these tools and make them available and accessible to the day-to-day managers. Then the task for the manager is to identify when and where it is appropriate to utilise each of the available tools. For example, if justification is required to establish a protected area, an economic valuation alone may be appropriate to fully identify and quantify the various benefits afforded to the local community as well as a wider community of potential users. There may be no need for an ecological model to be developed to justify the existence of a protect area if a number of studies from comparable areas are already in existence, which identify the physical benefits. A computerised decision support system that combines economic analysis and the ecological modelling may be more appropriate where a number of management options are being evaluated with different costs and benefits. These can then be assessed and compared in a flexible and accessible manner.

Each management situation will require a different set of tools to tackle the impediments. It is important that the initial analysis of the issues and problems in the area focuses on identification of the impediments. This will enable the manager to select the relevant tools, which may be a single tool or a combination of a number of tools.

CONCLUSIONS

8 Conclusions: Is integrated coastal management an impossible task?

8.1 Introduction

Tropical coastal zones, in particular coral reefs, are facing widespread degradation (Johannes, 1975; Hughes, 1994b; Hughes, 1994a; Cesar et al., 1997; Wilkinson & Salvat, 1997; Wilkinson, 1998; Hodgson, 1999; Goreau et al., 2000; Souter et al., 2000; Wilkinson, 2000). The main threats to these coasts initially came from local human activities such as coastal development, habitat destructive activities, over exploitation of resources, marine pollution and runoff from inland deforestation and farming (Jameson et al., 1995; Bryant et al., 1998; Olsen & Christie, 2000). More recently, it has become recognised that global environmental change is posing an equal or even greater threat to coral reefs than these direct anthropogenic impacts (Wilkinson, 2000). In the tropics many of the pressures on coastal zones are intensified by the rapid decline in resources and long recovery periods. Degraded coral reefs may take decades to return to pre-disturbance conditions, for example, recovery of areas in Guam and the Great Barrier Reef in Australia, affected by the Crown of Thorns Starfish, has taken 10-15 years to show signs of returning to pre-disturbance conditions (Bradbury & Seymour, 1997; Moran, 1997). Coral cover in Kaneohe Bay, Hawaii, doubled in 15 years, following the diversion of 25 years of sewage discharge (Hunter & Evans, 1995). An integrated approach to management is needed in these coastal areas because of the effects different users within and upstream of the management area have on the environment and on one another (Cicin-Sain & Knecht, 1998). Integrated coastal management (ICM) is seen as one mechanism with which to tackle these complex mix of activities and interests in the coastal zone (Bijlsma et al., 1993; Post & Lundin, 1996; Turner & Adger, 1996; Cicin-Sain & Knecht, 1998; Salomons & Turner, 1999).

The ICM survey, carried out as part of this study (see Chapter 2 and 4), supported the idea that different tropical coastal zones are facing similar management issues, characterised by a mix of activities, namely fishing and tourism. Future coastal management strategies need to address the issues of overfishing and poverty. Overfishing was reported in almost 80% of the survey locations and poverty was identified as one of the key driving forces behind much of the habitat destruction and over-exploitation of these coastal resources. The survey also identified that managing the depletion of fish and shellfish resources and tackling poverty had priority over conservation issues.

ICM is an ambitious task requiring a common vision among the different coastal stakeholders. In a world where individual interests and desires hold primary importance, the common good may often be overlooked and ICM is likely to face difficulties. Conflicts between users were identified in 90% of the survey locations, mainly between extractive and non-extractive users. Conflict management needs to be a major focus of ICM in the future. Dealing with the imbalance of power in societies will require vision, leadership and courage (Olsen & Christie, 2000).

8.2 The current status of ICM

The concept of ICM has been around since the early 1980s. The 1982 Law of the Sea Convention and Chapter 17 of Agenda 21 resulting from the United Nations Conference of Environment and Development (UNCED) have most of the necessary prescriptions for ICM (Cicin-Sain & Knecht, 1998). Surveys carried out by Sorensen (1993; 2000) show how ICM efforts have increased from about 180 efforts in 57 countries in 1993 to 380 efforts in 92 countries in 2000. Over the last 20-30 years capacity in ICM has been growing (Cicin-Sain et al., 1995; Christie & White, 1997; Cicin-Sain & Knecht, 1998; Burbridge, 1999). During this time, the theory behind establishing integrated approaches to management has been continuously developed (Bijlsma et al., 1993; Resource Analysis & Delft Hydraulics, 1993; Bower et al., 1994; Turner & Adger, 1996; Turner et al., 1998). However, regardless of the benefits that ICM may provide, the results of the management efforts have been mixed (Bijlsma et al., 1993; Burbridge, 1999). Sorensen (2000) acknowledges that this latest estimate of ICM efforts represents the number of efforts, as opposed to the success of these efforts. This study has shown through a survey of coral reef areas in the tropics, that only a few locations (12%) in these areas are fully implementing, monitoring and evaluating integrated management plans. The survey showed that many ICM programmes fail at the transition between the analysis phase and the implementation and enforcement phase. Whilst these findings support the claims of the advances made in the last 30 years in the analytical capabilities of ICM, they also identify what needs to be done in the coming years. If ICM is to progress to the next stage, namely implementation, the focus needs to be on building capacity in implementing ICM. Successful ICM and control over the degradation of coastal resources will only be achieved once the impediments to implementation are identified and overcome. While management remains limited and ineffective, the degradation of tropical coastal resources continues.

8.3 Identifying the impediments to integrated coastal management

One of the main aspects of this study was to identify why integrated management is being implemented with only modest success in the tropics. This study developed a set of criteria, measured on a qualitative scale, which identifies the actual impediments to the implementation of ICM. By analysing the impediments to implementing ICM, practitioners may be able take the management of tropical coastal zones beyond the analysis and planning phase. These criteria were based on six main categories of impediments, identified through ICM case studies as:

1. Conflicting and weak legislation
2. Lack of public support and participation
3. Weak institutional structure
4. Limited institutional capacity
5. Limited scientific support for management
6. Lack of political support and participation

The categories have been prioritised in terms of their perceived severity in impeding the ability to implement ICM, which was identified in the ICM survey. The analysis showed a clear relationship between the criteria and the level of achievement of ICM. This showed that the criteria developed were a good proxy for identifying impediments to ICM and enabling an assessment of the potential of an area to achieve ICM. Using such criteria in the problem identification stage will enable analysts to identify the specific impediments relating to the area in question. The impact of each criterion on the ability to implement ICM was also assessed. This information can be used in an analysis to prioritise and focus efforts enabling those issues that block the progression of ICM to be tackled first. Assessing the severity of each impediment criterion was achieved using the perceptions of the ICM experts responding to the survey. Measuring the impact a single impediment has on ICM is difficult because of the complex interaction of a number of factors. Using expert judgement enables a single criterion to be judged in context, taking into account all the other factors influencing implementation ability specific to that area, therefore enabling these types of complex systems to be qualitatively assessed (Geraghty, 1993).

The process of identifying impediments to ICM through such criteria needs to become explicitly incorporated into the ICM analysis phase that has traditionally focused on physical and economic assessments (Resource Analysis & Delft Hydraulics, 1993; Turner & Bower, 1999) and institutional arrangements (Sorensen & McCreary, 1990; Awosika et al., 1993). Development of ICM plans and programmes should focus on overcoming these impediments and be guided by prioritising those likely to have the greatest impact on the success of an ICM programme. The survey showed that many of the main impediments relate to the lack of political will and public support, being represented, for example by inadequate enforcement capacity and a top down approach to management. In most cases, management efforts will fail when imposed from a higher level of authority (Olsen & Christie, 2000). Interestingly there was no common consensus that the lack of adequate finances affects the ability to implement ICM. This suggests that substantial advances in sustainable integrated management can be made with limited finances if the political and public will and support are present. Examples of successful, locally run traditional forms of management support this (Veitayaki, 1997; Johannes, 1998; Lam, 1998; Veitayaki, 1998).

8.4 Overcoming the impediments to ICM and learning from the past

There are no easy solutions in overcoming the impediments to implementing ICM. Much of this requires a change in attitude towards existing forms of management. Persuading politicians that they need to take account of the environment and adapt their planning focus for the long term may not be met with eager anticipation. In addition, sustaining change will only be possible once a sufficient proportion of the population wants it (Olsen & Christie, 2000). For ICM to move into a successful implementation phase, the issues blocking ICM efforts need to be clearly identified and tackled.

ICM practitioners need to learn from existing experiences in terms of the successes as well as the failures in order to know what went right and what went wrong. These experiences can then be incorporated into new ICM efforts. At present, there is no indication whether examples of successful ICM exist because impediments were overcome or because there were no impediments and the conditions were right at the outset. Evaluation of ICM programmes needs to be holistic and those carrying out the evaluations should not be afraid to highlight the failures and causes of the failures. These types of evaluations will provide valuable information for future ICM efforts.

However, assessing success requires the setting of clear unambiguous objectives (Burbridge, 1997). In many situations, evaluation of programmes is seen as time consuming and costly, producing results that require potentially painful adjustments to be made to the programme's objectives and goals (Olsen et al., 1997). Consequently, detailed setting of criteria and evaluation of programmes are rarely carried out which has led to debate over the success of ICM implementation (Chua, 1998). However, moves towards assessing progress in ICM are being made, with a recent manual published by the University of Rhode Island (Olsen et al., 1999). This manual essentially provides a checklist of activities undertaken for the various steps in the management cycle (see Chapter 2). The assessment of the implementation stage focuses on identifying potential impediments to ICM, e.g., state of the coastal infrastructure, level of public participation. This type of assessment can be used to improve management by evaluating the impact these potential impediments have on implementation following a methodology similar to that developed for the ICM survey in this study. This will enable measures to overcome these impediments to be identified, developed and prioritised.

The time frame involved in evaluating ICM efforts is an important factor and success of an ICM programme may often take longer than many donor-funded projects allow (Olsen & Christie, 2000). However, intermediate outcomes, linked to the various stages in the programme cycle can be identified and used (Olsen et al., 1997). This study shows how identification of the impediments to ICM and the impact these will have on the ability to implement ICM need to be included in the planning process so actions can be focused and prioritised. In addition, evaluations of success need to move beyond simply assessing the programme components that have been implemented and assess the resulting outcome of each programme component, highlighting the successes and failures and the reasons behind these.

8.5 Developing management tools

As the concept of ICM was adopted, it received increased attention with a major focus being on the development of tools for planning and management. Since this time, there have been major advances in the development of practical tools for ICM (Burbridge, 1999). As computers have become user-friendlier and more accessible, the use of computerised modelling techniques as management tools has increased (Parker et al., 1995). These advances have brought about a number of technical tools applicable to ICM, such as decision support systems, remote sensing and geographical information techniques (Mumby et al., 1995; Green et al., 1996; Turner et al., 1998; van der Weide & De Vrees, 1999; Gustavson et al., 2000). The social sciences have also provided a number of tools for ICM, such as economic valuation, multi-criteria analysis, conflict resolution, and soft-systems analysis (Checkland, 1984; Turner, 1993; Bower & Turner, 1998; Turner & Bower, 1999; Cesar et al., 2000; Cesar, 2000).

In many areas of the tropics, ICM capacity and trained personnel may be limited. These types of tools could, therefore, play an important role in assisting in building capacity and enabling local communities to manage their own resources. The skill is to know when and how to apply these. Decision support systems and economic valuation are just two of these management tools, which were evaluated as part of this study.

Decision Support Systems

The attention placed on the development of decision support systems (DSS) for integrated coastal management (ICM) has been increasing and supported by a number of international organisations such as the European Union and the World Bank (Hogarth, 1999; Gustavson et al., 2000). Modelling key environmental and socio-economic processes is seen as a vital tool to support ICM in achieving its goals and objectives, particularly in relation to global environmental change (Turner & Salomons, 1999; Turner, 2000). DSSs should facilitate the information flow to policy makers, planners and local community stakeholders who are reportedly not getting the information and tools they need to make sound management decisions (ICRI, 1998). Systems are needed that structure the decision making process, facilitate dialogue with stakeholders and improve the quality of decisions (van der Weide & De Vrees, 1999). Decision support systems (DSS) are developed in the belief that these systems are able to improve our understanding of the inter-relationships between natural and socio-economic variables and hence result in improved decision making (Te'eni & Ginzberg, 1991; Fabbri, 1998).

This study looked at the potential to develop decision support systems for ICM by analysing the decision making environment and the modelling tools available to build an ICM-DSS. The study took three ICM-DSSs and evaluated their components and contributions to the decision making process. In addition, the CORAL model, developed specifically for the coral reefs of Curaçao and the Republic of the Maldives, was evaluated in the field with local ICM stakeholders. The ICM decision making environment is highly complex and variable and developing these systems into useful and useable systems is a challenging task. Users may be disappointed in the outcomes of a DSS because their expectations of such systems far outweigh the possibilities of a computer based model (Parker et al., 1995). Unlike the decision maker who will use his whole life experience to *make* a decision, the computer tool can only ever be expected to *support* a decision. Models have a role to play in planning but they cannot replace the planning process (Cohen, 1978).

Involvement in the development of the CORAL model and the continuation of the project after the finalisation of the DSS enabled a detailed evaluation of the DSS to be carried out (see Chapter 6). The evaluation was done through a series of meetings and discussions with the potential end users. The evaluation was carried out as individual open discussions so that people could talk freely and important comments and user attitudes towards the system could be identified. The development of CORAL was structured on the objectives and views of the coastal community identified through a number of initial stakeholder meetings. It uses a multi-criteria approach to the analysis, utilising both economic and ecological modelling techniques. However, the model was not widely accepted and used. Like many models, it simply served as the focus of a few spirited debates (Pearse & Walters, 1987). During the evaluation, it became obvious that consultations alone were not sufficient for model acceptance and use. Locally based counterparts who would ultimately maintain and promote the use of the model should have been identified and used in the consultations, in data collection and in the model development. Even so, consultations held during model development provided a forum for discussion on the main issues and management options within an integrated setting. Introducing different stakeholder groups to one another in these open forums may help in facilitating a more integrated approach to coastal management.

Much of the criticism of the CORAL model involved its inability to answer the user's specific questions. Flexibility, adaptability and the ability to be updated are paramount if the system is to assist users in planning decisions. In addition, the computer hardware capacity of the end users needs to be considered, unless computers and the required software are being supplied. One solution is to develop software with low requirements in terms of computational capacity. This may limit the use of some of the potential modelling techniques. The assumptions used in the model needed to be more explicitly available to the users so they could more readily evaluate the outcome of each analysis. Likewise, the system required that the users had a high level of prior knowledge regarding development scenarios and management measures. This was often unrealistic and the scenarios and strategies needed to be presented in simpler terms so the specialist in one field could understand the options relating to another field of expertise.

The main contribution of the CORAL DSS was not as an ICM-DSS, able to support management decisions, but was through its ability to facilitate discussion and raise stakeholder awareness of the issues surrounding ICM. It was also used as an educational tool and was successful in raising awareness for both adults and children who could explore the issues surrounding the development and management of their coastal resources. Although the tool may not have achieved the ambitious use for which it was initially intended, such a system appears able to tackle some of the major impediments to ICM such as raising political awareness and gaining public support. Evaluations of this type highlight the important and varied roles of a DSS and can provide useful information for similar projects in the future.

An ICM-DSS relies on the ability to formulate computer-based models of these coastal systems. Specifically, an ICM-DSS needs to incorporate the multiple views and objectives of the coastal stakeholders, cover a multi-disciplinary subject area and deal with limited data and information, the latter being particularly relevant to tropical situations. There are a number of tried and tested modelling techniques such as structural models, simulation models, hydrodynamic models, spatial models and fuzzy models that can be combined together to form an approximation of the coastal system (see Chapter 5). Technically modelling the physical aspects of the coastal zone may well be a reality, however, the lack of data is likely to limit the possible modelling approaches taken. Modelling uncertainty in the coastal zone is more difficult but can be dealt with by using 'scenarios', e.g., tourism demand and sea level rise. Modelling human behaviour, for example, the stakeholders' reaction to developing a marine park may not be possible. However, a DSS could simply draw attention to potentially controversial impacts or activities through a warning that could be initially identified through stakeholder meetings and interviews.

The evaluation showed that the models, as successful as they were in supporting different aspects of the ICM process, might not have fully achieved the goals of an ICM-DSS. What became clear through the evaluation was that developing a single system capable of modelling all aspects of the coastal zone relevant to ICM, both physical and social, was probably not financially feasible nor useful in the time scale required for management. In addition, use of such a system in the long term is likely to be limited, as it would soon be out of date. Time, expertise and financial resources to collect, input and update the required data for such a system would also rapidly diminish its ability to be updated and its usefulness. The three example DSSs showed how simpler systems may not only be more feasible but also more applicable as useful ICM tools and their contributions may well have been substantial. A DSS may actually take on a number of roles during its development as well as its implementation and use, each of these being a valuable tool for the ICM process. These were identified as:

- Collation of ICM data and information
- Facilitation of discussions
- Fulfilling an educational role
- Supporting decision making

Key points influencing the success of an ICM-DSS were identified as:

- Involvement of the end users in the development of the DSS
- Designing the DSS for the end users needs rather than the needs perceived by the developer
- Easy to use interface requiring limited time investment to learn how to use the system
- Flexible, adaptable and updateable system
- Visual display of results

Economic valuation

The failure to see the long-term costs of unsustainable resource management and the benefits that a sustainable approach such as ICM can bring, can be partly blamed on the inability to fully appreciate and account for the goods and services these coastal ecosystems provide (Dixon, 1998; Crooks & Turner, 1999). Failure to fully account for decisions can eventually lead to mismanagement and misallocation of resources (Turner & Adger, 1996). Economic valuation techniques have been developed as a means of placing monetary values on the broad range of goods and services that ecosystems provide. For ICM decision makers to realise that long-term sustainable use of the coastal zone makes not just conservation sense but economic sense, analysts need to capitalise on the broad array of valuation techniques available. The application of economic valuation has been in use for several decades but has increased dramatically over the last 20 years; initially the focus was in Europe and the United States and was gradually applied to developing countries (Bateman & Willis, 1999).

This thesis outlines three case studies that identify the values, costs and benefits of different aspects of tropical coastal resources, specifically coral reefs. These case studies have contributed to a number of recent studies focusing on coral reefs, compiled by Cesar (see Cesar, 2000; Spash, 2000; Westmacott et al., 2000) and have been part of the World Bank funded project on decision support modelling in coastal zone management (see Gustavson et al., 2000; Spash et al., 2000). However, the focus of this work has been to use these case studies to evaluate how different valuation techniques can be a useful management tool and potentially help to overcome the impediments to ICM. More specifically, the study has shown how economic valuation can support integrated coastal management in the tropics through:

- Identifying the benefits of improved management and the costs of inaction and ineffective management
- Identifying revenue generating potential for marine conservation
- Raising political and public awareness
- Understanding user behaviour and identifying who benefits and who looses

Economic valuation has been identified as a tool to quantify the benefits of ICM (Bower & Turner, 1998; Turner & Bower, 1999). The case study in Curaçao actually put this into practice by carrying out a valuation of improved biodiversity along the south coast of the island. This valuation formed the extension of the cost-effectiveness analysis of coral reef management in Curaçao (Rijsberman & Westmacott, 2000). This multi-criteria approach enabled decision makers to evaluate management scenarios in terms of costs and changes in reef health, measured by coral cover and diversity. This required development of an economic model driven by development scenarios, a water quality model and an ecological response model (Meesters et al., 1998; Rijsberman & Westmacott, 2000). The economic valuation component is able to show decision makers the value of the change in reef health in monetary terms, rather than simply ecological terms, which may carry less impact in a political decision. The Curaçao case study suggests that tourists and locals visiting and resident on the island would be prepared to pay US$9 million each year to a trust fund that through various management actions would aim to increase biodiversity by 25%.

The fisheries case study in Curaçao uses market-identified prices to calculate the revenues generated from the reef fishery. The study showed that current fishing effort exceeds the level of economic profitability and fishermen typically earn less than the minimum wage. Effective ICM could increase the stocks on the reef leading to an increase in the profitability of fishing. The benefits of ICM can be seen, for example, in terms of increasing productivity and hence revenues from the reef but also in terms of maintaining the current level of goods and services. Without ICM, the benefits and goods that the reef supports may well decline. Avoiding making sustainable management decisions carries a cost. This can be seen as the cost of inaction (see Figure 1). Economic valuation can be used to place monetary values on these costs and benefits, enabling them to be brought to the attention of both decision makers and the public.

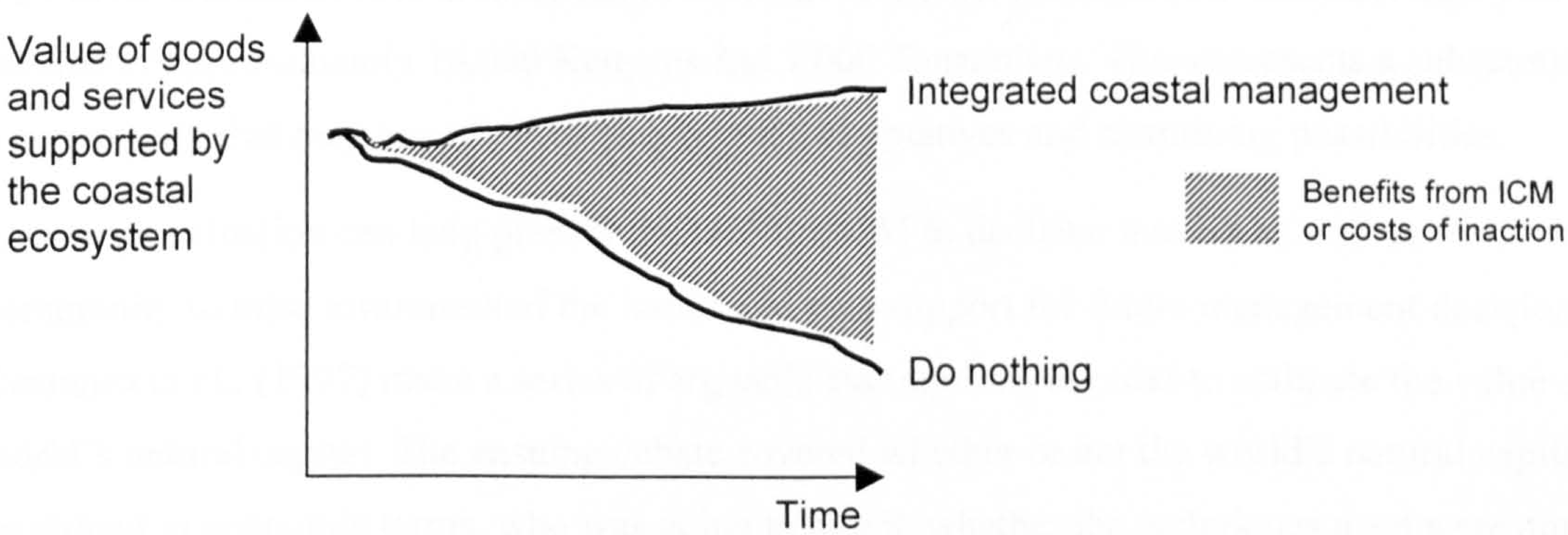


Figure 1 Graph illustrating the change in goods and services supported by coastal ecosystems resulting from the implementation of integrated coastal management highlighting the benefits of integrated coastal management and the costs of inaction

Likewise, economic valuation can be used to identify the costs of unsustainable management, which can be characterised by short term gains and long term losses (see Figure 2). A successful application of economic valuation in the tropics enabled unsustainable logging to be abandoned in exchange for long-term sustainable resource use, which eventually supported eco-tourism in El Nido in the Philippines (Hodgson & Dixon, 2000). Unfortunately, over fishing has now resulted in a decline in the fisheries resource. The application of economic valuation to the entire coastal zone in the framework of ICM could potentially have prevented this.

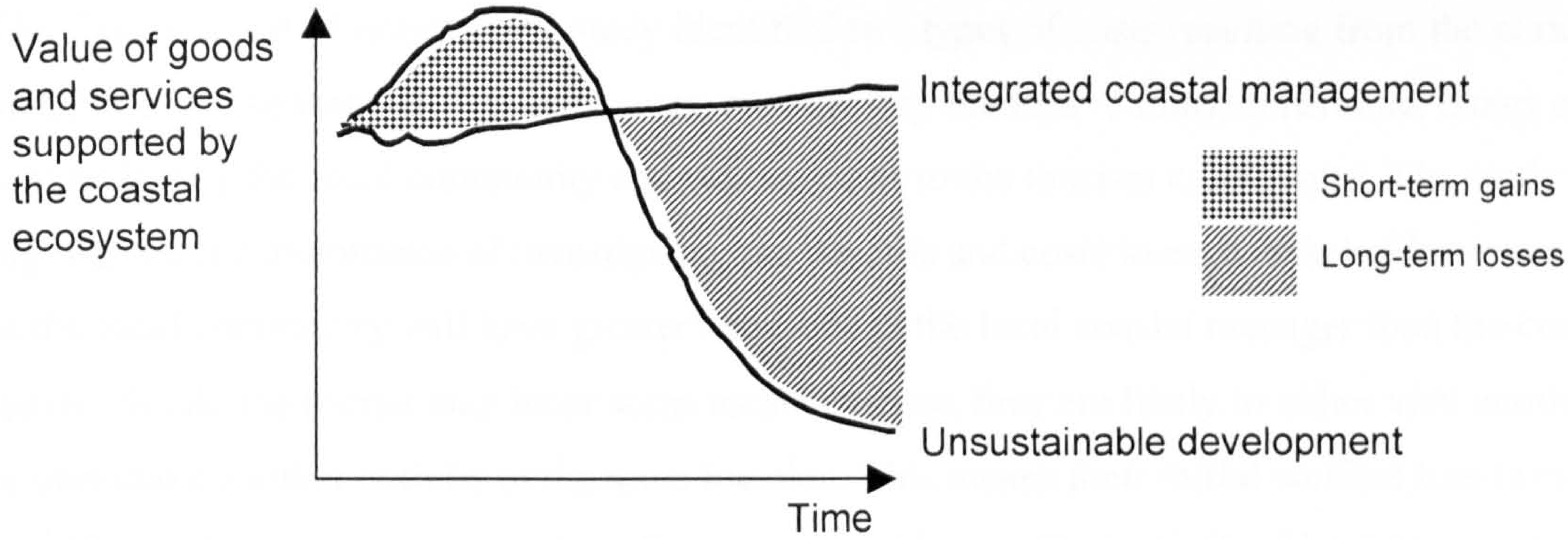


Figure 2 Graph illustrating the change in goods and services supported by coastal ecosystems resulting from unsustainable development choices highlighting the short term gains and the long term losses

The data from these types of valuations can be used to gain political attention. Comparing the reef related revenues from, for example, fishing and tourism in Curaçao shows the Government's investment in the management and protection of the resource is less than 1% of these gross revenues. Likewise the costs of the reef degradation from the coral bleaching in Mombasa and Zanzibar, measured in terms of loss in revenues to the local economy, is equivalent to the average yearly income of approximately 10,000 Kenyans and 7,000 Tanzanians. This represents a substantial loss to a community that may have limited employment alternatives and re-training possibilities.

Economic valuation can help present the case for ICM to decision makers as well as the local community to raise awareness of the issues and gain support for future management decisions. Costanza et al., (1997) make a series of arguable assumptions in order to estimate the value of the world's natural capital. The ensuing debate covered whether or not the world's natural capital should be valued in economic terms, who was going to buy it, whether the techniques used were applicable and the actual plausibility of the final range of values (see Costanza, 1998). However, whether or not the exact values arrived at were realistic, it brought to the attention of decision makers, the substantial value of these natural resources. The exact figure identified as the value may be less important. The fact that coastal resources have a substantial economic value is probably agreed upon and is what is most important in promoting sustainable development.

Economic valuation can also help management identify ways of generating revenue for conservation work. It has been widely used in the past to identify user fees for Marine Parks, the best-known examples coming from Bonaire and Saba in the Caribbean (Dixon et al., 1993; Dixon et al., 2000). The Curaçao case study showed that potential user fees can be identified through use values, while identification of the non-use values, enables the feasibility of setting up trust funds to be carried out. The case study also showed how similar techniques can be used to identify a willingness to volunteer time. This is already being used as a valuable resource, particularly in monitoring where human resources are limited (Wells, 1995).

The Zanzibar and Mombasa case study identified two types of costs resulting from the coral bleaching. These were the financial costs, measured by the loss of tourism revenue, a part of which will be lost by the local community and welfare costs to the tourism community. The study highlighted the importance of investigating the benefits and costs to each stakeholder group. The costs to the local community will have greater relevance to the local coastal manager than the costs to the tourist. While the tourist may incur some inconvenience, they are likely to either visit another location or undertake another activity at the same location. This means their initial welfare loss is replaced by a welfare gain from visiting another place or undertaking another activity. Those tourists having already pre-booked their vacation may continue to visit the area and subsequently be disappointed which would result in a welfare loss. However, the local community will have to cope with losses in revenues, subsequent unemployment and potential collapse of businesses.

The magnitude of the costs is important but equally so is the number of people involved. For example, the costs to a fisherman as their resource base is degraded may be small compared to the costs of the single investor resulting from a failed tourism operation. However, the total number of people affected in the fishing industry is likely to be large and include a high proportion of people with little ability to re-train and few employment alternatives available.

8.6 Is integrated coastal management an impossible task?

Integrated coastal management is an ambitious undertaking aimed at finding a sustainable level of utilisation of coastal resources. This level of utilisation needs to provide a 'socially desirable' mix of coastal zone products and services (Crooks & Turner, 1999; Turner & Bower, 1999). A mix that not only changes over time as demands change but one that generates the greatest number of economic benefits to society both now and in the future rather than maximizing financial gain focusing on one form of activity (Burbridge, 1999). ICM needs to account for the multi-objective decision making environment that characterizes the coastal zone and drives many of the coastal activities. Ignoring the needs and desires of the local community is likely to result in overlooking the forces undermining policies, plans and other measures designed to achieve national and international sustainable development objectives (Burbridge, 1999).

There are a number of management tools available to ICM managers and decision makers that can help in the analysis phase of ICM (Bijlsma et al., 1993; Salomons & Turner, 1999). There is capacity now available worldwide to analyse the issues and problems and develop ICM management plans for coastal zones. Capacity in ICM within the tropics is also increasing (Linden & Granlund, 1998; Olsen & Christie, 2000). The challenge now is to identify and focus on the implementation phase and utilise the tools available to overcome the issues that are currently blocking progress at this stage. The main issues facing management and the impediments blocking or hindering implementation of ICM need to be identified and tackled directly. In the majority of cases, it is unlikely these will be simple to overcome. However, these issues need to be prioritised and management efforts adapted accordingly. Accepting the ideal of ICM and the sustainable use of coastal resources may be facilitated once the issues are fully understood. One of the keys will lie in education of the future decision makers to form a generation who feel a responsibility to maintain the world's natural resources. Any tools that are able to inform decision makers and stakeholders of the long-term costs of unsustainable resource use and illustrate the interactions between the different activities in the coastal zone are likely to be useful management tools. This study has shown that decision support systems and economic valuation, if applied correctly, could both prove to be useful management tools.

In summary, this study has identified the following:

- ICM will not be an easy task, particularly in tropical coastal zones where the problems are exacerbated by rapid population increases, over-extraction of resources and poverty
- If ICM is to progress to the next stage, namely implementation, the focus needs to be on building capacity in implementing ICM
- By analysing the impediments to implementing ICM, practitioners may be able take the management of tropical coastal zones beyond the analysis and planning phase
- Development of ICM plans and programmes need to focus on overcoming the impediments which are likely to block the success of an ICM programme and prioritise activities to tackle these first
- Funding agencies need to be aware that to make progress in ICM, overcoming some of these impediments may take a substantial amount of time or resources
- Evaluation of existing ICM efforts, in terms of their successes and failures relative to clear criteria and the causes of these successes and failures could greatly assist future ICM efforts
- A decision support system can have a number of roles which should be carefully defined at the start of development, for example, collation of ICM data and information, facilitation of discussions, fulfilling an educational role and supporting decision making
- Decision support systems can be useful management tools but the design of the is development process is crucial to their acceptance
- Economic valuation can be an important management tool in raising both political and public awareness of the benefits of sustainable management and the costs of inaction and unsustainable resource use
- Economic valuation can identify who benefits and who looses from management decisions which could play a vital role in achieving the objectives of ICM

References

Awosika, L. S., S. Boromthanarat, R. Cornforth, M. Hendry, R. Koudstaal, M. Ridgley, J. Sorenson, L. de Vrees and S. Westmacott. 1993. *Management Arrangements for the development and implementation of coastal zone management programmes.* World Coast Conference Organising Committee, Noordwijk, the Netherlands.

Bateman, I. J. and K. Willis, G 1999. Introduction and Overview. In *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU and Developing Countries,* eds., I. Bateman, J and K. Willis, G, 1-16. Oxford, UK: Oxford University Press.

Bijlsma, L., M. Crawford, C. Ehler, F. Hoozemans, V. Jones, R. Klein, B. Miermet, N. Mimura, R. Misdorp, R. Nicholls, K. Ries, J. Spradley, M. Stive, L. de Vrees and S. Westmacott. 1993. *World Coast Conference Report.* Ministry of Transport, Public Works and Water Management, National Institute for Coastal and Marine Management, Coastal Zone Management Centre, Noordwijk, the Netherlands.

Bower, B. T., C. N. Ehler and D. Basta, J. 1994. *A framework for planning for integrated coastal zone management.* National Oceanographic and Atmospheric Administration (NOAA), Washington DC.

Bower, B. T. and R. K. Turner. 1998. Characterising and analysing benefits from integrated coastal management (ICM). *Ocean & Coastal Management* 38: 41-66.

Bradbury, R. and R. Seymour. 1997. Waiting for COTS. *Eighth International Coral Reef Symposium,* eds., International Society for Reef Studies, 1357-1362. Panama.

Bryant, D., L. Burke, J. McManus and M. Spalding. 1998. *Reefs at Risk. A Map-Based Indicator of Threats to the World's Coral Reefs.* World Resources Institute, Washington DC.

Burbridge, P. 1999. The Challenge of Demonstrating the Socio-Economic Benefits of Integrated Coastal Management. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 35-54. Berlin Heidelberg: Springer-Verlag.

Burbridge, P. R. 1997. A generic framework for measuring success in integrated coastal management. *Ocean & Coastal Management* 37: 175-189.

Cesar, H., C. G. Lundin, S. Bettencourt and J. Dixon. 1997. Indonesian coral reefs - An economic analysis of a precious but threatened resource. *Ambio* 26: 345-350.

Cesar, H., S. Westmacott, L. Emerton and S. Wells. 2000. *Economic Benefits of Marine Protected Areas in the Western Indian Ocean Region.* Coastal Zone Management Centre, The Hague, Netherlands.

Cesar, H. S. J. 2000. *Collected Essays on the Economics of Coral Reefs.* Kalmar, Sweden: Kalmar University.

Checkland, P. 1984. Rethinking a systems approach. In *Rethinking the Process of Operational Research and Systems Analysis,* eds., R. Tomlinson and I. Kiss, 43-66. London: Operational Research Society Limited & Pergamon Press.

Christie, P. and A. T. White. 1997. Trends in Development of Coastal Area Management in Tropical Countries: From Central to Community Orientation. *Coastal Management* 25: 155-181.

Chua, T.-E. 1998. Lessons Learned from Practicing Integrated Coastal Management in South East Asia. *Ambio* 27: 599-610.

Cicin-Sain, B. and R. W. Knecht. 1998. *Integrated coastal and ocean management: concepts and practices.* Washington DC and Covelo, California: Island Press.

Cicin-Sain, B., R. W. Knecht and G. W. Fisk. 1995. Growth in Capacity For Integrated Coastal Management Since UNCED - an International Perspective. *Ocean & Coastal Management* 29: 1-3.

Cohen, J. L. 1978. *Multiobjective Programming and Planning.* Cambridge, UK: Academic Press.

Costanza, R., R. D'Arge, R. de Groot, S. Farber, M. Grasse, B. Hannon, K. Limburg, S. Naeem, R. V. O'Neill, J. Paruelo, R. G. Raskin, P. Sutton and M. ven den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.

Costanza, R. e. 1998. Special Section: Forum on Valuation of Ecosystem Services. *Ecological Economics* 25: 1-136.

Crooks, S. and R. Turner. 1999. Integrated Coastal Management: Sustaining Estuarine Natural Resources. *Advances in Ecological Research* 29: 241-289.

Dixon, J. A. 1998. Economic Values of Coral Reefs: What are the Issues? In *Coral Reefs: chalenges and opportunities for sustainable management,* eds., M. Hatziolos, 157-162. Washington: World Bank.

Dixon, J. A., L. Fallon Scura and H. van't, Tom. 1993. Meeting Ecological and Economic Goals: Marine Parks in the Caribbean. *Ambio* 22: 117-125.

Dixon, J. A., L. F. Scura and T. van't Hof 2000. An Economic and Ecological Analysis of the Bonaire Marine Park. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 158-165. Stockholm, Sweden: Sida Press.

Fabbri, K. P. 1998. A methodology for supporting decision making in integrated coastal zone management. *Ocean & Coastal Management* 39: 51-62.

Geraghty, P. J. 1993. Environmental Assessment and the Application of Expert Systems: an Overview. *Journal of Environmental Management* 39: 27-38.

Goreau, T., T. McClanahan, R. Hayes and A. Strong. 2000. Conservation of Coral Reefs after the 1998 Global Bleaching Event. *Conservation Biology* 14: 5-15.

Green, E. P., P. J. Mumby, A. J. Edwards and C. D. Clark. 1996. A Review of Remote-Sensing For the Assessment and Management of Tropical Coastal Resources. *Coastal Management* 24: 1-40.

Gustavson, K., R. M. Huber and J. Ruitenbeek. 2000. *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.* Washington, DC: The World Bank.

Hodgson, G. 1999. A Global Assessment of Human Effects on Coral Reefs. *Marine Pollution Bulletin* 38: 345-355.

Hodgson, G. and J. A. Dixon 2000. El Nido Revisited: Ecotourism, Logging and Fisheries. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 55-68. Stockholm, Sweden: Sida Press.

Hogarth, A. N. 1999. SIMCOAST. *CoastNET.*4: 6.

Hughes, T. P. 1994a. Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science* 265: 1547-1551.

Hughes, T. P. 1994b. Coral Reef Degradation. A long term study of human and natural impacts. *Colloquium on Global Aspects of Coral Reefs: Health, Hazards and History, 1993,* eds., R. N. Ginsberg, 208-213. Rosentiel School of Marine and Atmospheric Aciences, University of Miami.

Hunter, C. and C. Evans. 1995. Coral Reefs in Kaneohe Bay, Hawaii - 2 centuries of Western influence and 2 decades of data. *Bulletin of Marine Science* 57: 501-515.

ICRI. 1998. *Renewed call for Action: International Coral Reef Initative 1998.* Great Barrier Reef Marine Park Authority, Townsville, Australia.

Jameson, S. C., J. W. McManus and M. D. Spalding. 1995. *State of the Reefs - Regional and Global Perspectives.* International Coral Reef Initiative, US Dept of State, Washington DC.

Johannes, R. 1998. Government-supported, village-based management of marine resources in Vanuatu. *Ocean & Coastal Management* 40: 165-186.

Johannes, R. E. 1975. Pollution and Degradation of Coral reef communities. In *Tropical Marine Pollution,* eds., E. J. Ferguson Wood and R. E. Johannes, 13-51. Amsterdam: Elsevier.

Lam, M. 1998. Consideration of customary marine tenure system in the establishment of marine protected areas in the South Pacific. *Ocean & Coastal Management* 39: 97-104.

Linden, O. and A. Granlund. 1998. Building Capacity for Coastal Management. *Ambio* 27: 589.

Meesters, E. H., R. P. M. Bak, S. Westmacott, M. Ridgley and S. Dollar. 1998. A Fuzzy Logic Model to Predict Coral Reef Development under Nutrient and Sediment Stress. *Conservation Biology* 12: 957-965.

Moran, P. 1997. *Crown of Thorns Starfish - Questions and Answers. Online Reference Series.* Australian Institute of Marine Science, Townsville.

Mumby, P. J., P. S. Raines, D. A. Gray and J. P. Gibson. 1995. Geographic Information-Systems - a Tool For Integrated Coastal Zone Management in Belize. *Coastal Management* 23: 111-121.

Olsen, S. and P. Christie. 2000. What are we learning from Tropical Coastal Management Experiences? *Coastal Management* 28: 5-18.

Olsen, S., K. Lowry and P. Tobey. 1999. *A manual for assessing progress in coastal management.* Coastal Resources Centre, University of Rhode Island, Narragansett, RI, USA.

Olsen, S., J. Tobey and M. Kerr. 1997. A common framework for learning from ICM experience. *Ocean & Coastal Management* 37: 155-174.

Parker, M., J. G. Thompson, R. R. Reynolds and M. D. Smith. 1995. Use and Misuse of Complex-Models - Examples From Water Demand Management. *Water Resources Bulletin* 31: 257-263.

Pearse, P. H. and C. J. Walters 1987. Perspectives on the Application of Economic-Ecological Models. In *Economic-Ecological Modeling,* eds., L. C. Bratt and W. F. J. van Lierop, 269-281. Amsterdam: North-Holland.

Post, J. C. and C. G. Lundin. 1996. *Guidelines for integrated coastal zone management.* Washington DC: International Bank for Reconstruction and Development & The World Bank.

Resource Analysis and Delft Hydraulics. 1993. *How to Account for the Impacts of Climate Change in Integrated Coastal Zone Management: Concepts and Tools for Approach and Analysis. Version 2.0.* World Coast Conference (WCC'93) Organising Committee, Ministry of Transport Public Works and Water Management, The Hague, the Netherlands.

Rijsberman, F. and S. Westmacott 2000. Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of Curacao. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.,* eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 49-66. Washington, DC: The World Bank.

Salomons, W. and R. K. Turner. 1999. *Perspectives on Integrated Coastal Zone Management.* Berlin Heidelberg: Springer-Verlag.

Sorensen, J. 1993. The International Proliferation of Integrated Coastal Zone Management Efforts. *Ocean and Coastal Management.* 21: 45-80.

Sorensen, J. 2000. *Building a Global Database of ICM Efforts.* University of Massachusetts, Boston.

Sorensen, J. C. and S. T. McCreary. 1990. *Institutional Arrangements for Managing Coastal Resources and Environments.* Washington DC: National Parks Service, US Department of Interior.

Souter, D., D. Obura and O. Linden. 2000. *Coral Reef Degradation in the Indian Ocean: Status Report 2000.* CORDIO/SAREC Marine Science, Sweden CORDIO Programme.

Spash, C. 2000. Assessing the Benefits of Improving Coral Reef Biodiversity: The Contingent Valuation Method. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 40-54. Stockholm, Sweden: Sida Press.

Spash, C. L., J. van den Werff ten Bosch, S. Westmacott and J. Ruitenbeek 2000. Lexicographic Preferences and the Contingent Valuation of the Coral Reef Biodiversity in Curaçao and Jamaica. In *Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling.*, eds., K. Gustavson, R. M. Huber and J. Ruitenbeek, 97-118. Washington, DC: The World Bank.

Te'eni, D. and M. J. Ginzberg. 1991. Human-computer decision systems: The multiple roles of DSS. *European Journal of Operational Research* 50: 127-139.

Turner, R. 2000. Integrating natural and socio-economic science in coastal management. *Journal of Marine Systems* 25: 447-460.

Turner, R. and W. Adger. 1996. *Coastal Zone Resource Assessment Guidelines.* LOICZ IPO, Texel, The Netherlands.

Turner, R., W. Adger and I. Lorenzoni. 1998. *Towards Integrated Modelling and Analysis in Coastal Zones: Principles and Practices.* LOICZ IPO, Texel, The Netherlands.

Turner, R. and B. Bower 1999. Principles and Benefits of Integrated Coastal Zone Management (ICZM). In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 13-34. Berlin Heidelberg: Springer-Verlag.

Turner, R. K. 1993. *Sustainable Environmental Economics and Management: Principles and Practice.* London: Belhaven Press.

Turner, R. K. and W. Salomons 1999. Introduction and Overview. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 1-9. Berlin Heidelberg: Springer-Verlag.

van der Weide, J. and L. De Vrees 1999. Methods and Tools to Support CZM. In *Perspectives on Integrated Coastal Zone Management,* eds., W. Salomons and R. K. Turner, 69-88. Berlin Heidelberg: Springer-Verlag.

Veitayaki, J. 1997. Traditional marine resource management practices used in the Pacific Islands: an agenda for change. *Ocean and Coastal Management* 37: 123-136.

Veitayaki, J. 1998. Traditional and Community - Based Marine Resources Management System in Fiji: An Evolving Integrated Process. *Coastal Management* 26: 47-60.

Wells, S. M. 1995. *Reef Assessment and Monitoring using Volunteers and Non-Professionals.* University of York and Coral Cay Conservation, UK, York and London.

Westmacott, S., H. Cesar, L. Pet-Soede and O. Linden 2000. Coral Bleaching in the Indian Ocean: Socio-Economic Assessment of Effects. In *Collected Essays on the Economics of Coral Reefs,* eds., H. S. J. Cesar, 94-106. Stockholm, Sweden: Sida Press.

Wilkinson, C. 1998. The 1997-1998 mass bleaching event around the World. In *Status of Coral Reefs of the World: 1998,* eds., C. Wilkinson, 183. Queensland and Western Australia: Australian Institute of Marine Science.

Wilkinson, C. 2000. *Status of Coral Reefs of the World: 2000.* Cape Ferguson, Queensland, Dampier, Western Australia: Australian Institute of Marine Science.

Wilkinson, C. and B. Salvat 1997. The Global Coral Reef Monitoring Network: Reversing the Decline of the World's Reefs. In *Coral Reefs: Challenges and Opportunities for Sustainable Management: proceedings of an associated event of the fifth annual World Bank Conference on Environmentally and Socially Sustainable Development,* eds., M. E. Hatziolos, A. Hooten, J and M. Fodor, 16-19. Washington DC: World Bank & International Centre for Living and Aquatic Resources Management (ICLARM).

APPENDIX A

SURVEY TO ASSESS THE ABILITY OF TROPICAL COASTAL AREAS TO IMPLEMENT EFFECTIVE INTEGRATED COASTAL MANAGEMENT

Appendix A Survey to assess the ability of tropical coastal areas to implement effective integrated coastal management

The survey contained in this Appendix was used for the research described in Chapter 2 and 4. It is accompanied with a letter describing to the respondent what was expected of them. It was distributed to coastal management experts throughout the tropics who were identified for their knowledge and expertise in the field.

Susie Westmacott
33 Old Priory Close, Hamble
Southampton, SO31 4QP
UK

26 November 1999

Survey to assess the ability of tropical coastal areas to implement effective integrated coastal management.

Dear

I have sent this questionnaire to you specifically because of your knowledge on the management situation of the coastal region(s) of . It should only take 10-15 minutes to complete.

I really hope you can find a few minutes to help me and complete this.

The aim of the research is to gain a better understanding of what is really standing in the way of implementing effective integrated coastal management (ICM). It is part of my PhD research into overcoming the impediments to ICM that I am carrying out at the Centre for Tropical Coastal Management at the University of Newcastle upon Tyne.

The survey consists of 2 parts. The first is a series of framing questions, related to your specific location. The second part is the main questionnaire, each question consists of two parts. The first part is a factual question and the second part is your opinion on how this does, or would impact attempts to implement ICM. Please answer the questions honestly, each questionnaire will be kept anonymous. At the end, there are some questions on basic information about the region selected. Please complete this as fully as possible.

Below are a few explanatory notes:

This is not a survey of ICM programmes in existence; it is a survey of the potential of coastal areas to effectively manage their coastal zones.

The **coastal zone** will differ in its boundary definition, but should include all, coastal and marine activities and resources that are specific to the land-water interface and have an influence on one another.

ICM institutions are defined as those agencies, stakeholders or organisations at national to local level which have an interest or are involved in the management of the coastal zone.

Integrated Coastal Management - ICM is the "ideal" situation where these institutions work in an integrated manner, managing multiple uses. The goal of ICM is to achieve the conservation and sustained multiple use of the coastal zone.

Each question asks you first about the way the coast is **currently managed** and secondly whether you think this issue affects the ability to achieve the "ideal" situation of ICM - where conservation and the sustained multiple use of the coastal zone is achieved.

Thank you in advance for you time and co-operation,

Susie Westmacott

Email: s.westmacott@ncl.ac.uk
Tel/ fax: +44 1703 457 950

Survey to assess the ability of tropical coastal areas to implement effective integrated coastal management.

Please answer the questions by checking one of the boxes for each question.

Once completed please return the questionnaire to me at 33 Old Priory Close, Hamble, Southampton, SO31 4QP, UK. Thank you.

If you give your name and contact details, I will inform you of the results of the questionnaire.

Your response will be kept confidential.

Name of respondent: ______________________________

Email address: ______________________________

Area selected: ______________________________

Personal involvement in ICM in the region selected: ______________________________

____

PART ONE: Framing information

a) **COASTAL ACTIVITIES:** Which of the following activities are found in the selected coastal zone?

☐ Hook & line fishing ☐ Spearfishing ☐ Fish traps ☐ Dynamite fishing ☐ Snorkeling

☐ Scuba diving ☐ Coralmining ☐ Sand mining ☐ Shell collection ☐ Coral collection

☐ Others, please list:

b) Are there conflicts between the coastal activities? ☐ Yes ☐ No

If so, which ______________________________

MAIN MANAGEMENT ISSUES IN THE COASTAL ZONE

c) Rank the priority of the following management issues in the selected coastal zone?

- Rapid population growth ☐ High ☐ Medium ☐ Low ☐ Non issue
- Deteriorating environmental quality ☐ High ☐ Medium ☐ Low ☐ Non issue
- Loss of biodiversity ☐ High ☐ Medium ☐ Low ☐ Non issue
- Loss of critical habitats ☐ High ☐ Medium ☐ Low ☐ Non issue
- Unemployment ☐ High ☐ Medium ☐ Low ☐ Non issue
- Poverty ☐ High ☐ Medium ☐ Low ☐ Non issue
- Vulnerability to natural hazards ☐ High ☐ Medium ☐ Low ☐ Non issue
- Diminishing levels of fish & shellfish ☐ High ☐ Medium ☐ Low ☐ Non issue

Please indicate other important issues: ______________________________

____

Continue to next page

d) INSTITUTIONS: List the main ICM institutions, organisations, stakeholders and their interest/ involvement

____

____

____

____

____

e) Explain briefly the Government structure ______________________________

____

____

____

GENERAL INFORMATION

f) Which of the following statements is true?

☐ There are no moorings ☐ The moorings reduce anchor damage ☐ The moorings stop anchor damage

g) Are there fishing regulations e.g., mesh size, seasons, reserves? ______________________________

h) Are there protected areas? ☐ Yes ☐ No

If so, describe, (eg., fish reserve, no go zone) ______________________________

i) Is over-fishing an issue? ☐ Yes ☐ No

j) How good are communications?

Telephone	☐ Reliable	☐ Unreliable	☐ Does not exist
Email	☐ Reliable	☐ Unreliable	☐ Does not exist
Internet	☐ Reliable	☐ Unreliable	☐ Does not exist

k) What level of education is available to the local people?

☐ Primary school ☐ Secondary school ☐ College of higher education ☐ University

l) Is there a marine research institute? ☐ Yes ☐ No ☐ It has closed down

m) Are there wastewater treatment facilities? __________ % wastewater treated__________

n) To what extent is (formal or informal) ICM being achieved in your selected site?

☐ There is no management ☐ Problems are known by management ☐ Integrated plans are being formulated ☐ Integrated plans are being implemented ☐ Monitoring and evaluation of ICM plans

o) Comments/ relevant information ______________________________

____

continue on separate page if necessary ______________________________

Continue to the next page

PART TWO: Questionnaire

1. How much active communication is there between the ICM institutions?

☐ None ☐ 6 monthly -Yearly ☐ monthly – 6 monthly ☐ Weekly - monthly ☐ Daily - weekly

How does or, would this level of communication affect the implementation of ICM in your site?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

2. How often do official committees with representatives of more than one ICM institution meet?

☐ There are no committees ☐ 6 monthly- Yearly ☐ monthly – 6 monthly ☐ Weekly - monthly ☐ Daily - weekly

How does or, would this affect the implementation of ICM in your site?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

3. How are the management plans of the different ICM institutes integrated?

☐ All are formally ☐ All are informally ☐ Some are formally ☐ Some are informally ☐ No integration

How does or would this level of integration of the plans affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

4. How do the ICM institutions function internally?

☐ Non-functioning ☐ Inefficient ☐ Slow but they function ☐ Moderately efficient ☐ Efficient

How does or would this internal efficiency affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

5. Is there local experience in ICM in the relevant institutions?

☐ In all institutions ☐ In most institutions ☐ In some institutions ☐ In a few institutions ☐ No local experience

How does/ would this level of experience affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

6. What level of education do personnel available for ICM have?

☐ No training ☐ Secondary school ☐ College ☐ University ☐ Post-graduates

How does/ would this level of training affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

7. Are there adequate finances to implement the necessary measures to achieve ICM?

☐ Yes ☐ Yes, for infrastructure but not personnel ☐ Yes, for personnel but not infrastructure ☐ Small funds ☐ Inadequate funds

How does/ would this level of funding affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

Continue to next page

8. Do institutions have sufficient authority to be effective?

☐ None do ☐ One does ☐ A few do ☐ Most do ☐ All do

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

9. Do the different institution's jurisdictions conflict?

☐ Never ☐ One situation ☐ A few situations ☐ Most situations ☐ Always

How does/ would this level of conflict affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

10. Is there sufficient legislation for effective ICM?

☐ Yes ☐ No

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

11. Is the legislation ever found confusing?

☐ Yes ☐ No

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

12. Is the Government committed to environmental protection?

☐ Actively ☐ Verbally ☐ Supports independent efforts ☐ Not committed ☐ No, against

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

13. Is the Government actively involved in sustainable development initiatives?

☐ Yes ☐ No

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

14. Are decisions a balance between environmental protection and economic development?

☐ Yes ☐ No

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

15. Do decisions have a long-term focus as opposed to short term?

☐ Regularly ☐ Sometimes ☐ Never

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

Continue to next page

16. Are the public aware of the importance of the environment?

☐ None are ☐ A few are ☐ Some are ☐ Most are ☐ All are

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

17. Are the public involved in decision making?

☐ Regularly ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

18. Would you describe the decision making as top down rather than bottom up?

☐ Yes ☐ No

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

19. Is there verbal communication between scientists and the managers?

☐ Regularly ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

20. Is there dissemination of information (reports, papers, etc.) from scientists to managers?

☐ Regularly ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

21. Is science used as the basis of management decisions?

☐ Regularly ☐ Often ☐ Sometimes ☐ Rarely ☐ Never

How does/ would this affect the ability to implement ICM?

☐ Very negatively ☐ Negatively ☐ No effect ☐ Positively ☐ Very positively

If possible, please supply the following basic information for the region selected:

If you do not have official statistics to answer these questions please estimate and indicate that it was estimated. If this is possible then simple leave a blank and return the questionnaire.

Coastal population: ______________________________

Average GDP*/ capita: ______________________________ Unemployment rate: ________________

Number of tourists: ______________________________

% tourists doing reef related activities: ________________ % GDP* from tourism ________________

Number of fishermen: ______________________________ % population engaged in fishing __________

% GDP* from fishing ______________________________

*Gross domestic product – given in US$ if possible

END of QUESTIONNAIRE – Thank you for you co-operation and time.

APPENDIX B

STRUCTURED INTERVIEWS

Appendix B Structured Interviews

The following structured interview was used for the solicitation of information from the coastal management stakeholders in Curaçao. Stakeholders were selected for their involvement in the coastal management process or because they were affected by decisions made in the coastal zone. The same structure was used in subsequent interviews in Zanzibar. Stakeholders were selected in Zanzibar for their knowledge on the coastal management situation on the Island. In both cases, care was taken to interview both the public and private sector from conservation and development perspectives. The results and methods are described in detail in Chapter 3.

Introduction to interviews for people with a stake in coastal zone management in Curacao
Prepared by Susie Westmacott and Leanne Fernandes,
Resource Analysis
Zuiderstraat 110
2611 SJ Delft
Nederland
Ph. 61 15 122622
Fax. 61 15 124892

12 July 1995

We/I are/am from/representing Resource Analysis a consulting company in the Netherlands that is involved in the management of natural resources and in particular coastal resources.

In earlier communications, various people and agencies on Curaçao expressed interest in our current project which is why we are conducting it here. The project has two main objectives:

- to contribute to coastal zone management initiatives here in Curaçao and

- to test a least cost method for formulating different reef management strategies.

Ultimately, the project will result in a computerised model that will enable decision makers and other interest groups to examine the issues found in the coastal zone today. Future impacts which alternative coastal management strategies may have on the coastal zone will also be illustrated. I can show you a preliminary example of what the model may look like after our interview. This will give you a better feeling as to where and how information you provide will be used.

We are attempting to incorporate the views of a wide spectrum of interest groups and relevant agencies into the model. To do this, we are carrying out standardised interviews using a prepared series of questions which are asked of individuals from all the groups. I am going to read this set of questions as we have worded them so that everyone in this survey answers the same questions. If you are unclear as to the meaning of the question or what is wanted then please feel free to ask.

I shall record your answers word for word by hand but, if you have no objection, I would like to tape the conversation so I can ensure I have your entire answers.

Do you prefer that we speak in Dutch or English?

Do you have a card with the spelling of your name and your address here at work?

For this project we define coastal zone management as the geographic area including the whole island of Curaçao and the adjacent waters within the 12 mile territorial limit. Do you have any comments regarding this definition?

1. What do you consider are the major issues in the coastal zone?

2. What do you consider are the major problems in the coastal zone? Anything else?

3. What would you like to see as objectives of a coastal zone management programme? (These may refer to maintenance or changes in a situation in or condition of the coastal zone).

4. Check list:- environmental, economic, social, political, institutional, any other objectives?

5. What actions do you think could be undertaken to achieve the objectives of coastal management that you just described?

6. What would you measure to see if you had reached these objectives?

7. Do you see any likely obstacles or constraints in implementing these actions? Any others?

8. The objectives you have described can be grouped into economic, environmental, social, institutional, political and other types of objectives. What relative values would you give to each of these? On this visual aid the relative values of the different types of objectives and/or issues must add to 100% (i.e. the values are represented in a cumulative manner)

9. What events or circumstances can you imagine occurring that may affect coastal management, but which the managers and decision makers on Curacao are unable to control or influence? Is there anything else?

10. Where would you position yourself in the decision making process and where would you like to be?

11. If you are not participating as fully as you wish, what is preventing you?

12. Is there anything else you would like to add?

13. Is there anyone else you think we should talk to?

Personal questions

1. Your age.
2. Where were you born?
3. What level of education have you completed?
4. Was any part of your education overseas?
5. If so, which part?
6. Do you consider yourself a permanent resident of Curacao?
7. Do you have children?

Levels of participation in coastal zone management:

Where you are now and where you would like to be

Very little/None

Being heard before decisions

Knowledge about decisions

Forming decisions

Having an influence on decisions

Participation in implementation of decisions

Agreeing to decisions

Thank you for your cooperation

Glossary of terms for questionnaire for CZM (CORAL) project - Curacao

coastal zone - the entire island of Curacao and adjacent waters included in the 12 mile territorial limit.

criteria - the unit by which to measure degree of achievement of objectives

economic - regarding all aspects of the economy of Curacao

environmental - natural marine, terrestrial and atmospheric components of the coastal zone, both living and non-living.

institutional - ability and willingness of relevant agencies and interested parties to co-ordinate and co-operate regarding coastal zone management.

issues - happenings or activities that are important in the coastal zone in any way at all, positive or negative

objectives - desired situation or condition to aim for.

political - governmental agreement and support in decision making regarding coastal zone issues and problems

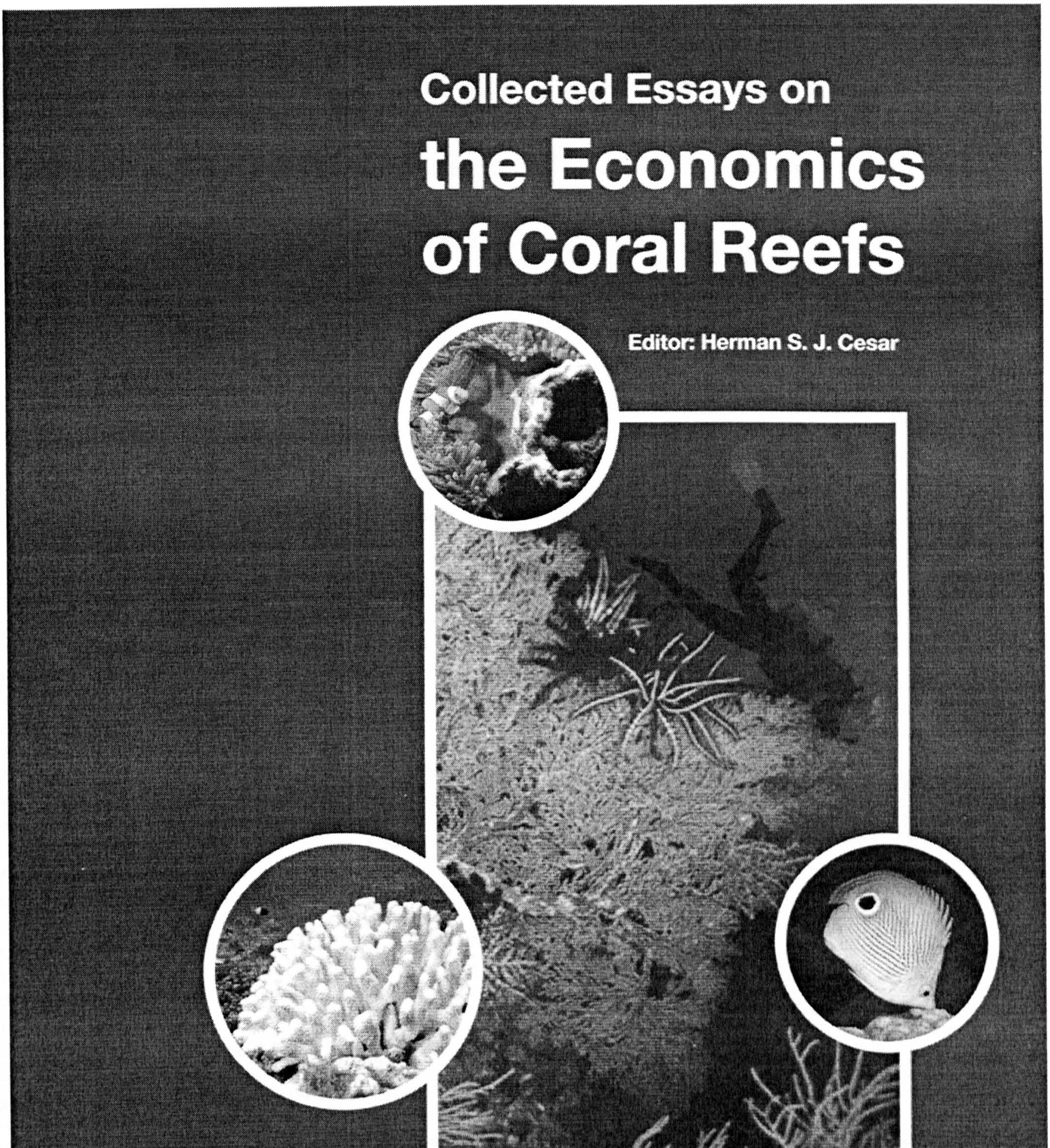
problems - conflicts between users, agencies or any people interested in the coastal zone. Any dissatisfactions you have or perceive associated with the coastal zone.

scenario - external events and conditions over which Curacao has no real control

social - related to the people of Curacao; their interactions with the coastal zone or each other regarding use of the coastal zone.

APPENDIX C

SELECTED PAPERS


Collected Essays on
the Economics
of Coral Reefs
Editor: Herman S. J. Cesar

Coral Bleaching in the Indian Ocean: Socio-Economic Assessment of Effects

SUSIE WESTMACOTT, HERMAN S. J. CESAR, LIDA PET-SOEDE & OLOF LINDÉN

ABSTRACT

The mean temperature on the planet is increasing. The rate of this increase appears to be accelerating and is at present approximately 2 degrees per century. 1998 was the warmest year since temperature recordings started some 150 years ago. Similarly the 1990s was the warmest decade. In addition, 1997 and 1998 saw the strongest El Niño ever recorded. As a consequence of this, very high water temperatures were observed in many parts of the oceans, particularly in the tropical areas. Due to the high water temperatures, the corals over much of the world bleached and subsequently died. In 1997–98, massive mortality occurred particularly among corals of the Indian Ocean. The reefs of Sri Lanka, Maldives, India, Kenya, Tanzania, and Seychelles were particularly hard hit, with mortalities of up to 95%. Reefs in other parts of the Indian Ocean showed mortality rates up to 50%. Hence the coral mortality during 1998 was the unprecedented in severity. The secondary effects on the socio-economic condition in the coastal communities of the Indian Ocean are presently studied as a part of the CORDIO Program (Coral Reef Degradation of the Indian Ocean). The event has so far not affected socio-economic indicators dramatically. Reef fisheries in many areas in the region have been showing a general decline over the last decade and data collected can not yet tell what the added negative impact of coral bleaching is. On the other hand, diving tourism has been affected, particularly in the Maldives. The financial costs in the Maldives were estimated at US$ 3.0 million, while economic costs over the last two years were roughly US$ 19 million. Also in East Africa, the first investigations have shown some impacts on tourism. Additional studies are presently carried out to evaluate the full impacts of the coral mortality on fisheries and tourism in the Indian Ocean. In addition to changes in fish stocks and negative effects on tourism, erosion may become an even more acute problem, particularly in countries such as Maldives and Seychelles.

INTRODUCTION

During 1998 most coral reefs of the world went through a major bleaching event, the most severe ever witnessed (Hoegh-Guldberg 1999; Wilkinson et al. 1999). Reports of coral bleaching that lasted for several weeks or months were obtained from all tropical regions of the globe (Wilkinson 1998). The subsequent mortality of corals was extensive. The Indian Ocean, in particular, was seriously affected with mortality frequently exceeding 75% and sometimes approaching 100% (Lindén & Sporrong 1999; Wilkinson et al. 1999). Further, almost half of all corals on several reefs in the East, Central and West Pacific, and the Caribbean were killed (Wilkinson 1998).

Many thousands of species of fish, invertebrates and plants depend on healthy coral reefs for their survival. Obviously, the death of extensive areas of coral had a major impact on other reef organisms also. The debate concerning these secondary effects of the dying corals started late in 1998. The consequences of mass coral death for local coastal fisheries, tourism and continued coastal protection were of primary concern. To address these concerns, the CORDIO Program (Coral Degradation in the Indian Ocean), supported by Sweden, the World Bank (Dutch Trust Fund), Finland, and World Wildlife Fund for Nature (WWF), was initiated early in 1999. To date, CORDIO is the only regional initiative that has been launched to assess the long-term impacts of the 1998 mass bleaching event on coral reefs, coastal commun-ities and national economies. The results of the initial assessments of coral mortality were presented in the first CORDIO Status Report (Lindén & Sporrong 1999). A summary of the first results of the socio-economic studies from the first full year studies are presented here.

CLIMATE CHANGE AND BLEACHING OF CORALS

Similar to previous mass bleaching events, bleaching was most pronounced in shallow water (<15 m) and was most severe on rapidly growing species such as *Acropora, Montipora* and *Echinopora*. Most alarming however, was that unlike past bleaching events in which massive corals such as *Porites* survived, the mass bleaching of 1998 affected virtually all species of coral and was evident at unprecedented depths (down to 42 m and 50 m in Sri Lanka and Maldives respectively). The severity of the 1998 bleaching event was further exemplified by the death of corals that had survived for the past 700 years or more (Hoegh-Guldberg 1999; Wilkinson et al. 1999).

A variety of environmental stresses are known to cause bleaching in corals. These include changes in water temperature, salinity, exposure at extreme low tides, and exposure to strong radiation (increased visible and UV radiation when the water is both calm and clear). During the bleaching process, the corals lose their endosymbiotic algae, the zooxanthellae (Warner & Fitt 1991). The most frequently reported bleaching stress is a rise in water temperatures of just a few degrees above the typical seasonal maximum for the corals (Glynn et al. 1993). When bleached, the coral appears white because the internal white skeleton is visible through the transparent tissue. If the algae which also exist in a flagellated planktonic form outside the coral return and repopulate the coral, it will recover and continue to grow normally. If not, the coral will eventually die after several weeks to months. Similar bleaching is known to occur in other organisms with symbiotic algae, such as giant clams, sponges, soft corals.

The global mean surface temperature in 1998 was the highest on record (Wilkinson et al. 1998). This year also coincided with the most extreme El Niño ever recorded. Beginning in late 1997, and continuing through to late 1998, sea temperatures rose sequentially around the world. The monthly progression of high sea surface temperature (SST) anomalies is clearly seen in AVHRR satellite images processed to show these increases above normal (Wilkinson et al. 1998). In many tropical areas where coral reefs are found, sea surface temperatures rose 2–3°C above the normal seasonal maximum, but in some locations 4–6°C increases were recorded (Wilkinson et al. 1998). Temperature records obtained from divers and other sensors indicate that temperature increases were not confined to surface waters, but extended to as deep as 40 to 50 m.

This powerful El Niño started as a small area of elevated SST off Ecuador, visible in NOAA satellite images at the end of January 1997. A band of water heated to as much as 4°C above normal seasonal maximum expanded westward into the eastern Pacific and was well-developed by July 1997. By January 1998 the El Niño was continuing in the eastern Pacific, while patches of anomalous hot water were appearing in the Indian Ocean off east Africa, Madagascar and along the east coast of Australia. Heating in these areas intensified in February, and bleaching was reported along the inner Great Barrier Reef, in Kenya, and in Madagascar by March. The area of hot water in the Indian Ocean increased in size and spread northwards by May reaching the south coast of India. Severe bleaching occurred in the Maldives, Sri Lanka, Andamans, and Lakshadweep followed by high levels of mortality, starting in April and being progressively later to the north (Wilkinson et al. 1998). The Indian Ocean then started to cool, while the South China Sea and far west Pacific started to heat up coinciding with a strong La Nina that commenced in July (Wilkinson et al. 1998).

The proximal cause of bleaching and mortality is uncertain and therefore controversial. While the SST anomalies have proved to be a reasonably good predictor of where coral bleaching may occur (Goreau & Hayes 1994), the actual cause of bleaching at a particular reef is likely to be a combination of physical factors such as temperature, number of days of sunlight, UV level, and biological factors such as the health of the coral, and presence of certain bacteria (Warner & Fitt 1991). There are stressors unrelated to temperature and large regional effects like El Niño that apparently also caused bleaching in 1998, including low temperatures (Sulawesi), low salinity due to high terrestrial runoff during large storm events (Comores and Reunion) and sub-aerial exposure during extreme low tides (Samoa and Tanzania).

ECOLOGICAL AND SOCIO-ECONOMIC SIGNIFICANCE OF CORAL MORTALITY

Massive mortalities of corals, such as during the event in the Indian Ocean in 1998, is likely to have both immediate and long-term impacts on the ecology of the coastal waters and the socio-economy of the communities in the coastal areas. A dead coral reef is likely to break down and form a rubble bed within a few years. When that process is completed the habitat complexity of the former coral reef is lost completely. A number of ecological processes are now affected, and several of these will influence the diversity and abundance of the fish fauna of the area. However, already during the acute phase the fish communities were affected on the reefs that suffered heavy mortality during the event in the Indian Ocean in 1998 (see Öhman et al. in Lindén & Sporrong 1999).

The recovery of the reefs that were affected by bleaching and mortality will be affected by a number of biological and physical factors. Reefs that did not suffer major damage, i.e. those in the southern Indian Ocean (Comoros, Madagascar, Mauritius, Mayotte and Reunion), can be expected to recover within 5 years. However, other areas with more extensive mortality of corals may have effectively ceased to function as coral reefs. Algae and other opportunistic organisms may have occupied the available space, effectively preventing corals from settling. A more detailed review of the situation on the reefs of the Indian Ocean as of the spring year 2000 can be found in the 2'nd CORDIO Status Report (Souter et al. 2000, in print).

The first year's study of the socio-economic impacts of the coral bleaching in the Indian Ocean is reported in Westmacott et al. 2000. The immediate impact is a loss of amenity for tourists; an algal covered reef lacks many of the attractive colours and shapes of a living reef. There is also likely to be impacts on fisheries. A summary of the results of the first year's studies of the socio-economic impacts of the bleaching and mortality are reported below.

TRENDS IN MARINE FISHERIES IN THE INDIAN OCEAN

Developments in the national demography and social-economy of most countries in the Indian Ocean suggest a continuously increasing pressure on fish resources. As a result the total fish production is increasing in several countries (table 1). However, it should be remembered that the fishing pressure has increased dramatically in most countries during the last 30 years. An example is Sri Lanka where the introduction of nylon nets, outboard motors and FRP boats, together with a doubling to tripling of the number of fishermen have increased the fishing pressure many times (Dayaratne et al. 1995). This development would indicate that the catch per unit effort has in fact gone down significantly.

Most of the catch from coastal fisheries is used for

Table 1. Marine fisheries catches in 1997 (in tons), with trends (Food and Agricultural Org (FAO) 1999).

Country	Marine Fish	Crustaceans	Molluscs	Trends since 1990 (%)
India	2,455,947	298,313	121,896	+28
Sri Lanka	208,350	11,000	300	+58
Maldives	107,087	–	271	+35
Madagascar	71,596	13,622	850	?
Tanzania	45,530	2,500	653	–29
Mozambique	14,500	12,906	659	–53
Mauritius	13,397	40	309	+16
Comores	12,480	20	–	+8
Reunion	5,581	301	–	+213
Kenya	4,382	950	726	–54
Seychelles	4,052	604	19	–27

local consumption, as it is the most affordable source of protein (FAO 1999b). Fish also contribute to the bulk of the animal protein in the diet in most of the countries around the Indian Ocean. Most of this fish is caught in the shallow coastal waters. Shrimp and tuna are the main export commodities.

The large number of small fishing vessels from which the millions of Indian Ocean fishers operate makes monitoring of stock status and implementation of fisheries management measures difficult. Methods used to sample marine fisheries and the way the collected information is processed and presented in reports differs greatly between countries. Little regulation of fishing effort exists, except in a number of marine protected areas around the region and a closed season for the large net fishery off Mauritius.

The number of fishers may be small compared to the number of people engaged in other economic activities. However, the most important aspect of the coastal fisheries is its contribution of animal protein in the diet. Fish protein provides 50 to 90% of the animal protein in the diet in most countries around the Indian Ocean. For the Southeast Asian region, 60% has been estimated as an average (Young 1989). In several of the island nations of the Indian Ocean, the figures are likely to be significantly higher. In Asia, it is estimated that over 1 billion people depend exclusively on fish for their protein requirements (FAO 1999).

ASSESSMENT OF THE EFFECT OF BLEACHING AND CORAL REEF DEGRADATION ON CORAL REEF FISH AND FISHERIES IN EAST AFRICA

Investigations in Mafia Marine Park, Tanzania, following the coral bleaching in 1998, showed that about 90% of the corals on Tutia Reef died. A year later, most of the dead corals, mostly Acropora, were still standing. Investigations of the fish fauna showed an increased fish abundance but few effects on the diversity (Öhman et al. 1999). As some of the most common reef fishes are herbivores, it was assumed that algal feeding fish species were finding more food on the recently dead coral reef.

In another study in Kenya, coral reefs were monitored to assess coral health and fish catches. The investigation includes a study of fish populations in Kenya's older (>25 years) fully protected marine parks (Malindi and Watamu MNP), a more recently created park Mombasa MNP (1991), and four sites on heavily fished unprotected reefs (Vipingo, Kanamai, Ras Iwatine and Diani). This study was conducted in late 1997 and repeated in early 1999, around four months before and 10 months after the coral bleaching event. For the purpose of assessing possible effects of the 1998 bleaching event, abundance and composition of the reef fish community was determined, together with biomass and composition of individual fish catches. The underwater visual census data showed no clear changes in fish community structure that can be attributed solely to the bleaching and mortality of corals. Only the increase in abundance of surgeon fish, which are grazers that feed on algae on the surface of the dead coral, may be related to coral mortality. It appears that there is a strong relationship between management (marine park versus exploited reefs) and fish abundance for many of the studied fish families (McClanahan & Arthur, in press). The catch assessment data show a significant decline in catch between 1995 and 1999, whereas the total fishing effort, measured in numbers of fishers or boats remained constant. There is no significant deviation from this trend after the 1998 bleaching event. Therefore, it must be concluded that, at this stage, the fishery has not been significantly affected by the bleaching and mortality of corals. Nevertheless, the declining catches may be a result of overall environmental degradation. Therefore, it is expected that the effects of the recent bleaching and coral mortality may become more evident once the reefs are further eroded in the future.

ASSESSING THE IMPACTS OF THE CORAL BLEACHING ON REEF BASED TOURISM

The second major socio-economic impact of coral bleaching would be expected on the tourism industry. Tourism will be affected by bleaching in those areas where a substantial proportion of the industry is based on reef activities and where there are few other attractions or activities for tourists to enjoy. Tourism varies throughout the countries of the Indian Ocean and the diversity of the tourism product ensures a greater or lesser dependence on coral reefs. Table 2 indicates the level to which each of the countries is dependant on coral reefs, and the national growth rate in tourism seen over the past five years. A few countries have suffered negative trends in their tourism lately. In Kenya for example, the occupancy rates in the coastal districts were only 30 to 36% during 1997. Another sign of the poor state of the hotel industry in Kenya is that, in 1997, 90,000 employees out of a total of 150,000 lost their jobs (Kenya Association of Hotel Keepers and Caterers 1997).

Reef based tourism is a major industry in both Maldives and Seychelles, although they are marketed quite differently. Maldives caters for the diving market (45% of all tourists dive) and the honeymoon market. Seychelles, on the other hand, offers a variety of activities and people may snorkel and dive as a small part of their vacation (only 7% of all tourists dive). Similar patterns were seen in Zanzibar where people spend, on average, less than 40% of their vacation time diving and snorkelling. In Kenya and mainland Tanzania, wildlife parks and safaris are probably the main attraction for visitors. However, visitors may often spend a week on safari and then a week at the coast where the reef based attractions

Table 2. Relative importance of reef-based tourism to the economy and 5 year trends in national tourism for countries of the Indian Ocean. ++++ = very high, +++ = high, ++ = medium, + = low, – = negative.

Country	Contribution of reef-based tourism to the gross domestic product (GDP)	National tourism trend
Maldives	++++	++
Mauritius	++++	++
Comores	+++	++
Seychelles	+++	+/–
Zanzibar, Tanzania	++	+++
Madagascar	+	++
Kenya	+	+
India	+	+
Reunion	+	+
Sri Lanka	+	–
Mozambique	+	No data
Rodregues	No data	++++
Mayotte	No data	+++

form an important component of their vacation. Island states, such as Comoros and Rodregues have small-scale tourism industries. In Comoros, tourism employs 600 people and in Rodregues 254 are employed, of which only five are employed directly in the dive industry. India supports a huge tourism market, although relative to the size of the country and its economy it is of lesser importance compared with some of the smaller island states. The reefs of India tend to be remote and difficult to access so reef-based tourism is limited. Sri Lanka has some reef based tourism, but has also many other attractions. There has been enormous overuse of certain areas, such as Hikkadua where over 90 glass bottom boats operate. Visitors to Reunion and Mayotte are generally friends and family of residents and those visitors that are genuine tourists are usually from France or, in the case of Mayotte, from Reunion.

Perhaps more importantly than the total arrivals, is the actual financial gain a country or region might receive from tourism. The World Travel and Tourism Council (1999) produce simulated forecasts of world tourism. In Maldives about 56% of the national economy is based on travel and tourism. For Mauritius the corresponding figure is 28%, and in Seychelles 21%. All these countries are small island states and most of this tourism will be all or partly based on the reefs. Those countries with lower revenue from travel and tourism depend heavily on industry for their national economies.

Two specific case studies were carried out to examine the financial and economic impacts of the coral bleaching on tourism. The first was conducted in Tanzania and Kenya and the second in Maldives and Sri Lanka. The following sections give a brief synthesis of these two studies.

ASSESSING THE IMPACTS OF CORAL BLEACHING ON TOURISM IN TANZANIA AND KENYA

One of the specific case studies initiated as part of the socio-economic assessment of the impacts of the coral bleaching within the CORDIO programme was carried out in Tanzania (Zanzibar) and Kenya (Mombasa). The aims of the research were to:

- establish whether tourists are familiar with coral bleaching;
- estimate the financial and economic cost of coral bleaching to tourism in Zanzibar and Kenya;
- compare the recreational value of the reef before and after the bleaching event.

Methods

This research is based on a questionnaire survey of tourist divers in Zanzibar and Mombasa. The economic analysis is based on the contingent valuation methodology (CVM). Financial costs are based on expenditure data given by the respondents. The questionnaire was initially developed for use in Zanzibar and Mafia Island, Tanzania and had been through pre-testing and a full survey (Andersson 1997). Although a few questions were omitted and a few added, it was not felt that it was necessary to pre-test the survey again. In Zanzibar, 199 divers were surveyed, the sample being split evenly between the two sites. Initially, in Mombasa, a total of 105 divers were interviewed. Surveys were carried out at the dive shops of Zanzibar and Mombasa.

Results

The divers visiting Mombasa were found to be on average older and more experienced divers than those in Zanzibar. However, the respondents in Zanzibar had a higher level of education than those in Mombasa. In Zanzibar, it was estimated that divers spent approximatley 42% of their vacation participating in reef related activities compared to 50% in Mombasa. The importance of the reef can be seen in the diver's ranking of the various attractions in figure 1 on next page.

DIVER AWARENESS OF CORAL BLEACHING

The study found that only a limited number of tourists surveyed at the two case study sites were actually aware of coral bleaching. In Zanzibar, this was 28% and in Mombasa this was 45% (figure 2 on next page). This low awareness could be related to their country of origin, level interest in the marine environment and dive experience. These links were explored but the sample size of

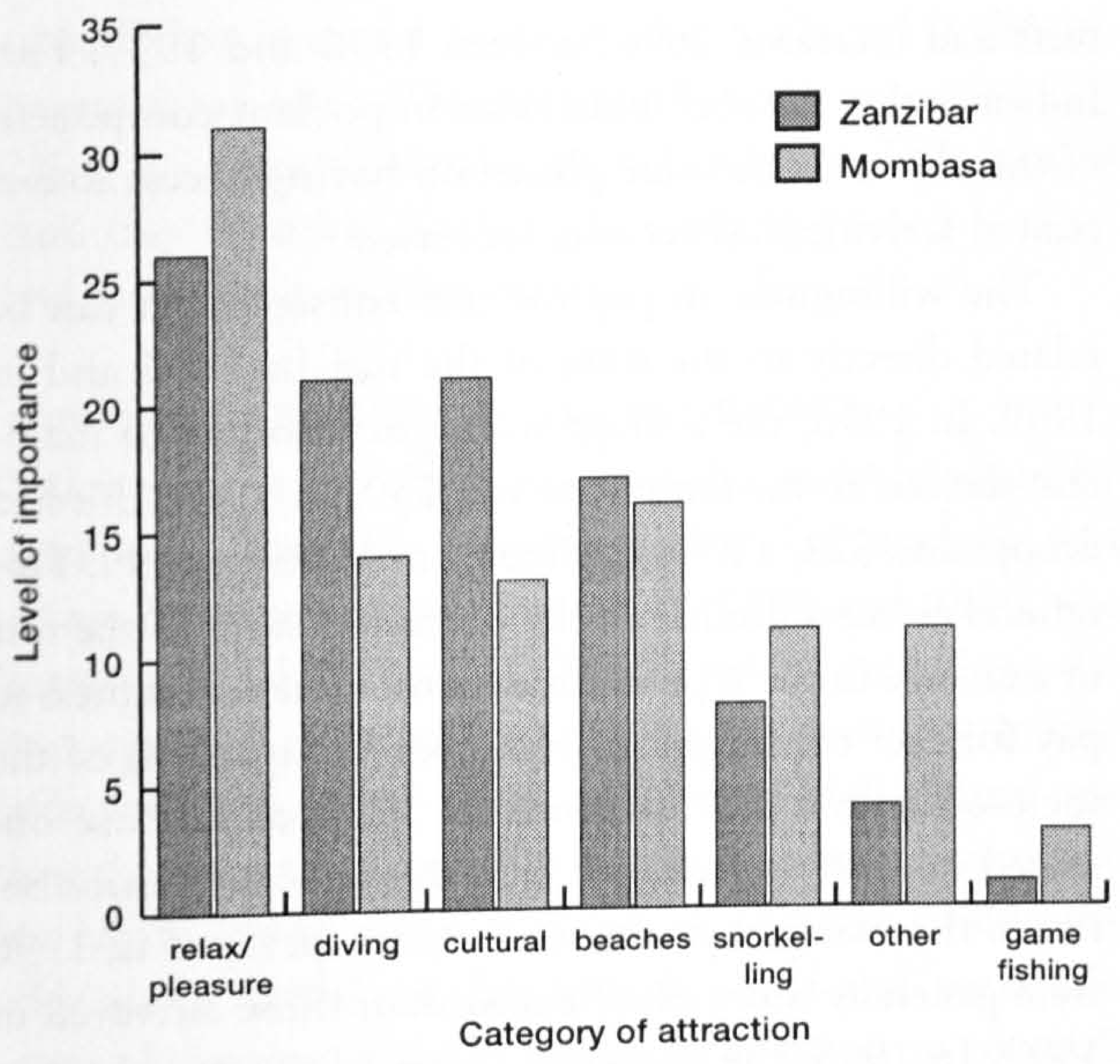


Figure 1. Ranking of the importance of the various attractions.

those aware of the bleaching was too small to make any significant conclusions. However, of those who were aware of the bleaching, over 80% stated that knowledge that an area was bleached would affect their decision to either visit that area or to dive and snorkel in that area (figure 2). This enabled estimations of the financial and economic costs of the coral bleaching to be made.

VALUATION OF THE REEF RESOURCES

In estimating the financial and economic costs of the coral bleaching, the survey techniques and the valuation methods developed by Andersson (1997) for the previous survey in Zanzibar were used. The financial cost of the bleaching are the losses to the local community and tourism economy resulting from those tourists deciding not to visit or simply not to dive in the locations because of the bleaching. This is calculated using the diver's and snorkeller's expenditure data collected during the survey. The economic cost of the bleaching represents the loss

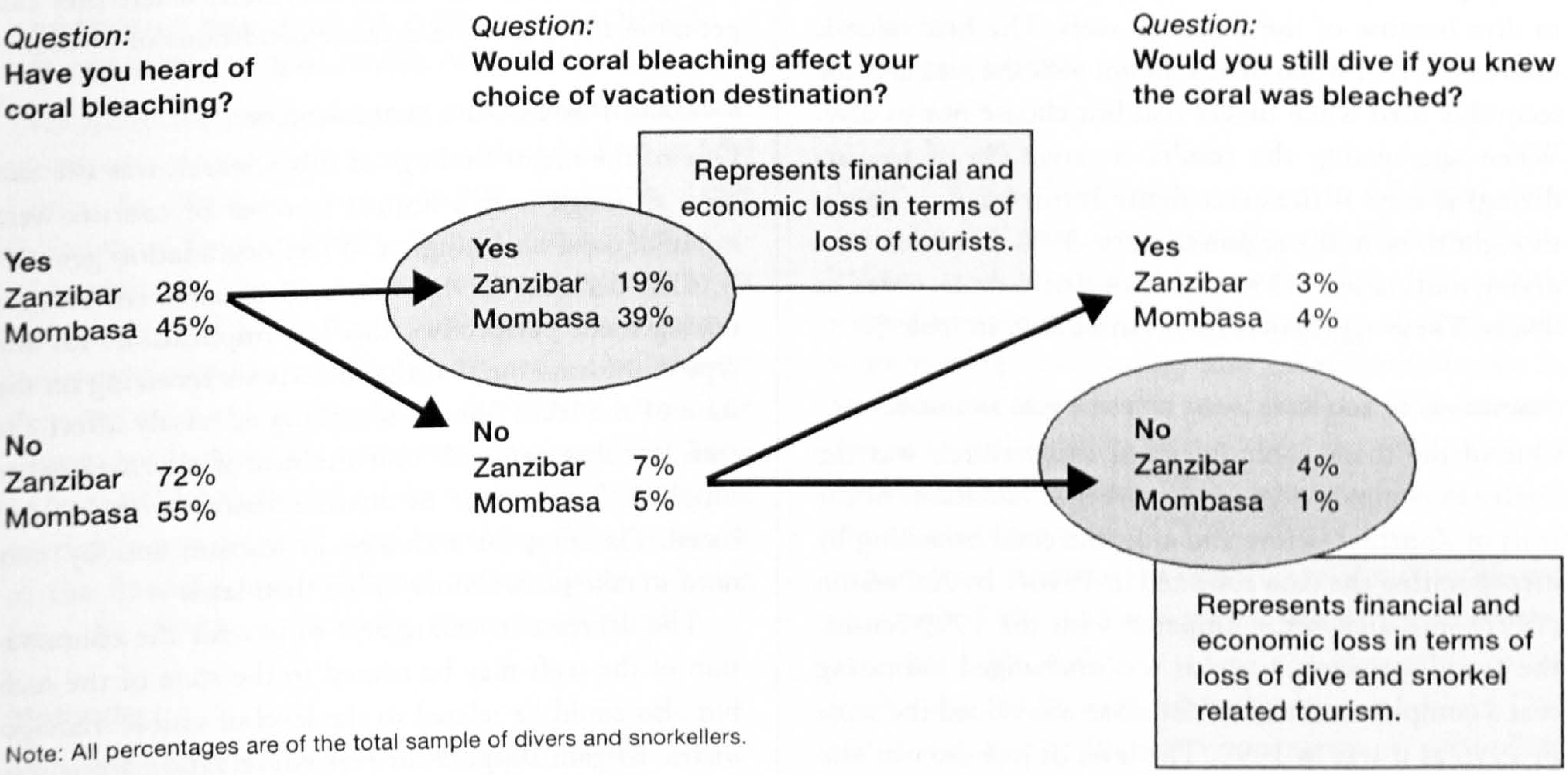


Figure 2. Responses to the questions regarding the knowledge of coral bleaching and its effect on choice of diving destination.

Table 3. Financial and economic cost of the coral bleaching on Zanzibar and Mombasa (range based on assumption that 20–30% of the tourists dive)

	Financial cost (million US$)	Economic cost (million US$)
Zanzibar	3.08– 4.62	1.88– 2.82
Mombasa	13.33–19.99	10.06–15.09

of value to the same group of tourists, either not visiting because of the bleaching, or visiting but not diving. This loss affects the divers and snorkellers for not having access to healthy reefs. The economic cost is calculated from the diver's and snorkeller's stated willingness to pay. There are two components to the willingness to pay. The first is the consumer surplus, which is the additional money the tourists would be prepared to pay to still visit the place. This reflects the value of the benefits they gain from recreation exceeding the total cost they have spent on visiting the place. The second is the willingness to accept compensation for the fact that they are unable to dive because of the degraded reefs. The first value is used as the cost when divers do not visit the area and the second is used when divers visit but choose not to dive. When aggregating the results, a range (% of tourists diving) is used if the exact figure is not known. This is thought to be in the region of 20%–30%. In Maldives, a diving destination, 45% of the tourists were recorded as divers. These aggregated costs can be seen in table 3.

COMPARISON OF ECONOMIC VALUE BETWEEN 1996 AND 1999

One of the main components of this research was the ability to compare diver and snorkeller valuations of the reefs of Zanzibar before and after the coral bleaching by incorporating the data collected in 1996/7 by Andersson (1997) into analyses. Compared with the 1999 results, the overall consumer surplus was unchanged indicating that a complete holiday to Zanzibar was valued the same in 1996 as it was in 1999. The level of reef use was also comparable. However, the willingness of the divers and snorkellers to accept compensation for non-access to the reefs had increased 20% between 1996 and 1999. This indicates that the reef remains an important component of the visit and the value placed on having access to reef related activities has actually increased.

The willingness to pay for reef conservation can be related directly to the state of the reef in 1996 and in 1999. In 1996, the average willingness to pay to maintain the reef in the same state was $30. In 1999, this had dropped to $22, a 27% decline from 1996 to 1999. This reflects either a decline in the perceived state of the reef or a change in the type of tourist and their willingness to pay for reef conservation. However, comparison of the socio-economic data obtained in 1996 with those obtained in 1999 determined that the only difference between the two groups was that divers surveyed in 1996 were generally more experienced than those surveyed in 1999. In 1996, the average number of dives each diver had completed was 83, compared with only 33 in 1999. This may be an indicator that the more experienced divers are aware of reef conditions and their decision has already been affected by stories of reef degradation or that these divers are travelling elsewhere, where they can get more adventure and extreme conditions of diving.

MANAGEMENT IMPLICATIONS OF THE RESULTS

One of the major findings of this research was the fact that, although only a limited number of tourists were aware of coral bleaching, or of reef degradation generally, their decision to visit may well be affected. From a management perspective, this has implications for the type of information that the tourists are receiving on the state of the reefs. Should bleaching adversely affect the reefs, tourists may still visit the area if alternatives are supplied. These may be marine based or even land based. Planning for a change in tourism activity may need to take place sooner rather than later.

The decrease in willingness to pay for the conservation of the reefs may be related to the state of the reefs but also could be related to the level of visible management. To gain support for reef conservation from visitors, management efforts need to be visible through public information, brochures, active rangers and patrols. What is useful from the data collected is the approximation of a willingness to pay being approximately 2%–3% of the total vacation expenditure. This type of data can be utilised when establishing protected areas and generating revenue through user fees.

LIMITATIONS OF THE STUDY AND FURTHER RESEARCH

There were several limitations of the study imposed by time and financial constraints. For full analysis and comparison of results obtained in 1996 and 1999, the survey needed to cover the higher-price hotels along the east coast also. In addition, Zanzibar was only mildly affected by the coral bleaching whereas Mafia Island was heavily affected. The 1996 survey was also carried out on Mafia Island and a re-survey of this area could provide some useful insights into financial and economic costs of the bleaching. Broadening the survey to cover all tourists both at home and abroad would also increase the understanding of tourist behaviour with respect to coral bleaching and reef degradation.

ASSESSING IMPACTS OF CORAL BLEACHING ON TOURISM IN MALDIVES AND SRI LANKA

This study focuses on impacts of coral bleaching and subsequent mortality on tourism in the Maldives and Sri Lanka. In Maldives, with 430,000 tourists in 1999 (Ministry of Tourism 2000), diving and other reef-related tourism are the main income generating activity in the country. Sri Lanka has a similar number of tourists but very few come specifically for reefs, even though they are attracted in general to the coastal areas. The current study addresses socio-economic questions related to coral bleaching and tourism primarily by recording tourists' perceptions of coral bleaching. Also, estimates of the financial and associated welfare losses resulting from the 1998 coral-bleaching event are provided.

Methods

This research was based on both questionnaire surveys and secondary data sources. Four different surveys were carried out:

(i) one for tourists departing from Male airport in Maldives and from coastal tourist locations in Sri Lanka;
(ii) one for key informants such as dive operators and glass bottom boat captains in Sri Lanka; and tour operators in Italy;
(iii) one for tourists at the airports of Amsterdam, Duesseldorf and Milan on their way to Maldives and Sri Lanka; and
(iv) dive tourists were asked via the internet about their knowledge of coral bleaching in Maldives and whether bleaching and coral mortality was a factor that influenced their decision to go there.

The secondary data sources were the official tourism statistics of the Maldives and Sri Lanka.

Results

INTEREST IN THE MARINE ENVIRONMENT

In Maldives, there seemed to be three main categories of tourists:
(i) divers;
(ii) honeymooners; and
(iii) 'relaxers'.

Around 45% of all tourists going to Maldives were divers. In Sri Lanka, only approximately 8% were divers. Italians tend to visit Maldives for their honeymoon while Germans go to dive. The number of dives made while visiting each country also varied considerably. In Sri Lanka, of the 8% that went to dive, 50% did only one or two dives while in the Maldives, 69% of divers did more than five dives. With respect to their interest in the marine environment, 52% of the tourists at Male airport responded that the importance of marine life was very high, 34% answered that is was rather important and only 13% said that it was not important. In Sri Lanka, the results were quite the opposite. Only 18% stated that marine life was very important, while 32% and 51% said that marine life was rather important and not important respectively.

DIVERS' AND SNORKELLERS' KNOWLEDGE OF CORAL BLEACHING

The media coverage of the coral bleaching episode of 1998 has been substantial. Dive journals have given considerable attention to the bleaching event and to reactions of divers. Yet, interviews at the European airports showed that many tourists on their way to Maldives did not know of the episode. Fifty percent of Germans surveyed had heard of the coral bleaching event in Maldives, compared with 30% of the Italians and 16% of the Dutch. This can be explained partly by the exceptionally large media coverage in Germany and by the large percentage of divers among German tourists. At Male airport, 68% of departing tourists had heard of coral bleaching, while in Sri Lanka, less than one third knew of this problem.

LOSSES IN TOURISM REVENUES IN MALDIVES

Possible losses to Maldives' economy were analysed based on the official tourism statistics up to December 1999. The statistics showing the tourist arrivals since 1972 show a steady increase from only a few thousand arrivals in the 1970-ies to over 400,000 in 1999. Surprisingly, there was not a significant drop in tourist arrivals in 1998–1999. In fact, tourism arrivals have increased 8% in both 1998 and 1999.

However, trends in bed occupancy rates since 1975 shows a slight but significant drop from 1998 to 1999. Given the time lag between the planning phase of expansion and the additional bed capacity, occupancy rates give a proxy for expected growth in tourism and the decrease in 1998/9 was substantial. However, the Asian crisis was also affecting tourist numbers. Another way of looking at expected growth of tourism arrivals is to check the official government tourism forecasts. In 1997, an annual growth of 10% was expected for the years of 1998 and 1999 (Ministry of Tourism, 1997), which was 2% higher than the realised figures. Here, we assume that half of this difference was due to coral bleaching.

WELFARE LOSSES FROM DIVERS

Besides financial losses to the local economies, coral bleaching can also affect tourists' holiday satisfaction and thereby create a loss in their welfare. In order to calculate these welfare losses, the surveys at Male airport focused on tourists' willingness to pay for 'better reef quality'. In order to ensure the tourists value the same change in reef conditions, two pictures were shown, one of a reef that had completely died because of bleaching and another that was still intact. The question asked of tourists was how much extra were they willing to pay to go to hypothetical remote areas in Maldives where reefs were not affected by coral bleaching and which were, in all other respects, the same. The answers show the distribution of this willingness to pay (WTP) and illustrates that the tourists surveyed were willing to pay an average of US$ 87 more to visit these hypothetical reefs. The data recorded here are from the second questionnaire in the Maldives only, where the pictures shown were more representative than in the first round of questionnaires.

Table 4. Losses in tourism revenues and welfare in the Maldives and Sri Lanka 1998–99.

	Financial costs (million US$)	Economic costs (million US$)
Maldives	3	19
Sri Lanka	0,2	2,2

The aggregated losses can be seen in table 4.

Finally, tourists were asked about the most disappointing part of their Maldives holiday. The possible answers were:

(i) the price of food and beverages;
(ii) the weather (humidity, clouds, etc.);
(iii) the fact that a lot of the corals were dead; (iv) the mosquitoes;
(v) the resort accommodation;
(iv) others.

Figure 3 (on next page) summarises the responses, showing that 37% considered the dead corals the most disappointing experience, while the price of food and beverages was also 37%.

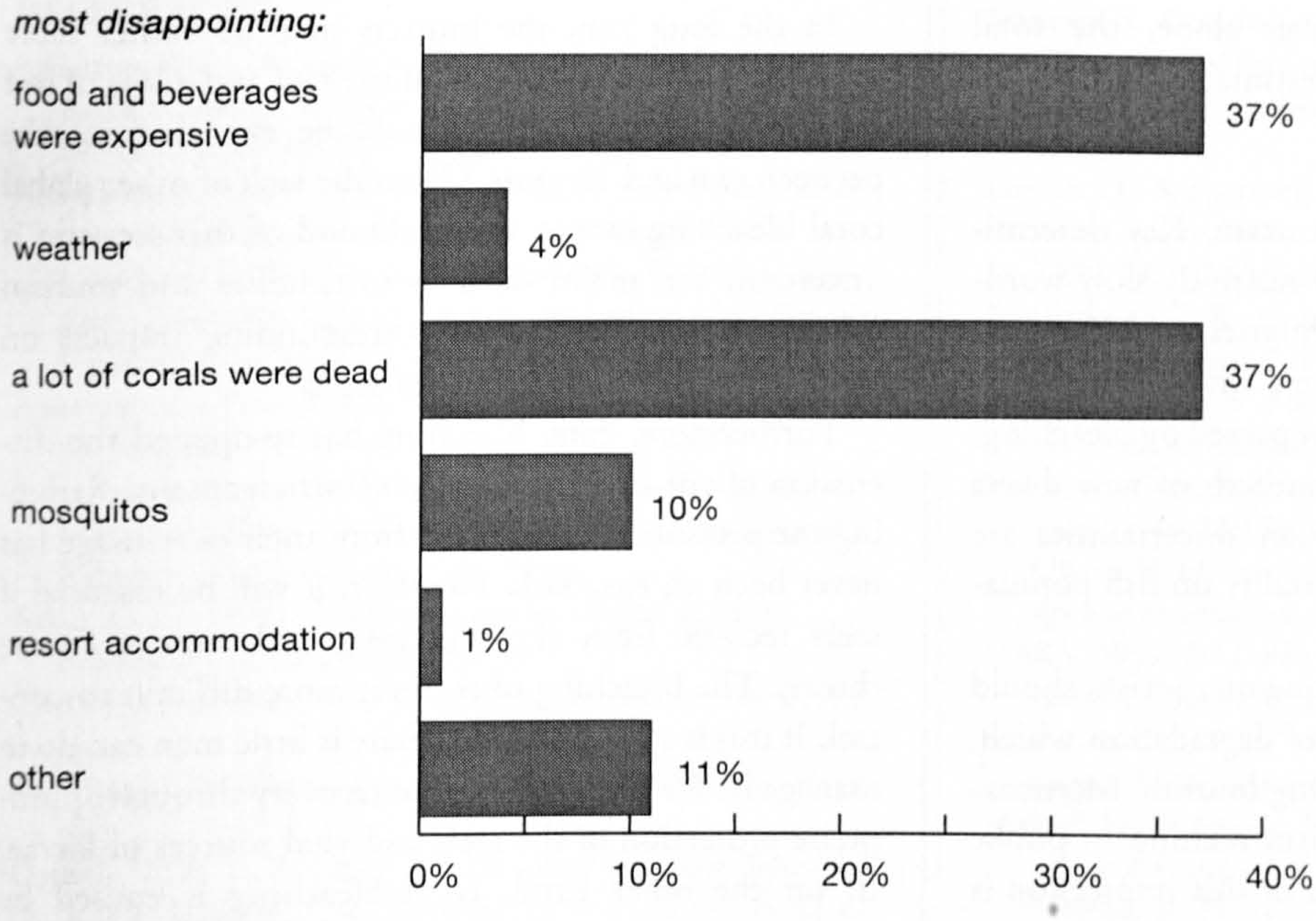


Figure 3. Answers of questions regarding the most disappointing part of the Maldives holidays.

This last result is interesting, because nearly all resorts are based on half or full board, so that the actual amount of money spent on additional food and beverages is quite low, though beer is expensive at around US$ 5 per bottle. The interesting aspect of these responses is that they allow us to compare and therefore scale the WTP values. Surprisingly, the average WTP for better reef quality was not statistically different for those who found coral mortality most disappointing and those who found other parts of their holiday most disappointing. Note that one could buy quite a large number of bottles of beer for the average WTP for improved corals, which might either suggest an inconsistency in the way people respond to the various questions or alternatively, there are quite a few very hefty drinkers among the tourists. Unfortunately, it might also mean that many tourists do not really care about the death of coral reefs.

ASSESSING THE FUTURE TOURISM IMPACTS

The two case studies show a number of interesting similarities as well as differences.

- Awareness of the 1998 coral bleaching event among tourists going to destinations with coral reefs is generally rather limited.
- Current losses in tourism revenue due to the coral bleaching event have, so far, been rather low. In Maldives, it is estimated that only US$ 3 million was lost during 1998 and 1999 combined. In Mombasa, the losses were estimated to be much higher (US$ 13–20 million), but these were hypothetical losses assuming permanent disappearance of tourists.
- A key determinant of losses in tourism revenues was the ability to attract other types of tourists who, despite being interested in coral reefs and reef based activities, were not interested only in diving. This flexibility could help explain the lower losses in Maldives compared with Zanzibar and Mombasa.
- Divers seemed willing to pay considerable sums for

better reef quality. In Maldives alone, the total welfare loss for 1998/99 was estimated at US$ 19 million.

Future tourism losses remain uncertain. Key determinants are the long-term impact of relatively slow word-of-mouth reports or TV documentaries on bleaching. Despite the loss of some avid divers who appear to be going to areas that have not been impacted by bleaching, they are easily replaced by the hundreds of new divers that appear on the market. The key uncertainties are related to the impacts of coral mortality on fish populations and on beach erosion.

The impacts of the coral bleaching on tourism should be seen in the wider picture of reef degradation which, in itself, is not the only issue affecting tourism. Mombasa has seen a huge decrease in tourism relating to public opinion on personal safety. Much of this impression is created in national newspapers indicating the power of the media in altering public perception.

A further aspect of analysing the impacts of events such as the bleaching is to look carefully at who is being impacted. The tourist has a variety of alternative locations and may not be affected, whereas the local dive guide may be unemployed as the dive industry adjusts or is impacted.

DISCUSSION

The 1998 El Niño event has so far not affected socio-economic indicators dramatically. Reef fisheries in many areas in the region have been showing a general decline over the last decade and data collected can not yet tell what the added negative impact of coral bleaching is. On the other hand, diving tourism has been growing rapidly all over the world (except in East Africa). Again, the added influence of coral bleaching on these trends is uncertain. Tourism studies show however, considerable financial costs ranging between US$ 3.1 and US$ 4.6 million in Zanzibar and US$ 13.3 and US$ 20.0 million in Mombasa. In Maldives, financial costs were estimated at US$ 3.0 million, while economic costs over the last two years were roughly US$ 63 million.

In the long run, the impacts may be rather more dramatic if increased erosion of the reef and a loss of reef complexity occurs, which would be expected to take between two and 10 years. Given the lack of other global coral bleaching events, the likelihood of this scenario is uncertain. Yet, major declines in fisheries and tourism can not be excluded, with corresponding impacts on marginal populations in coastal areas.

Furthermore, coral bleaching has re-opened the discussion about effective coral reef management. Reducing the pressure on coral reefs from their over-usage has never been an easy task. However, it will be essential if reefs recover from the bleaching and survive future threats. The bleaching of corals is more difficult to control. If this is a natural event, there is little man can do to manage it. We can only assist in recovery through appropriate protection of the reefs and vital sources of larvae. If, on the other hand, coral bleaching is caused by world-wide pollution and the consequences of climate change and global warming, it will take a massive global effort to reduce impacts in the future.

If continued coral reef degradation is going to be a widespread phenomenon in the Indian Ocean, the following questions need answering:

- To what extent will reef fish stocks be affected?
- Will a decline in reef fisheries or change in population composition affect pelagic fisheries?
- Will reef based tourism be replaced by other forms of tourism?
- What will happen to the Marine Protected Areas dependent on tourists visiting the reefs for their income?
- Can we maintain the tourism industry and utilise the tourism market for basic monitoring of reef fish and habitats?
- What are the links between reef usage and the bleaching?

REFERENCES

Anderson, R. C., Waheed, Z., Rasheed, M., & Arif, A., (1992) *Reef fish resources survey in the Maldives — Phase II.* BOBP/WP/80 – MDV/88/007. 54 pp.

Andersson, J., (1997) "The value of coral reef for the current and potential tourism industry on Unguja Island, Zanzibar". In: Johnstone, R. W., Francis, J., & Mohando, C., (eds.) *Coral Reefs: Values, Threats and Solutions. Proceedings of the National Conference on Coral Reefs, Zanzibar, Tanzania.* pp. 82–90.

Anonymous. 1998a. *Fisheries in Maldives 1983–1997. A descriptive analysis.*

Anonymous. 1998b. *Basic Fisheries Statistics Jan–Dec 1998.* Economic planning and co-ordination section, Ministry of Fisheries and Agriculture, Male. 18 pp.

Bakus, G. J., (1994) *Coral reef ecosystems.* Oxford & IBH Publishing Co. New Delhi. 232 pp.

CMFRI (1980) *Marine Fisheries Information Service,* No. 22. 22 pp.

CMFRI (1995) *Marine Fisheries Information Service,* No 136. 31 pp.

Darwall, W. R. T., & Guard, M., (in press) "Southern Tanzania". In: McClanahan, T. R., Sheppard, C. R. C., & Obura, D. O., (eds.) *Coral reefs of the Indian Ocean: their ecology and conservation.* Oxford University Press. pp. 131–166

Dayaratne, P., Lindén, O., & De Silva, M. W. R., (1995) "Puttalam Lagoon and Mundal Lake, Sri Lanka: A study of coastal resources, their utilization, environmental issues and management options". *Ambio* Vol. 24 No. 7–8.

Devaraj, M., (1997) *Status of research in marine fisheries and mariculture — Role of CMFRI.* CMFRI special report No. 67. 39 pp.

DOD & SAC (1997) *Coral reefs of the Indian Coast.* SAC/RSA/RSAG/DOD-COS/SN/16/97 report. Space Application Centre Ahmedabad India. 54 pp.

Food and Agriculture Organisation (FAO) (1999a) FAOSTAT online database. www.fao.org

Food and Agriculture Organisation (FAO) (1999b) *Number of Fishers 1970–1996.* United Nations, Rome. 124 pp.

Glynn, P. W., Imai, R., Sakai, K., Nakano, Y., & Yamazato, K., (1993) "Experimental responses of Okinawan (Ryukyu Islands, Japan) reef corals to high temperature and UV radiation". *Proc. 7th Int. Coral Reef Symp.* 1: 27.

Goreau, T. J., & Hayes, R. L., (1994) "Coral bleaching and ocean 'Hot Spots'". *Ambio* 23: 176–180.

Hoegh-Guldberg, O., (1999) "Climate change, coral bleaching and the future of the world's coral reefs". *Mar. Fresh. Res.* 50: 839–866.

James, P. S. B. R., Parameswaran Pillai, P., & Jayaprakesh, A. A., (1984) "Some observations on the fisheries of Lakshadweep". *CFRMI Bulletin* 43: 25–32.

Jennings, S., Grandcourt, E. M., & Polunin, N. V. C., (1995) "The effects of fishing on the diversity, biomass and trophic structure of seychelles' reef fish communities". *Coral reefs* 14: 225–235.

Lindén, O., & Sporrong, N., (eds.) 1999. *Coral reef degradation on the Indian Ocean. Status reports and project presentations 1999.* CORDIO, Stockholm, Sweden. 108p.

McClanahan, T. R., (in press) "Coral reef use and conservation". In: McClanahan, T. R., Sheppard, C. R. C., & Obura, D. O. (eds.) *Coral reefs of the Indian Ocean: their ecology and conservation.* Oxford University Press. 526 pp.

Naim, O., Cuet, P., & Mangar, V., (in press) "The Mascarene Island"s. In: McClanahan, T. R., Sheppard, C. R. C. & Obura, D. O. (eds.) *Coral reefs of the Indian Ocean: their ecology and conservation.* Oxford University Press. pp. 353–381.

NARA (1999) *Sri Lanka Fisheries Yearbook 1998.* NARA Crow island Colombo, Sri Lanka, 57 pp.

Semesi, A. K., (1998) "Mangrove management and utilisation in eastern Africa". *Ambio* 27: 620–626.

Shakeel, H., & Ahmed, H., (1997) "Exploitation of reef resources: grouper and other food fishes". In: Nickerson, D. J. & Maniku, M. H., (eds.) *Proceedings of the workshop on integrated reef resources management in the Maldives.* BOBP/REP/76. pp. 117–135.

Souter, D., Obura, D., & Lindén, O. (2000) *Coral Reef Degradation in the Indian ocean.* CORDIO 2nd Status Report.

United Nations Development Programme (UNDP) (1998). *Human Development Indicators, 1998.* UNDP, Nairobi. 262 pp.

Warner, M., & Fitt, W. K., (1991) "Mechanisms of bleaching of zooxanthellate symbioses". *Am. Zool.* 31 (5): 28A.

Westmacott, S., Cesar, H., Pet-Soede, L., & de Schutter, J., (2000) *Assessing the socio-economic impacts of the coral reef bleaching in the Indian Ocean.* A report to the World Bank African Environment Department. Draft.

Wilkinson, C. R., (ed.) (1998) *Status of coral reefs of the world: 1998.* Australian Institute of Marine Science and Global Coral Reef Monitoring Network, Townsville, Australia.

Wilkinson, C. R., Lindén, O., Cesar, H. S. J., Hodgson, G., Rubens, J., & Strong, A. E., (1999) "Ecological and socio-economic impacts of the 1998 coral mortality in the Indian Ocean: An Enso impact and a warning of future change?". *Ambio* 28: 188–196.

World Travel and Tourism Council (1999) *1999 Travel and Tourism Satellite Accounting Research Estimates and Forecasts.* WTTC.

Young, S. K. T., (1989) "Coastal resources management in the ASEAN region: Problems and directions". In: Chua, T.-E., & Pauly, D., (eds) *Coastal Area Management in Southeast Asia: Policies, Management Strategies and Case Studies.* ICLARM Contribution No. 543 xi.

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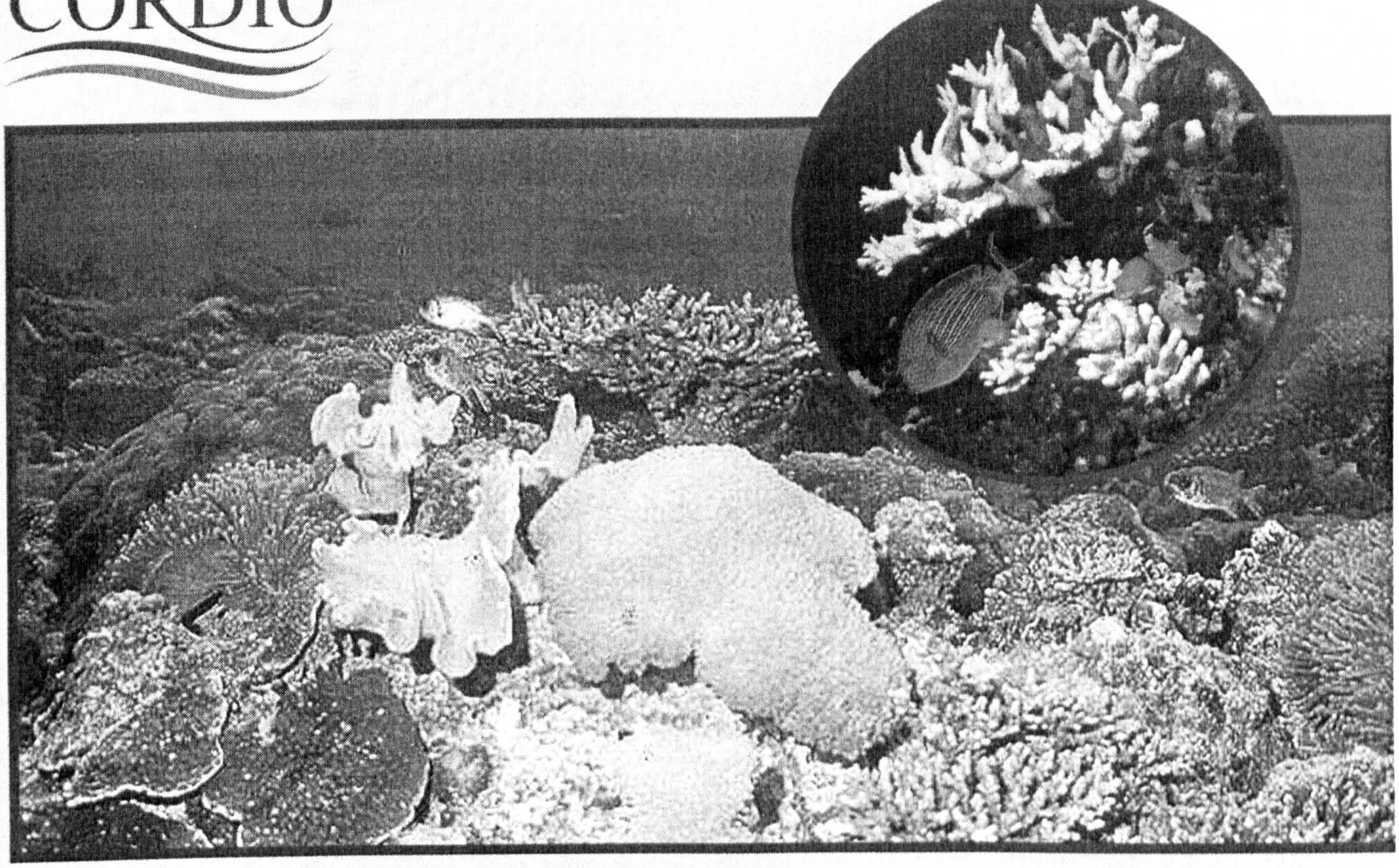

Coral reef degradation in the Indian Ocean

Status report 2000

EDITORS: DAVID SOUTER, DAVID OBURA AND OLOF LINDÉN

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MISTRA

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Socio-economic assessment of the impacts of the 1998 coral reef bleaching in the Indian Ocean: A summary

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INTRODUCTION

Coral reefs are a vital resource to many areas of the Indian Ocean. Coastal populations are continuously increasing (Table 1) and relying on this resource as the basis of the economy. Across the region, the two common socio-economic reef based activities are fisheries and tourism. For local subsistence fishermen, reef fisheries often represent their only livelihood. Degradation of coral reefs will first impact the reef fishery and subsequently, the local fishing community. Tourism also is often heavily dependent on coral reefs as the main attraction.

The countries of the Indian Ocean vary both physically and socio-economically (Table 1). The size of a country, the area of coral reefs, the coastal population utilising the reefs and the wealth of the country are all

Table 1 Physical and socio-economic indicators of each country participating in CORDIO.

Country	Length of coastline Km	Coastal pop density est 2000	Population growth rate (% 1997-2015)	Real 1997 GDP/ cap (PPP$)
India	7516	811	1.3	1670
Madagascar	4000	130	2.6	930
Mozambique	2500	351	1.8	740
Sri Lanka	1739	344	1	2490
Tanzania	800	412	2.3	580
Maldives	644	1648	2.6	3690
Seychelles	600	281	1	8171
Kenya	500	250	1.6	1190
Comoros	350	878	2.5	1530
Mauritius	200	697	0.8	9310
Mayotte	185	1177	—	—
Reunion	160	326	1.3	—
Rodregues	37	—	—	—

Sources: Delft Hydraulics, 1993; Gaudian, *et al.*, 1998; National Aquatic Resources Research and Development Agency, 1998; Semesi, 1998; United Nations Development Programme, 1998; Central Intelligence Agency, 1999; Linden & Sporrong, 1999; Mirault, 1999.

indicators of pressure and dependence on reef resources and their ability to cope with impacts such as coral bleaching. CORDIO was initiated in response to degradation of coral reefs caused by the 1998 coral bleaching event. However, other factors, such as rapidly expanding coastal populations or poor planning and management, may also cause reef degradation. Recently, Bryant *et al.* (1998) estimated that 9 000 km^2 of coral reef in the Indian Ocean were at high risk, 10 500 km^2 at medium risk and 16 600 km^2 at low risk of degradation from coastal development, marine based pollution, overexploitation of marine resources and inland pollution, including sedimentation. Within the CORDIO countries, the level of risk of reef degradation ranges from low in areas like the Chagos archipelago where there is negligible human activity, to high in areas such as Comoros and Mayotte where high population growth rates are exerting increasing pressure on these reefs (Figure 1).

This report is a summary of the complete project report assessing the socio-economic impacts of the coral bleaching in the Indian Ocean (Westmacott *et al.*, 2000) and presents the main approaches adopted to determine the importance of fisheries, particularly reef fisheries, and reef based tourism to countries and local communities in this region. Also, this report presents the results of specific case studies of the reef fishery of Kenya and of the tourism sectors of Maldives, Sri Lanka, Tanzania and Kenya. In addition, the assessment also highlights the need to account for other threats to coral reefs and the capacity to manage these resources.

POTENTIAL IMPACTS OF CORAL BLEACHING ON REEF FISHERIES

The effects of coral bleaching on reef fisheries are likely to be observed in the long-term through changes in the habitat complexity. Although controversy surrounds the proposed mechanisms by which reef fish communities are structured (Richards & Lindeman, 1987; Sale, 1991; Sadovy, 1996), it is generally thought that three ecological processes are involved. First, competition for food and space determines fish diversity and density (Robertson & Gaines, 1986). Second, patterns of recruitment of juveniles determine adult fish community structures (Eckert, 1984; 1987; Medley *et al.*, 1993; Lewis, 1997). Third, predation determines patterns of survival and consequently, the density of adult fish (Eggleston, 1995). The structural complexity of a reef habitat influences all three of these ecological processes (Figure 2). The reef provides niches for various species to coexist on a coral reef, suitable substrate for reproductive activities and larval settlement (Roberts, 1996) and also shelter for fish

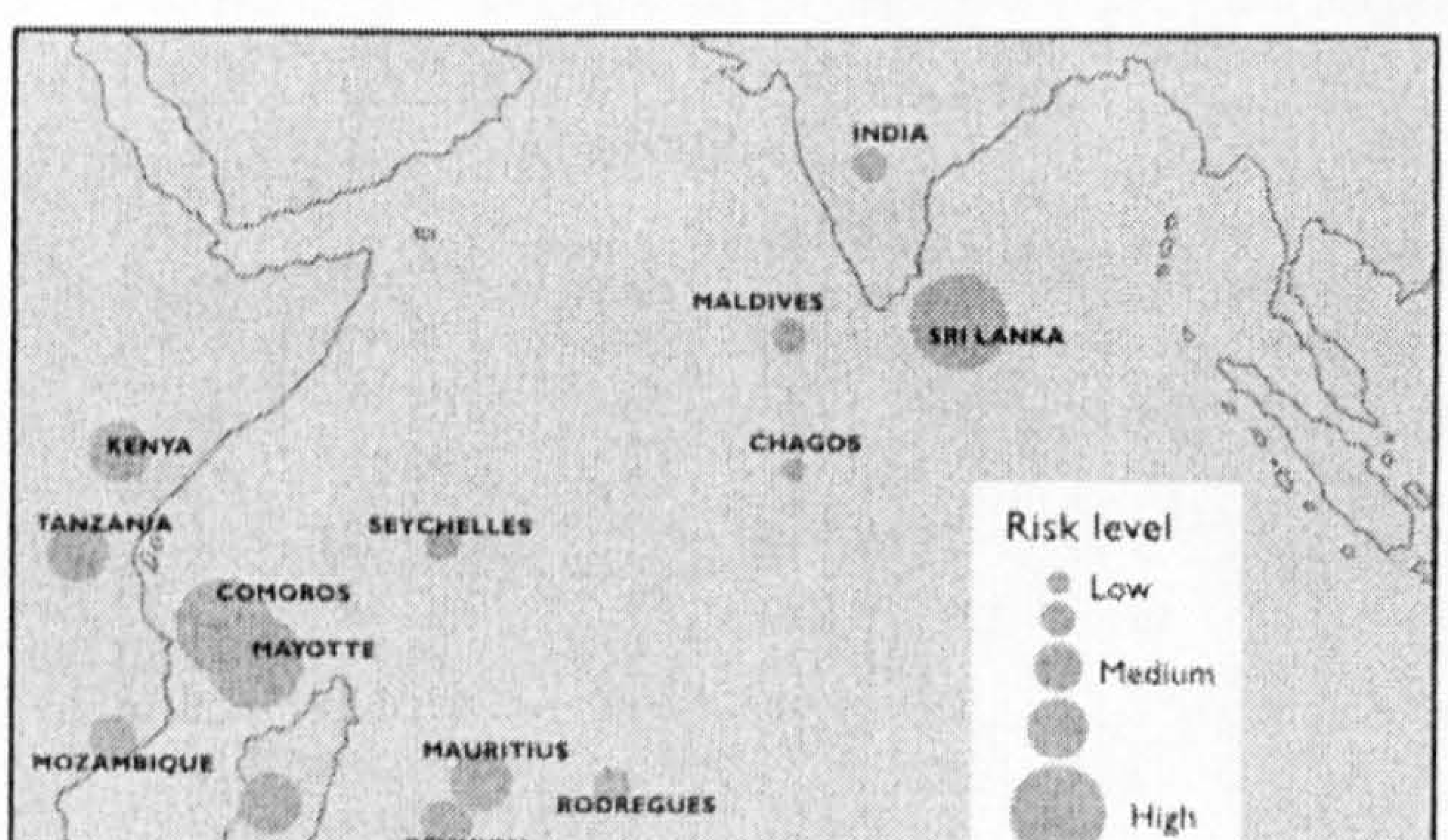

Figure 1. Level of risk to reefs from coastal and marine activities in the Indian Ocean.

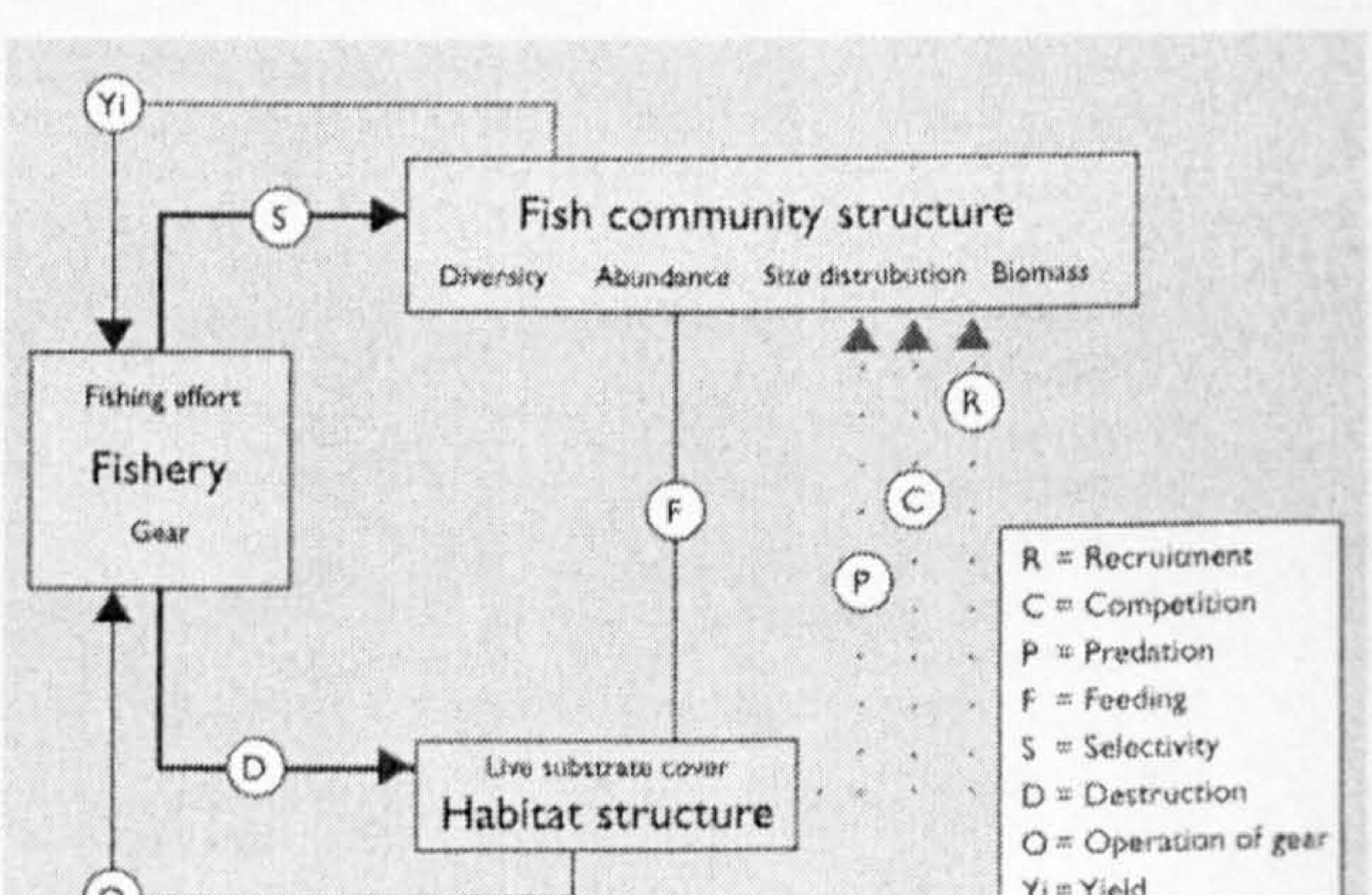

Figure 2. Relationships between the reef habitat, the fish community structure and the fishery.

to escape predation (Williams, 1991; Polunin, 1996). Population structure, species diversity, density and biomass of the fish community can be related to the state of the coral reef which can be measured using various parameters (e.g. rugosity, live coral cover, algal cover) (McClanahan, 1994).

The way reef habitats affect a coastal zone fishery takes three forms. First, maximum yields are limited by the status of the habitat through habitat-fish interactions as described above. Second, the characteristics of a reef habitat (e.g. high coral cover, sandy lagoon floor) and the risk of damage to gear they pose will determine the type of gear used and, to a degree, the species of fish caught. Third, the spatial distribution of physical features that are perceived by fisherman to be attractive to their target species, such as large coral heads or converging currents, will determine the areas in which fishing effort is concentrated.

In a fishery that is entirely dependent on reef fish, catch rates may decrease and the catch composition may shift more towards the herbivorous species. These fish are often lower in value so, as a result, the economic position of fishers may deteriorate. Fisher communities that live on islands with few alternative sources of income will have difficulty sustaining their livelihoods. A fishery that targets large predatory pelagic species that forage on reef fish may also experience lower catches when these fish are forced to move to other less destroyed areas to hunt for prey. A fishery that targets small pelagic species that occupy a reef area or lagoon during certain phases of their life cycle may also experience lower catches when reefs disappear.

METHODS

Fishery assessment

A study of the effects of coral bleaching and mortality on reef or coastal zone fish resources preferably includes historic data (Type I) and spatial data (Type II) enabling:

- An assessment of the qualitative and quantitative impact on the perspective of the total fishery performance – nation-wide.
- An assessment of the social/economic impact based on cases – coastal provinces/districts.
- Predictions of future developments in social/economic conditions of fishers, in response to the event based on past trends in the fishery performance.

Official marine fisheries statistics (Type I) were used to characterise the importance of reef fisheries in each country. Although the quality of official fisheries statistics is often weak, usually they remain the only information used by policymakers to assess the status of a country's fisheries. However, an analysis of data that were available previously and of those that were collected by contributors from each country in the region identifies weaknesses in the information needed to assess the importance of reef fisheries on both a nation-wide and region-wide scale. Information describing resource utilisation and fishery performance (Type II) was collected during a case study of the reef fishery of Kenya. This information, when combined with Type I data, enables an economic valuation of a reef fishery that includes both a financial analysis at the individual household level and, where possible, an economic analysis at the society level (Cesar & Pet-Soede, in prep).

RESULTS

Trends in marine fisheries in the Indian Ocean

Developments in the national demography and social-economy of most countries in the Indian Ocean suggest a continuously increasing pressure on fish resources (McClanahan, in press). In some countries, total fish production is declining (Table 2). Most of the catch from coastal fisheries is used for local consumption, as it is the most affordable source of protein (FAO, 1999b). Shrimp and tuna are the main export commodities. In most countries, fishing gears used in coastal areas include traps, spears, gillnets, seine nets, hook and line, and cast nets.

The large number of small fishing vessels from which the millions of Indian Ocean fishers operate makes monitoring of stock status and implementation

Table 2. Marine fisheries catch in 1997 (tons).

Country	Marine Fish	Crustaceans	Molluscs	Trend since 1990 (%)
India	2,455,947	298,313	121,896	+28
Sri Lanka	208,350	11,000	300	+58
Maldives	107,087	—	271	+35
Madagascar	71,596	14,622	850	?
Tanzania	45,530	2,500	653	-29
Mozambique	14,500	12,906	659	-53
Mauritius	13,397	40	309	+16
Comoros	12,480	20	—	+8
Reunion	5,581	301	—	+213
Kenya	4,382	950	726	-54
Seychelles	4,052	604	19	-27

Source: (Food and Agriculture Organisation, 1999a)

of fisheries management measures difficult (Table 3). Methods used to sample marine fisheries and the way the collected information is processed and presented in reports differs greatly between countries. Little regulation of fishing effort exists, except in a number of marine protected areas around the region and a closed season for the large net fishery off Mauritius.

The number of fishers may be small compared to the number of people engaged in other economic activities (Table 3). These fishers often have few other opportunities to make a living and the fish they catch is a vital source of protein. These factors make it relevant to study trends in fish catches to prepare for alternatives if capture fisheries collapse.

The importance of reef fisheries in the Indian Ocean

The percentage of the demersal fish landings compared to the total fish landings can be seen in table 4. However, when discussing the importance of reef fisheries per country, it is important to distinguish between its importance in providing food, foreign currency and em-

Table 3. Number of marine fishers in each country.

Country	Fishers (number)	Relative importance in Agriculture employment (%)	Full time (%)	Survey
India	5,958,744	2.3	40	1994
Sri Lanka	83,776	2.7	100	1996
Madagascar	67,566	1.3	69	1996
Kenya	43,488	0.4	?	1994
Maldives	22,109	78.6	100	1996
Mozambique	18,000	0.3	100	1990
Tanzania	12,564	0.7	100	1996
Mauritius	10,713	14.3	49	1996
Comoros	9,000	4.4	44	1994
Seychelles	1,960	—	100	1996
Reunion	500	3.3	100	1990

Source: (Food and Agriculture Organisation, 1999b)

Table 4 Demersal fish landings in 1996 per country in the Indian Ocean sorted by relative contribution to total marine landings.

Country	Demersal landings (tons)	Importance in total marine landings (%)	Trend in importance of demersal landings
Reunion	2,970	68	+/-
Mauritius	8,664	52	+
Tanzania	18,939	49	+
Seychelles	1,704	39	+/-
Kenya	1,349	34	+/-
India	805,408	33	+/-
Sri Lanka	36,922	18	+/-
Mozambique	165	17	+[1]
Maldives	11,856	11	+
Comores	na	na	na

Source: (Food and Agriculture Organisation, 1999a)

ployment (Table 5). A short description of the fisheries of each region within the central and western Indian Ocean is presented.

South Asia

In India, the relative contribution of the reef fishery to both earnings and total fish landings (1 790 702 tons in 1993) is low. This did increase from 1% in the early 1970's to 5% in the early 1990's. The importance of other demersal fish remained stable at 32% throughout the entire period (Figure 3) (CMFRI, 1980; 1995). This low importance is caused by the fact that most reefs are found in lightly populated regions such as the Andaman and Nicobar Islands (DOD & SAC, 1997; Bakus, 1994). In addition, there is a high demand for large pelagic fish, such as mackerel and tuna, at both domestic and export markets ensuring that the fishery in large reef areas, such as Lakshadweep, focuses on catching these large pelagics instead of demersal reef species (James *et al.*, 1984; Bakus, 1994). On the mainland, most of India's coastal fishers make their living from either the pelagic fisheries, the prawn trawl fishery or from small-scale

Table 5. Importance of marine and demersal fisheries in providing food (kg of fish), employment (part of overall population) and foreign earnings to Indian Ocean countries. ++++Very high; +++high; ++medium; +low.

	Food		Employment		US$	Other
Country	Marine	Demersal	Marine	Demersal		
India	++++	++++	+++	++	+	
Madagascar	+++	++++	++	+	+++	
Sri Lanka	+++	+++	+	+	-/+	Import equals export
Tanzania	++	+++		+++		
Kenya	+	++	+	+++		
Mauritius	++	++	+	++	++	Foreign fish licenses
Seychelles	+	++	+	++	+++	
Mozambique	++	+				
Maldives	+++		+++	+	+++	Baitfish supports tuna
Comores	++		+	+++		
Rodregues	+		+	+++	+	

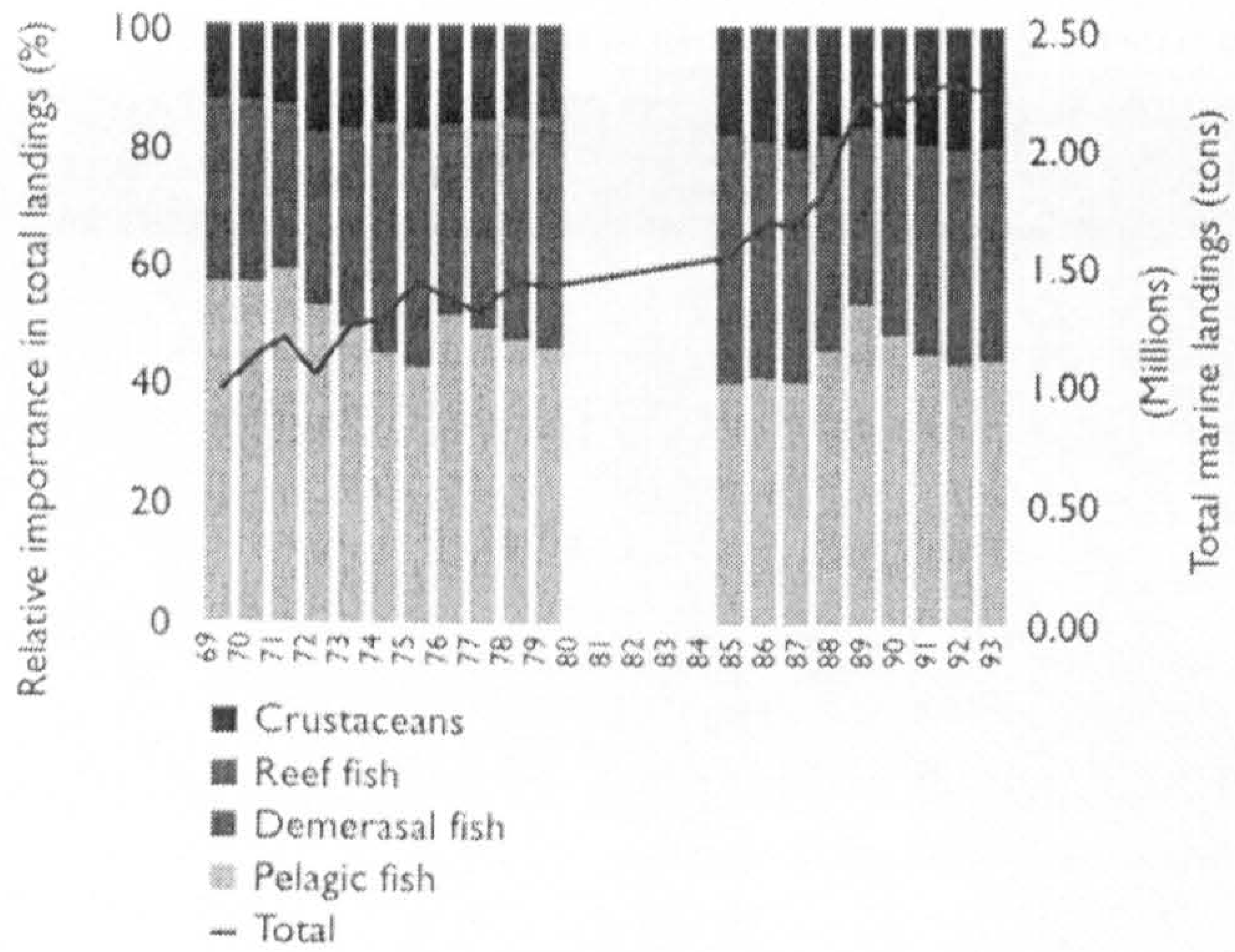

Figure 3. Trends in landings and composition of landings in India.

demersal fisheries using beach seines. However, this is likely to change as a result of increasing demand (foreign markets) for high quality reef fish such as grouper and snapper and because of declining catch rates resulting from over-capitalisation and exploitation of coastal shelf areas (Devaraj, 1997).

The reef fishery in Sri Lanka provides an important part of the fish consumed in the country. The demersal fishery does not provide employment to a large portion of the population. The coastal fish production is highly variable but increased five fold from 36 865 tons in 1951 to 157 500 tons in 1995 with highest production in 1982/83 of approximately180 000 tons (Figure 4). Coastal fisheries contributed almost 90% to the nations total fish production in the early 1970's but this importance decreased to 65% in 1996 with increasing importance of offshore fish landings of some 25% in 1996. Inland fish production was relatively important (18% - 19%) in the mid 1980's but decreased to approximately 9% in 1996.

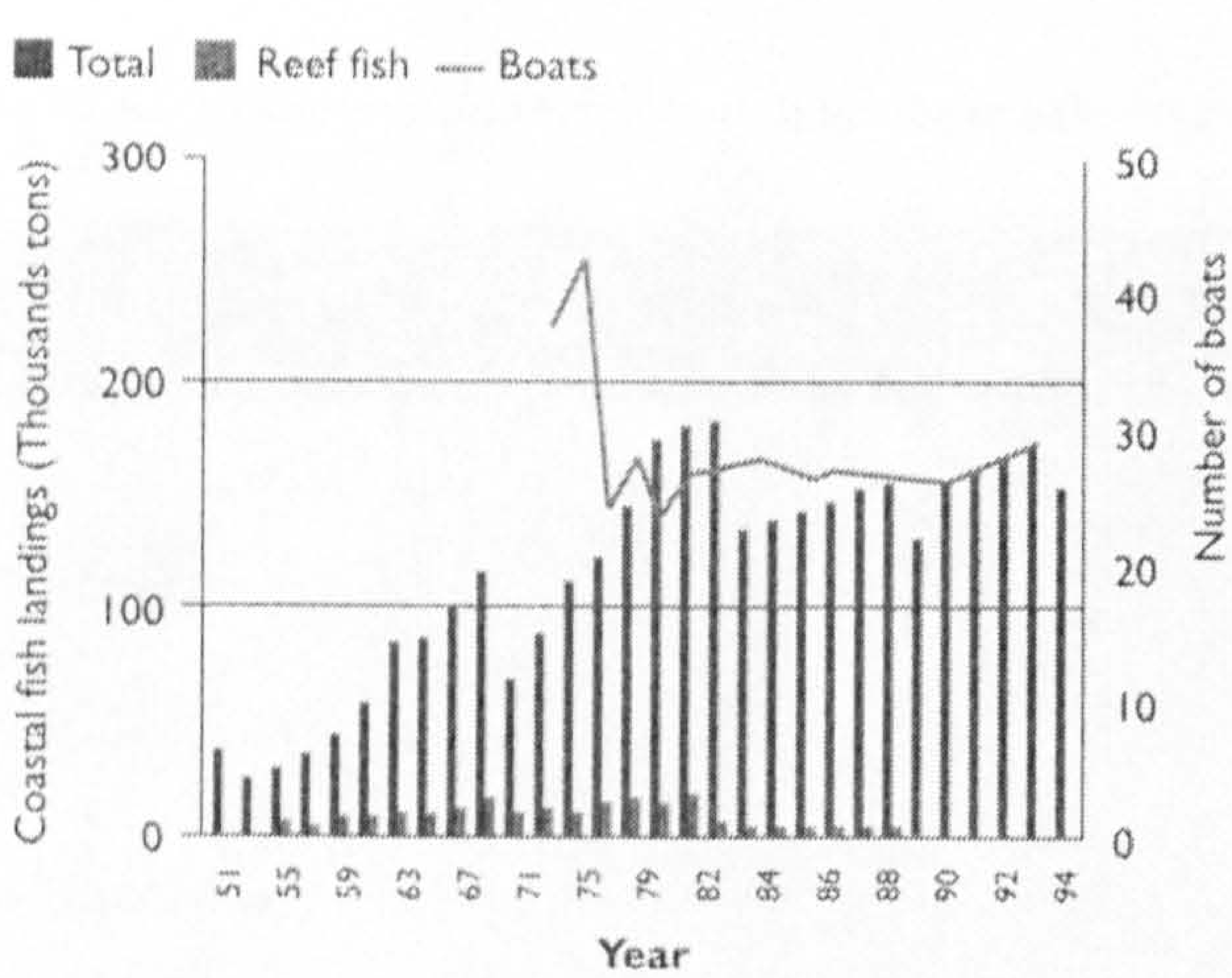

Figure 4. Trends in coastal fish landings in Sri Lanka.

In Maldives reef fisheries contribute least to total fish production, although this is increasing. However, the indirect importance of reef fisheries to the entire fish production is much higher because bait fish for the tuna fishery are caught in the lagoons and near the reefs. Total fish catches have increased dramatically in recent years from 39 000 tons in 1983 (Anon., 1998a) to 118 115 tons in 1998 (Anon., 1998b) (Figure 5). With its vast area of coral reefs, it is remarkable that reef-associated de-

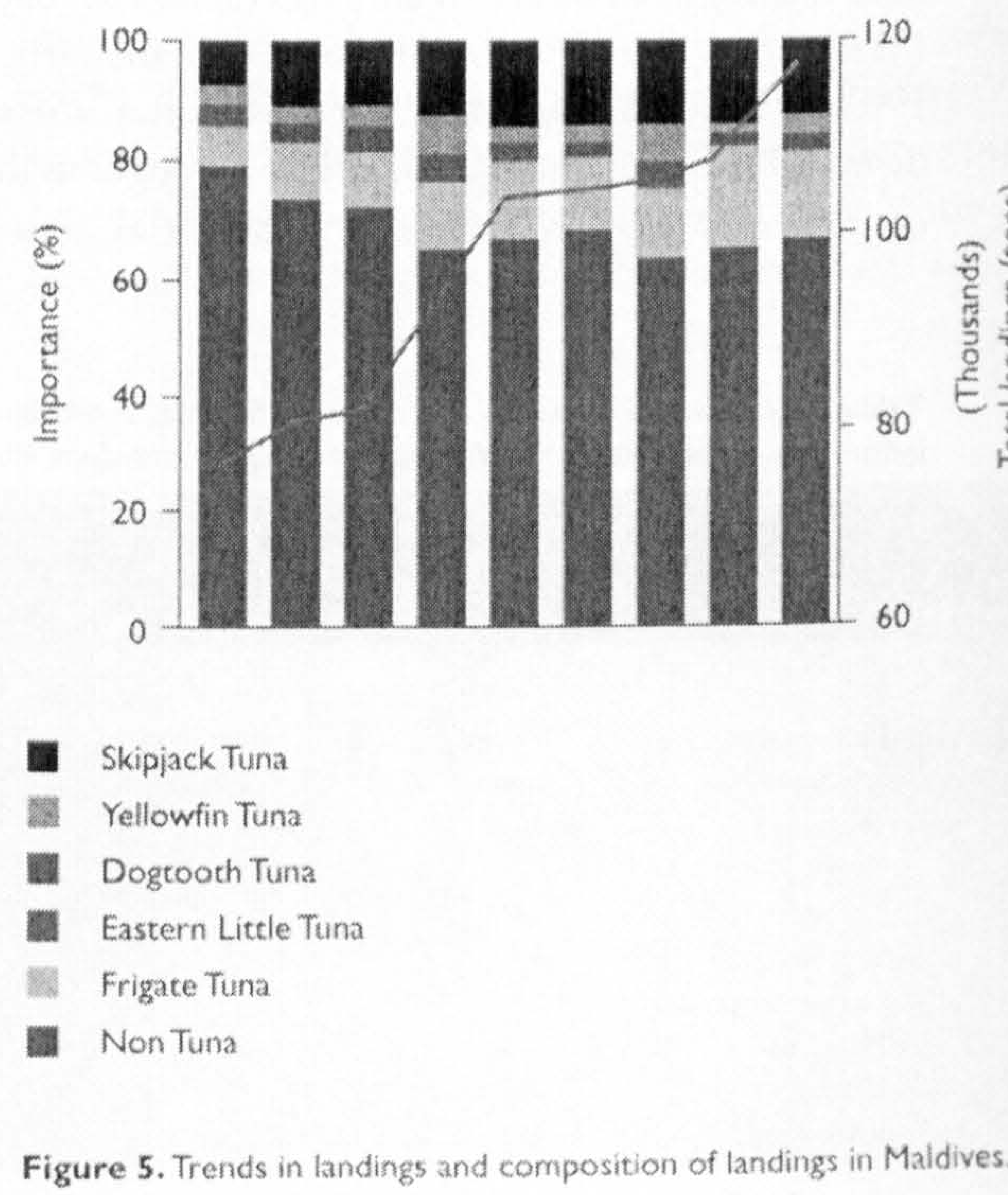

Figure 5. Trends in landings and composition of landings in Maldives.

mersal species have not been heavily exploited in the past. The majority of Maldivians have a high preference for tuna. Some demersal fish were caught, mostly with a single hook hand-line, to supply the tourist resorts and the Sri Lankan market for salt-dried low value reef fish (Anderson *et al.*, 1992).

The Ministry of Fisheries and Agriculture collects data from every inhabited island. However, the Catch Effort Data Recording System (CEDRS) focuses on tuna catches and fisheries. The importance of reef fish has increased following increased demands from new export and domestic markets. It is believed that the current expansion creates overexploitation of the resources and conflicts among resource users (Shakeel & Ahmed, 1997). Reef fishing is most important in the atolls where tuna fishing is poor. In the other atolls reef fishing remains the second most important fishing activity. Catches increased significantly (nearly 5 fold) between 1988 and 1994, but CpUE seems to have declined. Grouper fishing is increasingly important and caters to the international market.

East Africa

The catches of reef fish increased during the 1970's but at the beginning of the 1990's catches decreased to levels recorded in the 1950's. In Tanzania, especially in the northern districts and Zanzibar, the demersal fisheries provide employment to a large portion of the coastal population. Overall, marine landings are decreasing, mainly because of declining pelagic catches. This results in an increase in the relative importance of the demersal fish production (Table 4). The majority of Tanzanian fisheries (96%) are small-scale and exploit the reef-associated habitats (Darwall & Guard, in press). There are 3 232 registered vessels and their fish production varied between 36 000 tons and 56 000 tons between 1990 and 1995.

Reef fish in Kenya is less important in the total fish production. Nevertheless, the high numbers of coastal fishers have few alternatives to make a living. The total marine fish catch seems to have collapsed in the early

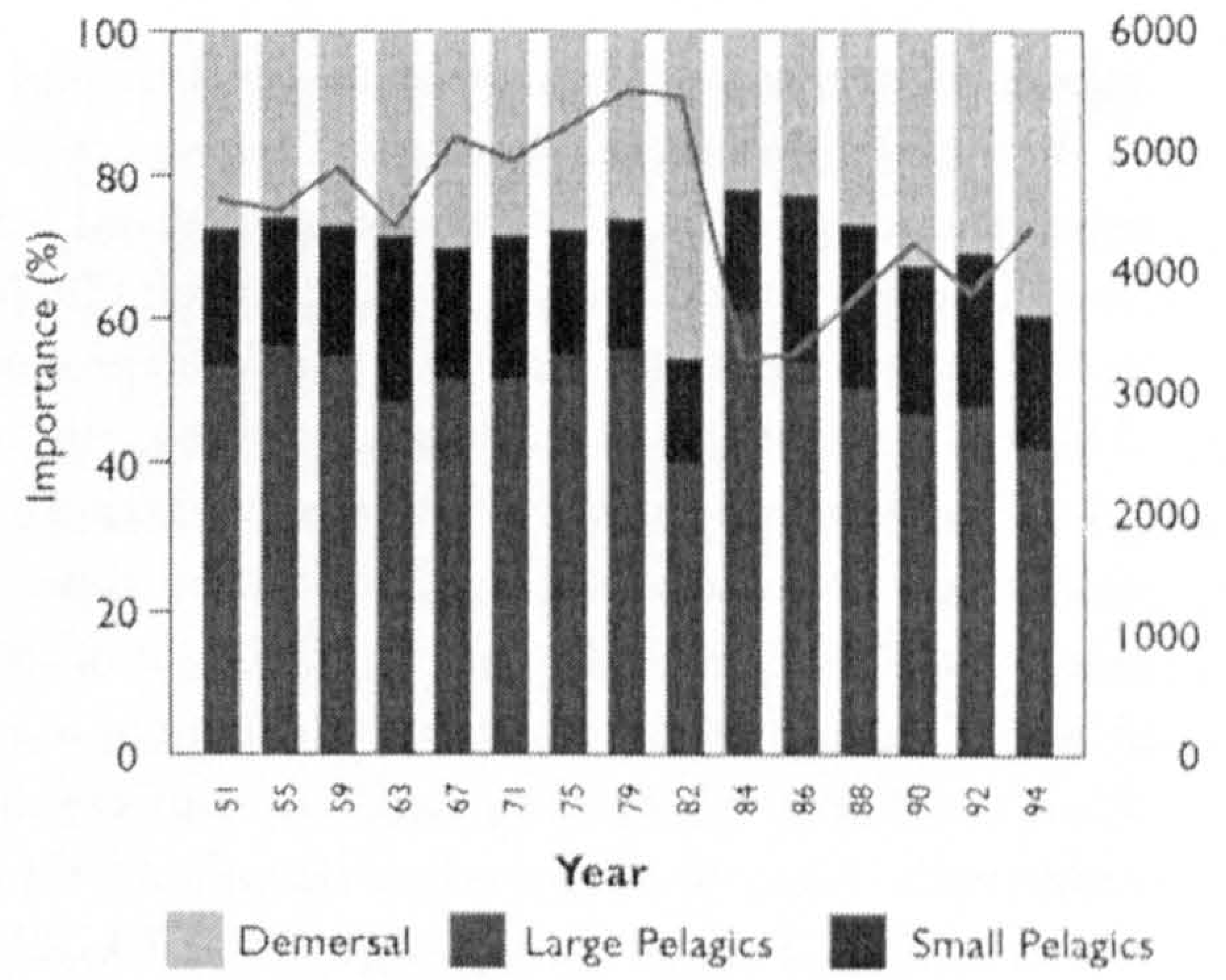

Figure 6. Trends in landings and composition of landings in Kenya.

1990's and, although catches have increased since then, only by the late 1990's was production back to 5 000 tons, the level that was produced in the early 1980's (Dept. of Fisheries, Mombasa) (Figure 6). Some 4 700 fishers are active in coastal regions of Kenya. The contribution of demersal fish to the total marine fish production has been quite stable during recent years at approximately 30% - 40%.

Indian Ocean Islands

In Madagascar, 43% of the fishery is based on the coral reefs (65 090 tons). Of the total fish production, 20% is exported, which means an important amount of foreign earnings is derived from the demersal fishery (Table 4). Export of fish almost doubled between 1986 and 1989 to 24 264 tons, of which 8 000 tons were shrimp. In 1994, the value of the exported shrimp catches was 80 million US$ and landed by-catch represented 45% of the total fish landings in that year. This was a 27% increase during 1994, therefore shrimp trawling poses a growing threat to the sustainability of Madagascar's demersal fisheries. In 1994, 117 500 tons of fish were produced of which 55% was captured in small-scale fisheries. Approximately 50 000 people are involved in this fishery using 22 000 boats and living in 1 250 villages. Total fishing effort increased five fold between 1977 and 1994.

In the island states of Mauritius, Reunion and Rodrigues the relative contribution of demersal and reef related fisheries to total fish production is high (Table 4). In 1999, there were between 2 500 and 3 000 professional fishers in Mauritius. Total landings in the artisanal lagoon fishery (traps) in Mauritius have been relatively stable and have increased only slightly from approximately 1 600 tons in 1991 to nearly 2 000 tons in 1999 (Naim *et al.*, in press). An important fishery in Mauritius is the Banks fishery along the Mauritius-Seychelles Ridge with 15 vessels that produced another 4 424 tons of fish in 1996. The vessels are large (200-430 GRT) each employing between 50 and 60 fishers and 20 crew.

Fisheries in Seychelles include an industrial fishery of foreign licensed tuna purse seiners and longliners, a semi-industrial fishery of longliners for swordfish, and the reef fishery. In 1992, handlining and traps set on sandy or sea-grass substrate that target rabbit fish contributed most of the total fishing effort (Jennings *et al.*, 1995). Handlines caught 78.3% of the 5 718 tons of fish landed in that year (Figure 7). Seychelles relies largely on fish exports and tourism for foreign revenue. In 1992, 200 tons of fresh fish and 839 tons of frozen fish were exported. In 1995, artisanal fish production was 4 313 tons of which 420 was exported for 10 million SR.

In Comores there are approximately 8 000 fishers.

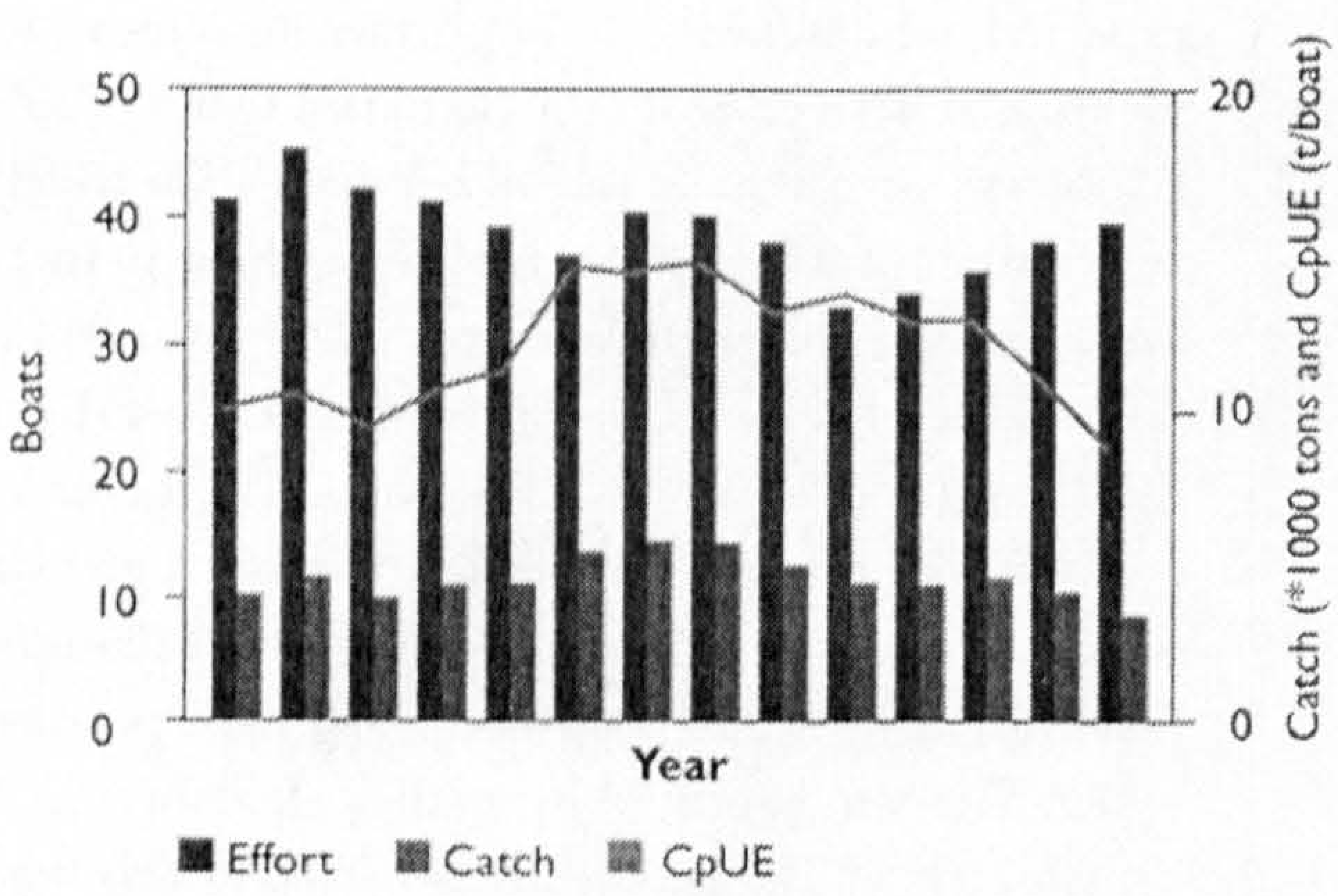

Figure 7. Catch and effort of the artisanal fishery in Seychelles.

All are artisanal fishers and live in approximately110 fishing villages.Total fish catch in 1995 was13 000 tons of which 72% was pelagics. (8 000 tons were caught at Grande Comores). The monetary value of the catch in that same year was estimated at 9 million francs of which 6 million was contributed by Grande Comores alone.

Assessment of the effect of bleaching and coral reef degradation on coral reef fish and fisheries in Kenya: A Case Study

The Coral Reef Conservation Project (CRCP) is a U.S. based NGO of The Wildlife Conservation Society that has monitored Kenyan coral reefs since 1986 and fish catches associated with coral reefs since 1995. The project includes a study of fish populations in Kenya's older (>25 years) fully protected marine parks (Malindi and Watamu MNP), a more recently created park Mombasa MNP (1991), and four sites on heavily fished unprotected reefs (Vipingo, Kanamai, Ras Iwatine and Diani). This study was conducted in late 1997 and repeated in early 1999, around four months before and 10 months after the coral bleaching event. For the purpose of assessing possible effects of the 1998 bleaching event, abundance and composition of the reef fish community was determined, together with biomass and composition of individual fish catches.

The underwater visual census data showed no clear changes in fish community structure that can be attributed solely to the bleaching and mortality of corals. Only the increase in abundance of surgeon fish, which are grazers that feed on algae on the surface of the dead coral, may be related to coral mortality. It appears that there is a strong relationship between management (marine park versus exploited reefs) and fish abundance for many of the studied fish families (McClanahan & Arthur, in press). The catch assessment data show a significant decline in catch between 1995 and 1999, whereas the total fishing effort, measured in numbers of fishers or boats remained constant. There is no significant deviation from this trend after the 1998 bleaching event.

Therefore, it must be concluded that, at this stage, the fishery has not been significantly affected by the bleaching and mortality of corals. Nevertheless, the declining catches may be a result of overall environmental degradation. Therefore, it is expected that the effects of the recent bleaching and coral mortality may become more evident once the reefs are further eroded in the future.

ASSESSING THE IMPACTS OF THE CORAL BLEACHING ON REEF BASED TOURISM

The second major socio-economic impact of coral bleaching would be expected on the tourism industry. Tourism will be affected by bleaching in those areas where a substantial proportion of the industry is based on reef activities and where there are few other attractions or activities for tourists to enjoy. Tourism varies throughout the countries of the Indian Ocean and the diversity of the tourism product ensures a greater or lesser dependence on coral reefs. Table 6 indicates the level to which each of the countries is dependant on coral reefs, and the national growth rate in tourism seen over the past five years.

Reef based tourism is a major industry in both Maldives and Seychelles, although they are marketed quite differently. Maldives caters for the diving market (45% of all tourists dive) and the honeymoon market. Seychelles, on the other hand, offers a variety of activities and people may snorkel and dive as a small part of their vacation (only 7% of all tourists dive). Similar patterns were seen in Zanzibar where people spend, on average, less than 40% of their vacation time diving and snorkelling. In Kenya and mainland Tanzania, wildlife parks and safaris are probably the main attraction for visitors. However, visitors may often spend a week on safari and then a week at the coast where the reef based attractions form an important component of their vacation. Island states, such as Comoros and Rodregues have small-scale tourism industries. In Comoros, tourism employs 600 people and in Rodregues 254 are employed, of which only five are employed directly in the dive industry. India supports a huge tourism market, although relative to the size of the country and its economy it is of lesser importance compared with some of the smaller island states. The reefs of India tend to be remote and difficult to access so reef based tourism is limited. Sri Lanka has some reef based tourism, but has also many other attractions. There has been enormous overuse of certain areas, such as Hikkadua where over 90 glass bottom boats operate. Visitors to Reunion and Mayotte are generally friends and family of residents and those visitors that are genuine tourists are usually from France or, in the case of Mayotte, from Reunion.

Table 6. Relative importance of reef based tourism to the economy and 5 year trends in national tourism for countries of the Indian Ocean. ++++Very high; +++high; ++medium; +low; -negative.

Country	Contribution of reef-based tourism to the gross domestic product, GDP	National tourism trend
Maldives	+++++	++
Mauritius	++++	++
Comoros	+++	++
Seychelles	+++	+/-
Zanzibar, Tanzania	++	+++
Madagascar	+	++
Kenya	+	+/-
India	+	+
Reunion	+	+
Sri Lanka	+	-
Mozambique	+	No data
Rodregues	No data	++++
Mayotte	No data	+++

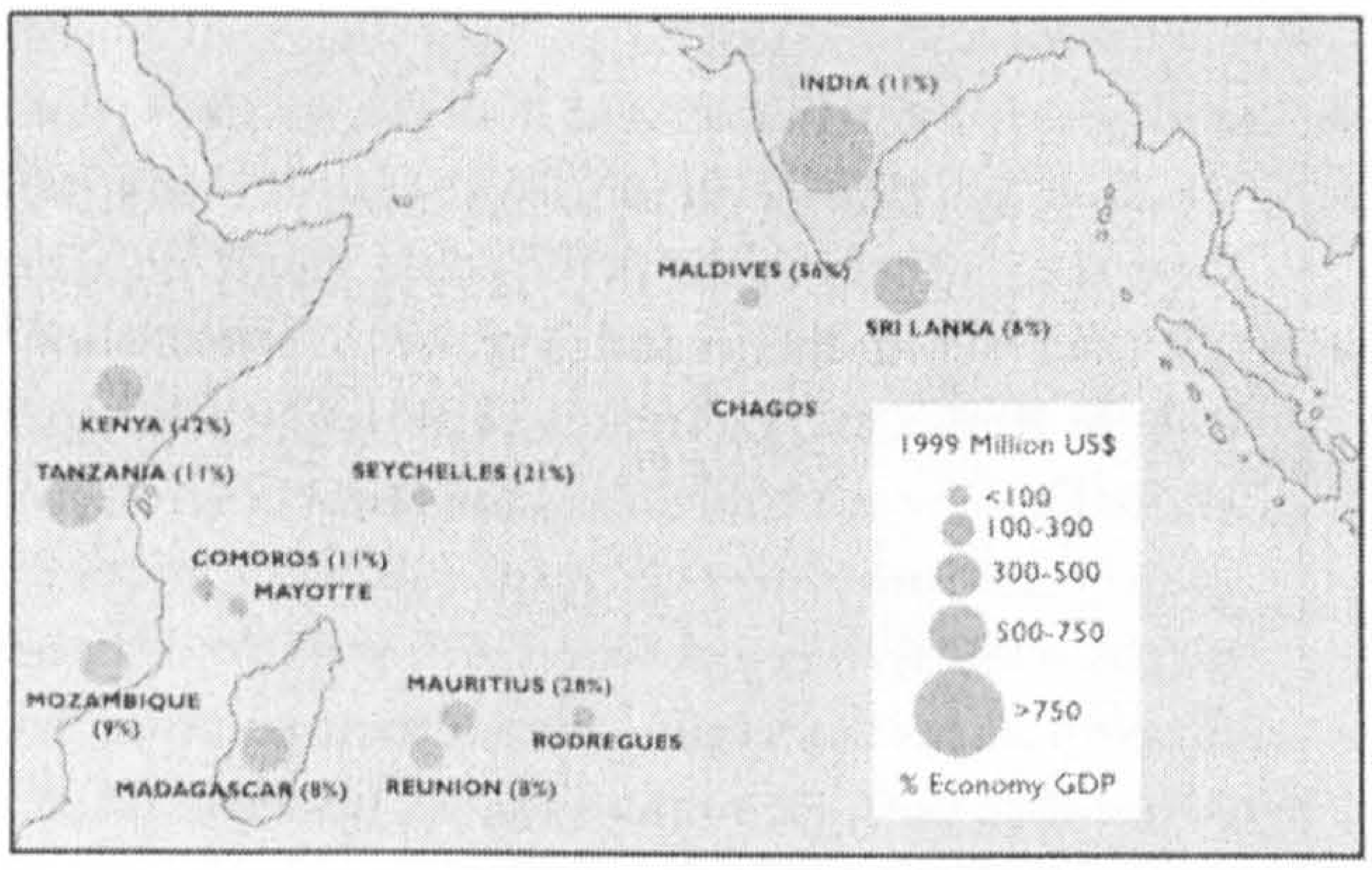

Figure 8. Revenue generated from travel and tourism and the contribution of this to the national GDP within the Indian Ocean. Source: World Travel and Tourism Council, 1999.

Perhaps more importantly than the total arrivals, is the actual financial gain a country or region might receive from tourism. The World Travel and Tourism Council produce simulated forecasts of world tourism. The revenue generated from travel and tourism and the contribution of this to the national economy (GDP) is shown in Figure 8. Maldives shows that 55.9% of the national economy is based on travel and tourism. The next highest is Mauritius at 27.9%, followed by the Seychelles at 20.7%. All these countries are small island states and most of this tourism will be all or partly based on the reefs. Those countries with lower revenue from travel and tourism depend heavily on industry for their national economies.

Two specific case studies were carried out to examine the financial and economic impacts of the coral bleaching on tourism. The first was conducted in Tanzania and Kenya and the second in Maldives and Sri Lanka. The following sections give a brief synthesis of these two studies.

Assessing the impacts of coral bleaching on tourism in Tanzania and Kenya

One of the specific case studies initiated as part of the socio-economic assessment of the impacts of the coral bleaching within the CORDIO programme was carried out in Tanzania (Zanzibar) and Kenya (Mombasa). The aims of the research were to:

- Establish whether tourists are familiar with coral bleaching
- Estimate the financial and economic cost of coral bleaching to tourism in Zanzibar and Kenya
- Compare the recreational value of the reef before and after the bleaching event.

METHODS

This research is based on a questionnaire survey of tourist divers in Zanzibar and Mombasa. The economic analysis is based on the contingent valuation methodology (CVM). Financial costs are based on expenditure data given by the respondents. The questionnaire was initially developed for use in Zanzibar and Mafia Island, Tanzania and had been through pre-testing and a full survey (Andersson, 1997). Although a few questions were omitted and a few added, it was not felt that it was necessary to pre-test the survey again. In Zanzibar, 199 divers were surveyed, the sample being split evenly between the two sites. Initially, in Mombasa, a total of 105 divers were interviewed. Surveys were carried out at the dive shops of Zanzibar and Mombasa.

RESULTS

The divers visiting Mombasa were found to be on average older and more experienced divers than those in Zanzibar. However, the respondents in Zanzibar had a higher level of education than those in Mombasa. In Zanzibar, it was estimated that divers spent approximatley 42% of their vacation participating in reef related activities compared to 50% in Mombasa. The importance of the reef can be seen in the diver's ranking of the various attractions in Figure 9.

Diver awareness of coral bleaching

The study found that only a limited number of tourists surveyed at the two case study sites were actually aware of coral bleaching. In Zanzibar, this was 28% and in

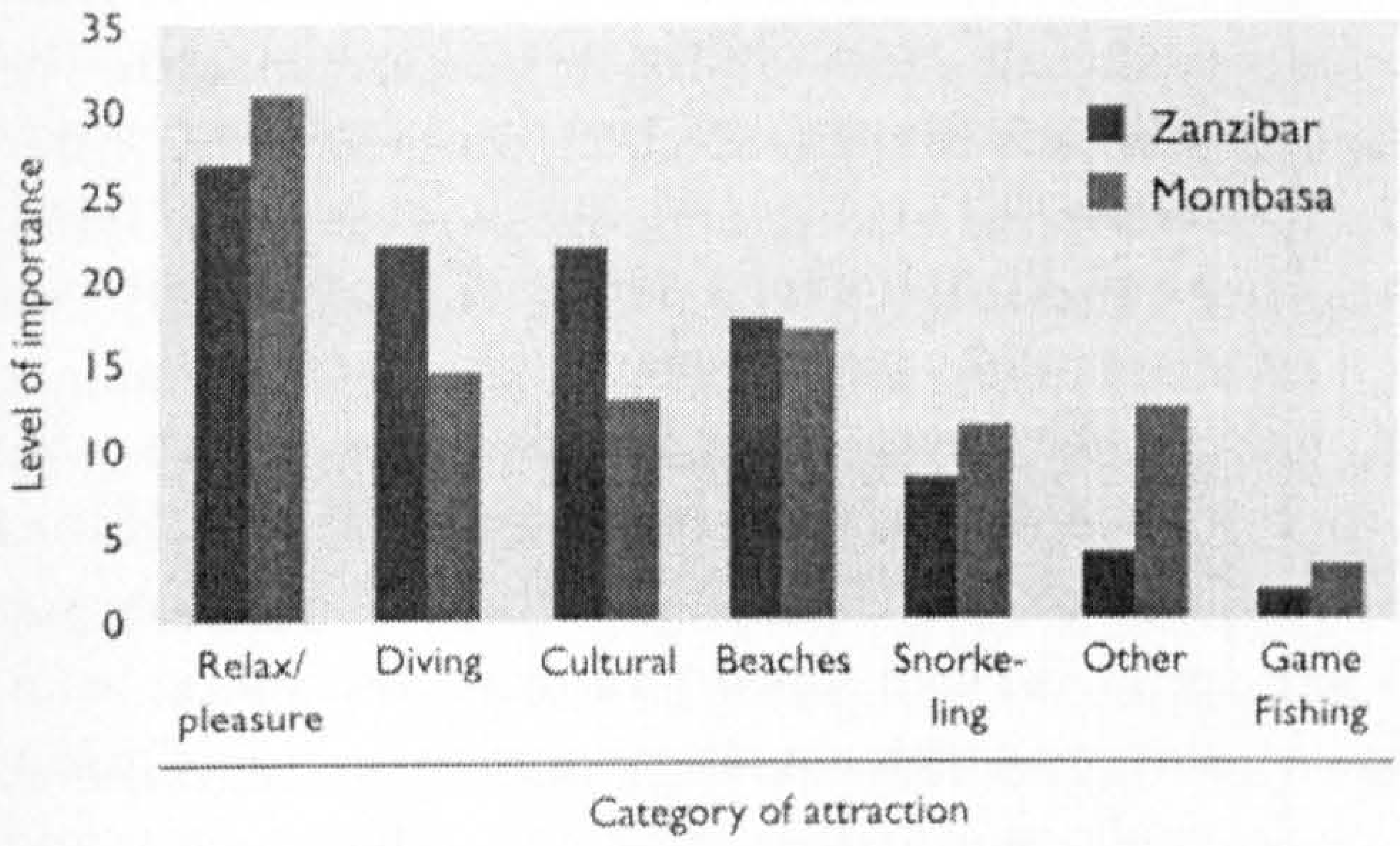

Figure 9. Ranking of the importance of the various attractions.

Mombasa this was 45% (Figure 10). This low awareness could be related to their country of origin, level interest in the marine environment and dive experience. These links were explored but the sample size of those aware of the bleaching was too small to make any significant conclusions. However, of those who were aware of the bleaching, over 80% stated that knowledge that an area was bleached would affect their decision to either visit that area or to dive and snorkel in that area (Figure 10). This enabled estimations of the financial and economic costs of the coral bleaching to be made.

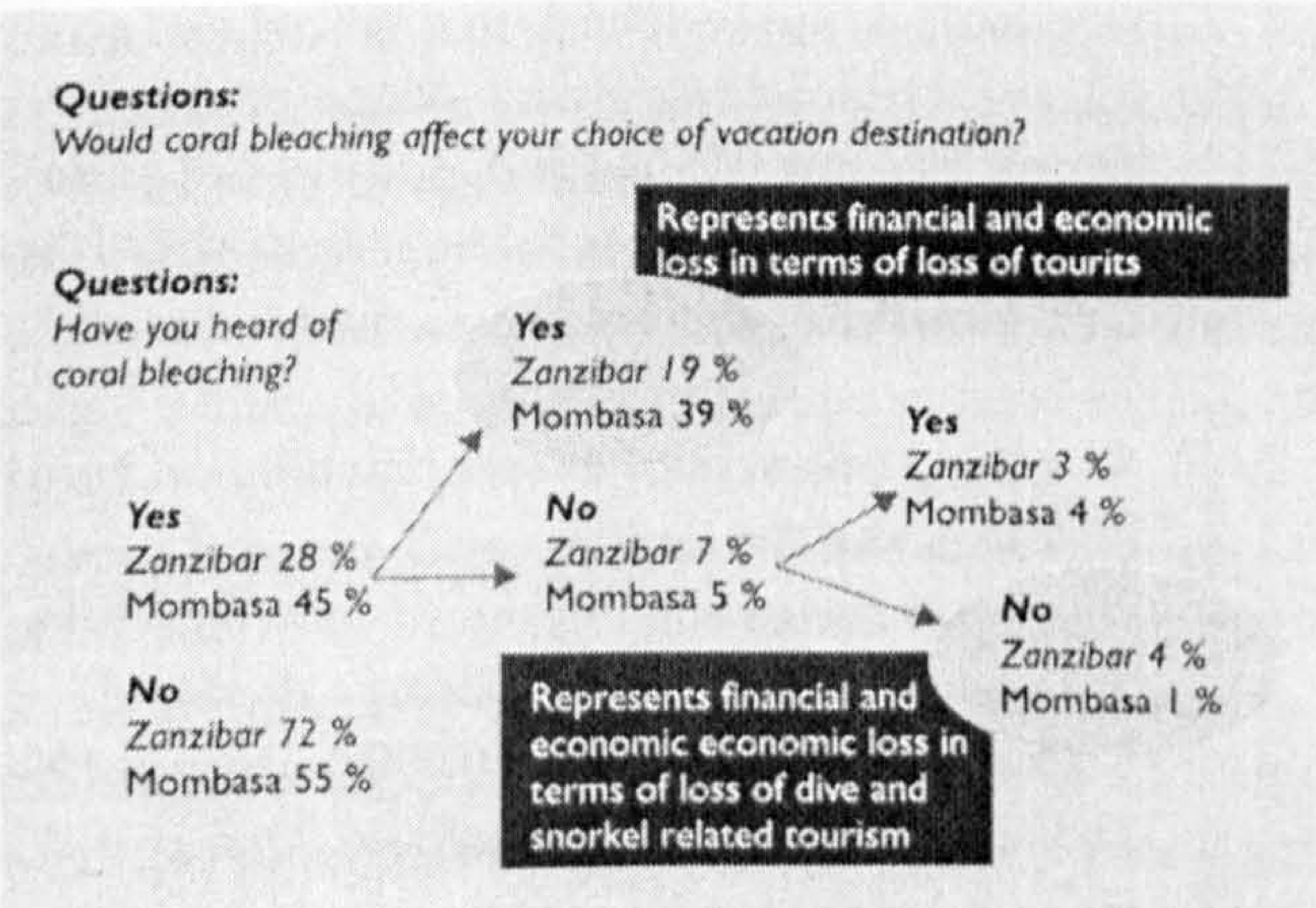

Figure 10. Responses to the questions regarding the knowledge of coral bleaching and its effect on choice of diving destination.

Valuation of the reef resources

In estimating the financial and economic costs of the coral bleaching, the survey techniques and the valuation methods developed by Andersson (1997) for the previous survey in Zanzibar were used. The financial cost of the bleaching are the losses to the local community and tourism economy resulting from those tourists deciding not to visit or simply not to dive in the locations because of the bleaching. This is calculated using the diver's and snorkeller's expenditure data collected during the survey. The economic cost of the bleaching represents the loss of value to the same group of tourists, either not visiting because of the bleaching, or visiting but not diving. This loss affects the divers and snorkellers for not having access to healthy reefs. The economic cost is calculated from the diver's and snorkeller's stated willingness to pay. There are two components to the willingness to pay. The first is the consumer surplus, which is the additional money the tourists would be prepared to pay to still visit the place. This reflects the value of the benefits they gain from recreation exceeding the total cost they have spent on visiting the place. The second is the willingness to accept compensation for the fact that they are unable to dive because of the degraded reefs. The first value is used as the cost when divers do not visit the area and the second is used when divers visit but choose not to dive. When aggregating the results, a range (% of tourists diving) is used if the exact figure is not known. This is thought to be in the region of 20% - 30%. In Maldives, a diving destination, 45% of the tourists were recorded as divers. These aggregated costs can be seen in Table 7.

Table 7. Financial and economic cost of the coral bleaching on Zanzibar and Mombasa (range based on % of total tourists who dive).

	Financial cost million US$	Economic cost million US$
Zanzibar	3.08- 4.62	1.88-2.82
Mombasa	13.33- 19.99	10.06-15.09

Comparison of economic value between 1996 and 1999
One of the main components of this research was the ability to compare diver and snorkeller valuations of the reefs of Zanzibar before and after the coral bleaching by incorporating the data collected in 1996/7 by Andersson (1997) into analyses. Compared with the 1999 results, the overall consumer surplus was unchanged indicating that a complete holiday to Zanzibar was valued the same in 1996 as it was in 1999. The level of reef use was also comparable. However, the willingness of the divers and snorkellers to accept compensation for non-access to the reefs had increased 20% between 1996 and 1999. This indicates that the reef remains an important component of the visit and the value placed on having access to reef related activities has actually increased.

The willingness to pay for reef conservation can be related directly to the state of the reef in 1996 and in 1999. In 1996, the average willingness to pay to maintain the reef in the same state was $30. In 1999, this had dropped to $22, a 27% decline from 1996 to 1999. This reflects either a decline in the perceived state of the reef or a change in the type of tourist and their willingness to pay for reef conservation. However, comparison of the socio-economic data obtained in 1996 with those obtained in 1999 determined that the only difference between the two groups was that divers surveyed in 1996 were generally more experienced than those surveyed in 1999. In 1996, the average number of dives each diver had completed was 83, compared with only 33 in 1999. This may be an indicator that the more experienced divers are aware of reef conditions and their decision has already been affected by stories of reef degradation or that these divers are travelling elsewhere, where they can get more adventure and extreme conditions of diving.

Management implications of the results
One of the major findings of this research was the fact that, although only a limited number of tourists were aware of coral bleaching, or of reef degradation generally, their decision to visit may well be affected. From a management perspective, this has implications for the type of information that the tourists are receiving on the state of the reefs. Should bleaching adversely affect the reefs, tourists may still visit the area if alternatives are supplied. These may be marine based or even land based. Planning for a change in tourism activity may need to take place sooner rather than later.

The decrease in willingness to pay for the conservation of the reefs may be related to the state of the reefs but also could be related to the level of visible management. To gain support for reef conservation from visitors, management efforts need to be visible through public information, brochures, active rangers and patrols. What is useful from the data collected is the approximation of a willingness to pay being approximately 2% - 3% of the total vacation expenditure. This type of data can be utilised when establishing protected areas and generating revenue through user fees.

Limitations of the study and further research
There were several limitations of the study imposed by time and financial constraints. For full analysis and comparison of results obtained in 1996 and 1999, the survey needed to cover the higher-price hotels along the east coast also. In addition, Zanzibar was only mildly affected by the coral bleaching whereas Mafia Island was heavily affected. The 1996 survey was also carried out on Mafia Island and a re-survey of this area could provide some useful insights into financial and economic costs of the bleaching. Broadening the survey to cover all tourists both at home and abroad would also increase the understanding of tourist behaviour with respect to coral bleaching and reef degradation.

Assessing impacts of coral bleaching on tourism in Maldives and Sri Lanka
This study focuses on impacts of coral bleaching and subsequent mortality on tourism in the Maldives and Sri Lanka. In Maldives, with 430 000 tourists in 1999 (Ministry of Tourism, 2000), diving and other reef-related tourism are the main income generating activity in the country. Sri Lanka has a similar number of tourists but

very few come specifically for reefs, even though they are attracted in general to the coastal areas. The current study addresses socio-economic questions related to coral bleaching and tourism primarily by recording tourists' perceptions of coral bleaching. Also, estimates of the financial and associated welfare losses resulting from the 1998 coral bleaching event are provided.

METHODS

This research was based on both questionnaire surveys and secondary data sources. Four different surveys were carried out: (i) one for tourists departing from Male airport in Maldives and from coastal tourist locations in Sri Lanka; (ii) one for key informants such as dive operators and glass bottom boat captains in Sri Lanka; and tour operators in Italy; (iii) one for tourists at the airports of Amsterdam, Duesseldorf and Milan on their way to Maldives and Sri Lanka; and (iv) dive tourists were asked via the internet about their knowledge of coral bleaching in Maldives and whether bleaching and coral mortality was a factor that influenced their decision to go there. The secondary data sources were the official tourism statistics of Maldives and Sri Lanka.

RESULTS

Interest in the marine environment

In Maldives, there seemed to be three main categories of tourists: (i) divers; (ii) honeymooners; and (iii) 'relaxers'. Around 45% of all tourists going to Maldives were divers. In Sri Lanka, only approximately 8% were divers. Italians tend to visit Maldives for their honeymoon while Germans go to dive. The number of dives made while visiting each country also varied considerably. In Sri Lanka, of the 8% that went to dive, 50% did only one or two dives, while in the Maldives, 69% of divers did more than five dives. With respect to their interest in the marine environment, 52% of the tourists at Male airport responded that the importance of marine life was very high, 34% answered that is was rather important and only 13% said that it was not important. In Sri Lanka, the results were quite the opposite. Only 18% stated that marine life was very important, while 32% and 51% said that marine life was rather important and not important respectively.

Divers' and snorkellers' knowledge of coral bleaching

The media coverage of the coral bleaching episode of 1998 has been substantial. Dive journals have given considerable attention to the bleaching event and to reactions of divers. Yet, interviews at the European airports showed that many tourists on their way to Maldives did not know of the episode. Fifty percent of Germans surveyed had heard of the coral bleaching event in Maldives, compared with 30% of the Italians and 16% of the Dutch. This can be explained partly by the exceptionally large media coverage in Germany and by the large percentage of divers among German tourists. At Male airport, 68% of departing tourists had heard of coral bleaching, while in Sri Lanka, less than one third knew of this problem.

Losses in Tourism Revenues in Maldives

Possible losses to Maldives' economy were analysed based on the official tourism statistics up to December 1999. Figure 11 presents tourist arrivals since the 1972. Surprisingly, there was not a significant drop in tourist arrivals in 1998-1999. In fact, tourism arrivals have increased 8% in both 1998 and 1999.

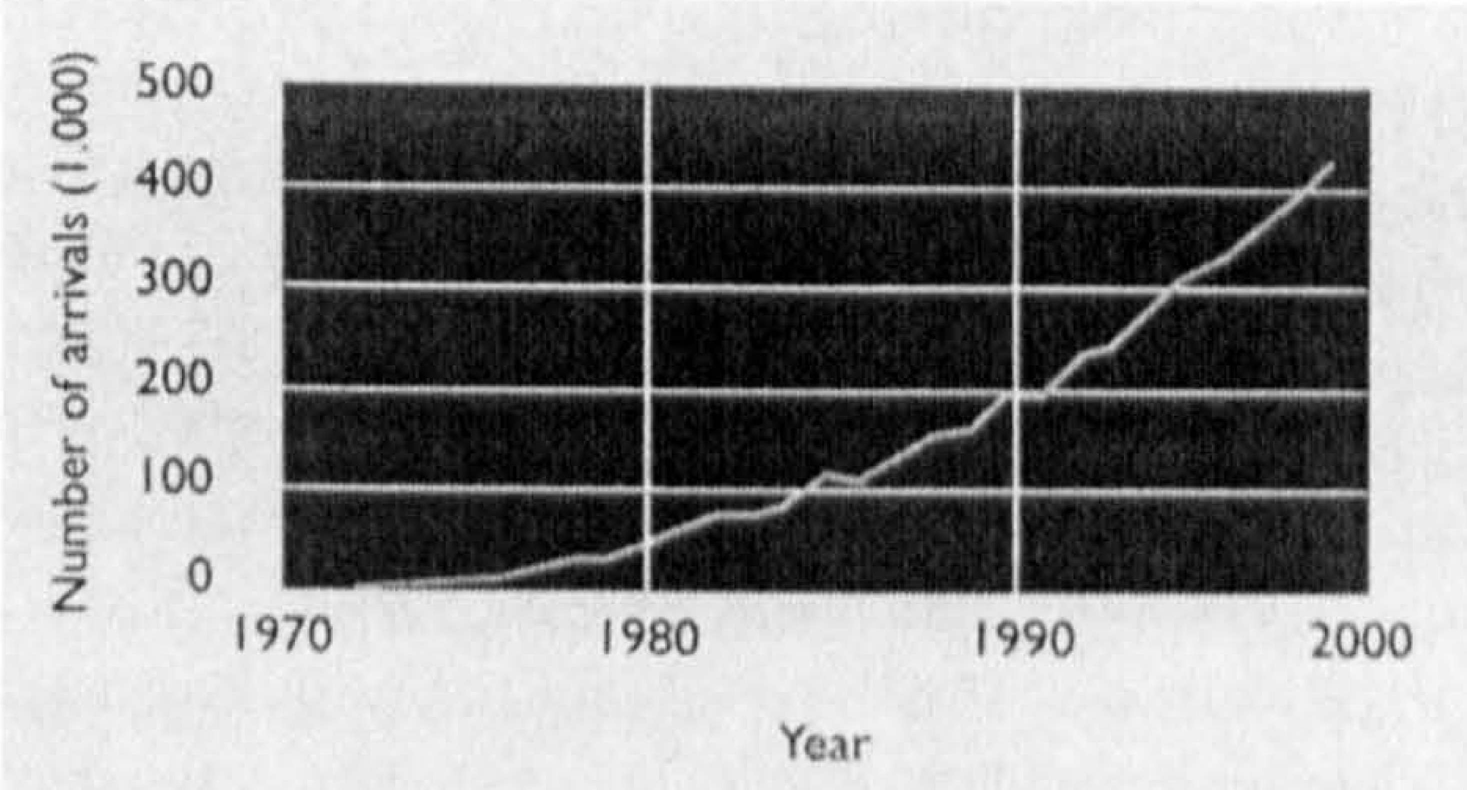

Figure 11. Number of tourist arrivals in Maldives between 1970 and 1999.

Source: Maldives Ministry of Tourism (1997, 2000).

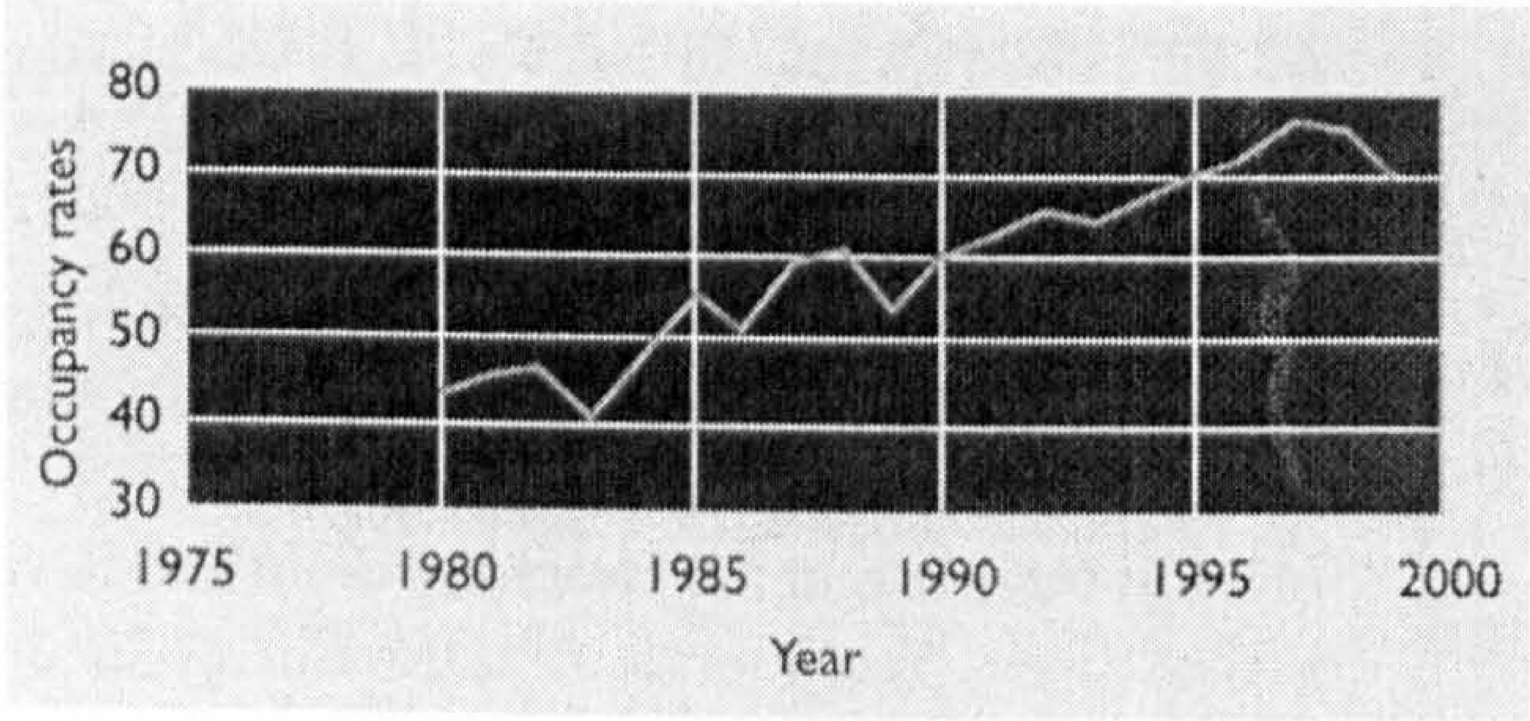

Figure 12. Bed occupancy rates in Maldives between 1980 and 1999. *Source:* Maldives Ministry of Tourism (2000).

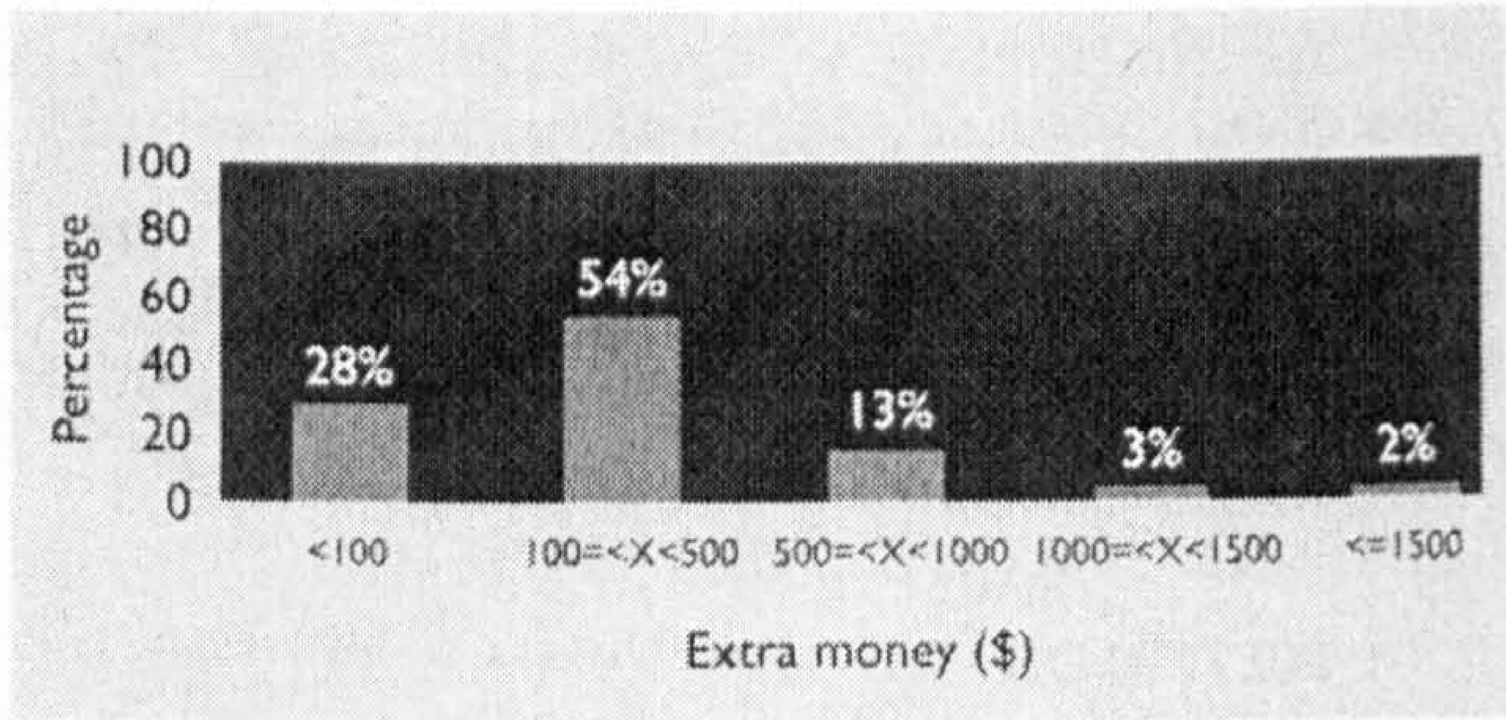

Figure 13. Willingness to pay for better reef quality in Maldives.

However, trends in bed occupancy rates since 1975 give a different picture (Figure 12). Given the time lag between the planning phase of expansion and the additional bed capacity, occupancy rates give a proxy for expected growth in tourism and the decrease in 1998/9 was substantial. However, the Asian crisis was also affecting tourist numbers. Another way of looking at expected growth of tourism arrivals is to check the official government tourism forecasts. In 1997, an annual growth of 10% was expected for the years of 1998 and 1999 (Ministry of Tourism, 1997), which was 2% higher than the realised figures. Here, we assume that half of this difference was due to coral bleaching.

Welfare losses from divers

Besides financial losses to the local economies, coral bleaching can also affect tourists' holiday satisfaction and thereby create a loss in their welfare. In order to calculate these welfare losses, the surveys at Male airport focused on tourists' willingness to pay for 'better reef quality'. In order to ensure the tourists value the same change in reef conditions, two pictures were shown, one of a reef that had completely died because of bleaching and another that was still intact. The question asked of tourists was how much extra were they willing to pay to go to hypothetical remote areas in Maldives where reefs were not affected by coral bleaching and which were, in all other respects, the same. Figure 13 shows the distribution of this willingness to pay (WTP) and illustrates that the tourists surveyed were willing to pay an average of US$ 284 more to visit these hypothetical reefs. Divers were prepared to pay more than other tourists, though the difference was surprisingly small. The mean WTP for divers was US$ 319 while for non-divers it was US$ 261. The aggregated losses can be seen in Table 8.

Finally, tourists were asked about the most disappointing part of their Maldives holiday. The possible answers were: (i) the price of food and beverages; (ii) the weather (humidity, clouds, etc.); (iii) the fact that a lot of the corals were dead; (iv) the mosquitoes; (v) the resort accommodation; (iv) others. Figure 14 summarises the responses, showing that 47% considered the dead corals the most disappointing experience, while the price of food and beverages was second with 28%.

Table 8. Losses in tourism revenues and welfare in Maldives and Sri Lanka for 1998/9.

	Financial costs million US$	economic costs million US$
Maldives	3	63
Sri Lanka	0.2	2.2

This last result is interesting, because nearly all resorts are based on half or full board, so that the actual amount of money spent on additional food and beverages is quite low, though beer is expensive at around US$ 5 per bottle. The interesting aspect of these responses is

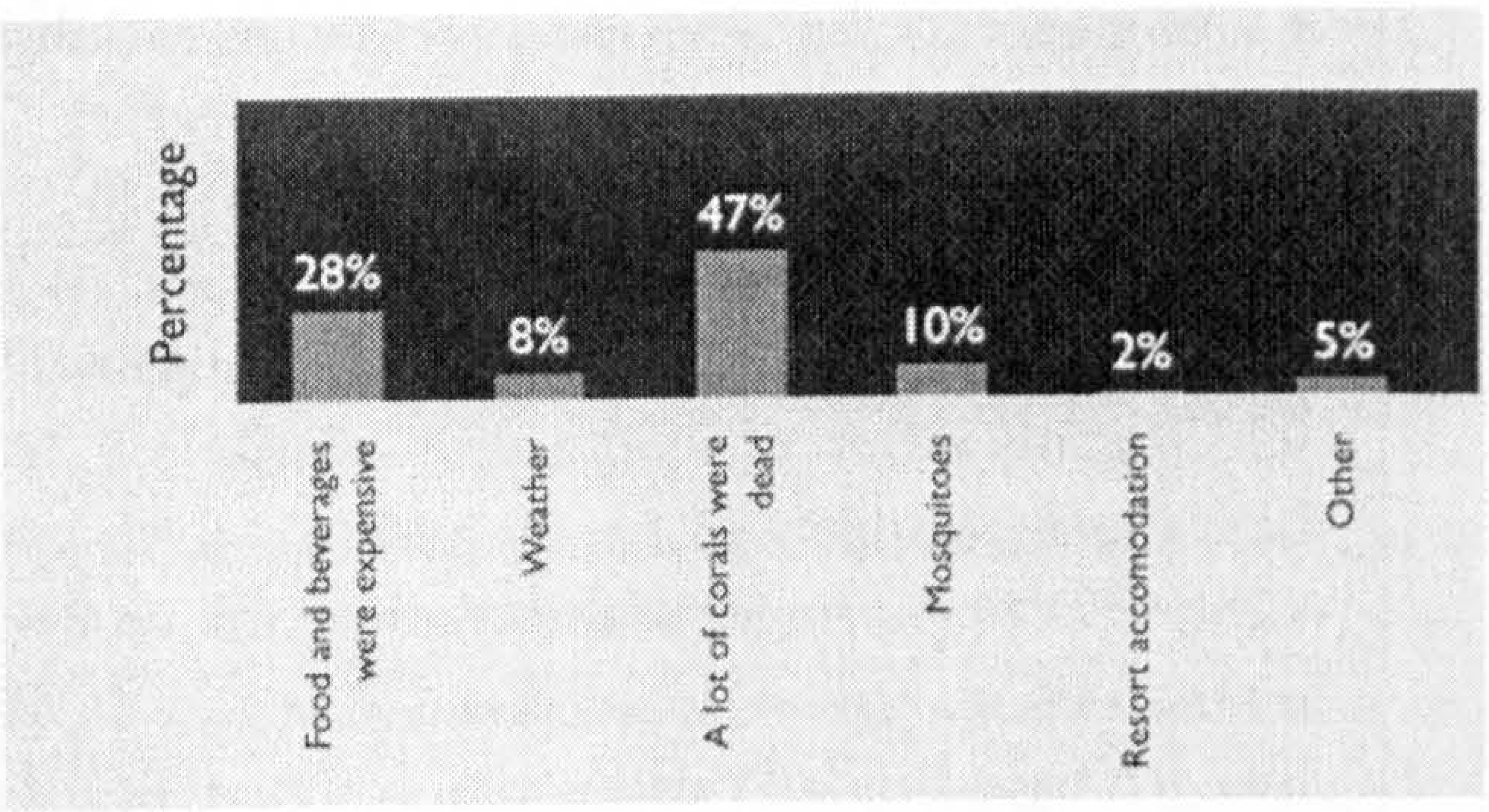

Figure 14. Question about the most disappointing part of the Maldives holidays.

that they allow us to compare and therefore scale the willingness to pay WTP values. Surprisingly, the average WTP for better reef quality was not statistically different for those who found coral mortality most disappointing and those who found other parts of their holiday most disappointing. Note that one could buy more than 50 bottles of beer for the average WTP for improved corals, which might either suggest an inconsistency in the way people respond to the various questions or, alternatively, there are quite a few very hefty drinkers among the tourists. Unfortunately, it might also mean that many tourists do not really care about the death of coral reefs.

Assessing the future tourism impacts

The two case studies show a number of interesting similarities as well as differences.

- Awareness of the 1998 coral bleaching event among tourists going to destinations with coral reefs is generally rather limited.
- Current losses in tourism revenue due to coral bleaching event have, so far, been rather low. In Maldives, it is estimated that only US$ 3 million was lost during 1998 and 1999 combined. In Mombasa, the losses were estimated to be much higher (US$ 13-20 million), but these were hypothetical losses assuming permanent disappearance of tourists.
- A key determinant of losses in tourism revenues was the ability to attract other types of tourists who, despite being interested in coral reefs and reef based activities, were not interested only in diving. This flexibility could help explain the lower losses in Maldives compared with Zanzibar and Mombasa.
- Divers seemed willing to pay considerable sums for better reef quality. In Maldives alone, the total welfare loss for 1998/99 was estimated at US$ 19 million.

Future tourism losses remain uncertain. Key determinants are the long-term impact of relatively slow word-of-mouth reports or TV documentaries on bleaching. Despite the loss of some avid divers who appear to be going to areas that have not been impacted by bleaching, they are easily replaced by the hundreds of new divers that appear on the market. The key uncertainties are related to the impacts of coral mortality on fish populations and on beach erosion.

The impacts of the coral bleaching on tourism should be seen in the wider picture of reef degradation which, in itself, is not the only issue affecting tourism. Mombasa has seen a huge decrease in tourism relating to public opinion on personal safety. Much of this impression is created in national newspapers indicating the power of the media in altering public perception.

A further aspect of analysing the impacts of events such as the bleaching, is to look carefully at who is being impacted. The tourist has a variety of alternative locations and may not be affected, whereas the local dive guide may be unemployed as the dive industry adjusts or is impacted.

DISCUSSION

The 1998 El Niño event has so far not affected socio-economic indicators dramatically. Reef fisheries in many areas in the region have been showing a general decline over the last decade and data collected can not yet tell what the added negative impact of coral bleaching is. On the other hand, diving tourism has been growing rapidly all over the world (except in East Africa). Again, the added influence of coral bleaching on these trends is uncertain. Tourism studies show however, considerable financial costs ranging between US$ 3.1 and US$ 4.6 million in Zanzibar and US$ 13.3 and US$ 20.0 million in Mombasa. In Maldives, financial costs were estimated at US$ 3.0 million, while economic costs over the last two years were roughly US$ 63 million.

In the long run, the impacts may be rather more dramatic if increased erosion of the reef and a loss of reef complexity occurs, which would be expected to take between two and 10 years. Given the lack of other global coral bleaching events, the likelihood of this scenario is uncertain. Yet, major declines in fisheries and tourism can not be excluded, with corresponding impacts on marginal populations in coastal areas.

Furthermore, coral bleaching has re-opened the discussion about effective coral reef management. Reducing the pressure on coral reefs from their over-usage has never been an easy task. However, it will be essential if reefs recover from the bleaching and survive future threats. The bleaching of corals is more difficult to control. If this is a natural event, there is little man can do to manage it. We can only assist in recovery through appropriate protection of the reefs and vital sources of larvae. If, on the other hand, coral bleaching is caused by world-wide pollution and the consequences of climate change and global warming, it will take a massive global effort to reduce impacts in the future.

If continued coral reef degradation is going to be a widespread phenomenon in the Indian Ocean, the following questions need answering:

- To what extent will reef fish stocks be affected?
- Will a decline in reef fisheries or change in population composition affect pelagic fisheries?
- Will reef based tourism be replaced by other forms of tourism?
- What will happen to the Marine Protected Areas dependent on tourists visiting the reefs for their income?
- Can we maintain the tourism industry and utilise the tourism market for basic monitoring of reef fish and habitats?
- What are the links between reef usage and the bleaching?

ACKNOWLEDGEMENTS:

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REFERENCES

Anderson, R.C., Waheed, Z, Rasheed, M. & Arif, A. 1992. Reef fish resources survey in the Maldives – Phase II. BOBP/WP/80 – MDV/88/007. 54 p.

Andersson, J. 1997. The value of coral reef for the current and potential tourism industry on Unguja Island, Zanzibar. In: Johnstone, R.W., Francis, J. & Mohando, C. (eds.). *Coral Reefs: Values, Threats and Solutions. Proceedings of the National Conference on Coral Reefs, Zanzibar, Tanzania.* pp. 82-90.

Anonymous. 1998a. Fisheries in Maldives 1983-1997 A descriptive analysis.

Anonymous. 1998b. Basic Fisheries Statistics Jan – Dec 1998. Economic planning and co-ordination section Ministry of Fisheries and Agriculture, Male. 18 p.

Bakus, G.J. 1994. *Coral reef ecosystems.* Oxford & IBH Publishing Co. New Delhi. 232 p.

Bryant, D., Burke, L., McManus, J. & Spalding M.1998. *Reefs at Risk. A Map-Based Indicator of Threats to the World's Coral Reefs.* World Resources Institute, Washington. 56 p.

Central Intelligence Agency 1999. CIA Factbook.

CMFRI. 1980. Marine Fisheries Information Service, No. 22. 22 p.

CMFRI. 1995. Marine Fisheries Information Service, No. 136. 31 p.

Darwall, W.R.T. & Guard, M. in press. Southern Tanzania. In: McClanahan, T.R., Sheppard, C.R.C. & Obura, D.O. (eds.). *Coral reefs of the Indian Ocean: their ecology and conservation.* Oxford University Press. pp. 131-166

Delft Hydraulics. 1993. A global vulnerability analysis, vulnerability assessment for population, coastal wetlands and rice production on a global scale. Tidal Water Disvision, Rijkswaterstaat, Ministry of Transport, Public Works and Water Management, the Netherlands.

Devaraj, M. 1997. Status of research in marine fisheries and mariculture – Role of CMFRI. CMFRI special report No. 67. 39 p.

DOD & SAC. 1997. Coral reefs of the Indian Coast. SAC/RSA/RSAG/ DOD-COS/SN/16/97 report. Space Application Centre Ahmedabad India. 54 p.

Eckert, G.J. 1984. Annual and spatial variation in recruitment of labroid fishes among seven reefs in the Capricorn/Bunker Group, Great Barrier Reef. *Mar. Biol.* 78: 123-127.

Eckert, G.J. 1987. Estimates of adult and juvenile mortality for labrid fishes at One Tree Reef, Great Barrier Reef. *Mar. Biol.* 95: 167-171.

Eggleston, D.B. 1995. Recruitment in Nassau grouper *Epinephelus striatus*: post-settlement abundance, microhabitat features, and ontogenetic habitat shifts. *Mar. Ecol. Prog. Ser.* 124: 9-22.

Food and Agriculture Organisation (FAO). 1999a. FAOSTAT online database. www.fao.org

Food and Agriculture Organisation (FAO). 1999b. Number of Fishers 1970-1996. United Nations, Rome. 124 p.

Gaudian, G., Koyo, A. & Wells, S. 1998. A Global Representative System of Marine Protected Areas. Marine Region 12: East Africa. World Bank Environment Department, Washington. 37 p.

James, P.S.B.R., Parameswaran Pillai, P. & Jayaprakesh, A.A. 1984. Some observations on the fisheries of Lakshadweep. *CFRMI Bulletin* 43: 25-32.

Jennings, S., Grandcourt, E.M. & Polunin, N.V.C. 1995. The effects of fishing on the diversity, biomass and trophic structure of seychelles' reef fish communities. *Coral Reefs* 14: 225-235.

Lewis, A.R. 1997. Recruitment and post-recruit immigration affect the local population size of coral reef fishes. *Coral Reefs* 16: 139-149.

Lindén, O. & Sporrong, N. (eds.). 1999. *Coral reef degradation on the Indian Ocean. Status reports and project presentations 1999.* CORDIO, Stockholm, Sweden. 108p.

McClanahan, T.R. 1994. Kenyan coral reef lagoon fish: effects of fishing, substrate complexity, and sea urchins. *Coral Reefs* 13: 231-241.

McClanahan, T.R. in press. Coral reef use and conservation. In: McClanahan, T.R., Sheppard, C.R.C. & Obura, D.O. (eds.). *Coral reefs of the Indian Ocean: their ecology and conservation.* Oxford University Press. 526 p.

McClanahan, T.R. & Arthur, R. in press. The effect of marine reserves and habitat on populations of East African coral reef fishes. *Ecological Applications.*

Medley, P.A., Gaudian, G. & Wells, S. 1993. Coral reef fisheries stock assessment. *Rev. Fish Biol.* 3: 242-285.

Ministry of Tourism 1997. Tourism Statistics 1997. Ministry of Tourism, Malé, Republic of Maldives.

Ministry of Tourism 2000. Tourism Statistics 2000. Ministry of Tourism, Malé, Republic of Maldives.

Mirault, E. 1999. CORDIO Tourism Data Sheets: Reunion. CORDIO.

Naim, O., Cuet. P., & Mangar. V. in press. The Mascarene Islands. In: McClanahan, T.R., Sheppard, C.R.C. & Obura, D.O. (eds.). *Coral reefs of the Indian Ocean: their ecology and conservation.* Oxford University Press. pp. 353-381.

NARA. 1999. Sri Lanka Fisheries Yearbook 1998. NARA Crow island Colombo, Sri Lanka, 57 p.

Polunin, N.V.C. 1996. Trophodynamics of reef fisheries productivity. In: Polunin, N.V.C. & Roberts, C.M. (eds.). *Reef Fisheries.* Chapman & Hall, London. pp. 113-136.

Richards, W.J. & Lindeman, K.C. 1987. Recruitment dynamics of reef fishes: planktonic processes, settlement and demersal ecologies, and fishery analysis. *Bull. Mar. Sci.* 41: 392-410.

Roberts, C.M. 1996. Settlement and beyond: population regulation and community structure of reef fishes. In: Polunin, N.V.C. & Roberts, C.M. (eds.). *Reef Fisheries.* Chapman & Hall, London. pp. 85-112.

Robertson, D.R. & Gaines, S.D. 1986. Interference competition structures habitat use in a local assemblage of coral reef surgeonfishes. *Ecology* 67: 1372-1383.

Sadovy, Y.J. 1996. Reproduction of reef fishery species. In: Polunin, N.V.C. & Roberts, C.M. (eds.). *Reef Fisheries.* Chapman & Hall, London. pp. 15-60.

Sale, P.F. 1991. Reef fish communities: open non-equilibrial systems. In: Sale, P.F. (ed.). *The ecology of fishes on coral reefs.* Academic Press, San Diego. pp. 564-598.

Semesi, A.K. 1998. Mangrove management and utilisation in eastern Africa. *Ambio* 27: 620-626.

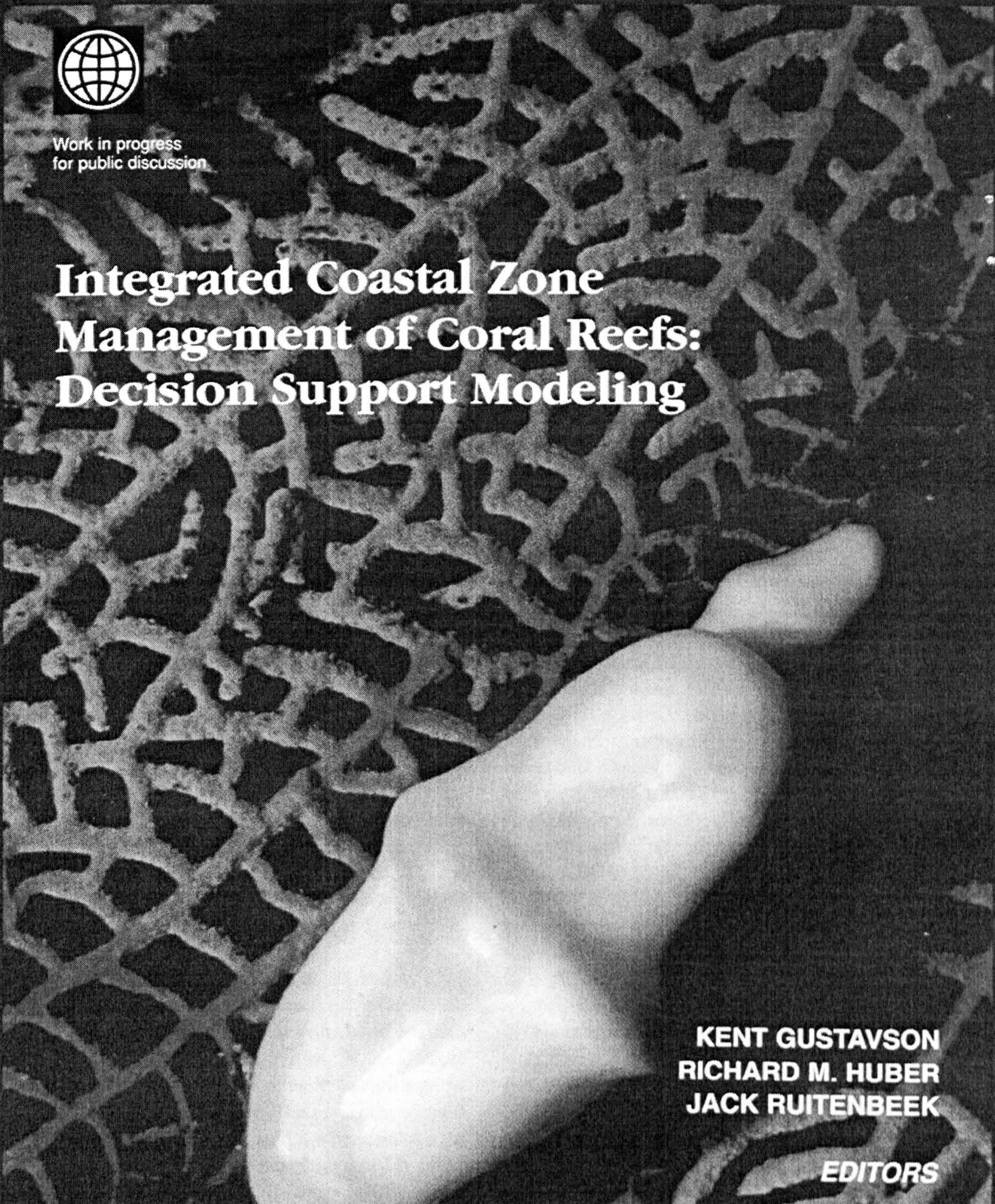
Shakeel, H. & Ahmed, H. 1997. Exploitation of reef resources: grouper and other food fishes. In: Nickerson, D.J. & Maniku, M.H. (eds.). *Proceedings of the workshop on integrated reef resources management in the Maldives.* BOBP/REP/76. pp. 117-135.

United Nations Development Programme (UNDP). 1998. *Human Development Indicators, 1998.* UNDP, Nairobi. 262 pp.

Westmacott, S., Cesar, H., Pet-Soede, L. & de Schutter, J. 2000. Assessing the socio-economic impacts of the coral reef bleaching in the Indian Ocean. A report to the World Bank African Environment Department. Draft.

Williams, D.M. 1991. Patterns and processes in the distribution of coral reef fishes. In: Sale, P.F. (ed.). *The ecology of fishes on coral reefs.* Academic Press, San Diego. pp. 437-474.

World Travel and Tourism Council 1999. *1999 Travel and Tourism Satellite Accounting Research Estimates and Forecasts.* WTTC, London. 70 p.



Work in progress
for public discussion

Integrated Coastal Zone Management of Coral Reefs: Decision Support Modeling

KENT GUSTAVSON
RICHARD M. HUBER
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EDITORS

Chapter 3

Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of Curaçao

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Curaçao lies in the southern part of the Caribbean Sea (Figure 3.1). It is one of the five islands making up the Netherlands Antilles, the others being Bonaire, St. Eustatius, St. Maarten and Saba. The total island area is 444km^2, with a length of 70km and a width varying from 5km to 14km. The capital of the island, Willemstad, is positioned in the center of the island around the Schottegat (Figure 3.1). This forms one of the largest natural harbors in the Caribbean Sea and is the center of the industrial zone of Curaçao. The main developments, both for housing and resorts, are currently along the central southern coastline. Oostpunt is the largest privately owned section of land on Curaçao and, as a result, is currently undeveloped. Westpunt has been gradually developing since the construction of a road that improved its accessibility; however, it still remains relatively undeveloped. The exposed north shore is also relatively undeveloped; this is the site of the Brievengat industrial zone and the airport, located at Hato.

Most of the coral reefs of Curaçao are in very good condition compared to many of the reefs in the Caribbean, although a stretch around the capital, Willemstad, has been seriously impacted by human activities. While Curaçao is still mostly dependent on its oil refinery, tourism is growing rapidly as a source of income. There are many planned tourism development projects, and the potential for the sector appears good, at least if the current quality of the coral reefs can be maintained. How can reef deterioration, which has occurred in many other places around the Caribbean, be prevented? Should certain areas be set aside? What will it take to rehabilitate the reefs in the Willemstad area, if that is at all possible? In 1995-96, a research project was carried out to develop an approach to answer these and similar questions.

Reef Research and Management

The Curaçao reefs have been well studied over the last 25 years in projects organized by or through the CARMABI Foundation in Curaçao (e.g., Bak and Nieuwland 1995). Most of the research that has taken place has been very specialized. It has focused on many aspects of marine biology, but rarely on the functioning of the reef as a whole. This is not as surprising as it may seem because coral reefs are extremely complex systems made up of hundreds of species of marine life that interact with each other in numerous ways. Where many biologists have worked for long periods to understand single species fisheries such as salmon, herring or anchovies without having completely succeeded, it is not that strange that coral reef biologists do not yet even have a generally accepted definition of coral reef health. Coral reef research often focuses on the response of a single species to a well defined disturbance under relatively carefully controlled conditions (e.g., Meesters *et al.* 1992; Veghel 1994).

From a perspective of coastal zone management, however, the relevant questions relate to the response of the reef system as a whole to a complex set of disturbances. Will the planned tourist developments and the associated wastewater discharges and artificial beaches have a significant impact on the coral reef? A coral reef biologist might answer this question by saying that the reefs are already under stress and that no new development should take place. A developer might answer this question by saying that the reefs of Curaçao are still in relatively good condition and that the economy of Curaçao needs the employment generated by tourism. In fact, the opposite argument is also used—because the reef is already

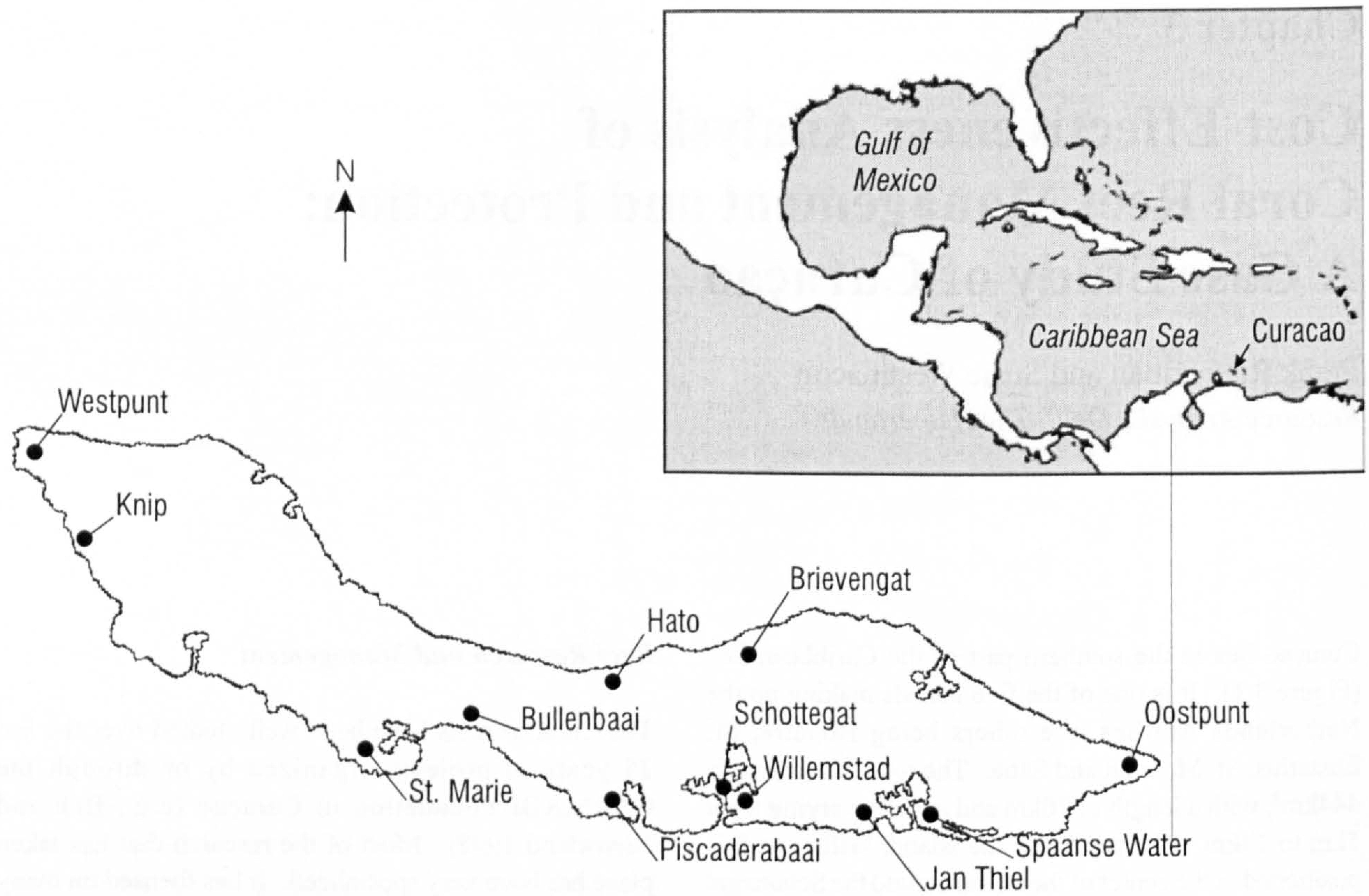

Figure 3.1. Curaçao, showing its location within the Caribbean.

degraded in certain locations, how can more development in those locations possibly harm the reef significantly? Both sides are likely to be partly right, but the more subtle answer to the question of how much development is sustainable requires: i) much more insight into the functioning of the reef as a whole; and, ii) a consensus among people involved concerning the quality of the reef that is desired or, in other words, the impacts to the reef that are socially acceptable.

Objective and Approach

The objective of the research project reported here is to develop an approach that will do two things, namely:

- Bring together the available knowledge in marine biology, economics and engineering to determine whether human use of the coastal zone will significantly affect the health of the coral reef system and what the most cost-effective manner is to prevent impacts on coral reef health; and,
- Provide a means to engage the various stakeholders in a discussion to determine what sustainable development of the coastal zone means for them and, therefore, what levels of reef health are socially desirable.

The Coral-Curaçao Decision Support System

The approach chosen to achieve these objectives has been to develop a computer-based decision support system, referred to as Coral-Curaçao (see also Chapter 4 and the companion CD-ROM). The two main innovative elements in the approach are: i) the interactive, computer-based approach to decision support for integrated coastal zone management (ICZM); and, ii) the ecological response model for coral reef health based on fuzzy logic.

The decision support system aspect of Coral-Curaçao has the following characteristics:

- It utilizes a graphics-based user interface that makes it easy for decision-makers or stakeholders to use;
- It utilizes a case study-based (i.e., location specific) approach, which has the advantage of demonstration through realistic examples rather than abstract theory;
- It guides users through a generic approach to ICZM that structures the development, analysis and evaluation of coastal zone management strategies;
- It is interactive (i.e., it allows user input with respect to setting of objectives and criteria, definition of scenarios, selection of measures and strategies, and evaluation of impact); and,

- It demonstrates inter-sectoral linkages and facilitates communication among stakeholder groups.

The fuzzy logic based response model for coral reef health has the following characteristics:

- The model is an expert system, based on fuzzy logic, that does not attempt to describe the behavior of the system deterministically (i.e., through equations that describe the behavior of the reef as a function of a set of driving variables and parameters), but simply uses a "black box" approach to describe reef behavior;
- The model encapsulates and synthesizes expert knowledge into a large number of decision rules that are subsequently used to "predict" reef behavior;
- The model brings together a large amount of varied experience and expertise, gained from many different sources, and applies it to the problem at hand; and,
- The response model for Curaçao links the concentrations of nutrients (i.e., nitrogen and phosphorus) and sediment over the reef to future values for coral reef health (defined by coral cover and relative species diversity) under various reef conditions (i.e., current reef health, available substrate and maximum colony size).

The development of the fuzzy logic model was originally based on the parallel model developed for Jamaica (Ridgley and Dollar 1996; Chapter 8). Subsequent revisions of both models show differences in the development due to the different local situations. The case study for the Maldives takes a more focused look at physical damage (Meesters and Westmacott 1996; Chapter 4).

Development of Scenarios and Environmental Strategies

The first use of Coral-Curaçao is to analyze the impact of alternative development scenarios for Curaçao on coral reef health, as well as on a number of other economic, environmental and social criteria. The second use is to determine the cost-effectiveness of alternative environmental and institutional measures to prevent impacts on coral reef health.

The development scenarios can be defined by the user through a combination of overall island-wide assumptions regarding expected economic growth, population growth, growth in expected tourist arrivals in Curaçao (the demand for tourism), and the discount rate (to determine the present value of future costs and benefits). In addition, the user can provide detailed assumptions on the preferred location of newly constructed or expanded hotels, apartments and residential developments, and new harbor developments.

Three example development scenarios are reported in this chapter. They illustrate the types of analyses that can be carried out with this model. Actual use of the model will require the identification of the scenarios and strategies in cooperation with the various coastal zone managers in Curaçao. The first scenario (the reference scenario) focuses on the current situation with little new investment, population growth as in the past, and a stagnating economy. Development is centered near Willemstad. The second scenario (the growth scenario) assumes 3% annual growth in the economy, particularly through the tourism sector. Two variations are made in this scenario: i) "growth-west", where a significant portion of residential and tourism development has been planned west of Willemstad and the east has been left largely undeveloped; and, ii) "growth-east", where growth concentrates more on the area east of Willemstad with at least one major hotel in Oostpunt. For each of these three scenarios, the impacts on the reefs have been analyzed and example environmental strategies have been developed to see how impacts could be prevented and at what cost.

It is intended that through further development and training with the model, it can be used in the development of coastal zone management plans. This will involve the coastal zone decision-makers to identify potential scenarios and formulate the environmental strategies. It will also involve a degree of cooperation and interaction between the different stakeholder groups, leading to the eventual formulation of alternative coastal zone management plans. Further information regarding the development of the Coral-Curaçao model can be found in Meesters (1995), Meesters *et al.* (1996a), Rijsberman *et al.* (1995a), Westmacott *et al.* (1995), and Rijsberman and Westmacott (1996).

Description of Coral-Curaçao

The approach adopted in the Coral-Curaçao model is based on cost-effectiveness analysis of coral reef health in an ICZM framework. The main components of the decision support system are a user interface, economic activity model, water quality model, and ecological response model (Figure 3.2). The user provides inputs concerning economic development scenarios and environmental management strategies through the user interface. The economic activity model translates these assumptions and choices into pollutant loadings along the coast and keeps track of a number of economic parameters (i.e., GDP per capita, employment, and environmental costs and investments). The base year for Coral-Curaçao is 1995 and projections are made over 10 years to 2005.

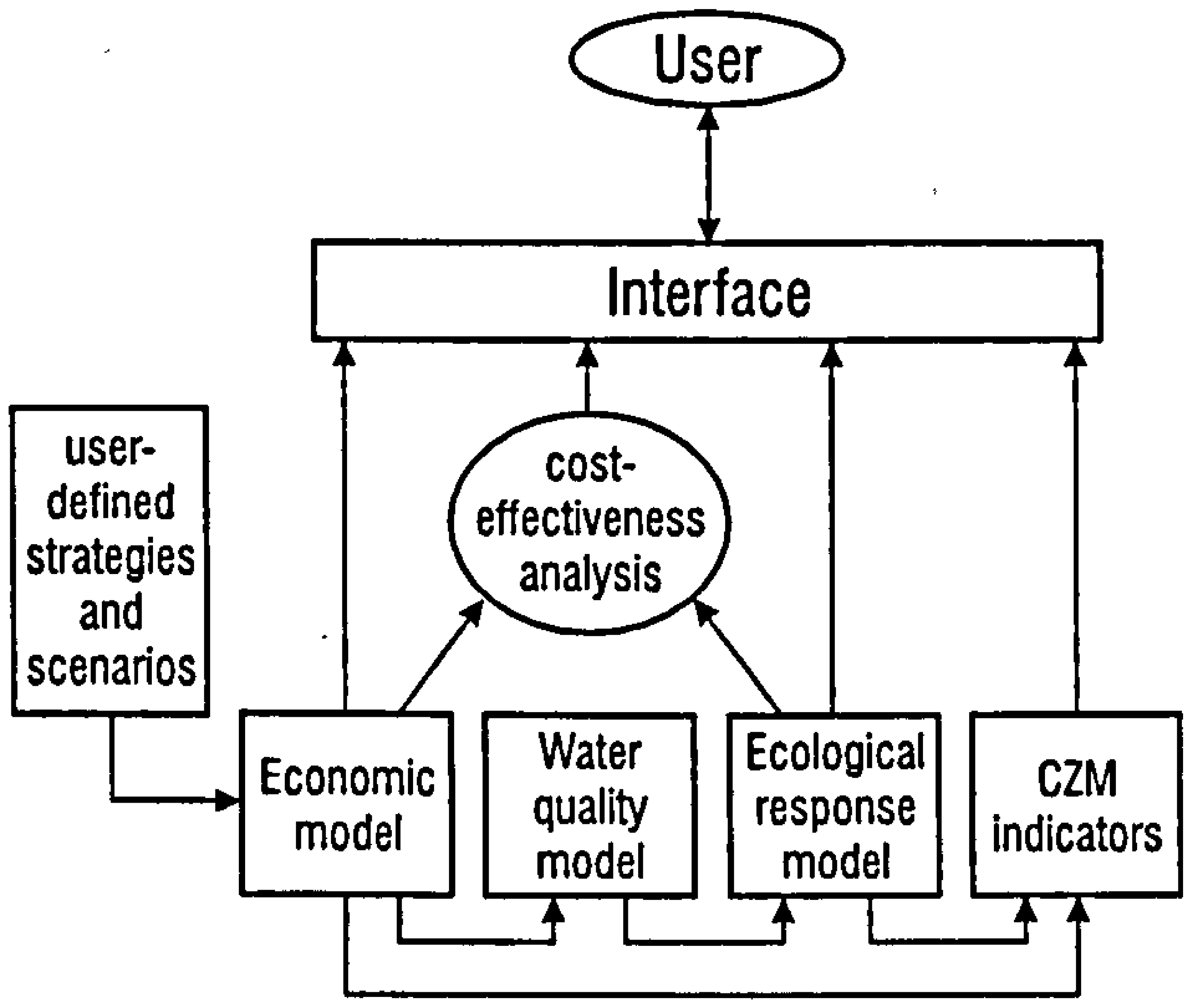

Figure 3.2. Structure of the Coral-Curaçao decision support system.

The water quality model determines the water quality that corresponds with the pollutant loadings for six sections along the southern coast of Curaçao (Figure 3.3). Water quality is defined in terms of concentrations of *E. coli* and in terms of nutrient (i.e., nitrogen and phosphorus) concentrations. Sediment impacts on the reefs are based on the locations and material of the artificial beaches, as well as the suspended material discharged by the land-based activities. The ecological response model then determines the resulting reef health (i.e., cover and diversity) for the six coastal sections. The outputs of the economic activity, water quality and ecological response models are shown to the user through tables and graphs in the user interface, along with several criteria that the user is asked to evaluate through user input (i.e., social acceptability and financial feasibility of the scenarios and strategies).

Cost-Effectiveness Analysis

In theory, if all benefits provided by coral reefs could be determined quantitatively and if all costs of protecting coral reefs from pollution or overuse could be enumerated, then one could determine the "optimal" level of investment in coral reef protection and management. Determination of the social and economic benefits provided by coral reef ecosystems is the subject of subsequent chapters. Although significant progress has been made in benefit valuation, it remains notoriously difficult, particularly for complex systems such as coral reefs.

The next best alternative would be to determine what level of coral reef health is socially desirable (a procedure similar to determining water quality standards, for instance) and then to analyze what the least expensive, or most cost-effective, manner is to provide the desired level of reef health. This is referred to as cost-effectiveness analysis.

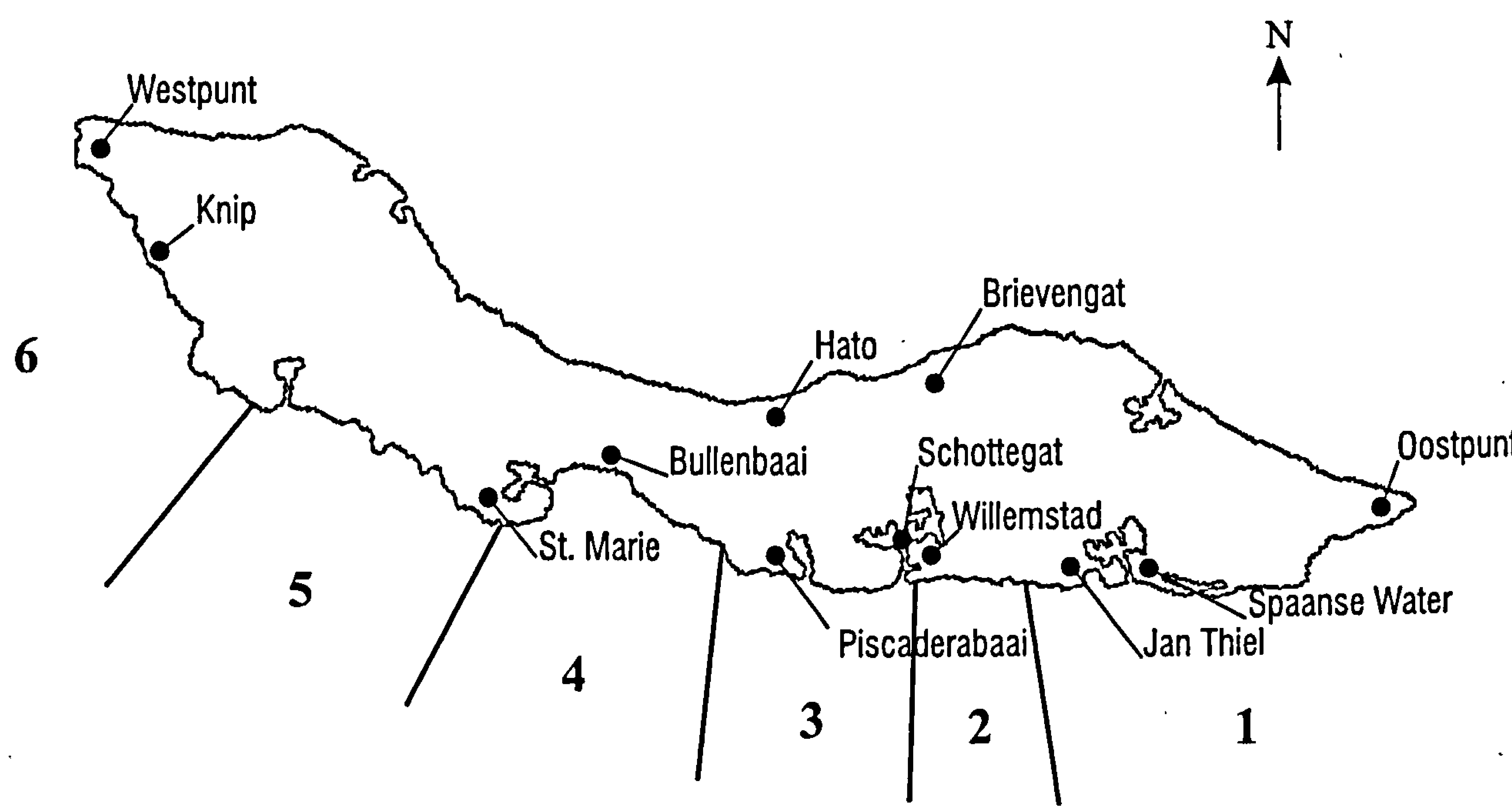

Figure 3.3. Coastal section divisions of Curaçao utilized in the model.

In the version of Coral-Curaçao presented here, no attempts are made to quantify the benefits of having a healthy reef. The basis for decision-making with Coral-Curaçao is, therefore, a form of cost-effectiveness analysis. An associated problem is then how to determine the level of socially desirable reef health. The socially desirable level of reef health has to be decided by the stakeholders. However, a model such as Coral-Curaçao can facilitate the discussion among stakeholders concerning these issues. For reference purposes, what is required to maintain the current level of reef health can be analyzed. Whether this is either necessary, or sufficient, remains a question that has to be answered by, in this case, the people of Curaçao.

The ICZM Framework for Analysis

The main structure of the coastal zone management analysis in Coral-Curaçao follows the structure of a generic framework for analysis that has been developed over the last 10 to 15 years (Bower *et al.* 1994; Resource Analysis and Delft Hydraulics 1993; Rijsberman and Koudstaal 1989; Westmacott 1995). Practical applications of this approach to coastal zone management issues are given by, for instance, Baarse and Rijsberman (1986, 1987) and Ridgley and Rijsberman (1992). Following this framework, the main steps in an ICZM analysis within Coral-Curaçao are as follows:

- Problem identification;
- Definition of objectives and criteria as yardsticks to measure fulfillment of objectives;
- Definition of scenarios for uncertain, exogenous developments;
- Definition of management strategies in terms of their component measures;
- Analysis of the impacts of the strategies in terms of the criteria; and,
- Evaluation and selection of the most desirable strategy.

The Decision Support System User Interface

The decision support system developed for Curaçao has a user interface of the type developed in 1993 for the coastal zone management training tools COSMO and CORONA (Resource Analysis and CZM Centre 1994; Rijsberman *et al.* 1995b). It has been shown in a series of workshops and seminars that this type of interface is easily accessible for specialists from various disciplines as well as policy-makers, including those with minimal or no computer experience or scientific background. The interface attempts to bridge the communication gap between policy-makers and coastal zone specialists. The interface is based mostly on graphic information to provide users with a quick overview with minimal text. The structure of the interface's main menu guides the user through the steps of the ICZM framework for analysis, as outlined above, and thereby structures the user's thinking about the problems at hand.

A major characteristic of the interface is that it is truly interactive. Many recent multimedia tools are called interactive but allow the user no more interaction than the order in which the screens are observed. Coral-Curaçao allows the user, as do similar decision support system tools in the "COSMO family", to input his or her own assumptions or preferences about scenarios and strategies, and examine the consequences. The development scenarios input screens in Coral-Curaçao provide the user with the opportunity to define a likely, or desirable, development path for the economy, with particular focus on development of the coastal zone. The user can provide detailed definitions of hotel, apartment, residential, artificial beach and harbor development projects in pre-defined locations along the coast.

The Economic Activity Model

The main purpose of the economic activity model is to determine the pollutant loadings resulting from assumptions about economic development combined with environmental strategies, as well as the costs of the environmental measures taken to reduce those pollutant loadings. The economic activities distinguished in Coral-Curaçao are tourism, harbors and shipping, manufacturing, fisheries, services and "other" (i.e., the rest of GDP), the oil refinery, and residences. Tourism, harbors and shipping, and fisheries are considered to be the coastal zone related activities, in the sense that they depend directly on the coastal zone. Manufacturing, the oil refinery, and residences are considered separately from the rest of the economy because of their potential impact on the coastal zone through discharges of pollutants. There is no agriculture to speak of in Curaçao with significant influences on the coastal zone.

Pollutant loadings are based on sectoral outputs multiplied by an emission factor per unit of output (in monetary terms) for all sectors except the oil refinery, residences and tourism. The base loadings produced by the economic activities can be reduced through end-of-pipe treatment. This yields the final loadings that are discharged. For residences, the loadings are based on emission factors per capita. For tourism, the loadings are based on the number of tourist nights. For the oil refinery, the loadings are based on emission factors multiplied by output in cubic metres of oil produced. The steps in the economic activity model are described in the following sections.

Step 1—Activity Levels

The total GDP in 2005 (in constant 1995 dollars), except for the tourism sector, is determined by an overall assumption of the annual economic growth (scenario variable). The sectoral output of tourism is determined by the lowest of: i) projected tourism demand (scenario variable); and, ii) hotel capacity, as influenced by hotel construction projects. The size of the population in 2005 is based on an assumption for annual population growth (scenario variable).

Step 2—Sectoral Shares and Spatial Distribution

The sectoral share of the GDP (except tourism) can be modified by the user through assuming that several investment projects (in harbors and manufacturing) take place. The overall growth rate is not affected by these investments; it is in fact assumed that the investments are shifts within an overall investment portfolio. The additional increase in the sectoral GDP due to the investment project is calculated as an assumed return on investment. The GDP of the other sectors (harbors, manufacturing, services and "other") are reduced by the same total amount, distributed proportional to their 1995 share of GDP. The investment projects, therefore, do not affect overall output, GDP or GDP per capita, but they can affect pollutant loadings because of the difference in emission coefficients per sector. Construction of housing and hotels is specified by the user and spatially distributed over six sections along the coast. The location of other sectoral activities (harbors, refinery, manufacturing, services and "other"), and consequent location of the discharges, is fixed in the model based on their current location. In short, the overall GDP and sectoral shares are determined by assumptions on overall economic growth and tourism demand together with assumptions on investment projects in harbors, manufacturing, hotel construction, residence construction, and artificial beach construction. Through the spatial distribution of, particularly, housing and hotels, the user specifies land use scenarios for the island. Such scenarios can determine development and conservation areas on the island (e.g., following ideas as presented in an approved island-wide development plan). The impact of such development choices on the reef is shown with the help of Coral-Curaçao.

The Coral-Curaçao user can actually define construction projects (houses, hotels, apartments, artificial beaches) in more detail than the six sections used for the water quality and coral reef computations. In the interface, the actual sites and locations (approximately 20 in total) along the coast are based on projects proposed by developers. This has the advantage of providing a better fit to the land use planning discussions and the public debate about projects that focus on specific hotel projects on specific beach or bay sites. This is intended to increase the acceptance and use of the decision support system for Curaçao.

Step 3—Base Pollutant Loadings

The activity levels (sectoral GDP shares and number of houses in 2005) multiplied by the emission factors generate base pollutant loadings. For each of the sectors, emission coefficients have been defined for nitrates (N), phosphates (P) and sediment (total suspended solids or TSS; see Rijsberman and Westmacott 1996).

Step 4—Final Pollutant Loadings (Wastewater Treatment)

In Coral-Curaçao, the user specifies wastewater treatment options for residential and tourism sector discharges. The following options are available:

- *No treatment.* The base load is discharged directly into the near-shore (septic tanks are assumed to play a marginal role).
- *On-site treatment for hotels and apartments.* The treated final load is discharged into the near-shore (if there is an outfall to move the discharge off the beach, it is assumed not to take the discharge beyond the reef area).
- *Sewage system connected to an ocean outfall.* This is assumed to bring the discharge beyond the reef area.
- *Sewage system connected to a sewage treatment plant.* There is subsequent discharge on the near-shore (no outfall or a short, near-shore outfall).
- *Sewage system connected to a sewage treatment plant with outfall.* There is subsequent discharge through an ocean outfall beyond the reef.
- *Sewage system for transport to a neighboring section.* Wastewater is removed completely from this section and subsequent discharge depends on treatment level and outfall construction in the neighboring section.

For the refinery, manufacturing, harbors and shipping, and services and "other" sectors, the user specifies base load reduction percentages directly. It is left undefined whether these reductions are the result of improved processes (i.e., reduced discharge coefficients) or end-of-pipe treatment. Only rough estimates of costs are available for these measures (see Step 6 below). Pollutant loadings (sediment discharge) from artificial beaches can be reduced by the use of coarser, more expensive types of calcareous sand. Sediment from artificial beaches is dealt with directly in the water quality model.

Step 5—Other Environmental Management Measures

The model also keeps track of assumptions on several other environmental management options (i.e., environmental awareness raising programs, establishment of a marine park, and increased inter-sectoral coordination). These are not assumed to modify loadings directly, but to increase the social acceptability and financial feasibility of the other environmental investments.

Step 6—Environmental Costs

The model calculates the cost of environmental management strategies. The major component of this is wastewater treatment. The costs of treatment consist of the investment costs of:

- On-site treatment systems for hotels and apartments;
- Construction of sewage systems;
- Construction of treatment plants; and,
- Construction of outfalls.

All investment costs are assumed to occur in year one and are not discounted. Annual costs of maintenance and operation are discounted (with a user-specified discount rate) to year one and added to the investment costs to obtain total costs. Other costs taken into account are:

- Additional cost of using calcareous sand for artificial beaches (3,500 NAF m^{-1} yr^{-1} additional investment costs and 500 NAF m^{-1} yr^{-1} additional maintenance costs);
- Cost of establishment and operation of a marine park (user defined);
- Cost of environmental awareness programs (user defined);
- Cost of reducing discharges from manufacturing (estimate); and,
- Cost of reducing discharges from the refinery (estimate).

The costs of the environmental management strategies are used for the analysis of cost-effectiveness of coral reef protection measures, where the effectiveness of a strategy is measured as the difference in reef health (either cover or diversity) as determined by the ecological response model.

Step 7—Other Indicators

The model also tracks several other parameters that are not used for the cost-effectiveness analysis. These do, however, provide the user with information about the economy under the given assumptions for economic growth, sectoral investments, and environmental management strategies. These parameters relate mainly to GDP, GDP per capita, GDP of coastal activities, total employment, and employment in coastal activities, as well as the financial and political feasibility of strategies (the latter two being user defined).

The Water Quality Model

A simple water quality model has been formulated to determine water quality (i.e., concentrations of nitrates and phosphates) in six sections along the coast (Figure 3.3). The model is driven by the average east to west current parallel to the coastline and takes into account the effects of tidal mixing (diffusion) perpendicular to the coastline, as well as decay of the pollutant materials within each of the six sections. This type of simple model is a relatively good approximation for a straight coastline with high lateral velocities compared to the tidal velocities. As this is the case for Curaçao, this type of model was used to provide approximate indications of water quality under average conditions in the six sections. Precise water quality determination for specified times and locations are not possible with this type of model, but, bearing in mind the level of accuracy of the ecological response model, this is not considered to be a major drawback.

For accurate estimates of water quality along beaches, the model that has been used is not very appropriate and could be improved. Estimates of sediment concentrations (in terms of low, medium and high, as required by the ecological response model) have been based on the location and composition (in terms of grain size) of artificial beaches. The water quality model is valid for the areas of reef flat. This is the part of the reef that is taken into account in the Coral-Curaçao model (see next section). If the model were to consider the reef slope then other aspects, such as the influence of mixing with ocean currents, would need to be considered.

The Coral Reef Ecological Response Model

An important component of the Coral-Curaçao modeling framework is an ecological response model to predict the impact of economic development on reef health. Reef health, defined as coral cover and relative species diversity, is used as the main indicator of the status of the marine ecosystem (i.e., the model outputs). The ecological response model has been designed to predict the impacts of the most significant pollutants on the reef flat. The reef flat has been selected because the majority of research and available information is based on this zone of the reef. This may result in a different level of impact than if the reef slope was also considered. The reef flat may be the first area to be affected from land-based pollution and storms, for example. The reef slope is the area most visited by recreational divers and potentially providing shelter and food for fish. However, on the grounds of data and knowledge availability, only the reef flat is included in this model.

The most significant pollutants in Curaçao have been identified as nutrient enrichment from the discharge of wastewater of land-based activities (i.e., sewage and industrial wastewater, and increased sediment concentrations that result from artificial beaches). There are other influences on reef health (e.g., consequences of anchoring, fishing or direct diver related impacts), but these have been evaluated to be relatively small in the current Curaçao context compared to the influence of nutrients and sediment. The main reef characteristics that influence how the inputs of nutrients and sediment affect reef health that have been accounted for in the model are: i) available substratum; ii) maximum colony size; iii) coral cover; and, iv) diversity. The methodology for the ecological response model has been developed by Ridgley and Dollar (1996) and has been modified and tested for Curaçao conditions. The Curaçao ecological response model has been developed as part of this project and is described in detail in Meesters (1995) and Meesters *et al.* (1996a, 1998).

The Curaçao reef response model determines coral cover and diversity for an imaginary situation 10 years after the impact levels have changed. The inputs are suspended particulate matter, soluble reactive phosphorus, dissolved inorganic nitrogen, maximum colony surface area, available substratum and, again, coral cover and diversity (species number). Each variable was divided into three triangular fuzzy sets reflecting low, medium and high values. Boundary values for the sets were based on fieldwork carried out for the project and on the literature (Meesters 1995). For each of the 2,187 possible input combinations, decision rules were formulated. Information on current reef conditions in Curaçao is provided in Table 3.1.

Case Studies for Curaçao

We now examine how the Coral-Curaçao decision support system can be used in the analysis of alternatives for coral reef management under different economic development scenarios. As stated previously, formulation of scenarios and strategies for both the economic development and the environmental protection measures should eventually be done in conjunction with the stakeholders in the region. Cooperation with the stakeholders on the island will enable a number of constraints and criteria to be identified that are likely to enter into decisions on reef management. The cases formulated in this chapter should be seen as examples of the how the Coral-Curaçao decision support system can potentially be used. The reader is encouraged to explore the model through use of the CD-ROM included with this publication.

Development Scenarios

As previously described, the following example economic development scenarios have been pre-defined in Coral-Curaçao: i) a reference scenario; and, ii) two growth scenarios, growth-west and growth-east. These scenarios are summarized in Table 3.2. These development scenarios are examples to demonstrate the use of Coral-Curaçao; they are not necessarily balanced development proposals for Curaçao.

Reference Scenario

In the reference scenario, no major investments are assumed to take place and most trends are, in essence, continued as observed in recent years. This means that the overall economic growth rate is near zero. There is some growth in the tourism sector (3% growth in demand per year) but this is balanced by some decline in other sectors.

Table 3.1. Curaçao reef conditions in 1995. The range of values shown is the values occurring in the sub-sections within the six main sections.

Section	*Cover* (%)	*Diversity* (% of species present)	*Available substratum* (%)	*Maximum colony size* (10^{-2} m^2)
1 (Oostpunt to Cornelisbaai)	14 to 23	33 to 61	40 to 50	77 to 316
2 (Cornelisbaai to Punda)	8 to 20	14 to 26	10 to 50	42 to 69
3 (Schottegat to St. Michael)	1 to 16	1 to 55	1 to 40	8 to 75
4 (Bullenbaai)	11 to 14	41 to 65	20 to 30	53 to 89
5 (Rif St. Marie to St. Martha)	12 to 16	26 to 100	20 to 40	89 to 143
6 (Jeremi to Playa Kalki)	15 to 23	17 to 98	40	275 to 455

Table 3.2. Development scenarios pre-defined in Coral-Curaçao.

Variables	*Units*	*Reference scenario*	*Growth-west*	*Growth-east*
Economic growth	%/yr	0	3	3
Population growth	%/yr	1.2	1	1
Growth in tourism demand	%/yr	3	8	8
Discount rate	%/yr	6	6	6
Residential development	# of houses	current pattern	600 from Westpunt to St. Martha Bay	600 in Spaanse Water and Jan Thiel
Hotels and apartments	# of rooms	600 in Piscadera and Cornelisbay	2,000 from Westpunt to Rif St. Marie	2,000 from Oostpunt to Marie Pompoen
Artificial beaches		none	Rif St. Marie Marie Pompoen	Oostpunt Cornelisbay Marie Pompoen Elyse Hotel
Harbor projects		none	Caracas Bay and Schottegat	none
Refinery output growth	%/yr	-1	-2	0
Manufacturing growth	%/yr	0	0	2

Population growth continues at about 1.2%/yr and, therefore, per capita income declines somewhat. Construction of new houses is assumed to continue in the present pattern without major shifts. The new tourist development projects (some 600 rooms) are assumed to be located around Piscadera Bay and the area just west of Seaquarium (referred to as Cornelisbay in Coral-Curaçao). No new artificial beaches would be constructed. There are no new harbor improvement or development projects.

Growth-West Scenario

In the growth-west scenario, an overall economic growth of 3%/yr is assumed to take place, with vigorous growth in the tourism sector (8% growth in demand per year). Population growth declines to 1%/yr. The scenario places emphasis on development of the western part of the island for tourism and residences, and expansion and improvement of harbor facilities in Caracas Bay and Schottegat. The refinery output is assumed to decline somewhat, while manufacturing stabilizes. Emphasis in development of the western part of the island to relieve congestion around Willemstad, as well as develop its tourism potential, implies that some 600 new houses are assumed to be constructed (following existing development plans) in the area from Westpunt to St. Martha Bay. Some 1,200 tourist rooms would be developed in the same area, from Westpunt to Rif St. Marie. The existing beaches would be supplemented by one artificial beach at Rif St. Marie. A second artificial beach would be constructed at Marie Pompoen. The harbor project consists of the proposed reception facilities in Caracas Bay. Oostpunt would, in essence, be preserved as a natural area in this scenario.

Growth-East Scenario

Growth east of Willemstad, with the same overall growth characteristics of the economy as for the growth-west scenario, places more emphasis on the eastern, rather than the western, part of the island. Residential development would be assumed to take place in the Spaanse Water and Jan Thiel areas. Tourist developments would emphasize at least one major hotel in the Oostpunt area (200 rooms) and other proposed projects between Oostpunt and Punda. In this scenario, four artificial beaches have been proposed for construction at Oostpunt, Cornelisbay, Marie Pompoen, and the Elysee Hotel. There would be no harbor development projects, relatively stable refinery output, and some growth in manufacturing.

Environmental and Other Impacts

The impacts of the development scenarios on both the economy and on the reefs are summarized in Table 3.3.

Table 3.3. Impacts of development scenarios without environmental strategies (GDP=gross domestic product; N=nitrogen; P=phosphorus; SPM=suspended particulate matter).

Criteria	*Units*	*Reference scenario*	*Growth-west*	*Growth-east*
GDP per capita	NAF/yr	13,000	17,300	17,300
Employment	number of jobs	58,000	77,000	78,000
GDP share of coastal activities	%	21	22	21
GDP tourism	million NAF	324	450	450
GDP fisheries	million NAF	10	13	13
GDP harbor and shipping	million NAF	115	176	154
Total N load	kg/day	2,100	2,200	2,200
Total P load	kg/day	790	840	870
Total SPM load	kg/day	17,800	17,700	18,900
Average coral reef diversity	%	32	32	32
Average coral reef cover	%	9	9	9
Problem beaches (bad water quality)	number	13	14	0

In essence, even though the development locations of the hotels, apartments and houses are quite drastically different, the overall impact of the three development scenarios on reef health is similar. There are differences within each of the coastal sections, but these are not drastic. The characterization of the situation remains that the eastern and western sections are relatively pristine and that the middle sections are heavily impacted. This impact reflects the effect of the industrial zone around the Schottegat. There is a significant difference in the water quality along the beaches. The western part of the island has a series of attractive beaches. The growth-east scenario maintains relatively good water quality conditions in the western part, at least at the first order accuracy of the simple water quality model used here. When there is some development in the western part, all these beaches become potential problem areas if there are no sanitation measures taken. The overall loadings of pollutants are determined more by the population growth rate than by tourism development (at least at the relatively modest tourism growth rates investigated here).

Environmental Strategies

A series of environmental measures are now investigated and subsequently combined into strategies to explore the potential improvement in coral reef health (i.e., cover and diversity) and the costs involved. These strategies are analyzed under each of the economic scenarios described previously.

The environmental protection options available to the user have been described above. The user can define these options for different locations, corresponding to the various settlements along the southern coast. The user is able to define any combination of measures and save these for the analysis. In addition, measures can be defined for the industrial area surrounding Schottegat Harbor.

To begin the analysis, the measures have been investigated on an individual basis. These are then combined into strategies or groups of measures all aiming to be complimentary in the achievement of an improved reef condition. Analyzing the individual measures allows the user to make an assessment as to the individual effectiveness. This will help in the formulation of effective combinations, rather than random combinations. Like the economic development options, the measures defined here are to be used to illustrate how the model works and explore its limits. They are not carefully formulated environmental management plans that have been decided upon by a group of decision-makers. Table 3.4 describes the environmental protection strategies that have been defined and used in the analysis. Three combinations of municipal waste disposal, industrial pollution control, and beach maintenance have been combined together to explore the effect of integrating measures and to examine the cumulative effect that these have on reef health.

Table 3.4. Descriptions of the environmental protection measures and strategies.

Code	*Description*
10H	100% treatment of hotel waste through onsite treatment.
10W6	100% connection of houses and hotels to sewage system; treatment with 60% reduction through five wastewater treatment plants.
10W9	100% connection of houses and hotels to sewage system; treatment with 90% reduction through five wastewater treatment plants.
10W9/10H	100% connection of houses to sewage system; treatment with 90% reduction through five wastewater treatment plants; 100% treatment of hotel waste through onsite treatment.
5W9	50% connection of houses and hotels to sewage system; treatment with 90% reduction through five wastewater treatment plants.
5W9/5H	50% connection of houses and hotels to sewage system; treatment with 90% reduction through five wastewater treatment plants; remaining 50% hotel waste treated through onsite treatment.
B	Maintenance of the artificial beaches with heavier calcarious sand reducing the transport from the shore onto the reef flat.
M9	90% reduction of manufacturing waste through onsite treatment.
O4	100% houses and hotels connected to the sewage system where disposal is through four outfalls.
O9	100% houses and hotels connected to the sewage system where disposal is through nine outfalls.
R	Reduction of refinery effluent.
R/S4/M9	Maximum reduction of industrial pollution through reduction of refinery effluent; 40% reduction of pollution from ships through improved reception facilities and 90% reduction in manufacturing waste through onsite treatment.
S4	40% reduction of waste from ships through improved reception facilities.
Strat1	50% connection of houses and hotels to sewage system; treatment with 90% reduction through five wastewater treatment plants; remaining 50% hotel waste treated through onsite treatment; reduction of refinery effluent; 40% reduction of pollution from ships through improved reception facilities and connection of manufacturing waste to sewage system.
Strat2	100% connection of houses to sewage system; treatment with 90% reduction through five wastewater treatment plants; 100% treatment of hotel waste through onsite treatment; reduction of refinery effluent; 90% reduction in manufacturing waste through onsite treatment.
Strat3	100% connection of houses, hotels and manufacturing waste to the sewage system and disposal through four outfalls; reduction of refinery effluent; 40% reduction of pollution from ships through improved reception facilities and beach maintenance.

Analysis of the Results

Tables 3.5 to 3.7 show the results of the environmental protection measures and strategies under the three economic development scenarios. The main indicators of the effectiveness of these measures and strategies are costs (investment, operation and maintenance) and the resulting coral cover and diversity. In addition, the number of problem beaches is also examined. This is an indication of the number of beaches likely to be threatened by fecal pollution.

The current reef health was found to decline in all of scenarios in a similar manner. The average for coral cover drops from 15% in the current situation (1995) to 9%, while the average for diversity drops from 55% to 32%. The major impact zone begins at the population center of Punda and moves westwards across the Schottegat entrance, extending up to Santa Marta Baai. This pattern is similar for both coral cover and diversity. The growth-east and growth-west scenarios follow similar patterns. This is due to the relatively small growth of population centers in the east and west. Compared to the pollution produced from the industrial zone and Willemstad, this appears to have a relatively small influence.

The eastern end of the island remains impact free in the reference situation and, for coral cover, the current situation is seen to improve by approximately 5%. This follows a pattern of steady coral growth without competition from algae and other competitors for space. However, the coral diversity declines slightly. This shows that the current diversity is not sustainable with the other reef conditions and eventually the reef will head towards an equilibrium with a lower diversity. This would represent a more developed reef than seen at present. The zone of greatest impact appears to spread along the coast from close to Schottegat westwards. This represents the effect of the westward current carrying pollutants from the industrial and heavily populated zone. This effect does not appear to reach Westpunt itself, having been sufficiently diluted along the coast.

These strongly declining conditions can be altered by the environmental protection measures and strategies implemented and shown in Tables 3.5 to 3.7. Each of these measures and strategies has a different reduction on the land-based loadings and, therefore, on reef health. The costs of the measures and strategies vary quite considerably. The major investments are linked to wastewater treatment and disposal that involves the construction of a complete sewage system. Septic tanks are not included in the model and these have, in the past, been widely used in Curaçao. In the more developed areas, they become increasingly less suitable; however, in the more sparsely populated areas, they may remain a feasible option. The model may need to take into account the seepage of the effluent into the groundwater table and, eventually, also into the near-shore waters. It is possible that seepage may be partly responsible for changes in the nutrient levels over the reefs. However, there has been limited research into this as yet.

The largest improvements in reef health can be obtained by a combination of measures addressing the various sources of pollutants. Disposing of sewage through four outfalls along the coast effectively removes the impact of sewage pollution from the reef. The average coral cover resulting from this measure is 11% and the resulting diversity is 38%. This does show an improvement from the reference conditions, with the major areas of improvement being the western sections. Coral cover does improve around Punda by 8% and in the far western sections by 7% to 12%. Diversity gradually improves from Bullenbaai to the west, where increases are seen between 5% and as much as 40%. Little change is seen around the Willemstad area. This is likely due to the remaining influence of the industrial pollution.

Table 3.5. Environmental protection options under the reference scenario.

Strategy code	*Investment cost (million NAF)*	*Operation and management (million NAF)*	*Coral cover (%)*	*Coral diversity (% of maximum)*	*Number of problem beaches*
10H	2.4	0.1	9	32	13
10W6	240	2.2	10	37	0
10W9	270	2.3	11	38	0
10W9/10H	270	2.4	11	38	0
5W9	130	1.1	10	36	0
5W9/5H	130	1.2	10	36	0
B	0	0.12	9	32	13
M9	0.41	0.01	9	32	13
O4	220	2.1	11	38	0
O9	220	2.5	11	38	0
R	47	3.4	10	36	13
R/S4/M9	52	3.8	10	36	13
S4	5.3	0.43	9	32	13
Strat1	190	5	14	47	0
Strat2	310	5.8	14	50	0
Strat3	270	6	15	51	0

Table 3.6. Environmental protection options under the growth-east scenario.

Strategy code	*Investment cost (million NAF)*	*Operation and management (million NAF)*	*Coral cover (%)*	*Coral diversity (% of maximum)*	*Number of problem beaches*
10H	3.4	0.15	9	32	0
10W6	240	2.2	9	34	0
10W9	270	2.3	10	37	0
10W9/10H	270	2.4	10	37	0
5W9	130	1.2	9	34	0
5W9/5H	140	1.2	9	34	0
B	3.0	0.16	9	34	0
M9	0.54	0.01	9	32	0
O4	220	2.0	11	37	0
O9	220	2.5	11	37	0
R	47	3.7	10	35	0
R/S4/M9	53	4.3	10	35	0
S4	5.3	0.58	9	32	0
Strat1	190	5.6	13	44	0
Strat2	320	6.2	14	49	0
Strat3	270	6.5	14	50	0

Table 3.7. Environmental protection options under the growth-west scenario.

Strategy code	*Investment cost (million NAF)*	*Operation and management (million NAF)*	*Coral cover (%)*	*Coral diversity (% of maximum)*	*Number of problem beaches*
10H	3.1	0.13	9	32	14
10W6	240	2.3	10	35	0
10W9	270	2.4	11	37	0
10W9/10H	260	2.5	11	37	0
5W9	130	1.3	9	35	0
5W9/5H	130	1.3	10	35	0
B	1.6	0.14	9	32	14
M9	0.54	0.01	9	32	14
O4	210	1.9	11	38	0
O9	220	2.5	11	38	0
R	47	3.0	10	35	14
R/S4/M9	53	3.6	10	36	14
S4	5.3	0.58	9	32	14
Strat1	190	5	13	45	0
Strat2	310	5.5	14	50	0
Strat3	270	5.6	15	51	0

As with the implementation of sewage disposal through outfalls, the reef improves in the western sections after a reduction in pollution from the refinery by 70%. Increase in coral cover ranges from 7% to 10% and increases in diversity range from 8% to 24%. Little improvement is actually seen around Schottegat. This is due to the continuing influence of sewage pollution around those sections.

These results clearly show the impact different environmental protection measures potentially have on the reef system and show that, with careful management and planning, development of the island does not need to lead to the gradual decline in the coral reef conditions as has been seen over the past 20 years (Bak and Nieuwland 1995). However, implementing the maximum environmental protection strategy may not be a feasible option in financial terms. The following sections examine the costs of the measures and their associated cost-effectiveness.

Cost-Effectiveness Analysis

A core feature of the Coral-Curaçao decision support system is the cost-effectiveness analysis, which allows for the comparison of sets of environmental protection measures and strategies in terms of the cost per unit gain in reef health. The unit of reef health is either the percent change in coral cover or diversity. Each comparison of environmental measures is carried out under the same economic scenario so that the different measures are directly comparable. As a result, a separate analysis should be carried out for each scenario defined. Figure 3.4 shows the cost-effectiveness of individual measures under the reference scenario using coral cover as the indicator of reef health. Figure 3.5 uses the same reference situation but analyzes the cost-effectiveness of strategies (i.e., combinations of measures).

Beach maintenance, the reduction of sewage pollution through on-site treatment of hotel waste, and the reduction of waste from manufacturing have no significant effect on the health status of the reef averaged for the south coast as a whole. They have, therefore, been left out of the cost-effectiveness analysis as their cost per unit of reef health will be infinite. On a local scale, these measures may have a significant effect, making the relatively small investments cost-effective. Reducing the waste from the refinery appears to be one of the more cost-effective measures. However, the cost data for the refinery should be treated as preliminary as there was

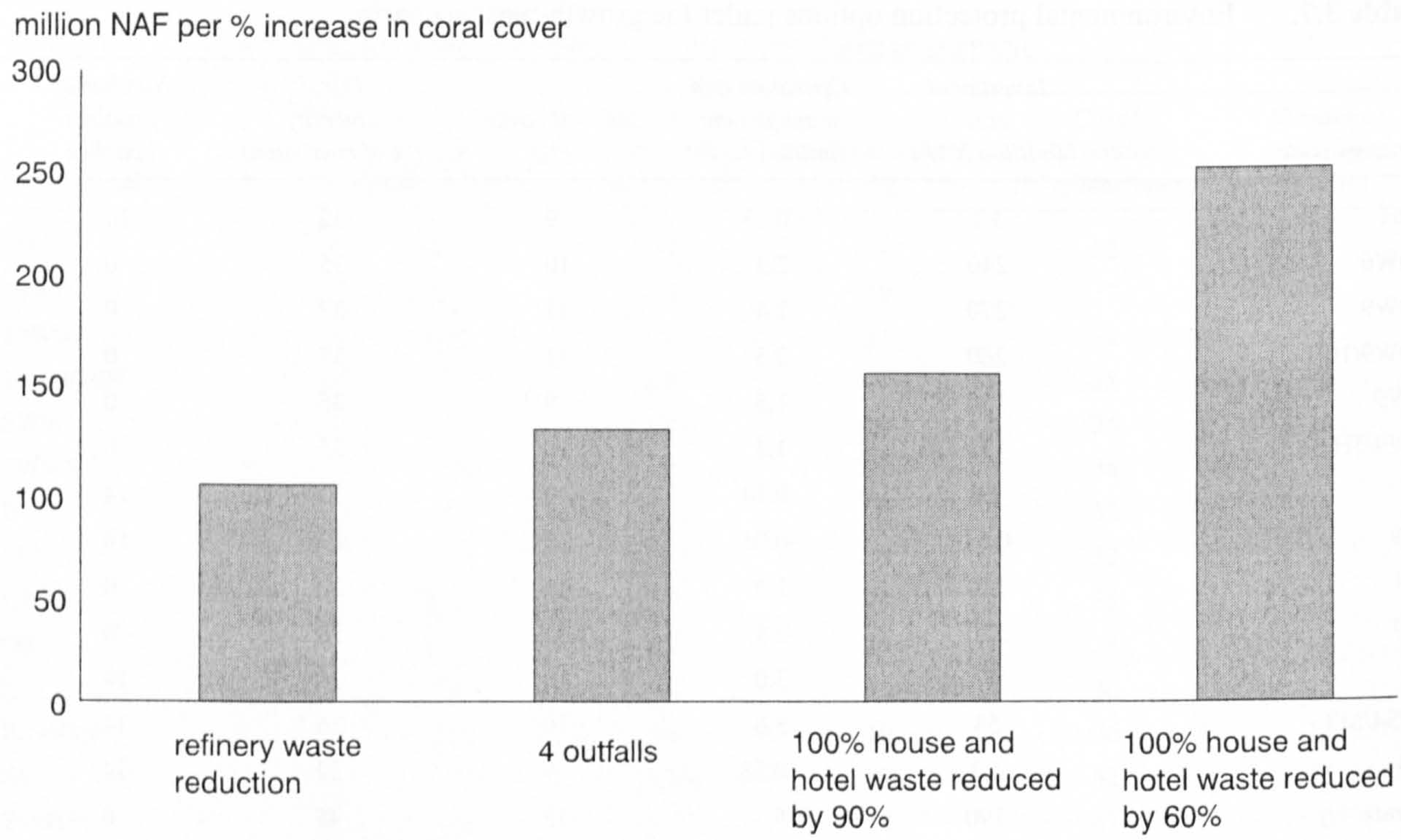

Figure 3.4. Cost-effectiveness of individual measures under the reference scenario using coral cover as the indicator of coral reef health.

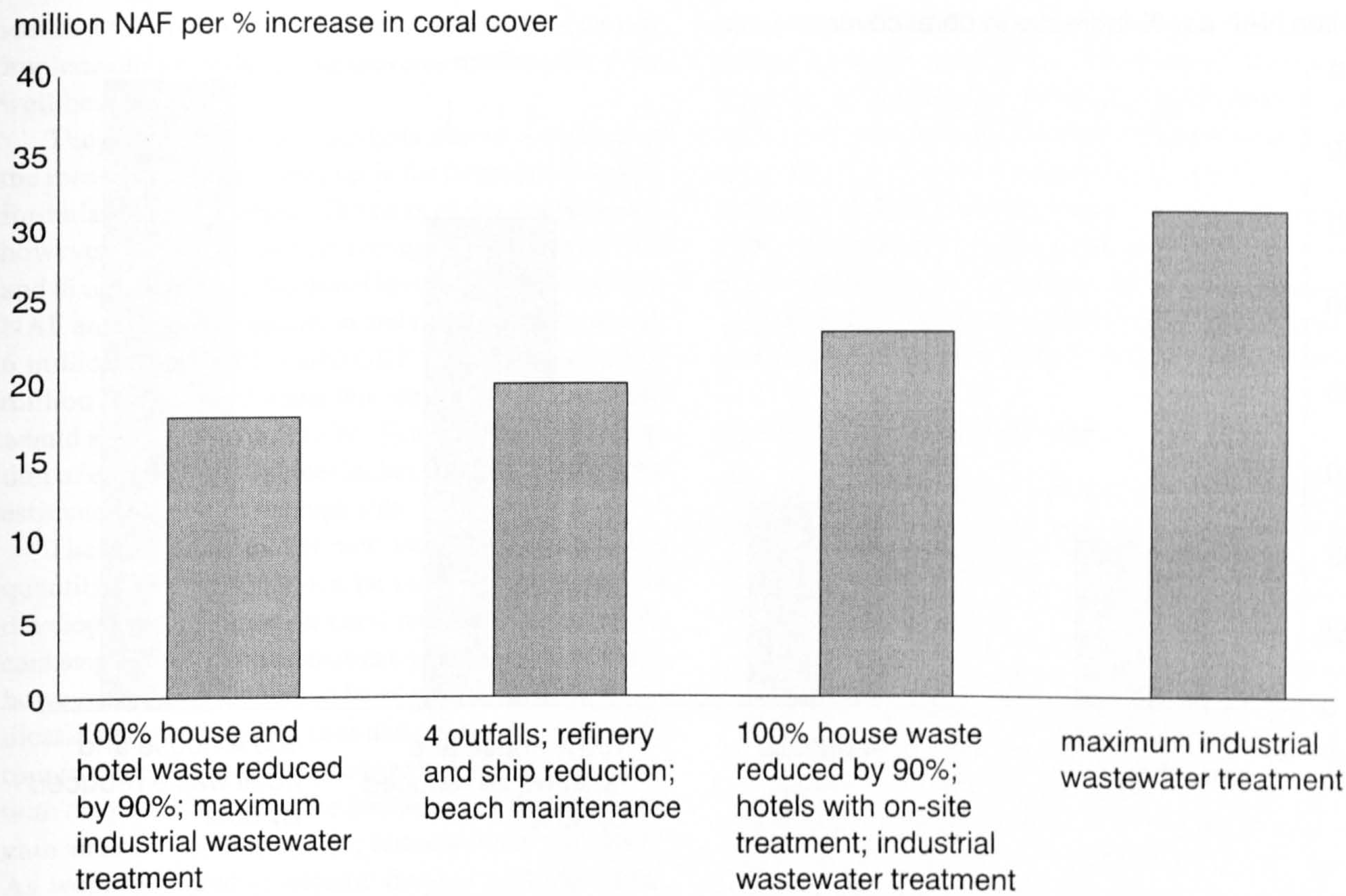

Figure 3.5. Cost-effectiveness of strategies or combinations of measures under the reference scenario using coral cover as the indicator of coral reef health.

very little data available. The least cost-effective measures are the implementation of sewage systems and wastewater treatment plants. These are expensive; however, they are important for public health reasons as well as reef health.

Combining the measures into strategies creates more cost-effective options. All the combinations shown create a cost-effectiveness of 15 million NAF/% change in reef health (for both cover and diversity) compared to 30 to 60 for coral diversity and 100 to 250 for coral cover. This illustrates the need to address more than one source of pollution simultaneously.

A similar analysis is carried out for the both the growth-east and growth-west scenarios. Figure 3.6 shows the cost-effectiveness of individual measures for the growth-east scenario using coral cover as the indicator of reef health. Further results are reported in Rijsberman and Westmacott (1996). Again, the improved beach maintenance, reduction of waste from ships, and manufacturing has little effect at the scale of the southern coastline and are, therefore, not included in the analysis. The patterns seen in the cost-effectiveness of individual measures are similar to those seen under the reference scenario, with the construction of sewage systems and wastewater treatment plants being the least cost-effective options.

There are no real significant differences between the scenarios, partly due to the similarity in the change seen to reef health and the general nature of the cost model—specifically, the fact that the model averages over the coastline will mask significant local changes. Further developments of the model may want to focus on smaller sections of the coast. An interesting feature is the increase in the cost-effectiveness of all the strategies. The cost-effectiveness of individual measures rarely falls below 100 million NAF/% increase in coral cover, whereas the strategies are generally considerably more cost-effective. This shows that the improvement of the reef is limited by more than one pollutant and undertaking one measure alone may be restricted in its effectiveness if other impacts remain in place. Significant improvements to cost-effectiveness come through addressing combinations of measures.

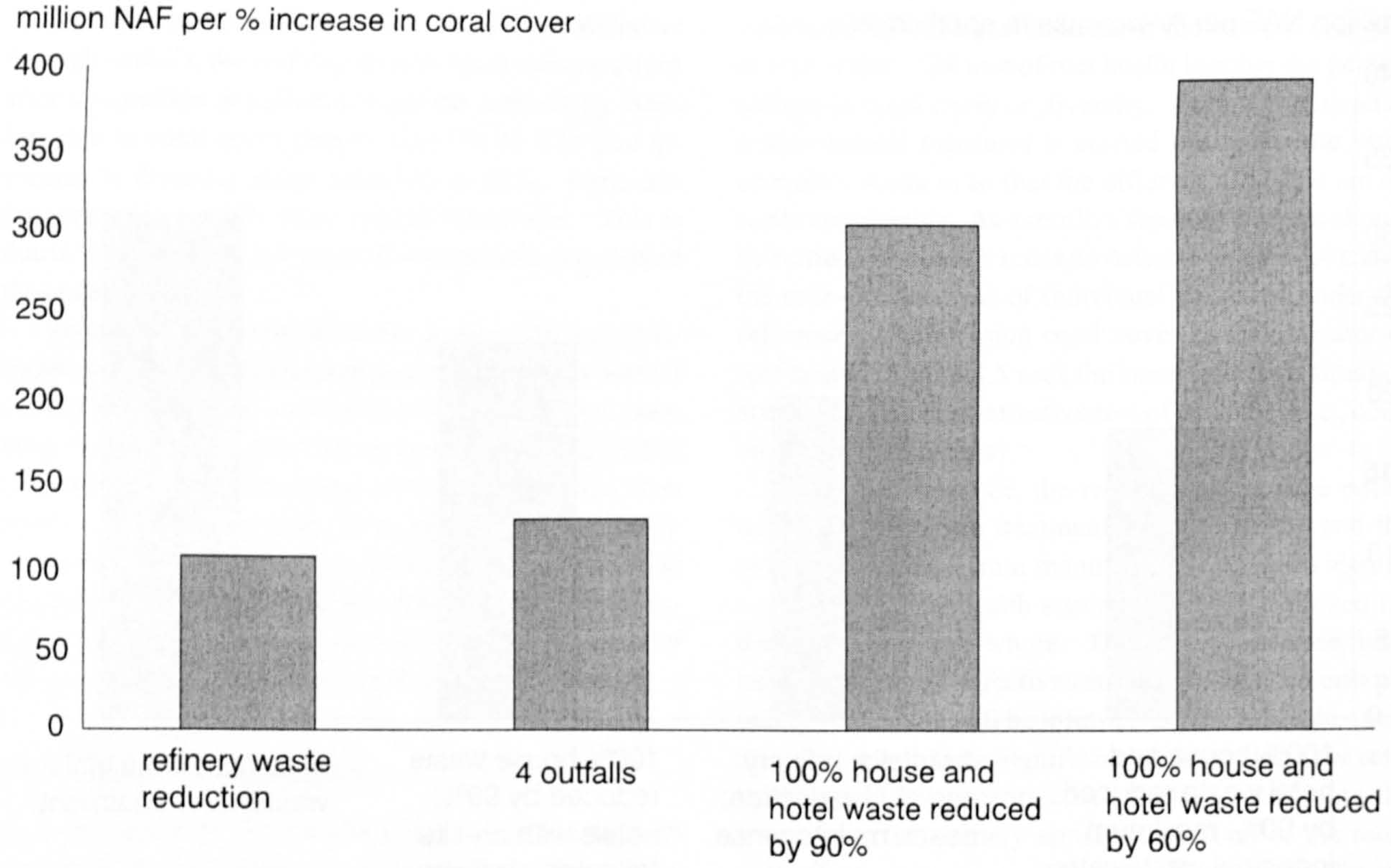

Figure 3.6. Cost-effectiveness of individual measures under the growth-east scenario using coral cover as the indicator of coral reef health.

Conclusions

A decision support tool has been developed that can be used for:

- Communication among stakeholder groups concerning desirable development directions and environmental strategies for the coastal zone in Curaçao;
- Analysis of the impacts, through the discharge of wastewater and sediment, of planned developments in the coastal zone on coral reef health, thereby integrating sectoral land use, tourism and nature conservation planning in one framework; and,
- Analysis of the cost-effectiveness of environmental measures and strategies in maintaining coral reef health.

The main innovations of Coral-Curaçao are its user-friendly but structured interface and its coral reef response model. The developers are of the opinion that the tool has shown to have potential for use, but that the real proof of whether this is an appropriate tool for management of coral reefs and the coastal zone of Curaçao will have to be demonstrated through an application. The tool has been developed in cooperation with government representatives, environmental non-government organizations (NGOs), representatives of the tourism and diving industries, and the management of the Curaçao Underwater Park. Most of these stakeholders have indicated a keen interest in the possibilities of using the tool in a "real life" management application.

Model Results

The model shows through the three scenarios developed that there is likely to be a very significant coral reef decline over the next 10 years. This is in line with the trend seen during the past 20 years reported by Bak and Nieuwland (1995). The model also shows that, with the implementation of environmental protection strategies, this trend can be halted and, in some cases, reversed with recovery to a state of coral reef health better than the current.

Improving the status of the reefs of Curaçao can be done through combinations of comprehensive sewage treatment and disposal methods, as well as reductions in refinery pollution. Measures such as environmentally friendly beach maintenance and the reduction of waste from manufacturing and shipping are not effective at the scale examined. The model can, however, be used to identify the areas where the reef conditions are poorest. Implementation of these measures on a smaller scale could well be effective.

The cost-effectiveness analysis allows a ranking of the measures, assisting the user in the formulation and reformulation of strategies. The costs of the strategies are, however, high. To reach an average coral cover of 14% and diversity of 50%, the initial investment is 310 million NAF and the yearly operation and maintenance costs are 6 million NAF. With a total GDP for Curaçao of 1,620 million NAF in 2005 under this scenario, the investment would amount to 20% of GDP. Since a careful optimization of environmental strategies has not taken place, these estimates may be on the high side.

The fact that a tool is now available with which a quantitative assessment can be made of the impact of development scenarios on coral reef health is a significant step forward. Experience in Curaçao showed clearly, however, that for the tool to be accepted as a reliable indication of sustainability, time and effort will be required to introduce its use. Users need to become both familiar with the possibilities and the limitations of the model and gain an understanding into the formulation of the model. As well, they need to become familiar with the multi-criteria approach used in the model.

Limitations of the Model

Although the issues included in the model have been selected through interviews and meetings with the various stakeholders in the regions, there are certain issues that could not be taken into account. Solid waste disposal, for example, is currently an issue. This will be an important factor, for aesthetic reasons as well as environmental reasons, when considering coastal zone management plans. Sediment and nutrients were considered the major pollutants and impacts on the reef in the current model.

The impact of implementing a marine park is difficult to assess in terms of the reduction of pollutants. It may be that the user would like to set standards of water quality that the marine park would monitor and enforce. By altering the focus of the model, it could be possible to calculate the cost of achieving these levels.

Fishing pressure and the effect on the reef that the extraction of certain fish species (e.g., algae grazers) may have is also not included. This is an issue that has been successfully included in the revised model for Jamaica (Ridgley and Dollar 1996; Chapter 8). The inclusion of oil pollution should also be considered.

It will be necessary to improve the database for the simulation results, as well as the detail with which both the economic development scenarios and the environmental strategies are defined. The data used in the model has been collected from a series of project reports. Little of the data was collected through fieldwork and, as a result, may have had to be adapted. In some areas, data was not available or hard to obtain. Subsequent updates of the model should attempt to improve this aspect. Once the model begins to be used by the various groups and departments as is intended, more data may be identified and produced that can be directly inserted into the model.

Further Model Developments

The modeling results reported in this chapter were completed in 1996. Since that time, Coral-Curaçao has been expanded, revised and used. A valuation study of benefits due to changes in reef health was incorporated. The model has also been demonstrated to the different stakeholder groups. For example, it was used as the basis for a university evening course for professionals, in which most of the relevant Curaçao coastal managers participated. Subsequently, the model was installed at the offices of most of the coastal managers. Various talks were also given at schools and for environmental NGOs to explain the project and the tool. The most recent version of Coral-Curaçao is described in Chapter 10 and a companion CD-ROM is included with this publication.

The overall conclusion to be drawn from the experience to date is that the model is quite helpful as a teaching, training and awareness raising tool, but too complicated and cumbersome to be used for quick reference during the day-to-day work of the coastal managers. As stated previously, the model was developed with sufficient realism to represent "real life" problems, but the day-to-day questions of the coastal managers appear to be slight variations, requiring changes to be made in the model.

Chapter 4

Cost-Effectiveness Analysis of Coral Reef Management and Protection: A Case Study of the Republic of the Maldives

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The specific objective of the research is to develop a quantitative ecological economic model of coastal zones in the developing tropics, designed to assist in the formulation, evaluation and ranking of various cost-effective coastal zone management plans. The Republic of the Maldives, where the coral reefs are in many areas still relatively undisturbed but where development is rapidly changing these coral reef systems, was utilized as a case study site. The condition of the coastal zone is represented by an indicator of coral reef health that is measured in terms of coral cover and rugosity (an indicator of the structural development of the reef). In order to cope with the difficulties of assessing the benefits of improved coastal zone management, the research has been limited to assessing the costs of management using a framework that focuses on four main steps: i) the specification of economic sector interventions; ii) the modeling of the changes of these interventions on production and consumption; iii) the quantification of the physical response of these in terms of the wastes and physical damage generated; and, iv) the modeling of the impact of the wastes and physical damage on reef health. The final cost of each intervention is then computed, taking into account potential negative costs (e.g., from production changes). This enables interventions to be formulated in such a way as to incur the minimum costs while retaining a certain quality of reef.

The two objectives of the Maldives case study are:

1. To test and validate the cost-effectiveness analysis model of coral reef protection and management developed for Jamaica (Chapter 8) and Curaçao (Chapter 3); and,
2. To investigate whether the cost-effectiveness analysis model can be a useful tool for decision support for coastal zone management for the Republic of the Maldives.

The second objective required the establishment of a wider framework of multi-criteria decision-making in integrated coastal zone management (ICZM). This involved cooperating closely with local decision-makers and experts in order to shape the final product into a useful tool. The involvement of local decision-makers and experts was achieved through a series of workshops and consultations. The project was divided into four main phases:

1. *Project preparation.* The site was identified, contacts established and a detailed work plan was developed (Rijsberman 1995).
2. *Fieldwork.* The fieldwork involved problem formulation and data collection (Westmacott 1996).
3. *Model development.* This required the development of the socio-economic model (Westmacott and Rijsberman 1997) and the ecological response model (Meesters and Westmacott 1996). The cost-effectiveness methodology is incorporated in the linking of these two models. The computer user interface was also developed in this phase.
4. *Testing and validation.* This involved presentations of the model to those involved in its development and lead to the final revisions.

Research began during the fall of 1995. This chapter presents the results of the final report, which was completed early in 1997. Further detail can be found in Westmacott and Rijsberman (1997) and within the companion CD-ROM.

The area defined in the model is that of North and South Male within the Republic of the Maldives. This specific study site was selected as it is the most developed and contains some of the most densely populated islands. For modeling, the two atolls have been divided into 10 sections based on physical location (i.e., inner atoll islands or outer/surrounding islands and reefs, subsequently dividing east to west and north to south; Figure 4.1).

Description of the Coral-Maldives Model

Coral-Maldives is a coastal zone management decision support system that incorporates a cost-effectiveness analysis for coral reef management. The decision support system is structured in such a way that different users are able to explore a series of different coastal zone management options under varying assumptions for exogenous variables (e.g., population growth rates). The analysis allows the users to focus on the most cost-effective options for coral reef management and protection for the various economic development options. The impacts can be seen in terms of economic, social and environmental indicators that are selected at the outset of the analysis. In addition to the selected indicators, the user is able to explore more detailed information relating to the economy, reef health and coastal erosion. The final step of the analysis shows a scorecard of all the selected indicators. The user can also use the cost-effectiveness analysis to rank the coastal zone management strategies in terms of cost per unit gain in reef health.

The user is able to structure analysis through the user definitions of indicators, scenarios and strategies and the final formulation of cases. First, users can choose which indicators to select in the analysis. This means they are able to include specific aspects of interest to themselves as well as more general coastal zone management aspects. In the case where the model does not adequately cover all

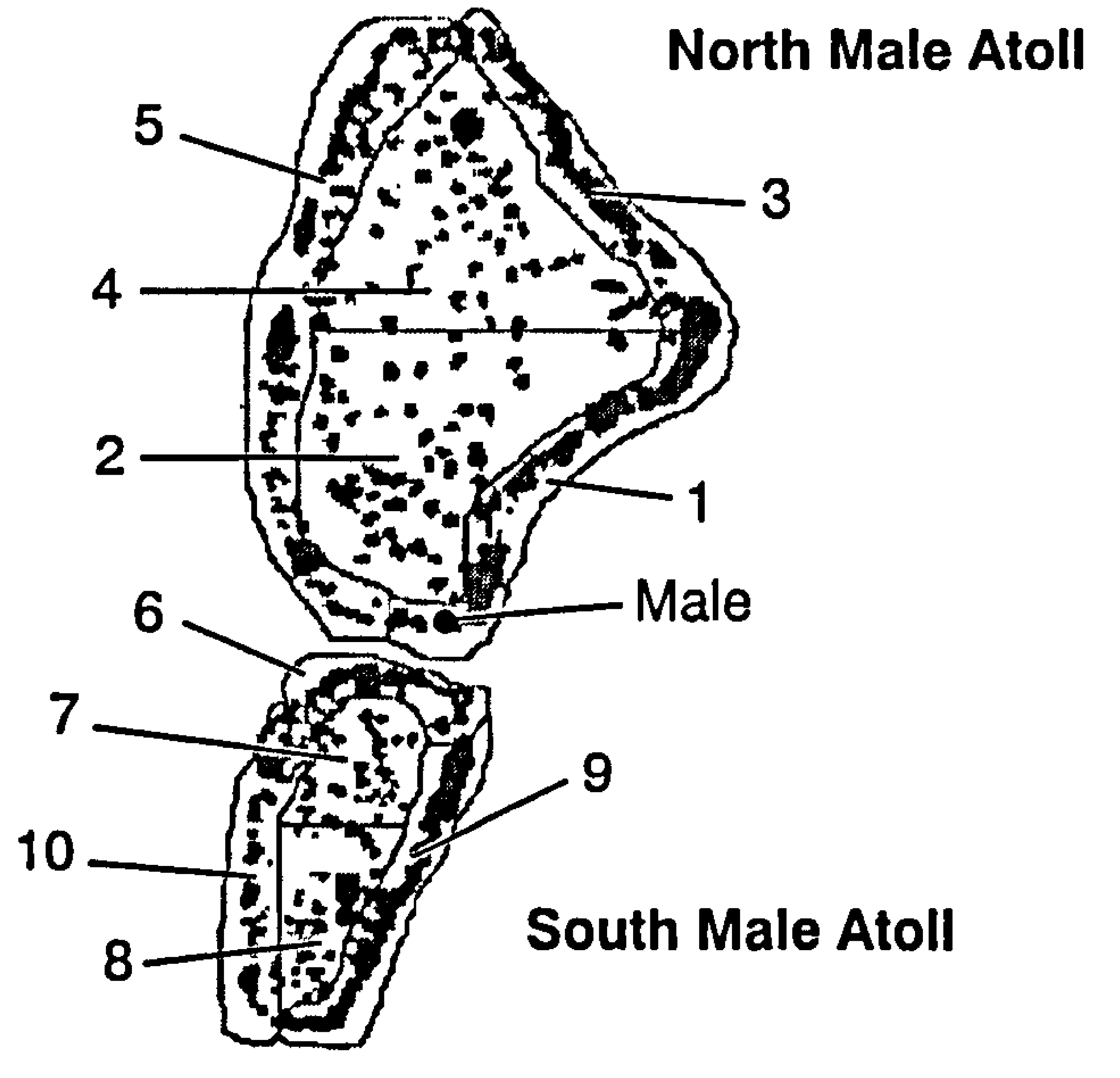

Figure 4.1. Sections of North and South Male utilized in the model.

the interests of the user and where more research has been undertaken, additional indicators can be added to the analysis. Second, the user is able to define the scenarios. The scenarios represent a series of overall growth rates or policy decisions. The economic development and environmental protection options have been selected through discussions with various government agencies involved in coastal zone management within the Republic of the Maldives. The user is again free to define different combinations of these developments and protection measures. Once the definition of scenarios and formulation of strategies has been carried out, the user is able to select combinations of these (cases) for the analysis. The decision support system allows the user to delete less favorable cases so as to keep the analysis tractable.

Structure of the Decision Support System and the Coral-Maldives Model

The Coral-Maldives decision support system consists of the following:

- A user interface;
- The computational model in a spreadsheet;
- The database of model parameters in the spreadsheet; and,
- The database of information contained in interactive text and graphic files available to the user.

The steps involved in the analysis can be seen in Figure 4.2. The interface helps the user to assess the problems and issues found in the coastal zone and define the objectives of the analysis and the criteria or indicators with which to measure the success of each plan. The user definitions include scenarios, economic development and environmental protection options. The user can work through different options, saving each with a name and a description. These are then combined into cases in the analysis and analyzed on an individual basis and in a comparisons of all cases.

The user definitions (scenarios, economic development and environmental protection options) drive the socio-economic model, which results in a set of impacts distributed over the area. The impacts are measured by sediment loadings and levels of physical damage. These are then used as input into the ecological response model, which estimates changes in reef health over the impact areas. These changes will, in turn, affect the health of the reef fisheries, which has a feedback effect on commercial fisheries production. The costs of the environmental protection options and the changes in the reef health are considered in the cost-effectiveness analysis, which allows

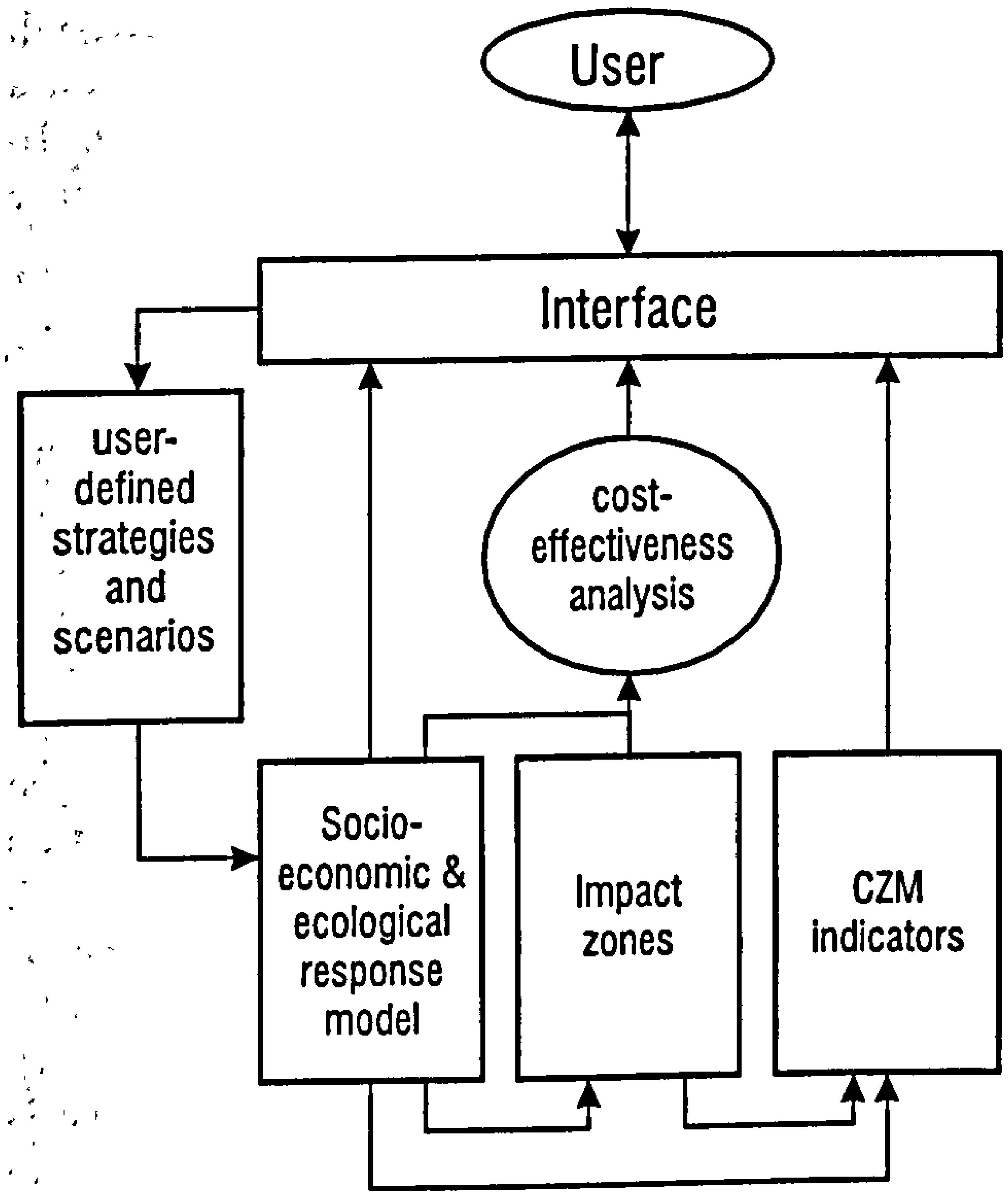

Figure 4.2. Structure of the Coral-Maldives decision support system.

a ranking in terms of total cost per unit change in reef health. Two indicators of reef health are used—coral cover and rugosity. The user defines scenarios and strategies. The scenarios are exogenous developments, such as overall economic growth and population growth, which are used to drive the socio-economic model. The strategies are combinations of economic developments and environmental protection measures.

User Definitions

The model is driven by user-defined scenarios relating to external growth factors and policies. Growth is distributed throughout the islands through the definition of economic development options. Furthermore, the user can define various environmental protection measures and can examine the impacts of these under different scenarios. During the analysis, the user selects a growth scenario, an economic development scenario and a set of environmental protection measures that form a case. This is then compared to a reference case, which is defined as the projected situation in the year 2005 if no additional environmental protection measures are taken. This allows the analysis of only the environmental protection measures or of the coastal zone management strategies (i.e., economic and environmental options) or analysis of strategies under different scenarios.

The available user definitions are assumed to represent the major issues currently of concern in the coastal zone within the Republic of the Maldives:

1. Growth scenarios, defined for the study site and at the national level, including overall economic growth; population growth rates; investment in boats; an increase in number of tourists; an increase in price of foreign aggregate (alternative construction material); and the discount rate.
2. Economic development options, defined at the island level, including an increase in the number of houses; an increase in the number of resort rooms; an increase in the capacity for boats through development and/or expansion of harbors and jetties; and protection of islands against coastal erosion and flooding through construction of seawalls or groynes.
3. Environmental protection options, defined for the study area, including reduction of pollution through treatment of wastewater by means of sewage treatment plants, septic tanks and outfalls; a setback policy for resorts; protected areas/marine parks; reduction of the areas available to mining through land use regulations; limitations to the use of coral in construction; reduction of sedimentation from construction through the use of sheet piling; construction of open jetties to minimize erosion; and education and awareness campaigns.

Population Growth and Migration Patterns

Population growth and the migration to Male is one of the major issues of concern at present in the Maldives. The model addresses this through user-defined scenarios. The user has several options. The first step is to define the natural growth rates for Male and the outer islands. These have been seen to differ and are, therefore, specified separately by the user. In addition to these growth rates, the user has the option to specify an out-migration rate. This represents potential decentralization policies, providing housing and services out of the Male area. Once the growth rates are established, the user can specify houses to be developed on each island. This defines the spatial distribution of population, based on current population densities and housing patterns, and assumes that people will remain on an island outside of Male if housing is provided. If housing is not provided, based on current migration patterns, it is assumed that people will migrate to Male. In the case of new land being created, the user specifies a number of houses for the reclaimed land and the model calculates the land area required based on an assumed area required per house.

Economic Growth

The model contains a simple sector economic module. The fishery and tourism sectors are modeled, with the remaining sectors being aggregated. The total GDP figure used by the model takes into account that for North and South Male only and not that for the whole of the Republic. This division is based on fisheries production data and the tourism capacity of the atolls. The overall GDP is based on 1993 data.

The economy grows according to a growth rate specified by the user. The growth in the fisheries is based on two limiting factors. The first is the fishing capacity. This can be expanded through an investment in boats, specified by the user in terms of total number of boats. The second limiting factor is the available fish stocks. The model takes into account the state of the reef and, therefore, the potential density of reef fish based on a study by Brown *et al.* (1990) showing a relationship between reef fish density and the rugosity of the reef. As a result, this also affects the tuna fisheries through the availability of baitfish, which is dependent on the reef condition.

Tourism is limited by the demand from the international market or the capacity of the resorts based on the number of beds. The exogenous character of the growth of the international tourism market means it is dealt with as a scenario variable defined by the user. The capacity of the area to accept this demand is again user defined. Decisions can be made to expand existing resorts or create new resorts. Development can also be limited through setback policies.

The remaining economic sectors, which are combined, are modeled from the overall growth rate specified in the scenarios and fisheries and tourism GDP. The scenario provides a new overall GDP for the year selected. This GDP is then re-distributed in the economy through changes seen in the fisheries and tourism sectors, the remaining GDP belonging to the aggregated sectors. Although this simple model allows a clear and transparent modeling of the economy, it does omit several important side effects of changing the sector balance. For example, growth in tourism may increase GDP in the transportation sector, which in turn has an effect on the boat building industry and, perhaps, also provides employment for coral miners, currently working in a declining industry. This version of the model does not model these links between the sectors.

Economic Development Options

The economic development options spread the economic activity and the population spatially through the islands. These activities produce impacts on the reefs through sediment loadings and physical damage. Impact zones are used as input into the ecological response model. To minimize the impacts, the user is able to undertake a series of environmental protection measures.

Housing Development and Tourism Development

Housing and tourism activities increase the number of people on an island. Insufficient housing development for the growth in population will result in the excess population migrating to Male. An island can be developed as either a tourist island or a local island. The population on the tourist islands is related to the number of rooms, the quality of the resort, and the occupancy rate. The presence of people produces wastewater that is discharged off the reef. Any construction will place a demand on construction materials that is assumed to be coral rock unless otherwise specified. Any land reclamation depends on the additional houses constructed, expansion of the resorts or harbors developed. An estimation of the area that a house or resort room occupies is taken as the basis of the calculation. There is also an estimation made as to the current availability of land for each island.

Development of the Island's Accessibility

The user can define an investment in the number of boats in the specification of the scenarios. These are then distributed over the islands in the development options as expansion or construction of existing or new structures in the form of harbors or jetties. The size of the harbor or jetty is defined by the size of the boats with which it must be able to cope. Jetties and harbors do, however, create sediment loading, which can be minimized through sheet piling. They also create potential erosion that can, in the case of the jetties, be minimized through the design of the jetty on piles. In some cases, access channels are also required, which add to the localized erosion problems. Land reclamation will occur in the areas where harbors are developed. This assumes that the dredged material is dumped on the edge of the island to create new land areas. Again, this has a sediment loading effect.

Coastal Protection

Island development may lead to a certain level of instability through land reclamation and other activities such as the construction of jetties. This will lead to erosion of the island. There is also a certain level of natural erosion seen; however, this is not accounted for in the model as the islands are relatively dynamic and the seasonal changes, in many cases, transport the sediment from one part of the island to another, reversing direction at the change of season.

Environmental Protection Measures

Environmental options are available to the user to minimize the impacts of economic development on the reef. Taking each measure separately, the user can define, for example, different levels of treatment or the number of protected areas. These can then be formulated into strategies (i.e., combinations of individual measures). These strategies should be formulated with the objectives of the plan in mind. This will also aid the user in the first stages of the analysis to selectively delete those less successful or unfeasible strategies. Strategies may be unfeasible for financial or social reasons. Each measure or combination of measures has an associated reduction in the loading modeled in terms of the sediment produced or the level or physical damage seen. In addition, each measure has an associated cost. This varies depending on the measure and the scale in which the measure is implemented.

Sewage Treatment and Disposal

Sewage from the islands can be treated in several ways. These are through construction of septic tanks, primary treatment plants or secondary treatment plants. Each treatment type results in a different level of reduction to the loading. The ecological response model only accounts for sediment loadings. Any level of treatment has an associated cost that also includes the cost of installing a sewage system. Disposal is either in the near-shore, where any remaining sediment will be discharged over the reef, or through a deep water outfall, which is assumed to result in no additional sediment on the reef. This version of the model does not allow for specification of environmental measures per island or per section. Later versions could include a different option for each level of treatment (e.g., secondary wastewater treatment) that is more appropriate to each population. Current data limitations meant that this would not have produced realistic or useful results.

Control of Sediment Movement

One major impact from construction activities, such as harbor development and land reclamation, is the spread of sediment during the construction phase. One method to minimize this impact is through the use of sheet piling. This is used to surround the land reclamation works or harbor dredging activities. It is assumed this will reduce the sediment loading onto the reef by 80%. In order to maintain natural sediment movements around the islands and reduce any potential for erosion through the construction of jetties, design standards can be enforced, specifying that all jetties should be built on piles. This reduces the erosion effect of the jetties.

Restricted and Protected Areas

In the model, coral is mined over the reef flats or concentrated to a single reef or faro. Mining a faro may be a more costly procedure, but will, however, reduce the overall area of reef destroyed. The user is able to define which percentage of coral rock is mined from which location. Setback policies can be implemented on the tourist islands. This limits the number of resort rooms through the size of the island. It is assumed that, by implementing a setback policy, no land reclamation is allowed to take place. Protected areas can also be defined for each section. It is assumed that, on each area, the impact from sediment and physical damage is reduced to a minimum. In some cases, this may result in regeneration of the reef.

Coral Mining

The user can limit the use of coral in construction of resorts and housing and in the construction of coastal protection structures. The alternative available for housing and resort construction is concrete block. This is a less expensive option than coral rock; the costs of the measure are, therefore, negative. However, it will reduce the demand for coral rock, increasing unemployment among miners but reducing the reef areas subject to physical damage. This also applies to coastal protection options, where the alternatives are the more expensive imported materials. The actual price of these imported materials can be regulated by taxes and duties defined by the user in the scenarios.

Cost of the Environmental Interventions

Each environmental intervention has a cost. This is modeled in terms of investment cost and maintenance cost and discounted to the base year. The discount rate is defined by the user as part of the scenario. In most cases, the maintenance cost is a percentage of the investment that is set in the definitions of the model parameters. In some cases, such as sewage treatment plants, scale factors are applied (i.e., the smaller the installation, the more expensive it is per unit capacity).

Summary of the Impacts From Economic Development and Environmental Protection

The major impacts on the reefs in the Maldives are through sedimentation and the production of rubble (Meesters and Westmacott 1996). In addition, constructions such as harbors and jetties cause erosion. Some impact coefficients used in the model are based on observations, while others are based on best estimates due to lack of more detailed data. The project fieldwork report (Westmacott 1996) outlines the data collected in detail.

Sediment and Rubble Impacts

Sediment and rubble are produced by the socio-economic activities and limited through the environmental protection options. The extent of the impact is dependant on the options chosen and the scale of the developments or mitigation efforts. Rather than modeling the dispersion of sediment and production of rubble in a dilution/dispersion model, Coral-Maldives makes use of impact zones. This style of modeling was selected due to the relatively little data available on the spread of the sediment and production of rubble. Three impact zones are defined—high, low and minimal. The distance these extend from the construction or outfall depends on the activity's size. The area of each impact zone is then calculated using the average reef width. The impact zones are calibrated using as many actual sets of observed data as possible. The resulting impact zones are then combined with the database formulated from the results of the ecological response model, providing, for example, total areas of reef lost.

Erosion

As with the modeling of sediment and rubble, there was little data available to develop a deterministic model of erosion. The results of the model are again based on a scaling, making use of field observations. Areas eroded are computed on the basis of exposure of the island and previous observations of eroded areas where human influence has played a role. During the fieldwork, there was no specific measuring of eroded areas. As a result, the data used in this version of the model is very approximate.

Reef Health

The ecological response model of reef health under impact of sediment and rubble is described in Meesters and Westmacott (1996). The model was developed using fuzzy logic, a method able to capture expert knowledge on the behavior of a system. Experience of the Jamaica case study (Ridgley and Dollar 1996; Chapter 8) was utilized. The main impact factors considered in the Maldives were those relating to sedimentation and the production of rubble. These are outputs of the socio-economic activities. Levels of sedimentation and rubble are directly dependant on the user's definitions of both island development and environmental protection.

A set of base reef conditions are defined for each section. These combine with the sediment and rubble values resulting from the environmental protection measures taken and the economic development options and are used as the input values for the ecological response model. The outputs of the model are the reef health descriptors used in the cost-effectiveness analysis (i.e., coral cover and rugosity). Rugosity is subsequently used as an input for the fisheries module, affecting the density of reef fish to be found on the reefs.

Case Studies in Coral-Maldives

Cases pre-defined in the model are developed as examples to show the user the options available in the model and to illustrate how the model can be used to explore different economic developments and environmental protection options. The user is entirely free to define those scenarios and alternatives of interest to him or her. The structure of the decision support system should assist the decision-maker in the selection of the "best" strategy. This may be a decision on where to locate certain developments or which environmental protection options are the most cost-effective. Coral-Maldives allows combinations of scenarios and strategies to be examined. The following cases have been selected by the authors to illustrate the potential and the limitations of the model.

Scenarios

Scenarios can be used to explore different population growth patterns and set the boundaries for different levels of economic activity. Three scenarios have been developed as an example. First is a reference scenario (REF) that is based on past trends in the population with high growth on Male and lower growth on the surrounding islands. Different levels of economic activity have also been examined. REF is based on the growth rates seen in 1995 with a slow increase in the fishing fleet of 5 boats per year. Foreign aggregate is also assumed to be slowly increasing by 1%/yr.

A second scenario (POP) reflects a decrease in population growth rate to 3%/yr. This may be related to sustained high levels of economic growth and the desire to have less children. There is also a move away from fisheries into, perhaps, the tourism industry. This is seen by the low increase in the fishing fleet of 2 boats per year. The increase in price of foreign aggregate is negative; this represents policy options to reduce import tax or subsidize its import to increase the use of imported materials above that of coral rock.

The third scenario (OUT) examines the changes in population caused by a gradual 2%/yr out-migration. This could be the result of a decentralization policy or low economic growth rates, making areas out of Male more attractive again. The values used in these scenarios can be seen in Table 4.1.

The impacts of the scenarios can be seen in Table 4.2. The estimates are simulated over the 10 year period. The different population growth rates make significant differences, particularly when looking at housing demand. The POP scenario would require provision of half the number of houses compared to the REF scenario. The population growth on the outer islands is relatively small compared to the high growth that can be seen on Male. These scenarios indicate that the housing situation on Male, currently reaching its maximum capacity, is a high priority issue in island development.

The demand for resort rooms indicates that, if this growth in tourist numbers is going to continue at a rate of 14%/yr, the capacity is unlikely to be totally satisfied. Even at the lower growth of 8%/yr, as seen in the OUT scenario, the capacity demand remains high. With the size of resorts in general varying between 100 to 200 rooms, satisfying the 8%/yr growth could mean the construction of 100 to 150 resorts. This rate of construction is unlikely to be reached in the next 10 years. The current total number of resorts in North and South Male is 70.

The fisheries are, as of 1996, not threatening the fish stocks; however, with a large increase in the fishing fleet (e.g., 150 boats in 10 years), the catch of reef fish closes on the maximum sustainable catch. These results are based on the majority of the human population migrating to Male and there being no additional construction on the island.

The change in the price of foreign aggregate is controlled by the user. A 1% decrease per year leads to a price of $150/m^3. In the model, the price of coral rock increases at a fixed rate of 5%/yr. It may be that the user will also want to change this parameter in future versions of the model to reflect certain taxes on the use of coral rather than simply prohibiting its use. In the model, the price of imported aggregate will not affect the use of coral until either there are measures taken that prohibit the use of coral rock or the price falls below that of coral rock. In a 10 year period, this will occur at a decrease in price of over 15%/yr.

Economic Development Strategies

There are four main options available to the user for economic development of the islands. These are the provision of housing, the development of resorts, an increase in the island's accessibility and coastal protection. Three strategies relating to housing development have been formulated to show the different options available. In addition, several different options relating to the development of resorts and coastal protection have been examined. The first strategy, REF, is again a reference strategy that does not include any specific measures to be taken. NOMIG aims to provide housing for the natural population growth on each island. There are several variations of this strategy allowing a comparison of developing the northern or southern islands. The final strategy, RECLAIM, looks at the possibility of reclaiming large areas of land for housing. The model enables the user to look at the impact this will have on the housing situation on Male as well as on the environment. In addition to the basic strategy, a variation that includes coastal protection for reclaimed areas is examined. These strategies are described in Table 4.3.

A few selected criteria (Table 4.4) highlight the main differences between the economic development strategies.

Table 4.1. Example growth scenarios (REF=reference scenario; POP=population growth rate scenario; OUT=out-migration scenario).

	Units	*REF*	*POP*	*OUT*
Overall economic growth rate	%/yr	6	6	4
Growth in number of tourists	%/yr	14	14	8
Investment in boats	number	50	20	100
Change in price of foreign aggregate	%/yr	3.5	-1	3.5
Population growth on Male	%/yr	6	3	6
Population growth on inhabited islands	%/yr	4	3	4
Out-migration from Male	%/yr	0	0	2
Discount rate	%	6	6	6
Number of years	number	10	10	10

Table 4.2. Impacts of the growth scenarios (REF=reference scenario; POP=population growth rate scenario; OUT=out-migration scenario).

	Units	*REF*	*POP*	*OUT*
Population in 2005	number	125,000	96,000	104,000
Population on Male in 2005	number	112,000	84,000	95,000
Housing demand	number	6,700	3,000	4,000
Demand for resort rooms	number	7,000	7,000	2,800
Fisheries catch as percent of maximum	%	77	70	87
Price of foreign aggregate	US$/m³	230	150	230

Table 4.3. Description of economic development strategies.

Scenario	*Housing*	*Resorts*	*Accessibility*	*Coastal protection*
REF	No specific action, resulting in the population moving to Male	No tourist developments	No further developments	No coastal protection
NOMIG	Construction of houses on local islands to meet demands of natural population growth; remaining population stays on Male although no specific housing or reclamation is carried out	NOMIG: no tourist developments; NOMIG-N: four tourist developments in the North of 100 rooms each; NOMIG-S: four tourist developments in the South of 100 rooms each	Expansion or construction of the harbors where additional houses are built; jetties built for the tourist resorts	No coastal protection
RECLAIM	Large reclamation projects, housing the Male population growth on Vilingili (500) and Hulule (2,000)	No tourist developments	Expansion or construction of the harbors where additional houses are built	RECLAIM: no coastal protection; RECLAIM-C: sea walls constructed around reclaimed areas

Table 4.4. Results of the economic development scenarios (REF, NOMIG and RECLAIM defined as in Table 4.3).

Criteria	*Units*	*REF*	*NOMIG*	*RECLAIM*
Population of Male	number	86,300	84,000	60,300
Density on Male	number/km²	51,000	50,000	36,000
Density on Hulule and Vilingili	number/km²	480	630	40,000
Density on other inhabited islands	number/km²	3,100	4,200	4,200
Housing demand	number	2,960	2,700	-300
Area reclaimed	m²	0	7,400	341,000
Area of reef lost	m²	173,000	186,000	266,000

As yet, none of these have any environmental protection measures to minimize the impacts. The model can also be used to see which areas are more heavily impacted through certain developments. For example, the development of four new resorts of 100 rooms each in the south is predicted to result in the loss of 208,000m^2 of reef, while if occurring in the north the loss is predicted to be 206,000m^2 of reef. Thus, the costs of retaining coral reef health can be expected to be greater in the south due to the more fragile systems that exist there as predicted by the model.

The REF economic development scenario, with sustained high population growth, leaves a housing demand of approximately 3,000 houses. The reclamation of 0.8km^2, along with the loss of 340,000m^2 of reef through mining and sedimentation, could satisfy that demand. Over a 20 year period, the demand is predicted to rise to 18,000 houses. Satisfying this through reclamation would require a total of 2km^2 of land to be reclaimed. This would keep the housing density of Male and on reclaimed land at approximately 50,000 people per square kilometre. The model indicates a potential high risk of coastal erosion. However, further verification is required due to the preliminary nature of the data. Protecting the coastline, now extended to 5km due to the reclamation, would cost in the region of US$14 million based on the use of coral rock. Imported aggregates would cost approximately US$60 million. The coral reef loss would be 500,000m^2, as opposed to 600,000m^2 if coral were to be mined. These areas are, however, less than 1% of the total reef area of North and South Male.

Environmental Protection Options

As described previously, there are a series of environmental protection options aimed to minimize the impacts of developments on the reefs. These can be examined on an individual basis or combined into strategies (i.e., groups or combinations of measures). In order to formulate effective strategies, the user can begin by examining each measure on an individual bases. Table 4.5 describes a series of measures defined for this analysis. As the first step in the analysis, the aim is to explore the effectiveness of each of the measures in terms of changes to reef health and impact areas affected.

Figures 4.3 to 4.5 show the results of the cost-effectiveness analysis for the three indicators of coral reef health (i.e., rugosity, coral cover and area of reef lost or gained). There is some difference in the ranking of the strategies, depending on the indicators chosen. In all three cases, however, sheet piling is the most expensive option when considering coral reef protection. The wastewater treatment measures are also high in cost. Sheet piling would not, at a first glance, seem a useful option. However, it may create protection for the reefs surrounding the islands. This could provide a valuable natural coastal function and an additional attraction for the island as a resort. These issues go beyond the initial costing carried out in this version of Coral-Maldives.

Wastewater treatment measures are expensive when considering the range of options available for coral reef management and protection. However, what is not seen in only examining these indicators is the public health impact of clean wastewater and disposal beyond the reef. With the cost-effectiveness utilizing social indicators as a gage, these options may be higher in the ranking. It may be that no level of risk is acceptable for the public.

The most cost-effective measures would appear to be those focusing on land use regulations. This may be in the restriction of coral mining areas or the provision of alternatives to the coral mining industry. Likewise, protection of certain areas predicts an improvement in the reef health, assuming that impacts from sedimentation and physical damage are reduced to a minimum. These have similar cost-effectiveness; however, the exact ranking varies considerably between each indicator. This demonstrates the differences due to the selection of the particular indicator of coral reef health.

The effects of the individual measures are not cumulative. The results given above can be used as an indicator to prioritize which measures to take. The next step in the formulation of environmental protection options is to look at combinations of measures (i.e., strategies). The user may have specific information on the budget available for these interventions. The costs shown in this analysis are the total discounted 1995 dollar costs over the 10 year period. Table 4.6 provides descriptions and the values used for the combinations of measures formulated for the analysis. Each strategy aims to focus on a specific issue, goal or type of measure, covering control through land use regulations, reduction in sediment reaching the reef, and regulations focusing on the tourist resorts.

Figures 4.6 to 4.8 show the cost-effectiveness results of implementing the environmental protection strategies. Sediment mitigation through the use of sheet piling appears to have limited effect. This may be for two reasons. First, the developments in this example are small harbor extensions and, in some cases, the associated reclamation is only a few hundred square metres. Surrounding works with piling is going to have a more dramatic effect the larger the reclamation and harbor works. Second, the area of coral gained clearly reflects the implementation of

Table 4.5. Description of environmental protection measures.

Measure	*Description*
Outfall (OUT)	Disposal of sewage through outfalls on each island; orientation of the outfalls is towards the inside of the atolls.
10 marine parks (10MP)	A marine park is established in each section of 0.5km² each.
Setback (SET)	Setback policy for tourist islands is implemented, generating no cost but may limit the number of rooms able to be constructed.
Prohibit coral use for resorts (RES)	This measure does not allow resorts to use coral rock for construction of resort rooms or sea defenses on resorts.
Prohibit all use of coral rock (ALL)	Neither locals nor resorts are permitted to use coral rock for construction of houses and rooms or sea defenses.
Mining 100% from Faro (100F)	Mining demand is satisfied through the selective mining of one reef to a depth of 15m.
Prohibit local use of coral (LOC)	This measure does not allow local islands to use coral rock for construction of houses or local sea defenses.
5 marine parks in the South (MPS)	A marine park is established in each section of South Male of 0.5km² each.
5 marine parks in the North (MPN)	A marine park is established in each section of North Male of 0.5km² each.
Mining 50% from Faro (50F)	50% of the mining demand is satisfied through the selective mining of one reef to a depth of 15m.
Secondary wastewater treatment (2WWT)	Sewage collected in a pump driven sewage system and treated through the construction of secondary wastewater treatment plants on each island; subsequent disposal in the near-shore.
Septic tanks (SEP)	Sewage is treated through individual septic tanks and excess liquid collected in a gravity run sewage system before being disposed in the near-shore.
Sheet piling (SHP)	All coastal construction works are surrounded by sheet piling to restrain sediment flow.

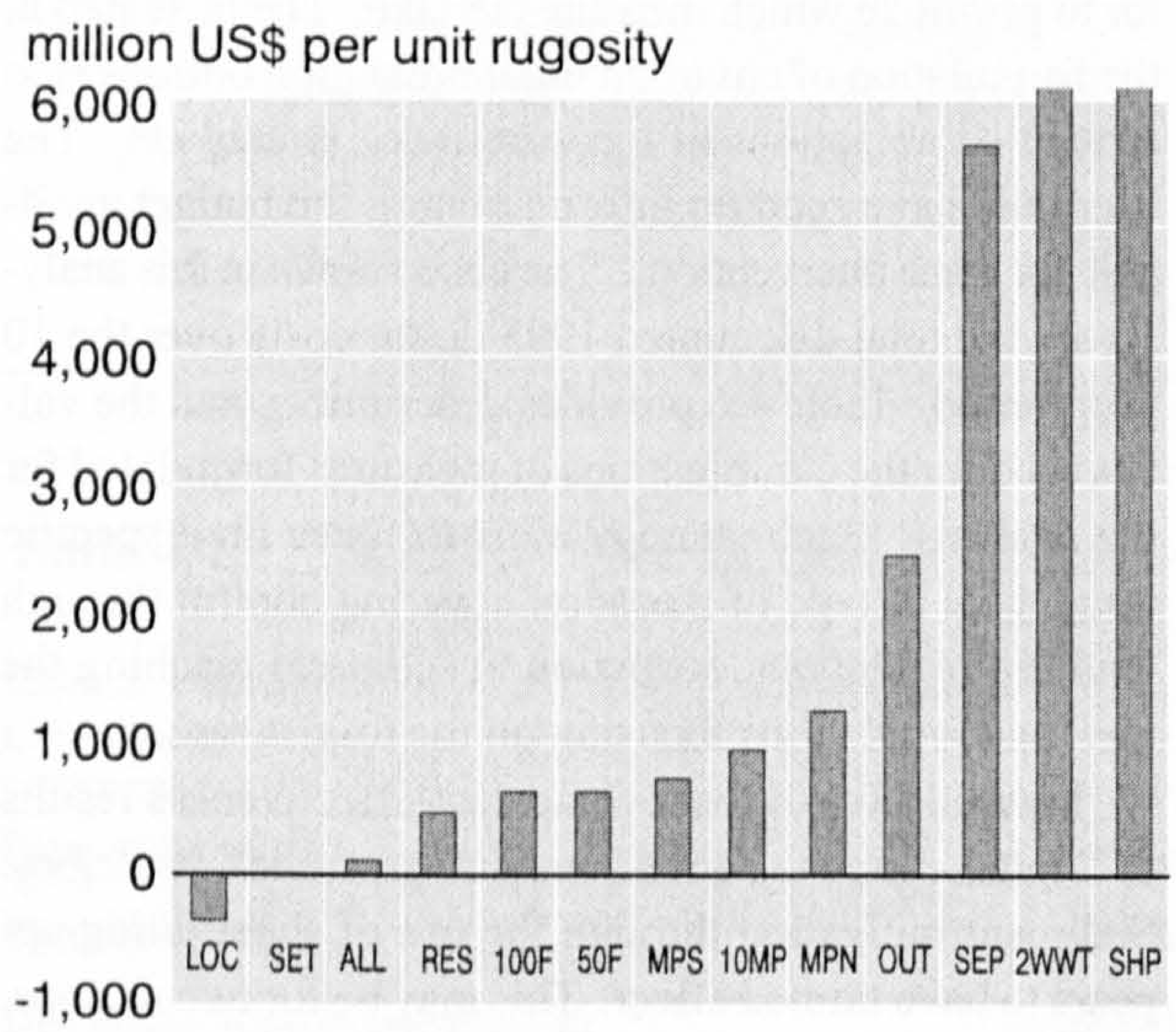

Figure 4.3. Cost-effectiveness of environmental protection measures defined in terms of rugosity as an indicator of coral reef health (environmental protection measures defined in Table 4.5).

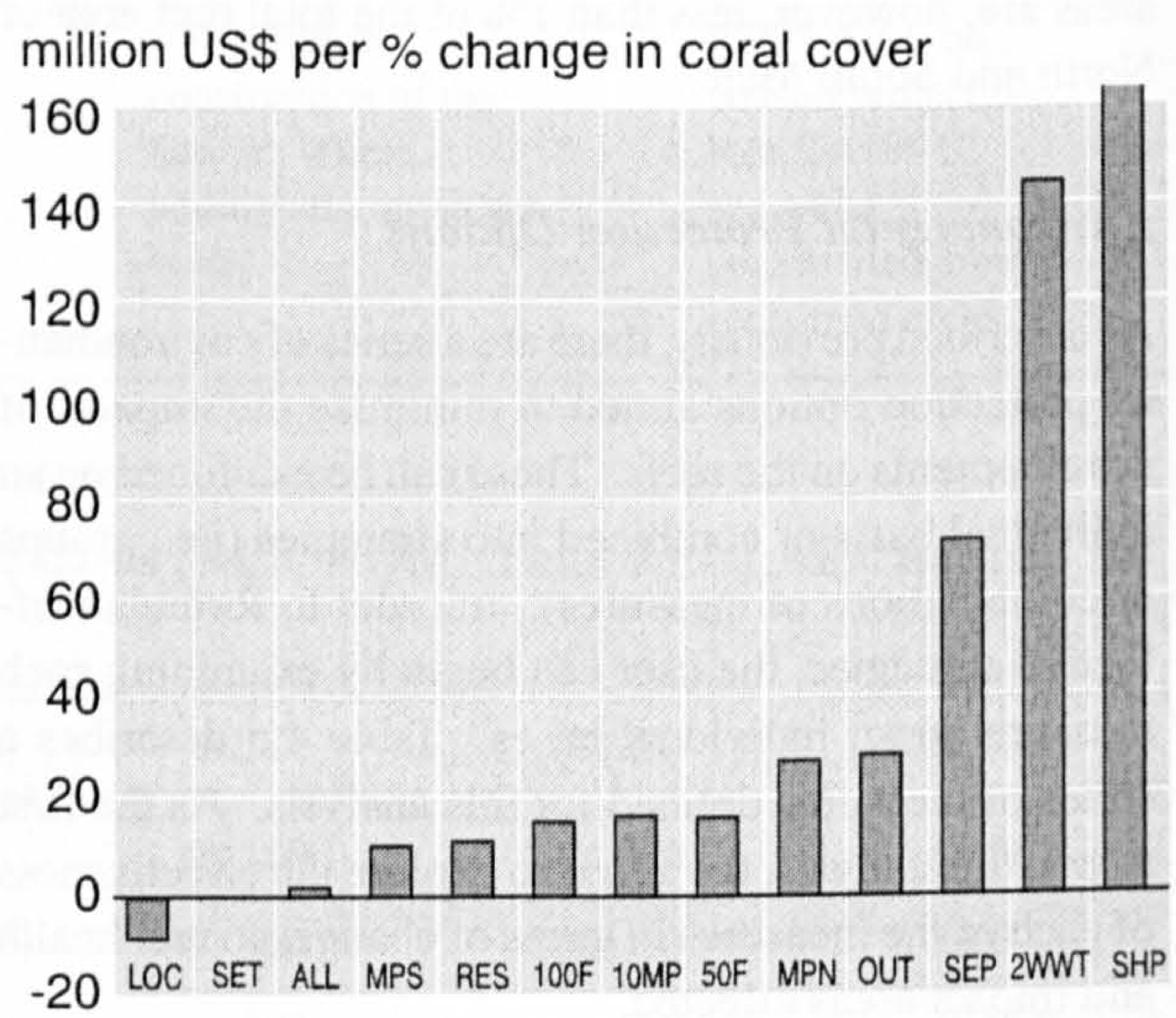

Figure 4.4. Cost-effectiveness of environmental protection measures defined in terms of coral cover as an indicator of coral reef health (environmental protection measures defined in Table 4.5).

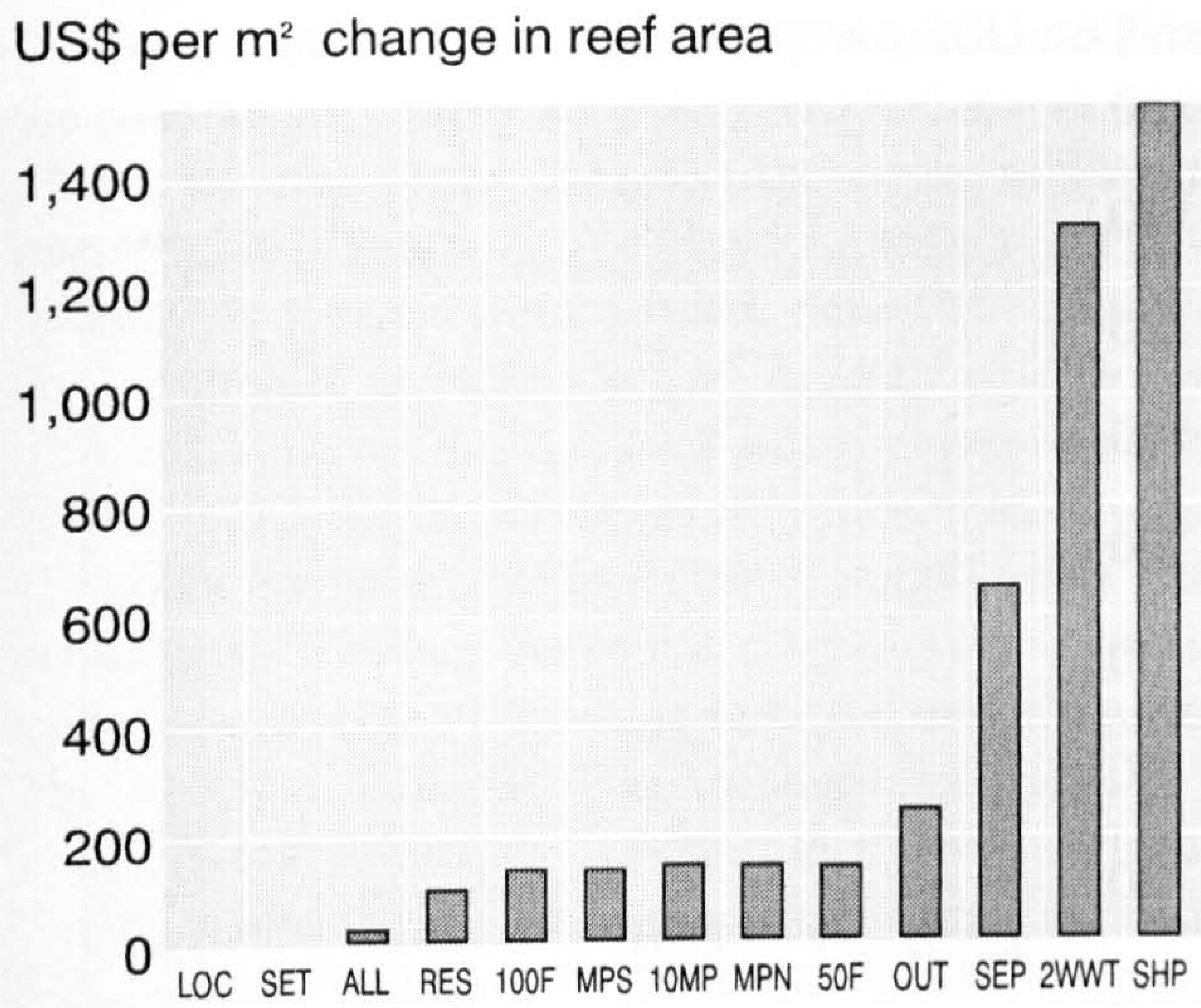

Figure 4.5. Cost-effectiveness of environmental protection measures defined in terms of reef area as an indicator of coral reef health (environmental protection measures defined in Table 4.5).

marine parks. In these areas, any impacts are assumed to be reduced to a minimum, resulting in an improvement of the reef in many cases.

Again, one should also consider the public health issue. Although the options of treating sewage are expensive when considering reef health, they should not be ruled out as valuable alternatives in terms of public health. Likewise, the indicators of housing densities are important when considering social issues.

One could also consider indicators of social acceptability through the use of user-defined criteria. For example, the ZERO option does not require any specific actions to be taken and, as such, may be more acceptable. LANDUSE requires people to be retrained, potentially resulting in the loss of jobs. It may also prohibit use of certain areas for traditional activities. In addition, for both of these strategies there is assumed to have been no awareness programs to inform the public as to the need for these strategies. The strategy ALL considers this aspect. The total cost of the proposed awareness program is estimated at less than 1% of the total costs.

Table 4.6. Description of environmental protection strategies.

	Landuse	*Sediment*	*Tourist*	*All*
Description	Protection of reefs through land use regulations	Reduction of sedimentation reaching the reefs	Restrictions for tourist resorts regarding building regulations and waste disposal	Combination of all measures to improve the environment
Sewage treatment	None	Secondary treatment	Disposal through outfalls on tourist islands	Disposal through outfalls
Setback policy	On tourist islands	None	Yes	Yes
Marine parks	10 marine parks of $0.5 km^2$ each	None	10 marine parks of $0.5 km^2$ each	10 marine parks of $0.5 km^2$ each
Mining locations	None	None		100% Faro
Use of coral rock	Prohibit all	None	Prohibit in tourist industry	None
Awareness raising	None	None	None	US$1 million spent on environmental awareness
Sheet piling	None	For all construction	On tourist resorts	For all construction
Open jetties	None	All	On tourist resorts	All

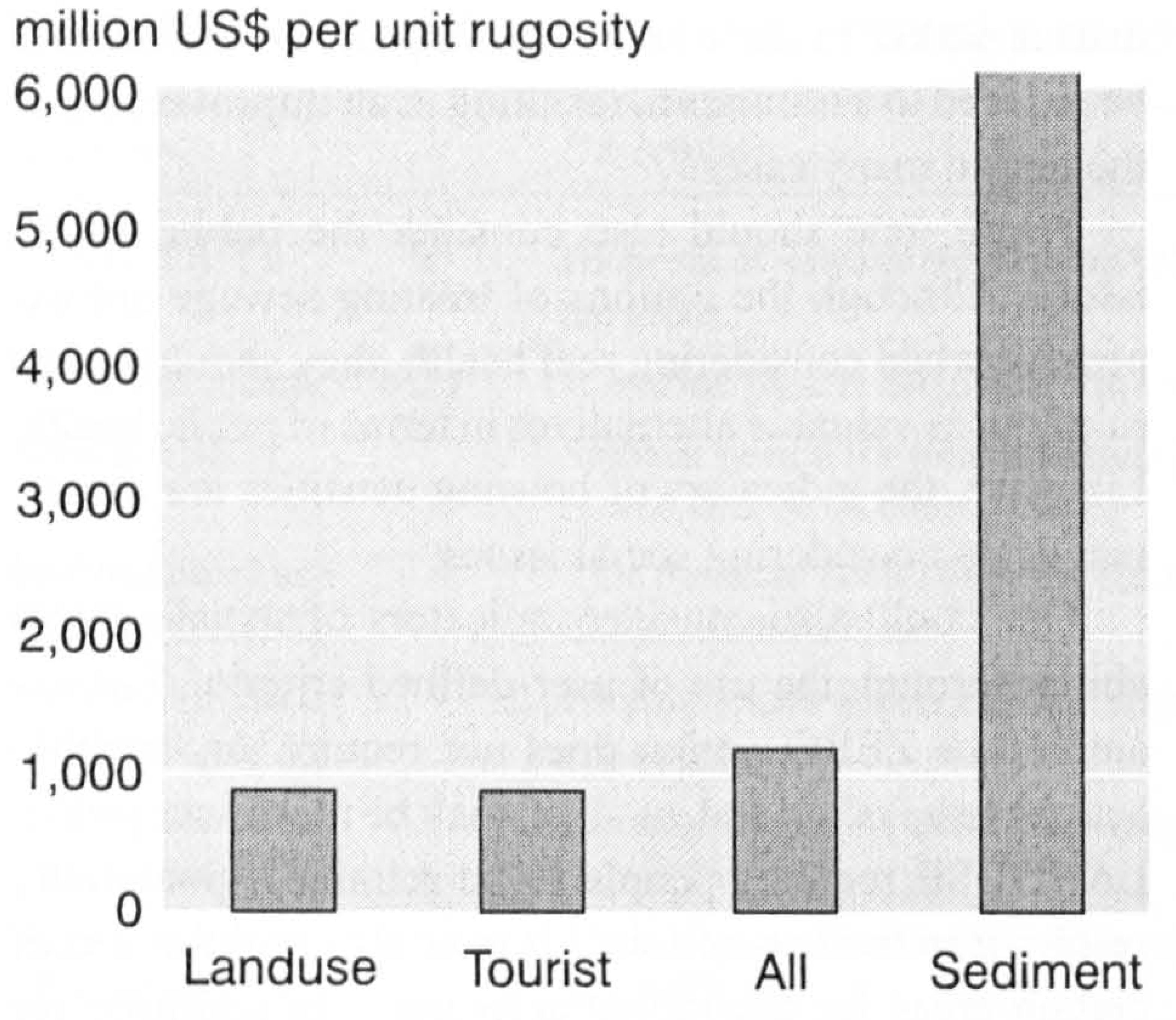

Figure 4.6. Cost-effectiveness of environmental protection strategies defined in terms of rugosity as an indicator of coral reef health (environmental protection strategies defined as in Table 4.6).

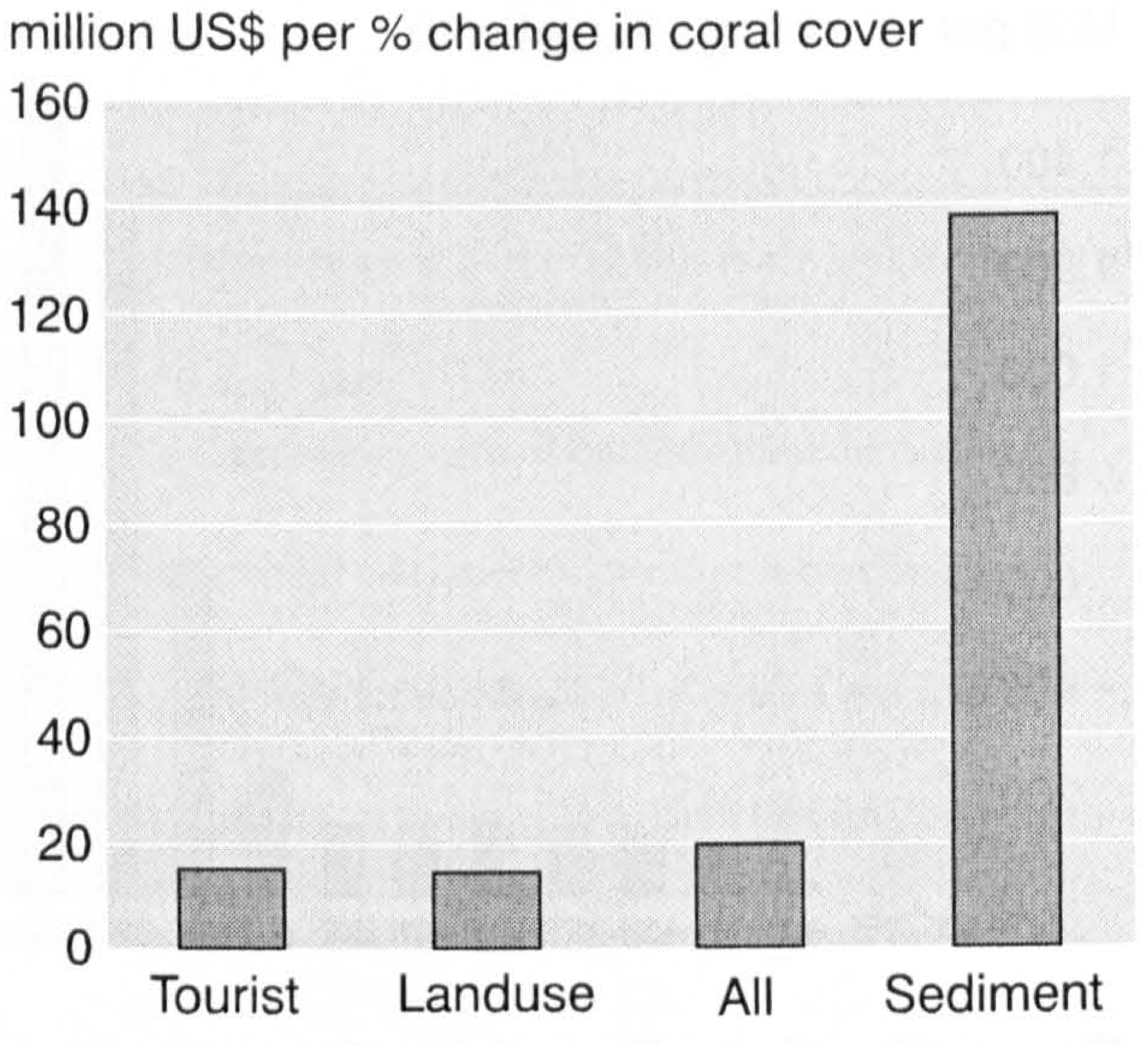

Figure 4.7. Cost-effectiveness of environmental protection strategies defined in terms of coral cover as an indicator of coral reef health (environmental protection strategies defined as in Table 4.6).

Conclusions

The two objectives of the Coral-Maldives model were to test and validate the cost-effectiveness analysis model of coral reef management and protection and to investigate whether the cost-effectiveness analysis model can be a useful tool for decision support for coastal zone management in the Republic of the Maldives. This chapter has described the model and examined different analyses. The model was presented to the decision-makers within the Ministry of Planning, Human Resources and the Environment of the Republic of the Maldives in late 1996. As a result of the work completed up to that time, the following conclusions can be drawn and further recommendations made as to future developments of the model.

Cost-Effectiveness Analysis

Ranking the interventions in terms of their cost-effectiveness for coral reef management and protection is a useful and potentially valuable tool for reef managers. The results from the Coral-Maldives model should provide reef managers with a clearer picture of the different options available and the likely benefits and costs associated with these management interventions. There are, however, an array of potential indicators describing the success or failure of a coastal zone management strategy. These may be ignored by focusing only on the costs of environmental protection measures and changes in coral reef health. For instance, the issue of public health or coastal erosion and flooding risk may not be taken into account. These are important factors when analyzing options for coastal zone management.

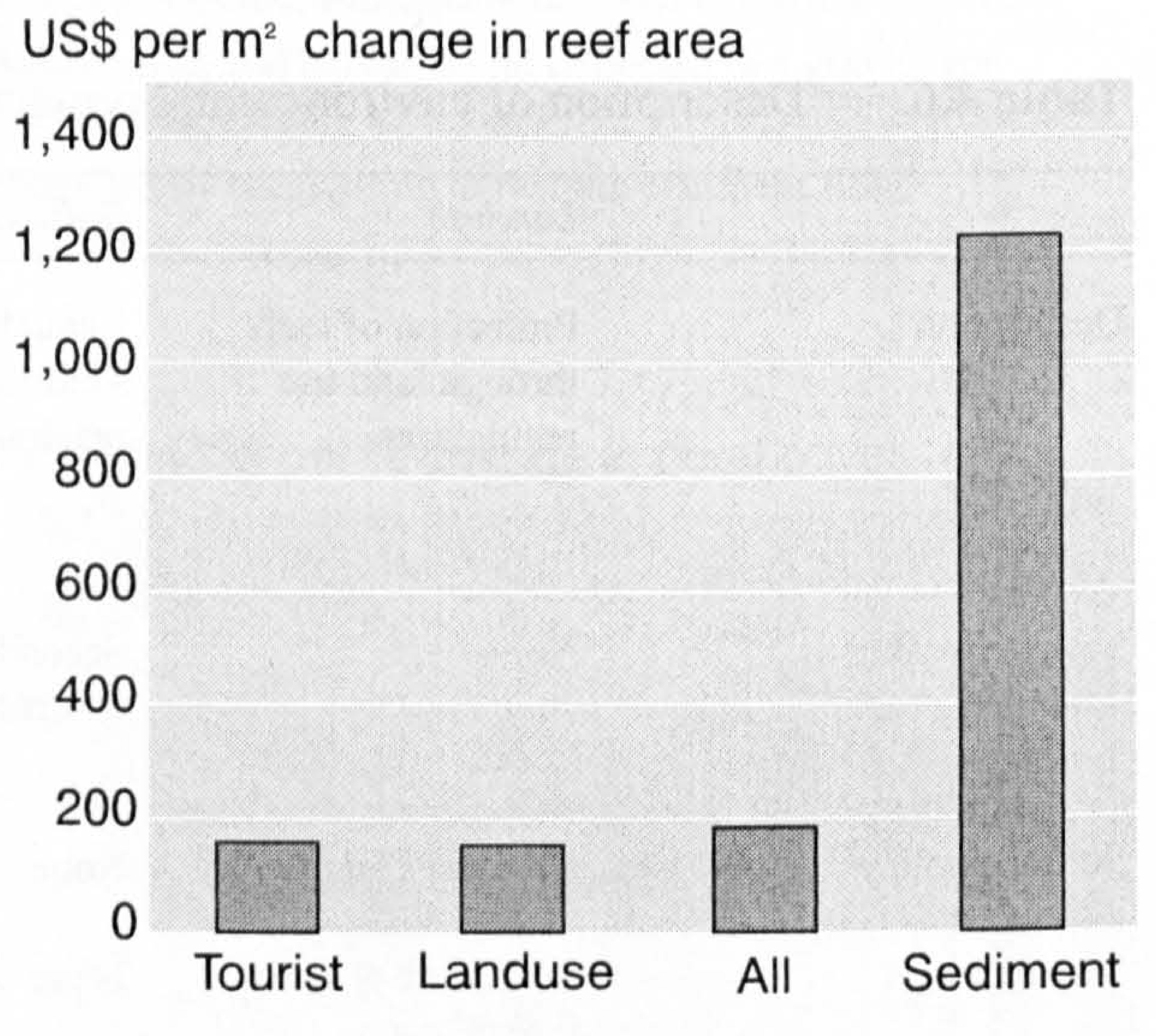

Figure 4.8. Cost-effectiveness of environmental protection strategies defined in terms of reef area as an indicator of coral reef health (environmental protection strategies defined as in Table 4.6).

The Maldives case study shows different results from the case studies carried out in Jamaica (Ruitenbeek *et al.* 1999a; Chapter 8) and Curaçao (Rijsberman and Westmacott 1996; Chapter 4). The three case studies take geographically different areas. In the Jamaica case study, the construction of an outfall appears to be a cost-effective measure; however, this is a stand-alone intervention that, in the Maldives, is connected to either a pumped sewage system or a gravity sewage system in combination with septic tanks. The land use zoning programs in the Jamaican case are some of the most cost-effective measures. This pattern is also seen in the Maldives case study.

The Curaçao case study focuses much more on land-based pollutants as these were identified as the major local threats to the reefs. In the Maldives, industrial activity is very small and damage from sewage is low due to the high flushing from the relatively strong water movements; thus, the focus is on minimizing physical damage to the reefs. The Curaçao study primarily examines the different options for treating wastewater flows. Land use regulations are again different. In the Maldives, the protected areas are assumed to be away from sources of pollution and are feasible due to the large area of reefs. It is assumed these areas are able to be protected from physical damage. The situation in Curaçao is different in the sense that the water quality standards that may be imposed for marine parks are entirely dependant on the ability of industries and local government to pay for the interventions to reach these standards. The cost of implementing a marine park can be taken into account; however, the total cost, including wastewater treatment facilities to reach marine park standards, should also be examined.

Cost-effectiveness is a useful indicator to rank the different strategies and start to prioritize individual measures. This could play a substantial role in assisting decision-makers in formulating environmental protection strategies. These, in turn, can be compared as to their effectiveness for coral reef management. Taking the broader view of coastal zone management, the use of such an indicator for the assessment of projects and plans can be complimentary to other coastal zone management indicators. Coral-Maldives demonstrates the use of these additional indicators.

Decision Support System for Coastal Zone Management

The second objective of the model was to develop a decision support system for coastal zone management that could eventually aid the decision-makers in the Maldives in the formulation of their coastal zone management plans. The model was formulated during discussions with various government agencies where the main issues currently of concern and the alternatives available to management were identified. The issues in the decision support system should, therefore, be a fair representation of the current concerns of the Maldives. The model should be able to highlight these issues and show the different impacts alternative strategies may have on a series of coastal zone management indicators. Within these indicators, the user can examine the cost-effectiveness of each strategy as described above.

The decision support system is aimed at decision-makers as well as analysts. The structure is such that analysts can prepare and save case studies that can be later assessed and utilized by the decision-makers. During the comparison of cases, there is a ranking option that can be used to centralize discussions around the selection of cases. These rankings can also be saved and retrieved for later discussions or analyses. The following sections discuss the potential use of the model as a decision-making tool and suggest ways to improve or further develop the model.

The following areas were identified as potential uses of the model:

1. *Coastal zone management workshops and training programs.* Coral-Maldives would be suited to a training workshop for coastal zone management. Participants could include analysts, where model capabilities, data needs, formulation of the scenarios and strategies, and selection of the more successful measures or strategies are discussed. Alternatively, workshops may be held for decision-makers who can examine the alternatives formulated by the analysts and use the decision support system as the discussion forum where specific objectives and indicators, as well as the eventual ranking of alternatives, is the focus.
2. *Preparation of scenarios for environmental reports.* Coral-Maldives can be used to illustrate the impact that different future development scenarios may have on the environment. The decision support system provides a quick method of viewing and comparing different scenarios. These can be used to illustrate environmental reports showing the likely impact of certain development options. The model is not, however, formulated at a level of detail capable of carrying out individual project assessments. Rather, it can indicate trends over the simulation period. The data used has had to be adapted and, in many cases, estimated. For more detailed results, new data sets will be required.
3. *Analysis of different regional development plans.* Similar to the preparation of scenarios for reports, the model can be used to input and examine the impacts of alternative regional development plans. The model

focuses on coastal zone management issues and may, however, miss some social issues such as provision of schools and hospitals, and the provision of fresh drinking water. The spatial extent of the model is also limited to North and South Male in this version and is not able to show the impacts of, for example, decentralization strategies. The model will give graphical information on the likely impacts of the different plans and will allow the decision-makers to compare the results under a series of different indicators.

4. *Identification of areas to protect or develop.* Coral-Maldives can show trends likely to be seen rather than point to specific reefs that should be protected or identify certain islands more suitable for development than others. It will, however, show the differences at the level of the sections defined in the model of the impacts of protection measures or development. Likewise, the model distinguishes between developments on the islands of the inner and outer sections of the atoll and the orientation of developments actually on the island.
5. *Environmental impact assessments.* Environmental impact assessments (EIAs) tend to be carried out for a specific project. As the model stands, the scale is too general for specific project evaluations. However, the concept and much of the techniques used for modeling could be used to create a project-based EIA tool, given further detailing and verification by ground data collection. This could be a useful tool for nonprofessionals to carry out analysis of environmental impacts. For example, a tool freely available to resort developers may allow certain developments to be redesigned on the basis of more firm environmental evidence.
6. *Indicators for coastal zone management.* Coral-Maldives contains a series of coastal zone management indicators. These can also be added to by user-defined criteria. This allows the user to include recently arising information or issues. The structure of Coral-Maldives also allows the user to focus on the objectives of the management plan through the selection of the indicators. It may also stimulate discussions of gaps missing in the analysis and identify issues that may not otherwise have been discussed.
7. *Establishment of an environmental database.* The Ministry of Planning, Human Resources and the Environment (MPHRE) of the Republic of the Maldives is working towards the establishment of an environmental database. Coral-Maldives contains data that has been collected from a variety of sources. The data used in the model can be either used to add to the database or as a basis for a new database. Updating the data, both in the MPHRE environmental database and in the model database can be achieved through the training of MPHRE staff.

Further Developments of the Model

The model was received well in the Maldives. Several suggestions were made as to how the model could be expanded and improved. One of the first tasks should be to achieve wide acceptance of such a decision-making tool and, through training of different departments, allow the tool to be updated and further developed. The following sections highlight the issues brought to light for use of the model and its further development.

Cost-Effectiveness Analysis

Studies were continued in the case study sites of Curaçao and Jamaica (see subsequent chapters), including valuation studies and consideration of the benefits and costs associated with changes seen in the reef health as a result of environmental protection measures. These studies provide additional valuable indicators for decision-makers, leading to a clearer understanding than information regarding a change in the physical state of the reef alone may do.

Spatial Extent of the Model

One main comment received was to expand the model to cover the whole of the Republic of the Maldives. This would allow the user to examine the possibilities of assessing the development of different atolls. At this level of regional planning, users would be able to obtain a clearer picture of alternative development plans. This would require additional data at the same level as is currently in the model. The data would cover population and other socio-economic data, and physical data such as island size, reef conditions, and exposure of the islands. Such a model would allow the user to assess the impacts and explore the alternatives to various regional development plans.

Inclusion of Additional Issues

In addition to expanding the spatial extent of the model, certain additional issues were also identified as important for coastal zone management in the region:

- *Solid waste.* The issue of solid waste was not included in the current version of the model. It was omitted due to the focus on environmental impacts that were quantified in terms of sediment and physical damage. The issue of solid waste and the impacts of dumping or incineration in selected sites is a current topic of concern for the Maldives. For example, limitations on the amount of land area available has resulted in the infilling of a lagoon close to the capital, Male. The alternatives are limited; however, the full impacts of these actions have not been fully examined.

- *Vulnerability to flooding.* Another issue that is not included in the current version of Coral-Maldives is the increased risk of flooding resulting from reclamation works. Impacts of reclamation are seen in terms of increased coastal erosion that can be mitigated through the construction of coastal protection works. A useful method of including the effects of erosion and the likely risk of flooding is for the user to select a risk level that is acceptable and the costs of achieving this will be computed through the model. To fully implement such a model, data and information would need to be collected on the current erosion patterns on the islands. In addition, if longer time scales were examined, the ability of the reefs to keep pace with sea level rise could be incorporated.

Database

The data included in the model will require continued updating and expanding. Certain parts of the database are based on expert judgment, rather than actual field measurements. This may be adequate for the current model; however, this could be improved in subsequent revisions, particularly if more detail was required for more project-orientated analyses. In particular, data on erosion rates, sediment loadings from construction, impact areas surrounding land reclamation works, reef health parameters available on a larger scale, reef areas surrounding islands, and those areas utilized for mining activities are suggested points of focus for data improvements.

Development of the Decision Support System

Certain areas of the decision support system could also be improved. Optional ways of defining the environmental protection measures, for instance, could assist the decision-maker. For example, selecting the type of wastewater treatment for each island does not give a clear indication of the level of treatment that will be received. The user could, in theory, also select the public health risk that he or she is willing to accept or the reduction level required and the model could select for each island the least expensive and most effective method for that particular capacity. The user could also be able to spatially define the mining areas and, with more detailed information on reef health, the user could expand these to include defining more specifically the actual reefs targeted for protection.

GIS Options for Display of Results

The analysis stage in the decision support system allows the users to examine the result in tabular format as well as more detailed information in charts. Geographic information system (GIS) tools and applications may be able to improve this display of results, linking the datasets to the graphical locations. The feasibility of achieving this should be examined from the perspective of additional data requirements and software availability. Such a development to the current Coral-Maldives model could be carried out as a capacity building exercise.

Environmental Impact Assessment and Project Evaluation

The present version of Coral-Maldives is not designed to be used for project evaluation. The level of detail has been generalized and the islands grouped into sections. If such a model were to be available for project evaluation, the level of detail required would need to be far greater. It could be that data is collected for certain project evaluations and that a model is developed for that island or situation only. The detail contained in the model would again be more in-depth and relevant to the specific purpose. The structure of the analysis could, however, follow the same structure as that of the current decision support system.

The current version of the model shows the major trends in the socio-economic conditions and environmental health of one section of the Republic of the Maldives. The model is capable of facilitating discussions and being utilized as a training tool, and is valuable in the identification of areas requiring additional information and data collection. The model can be seen as the basis of an environmental database and, through its further development, could be used in a capacity strengthening exercise for various government ministries within the Maldives. Additional issues and indicators can be added in a similar manner. Updating of the model could be achieved through trained personnel within the country who would be responsible for maintenance and development.

Chapter 6

Lexicographic Preferences and the Contingent Valuation of Coral Reef Biodiversity in Curaçao and Jamaica

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The contingent valuation method (CVM) is a stated preference method that directly surveys individuals to obtain their preferences rather than analyzing their actual behavior as revealed in the market place. In contrast to other methods for cost-benefit analysis (CBA), CVM has received considerable and increasing attention in the literature. The main advantage attracting this attention is the ability of CVM to estimate option, existence and bequest values in addition to direct use values.[1] The travel cost method, production function analysis, and hedonic pricing are all restricted to assessing only the direct use values of the environment (Hanley and Spash 1993).

There are several stages involved in conducting a CVM study—designing and pre-testing the survey, carrying out the main survey, estimating willingness-to-pay (WTP) and/or willingness-to-accept (WTA), bid curve analysis, data aggregation, and final assessment. In making decisions at each stage of the studies' design and conduct, economists impose their implicit value judgments as to what seems appropriate. While the art of survey design may make CVM more controversial, similar judgments are required in the application of any CBA method. What CVM adds is the ability to probe motives and attitudes.

Issues in Survey Design

Practical CVM survey design must be carefully conducted with awareness of the need to make the trade-off being described both realistic and easy for the general public to understand. This is often a careful balancing act between depth and comprehensibility. Thus, for example, the lengthy technical discussions of ecologists about coral reef degradation have to be simplified to a set of stylised facts. In addition, the length of the survey must be controlled to achieve an administration time that maintains the average interviewee's attention.

The Design Process

The design of a CVM study includes the way information is presented to individuals, the order in which it is presented, the question format, and the amount and type of information presented. There is a wide body of evidence to suggest that survey design can affect responses. Survey design requires framing a realistic decision concerning the environment where the monetary question to be asked is accepted as a possible state of the world in which individual respondents might find themselves. Thus, the analyst must take several decisions, including a reason for the payment, how funds will be raised (i.e., the bid vehicle), and the arrangements for and regularity of payments. For example, Rowe *et al.* (1980) found that WTP to preserve landscape quality was higher when an income tax increase was suggested than when entry fees were used. The technique for bid elicitation may be an open-ended question (with or without a bidding card), a dichotomous choice, or a bidding game. Also, information on physical changes will need to be summarized and the method of their description chosen (e.g., text, graphics, maps).

Due to the sensitivity of responses to the information supplied, the pre-testing of the survey has become of increasing importance. This can be conducted via a small sample test run to see if respondents have problems and special sections can be included to pick out the occurrence of difficulties. A focus group is another method now in use for pre-testing. Generally, the pre-test will enable the identification of problems with regard to the framing of the decision problem, as well as divergence between encoding and decoding of information.

The conduct of the main survey can use several variations. The in-house interview is now most favored in developed country surveys, although the expense of this approach often means surveys are completed in the street, by telephone interviewing, or by mail. In the Caribbean, the difficulty of obtaining a representative sample via in-house interviews and obtaining a tourist sample meant the equivalent of "in-street" surveying was required (i.e., approaching people in the street, at shopping centers and on the beach) in addition to the developed country preference for in-house interviewing. While random samples are recommended, in practice a truly random sample is difficult to obtain. This is especially true in developing countries where large sections of the population may lack telephones or have no postal address. Again, sampling tourists can pose problems in terms of predefining and selecting a random sample. Even in developed countries, the sample is often based on a quota as it is less expensive (although a random element may be included, such as the random walk method).[2] The sample is also often weighted in terms of the local or regional population, whichever is seen as politically more important to the decision and likely to have strong direct economic connections to the outcome.

Responses to the survey may include "protest bids", and these are often omitted from the mean WTP or WTA calculation without adequate reason. Protest bids are zero bids given for reasons other than a zero value being placed on the resource in question. For example, a respondent may refuse any amount of compensation for loss of an environmental asset, which they regard as unique, or a species that they feel should be protected at all costs. Respondents may refuse to state a WTP or WTA amount because they reject the survey as an institutional approach to the problem, or because they have an ethical objection to the trade-off being requested (e.g., a lexicographic preference; Spash and Hanley 1995). Another potential problem is the outlier who bids a very large amount and so has a strong influence on the mean. This should only be regarded as a problem when the bid is unlikely to occur because the individual lacks the income to pay (under WTP) or would actually accept a much lower amount (under WTA). In this case, the respondent would be acting strategically, thus creating a bias.

Analysis of the bid curve is used to test construct validity (i.e., that the socio-economic variables have the expected signs and the regression is statistically significant). Other relationships can also be investigated at this stage. In general, bid curve analysis has tended to be of academic rather than policy interest. However, this analysis can provide useful insights into the behavior of respondents and the determinants of their bids. In this chapter, such analysis is used to investigate the importance of ethical positioning.

Final reflection upon the CVM study can include convergent validity and success of repeatability where there exist other similar studies. The overall success of the exercise will also become apparent as the results are being analyzed (e.g., a high number of protest bids). There are several specific problems that are recognized as possible causes of bias, some of which have been mentioned (e.g., strategic bias, design bias). More problematic are the impacts of the information, as this is, by necessity, restricted but can have serious influence upon the resulting bids and the problem of embedding as raised by Kahneman and Knetsch (1992).

Information Provision

In a hypothetical market, respondents combine information provided to them regarding the good to be valued and how the market will work with information they already hold on that good. Either the hypothetical market or commodity-specific information given to them in the survey may influence their responses. This phenomenon implies that WTP and WTA values are endogenous to the valuation process. Thus, bids to preserve different animal species may vary significantly according to the information provided by researchers (Samples *et al.* 1986). Ajzen *et al.* (1996) concluded from experimental research that the nature of the information provided in CVM surveys can profoundly affect WTP estimates and that subtle contextual cues can seriously bias these estimates under conditions where the good is of low personal relevance. However, Randall (1986) has argued that CVM answers should vary under different information sets, otherwise the technique would be insensitive to significant changes in commodity framing.

Indeed, the effects of information may be inappropriately labelled as bias, depending on the way in which WTP or WTA is changed. Information that improves the knowledge of an individual concerning the characteristics of a good can be regarded as informing a consumption decision. Information that alters the preferences is more problematic in the neo-classical framework and could be regarded as creating a bias. For example, Baron and Maxwell (1996) show that individuals' WTP can be biased by information on the cost of provision of public goods and suggest eliminating information from which costs could be inferred from CVM surveys so that respondents can focus more easily on benefits alone. While such redesign may avoid some types of bias, a more general issue, which remains, is how far individual preferences can be regarded as exogenous to the valuation process and, especially so, when goods are unfamiliar and/or never traded in a market.

Part-Whole Bias and Embedding

This problem arises when the component parts of an individual's valuation are evaluated separately and, when summed, found to exceed the valuation placed upon the whole. CVM studies have found part-whole bias, also termed embedding, and this has been attributed by some to valuation of the moral satisfaction from contributing to a worthy cause ("warm glow") rather than the good itself (Kahneman and Knetsch 1992). The counter reaction has been that CVM surveys finding embedding are flawed in some way that creates the part-whole bias and that this can be corrected by careful survey design (Carson and Mitchell 1993, 1995; Hanemann 1994). However, Bateman *et al.* (1997) have provided experimental evidence for the existence of part-whole bias for private goods outside of the CVM context. They therefore suggest that the problem lies with economic preference theory rather than the CVM approach.

Hypothetical Market Error

Valuations in a hypothetical market could make responses differ systematically from actual payments in actual markets. Random over and under statement would be a non-systematic error term and, therefore, would not represent a hypothetical bias (Mitchell and Carson 1989). In general, CVM studies avoid actual trade-offs, unless they are specifically testing for a hypothetical bias, and so the evidence on the impact of this bias is limited. A CVM study will be different from actual markets because there is no debate over the value of goods, no sequential learning from a series of purchasing decisions, and no enforcement of actual purchases. Thus, the extent to which hypothetical market bias occurs will be dependent upon how realistic the trade-off described is felt to be by respondents. Also relevant is whether the design has considered the type of incentives that might unintentionally be given to respondents.

WTP versus WTA

WTA formats can generate more protest bids and outliers than WTP. Protest bids may occur because people are unwilling, on ethical grounds, to accept monetary compensation for the loss of an environmental asset (an implied loss of property rights). Outliers may be due to a rejection of the notion of compensation resulting in a large request for compensation based upon rejection of the implied trade-off, rather than an amount intended to represent their welfare loss.

Willig (1976) showed that these two welfare measures would be close if the ratio of consumer surplus to income was sufficiently small and if the income elasticity of demand for the good in question was sufficiently low. Where these conditions failed to hold, precise limits on the difference between the two measures could be calculated. While some criticized the applicability of Willig's findings to environmental benefits (Bockstael and McConnell 1980), others extended Willig's theorem to the quantity changes more commonly encountered in environmental valuation (Randall and Stoll 1980).

However, stated WTP has been found to be significantly lower than stated WTA (e.g., Hammack and Brown 1974; Rowe *et al.* 1980). In addition, experimental work has also found that WTA exceeded WTP (Gregory 1986; Knetsch and Sinden 1984). Several reasons have been given as to why WTA may be greater than WTP. First, actual WTA is greater than actual WTP when loss aversion occurs. Individuals value a given reduction in entitlements more highly than an equivalent increase in entitlements (Knetsch 1989). Second, income constrains WTP bids, unless limitless borrowing is possible, whereas WTA bids are unconstrained, making bounded trade-offs hard to enforce. Third, the availability of substitutes provides theoretical evidence for a difference. If private goods are poor substitutes for public goods, then WTA can be greater than WTP (Hanemann 1991). A public good with few private goods as substitutes will be valued differently because under WTP the loss of public good is prevented, while under WTA the private goods are meant to provide compensation and the public good is lost. Fourth, risk-averse consumers find they have only one chance to value the good under the typical CVM and will tend to overstate WTA and understate WTP. They do so due to uncertainty concerning the value of the good and in order to avoid a potential loss (Hoehn and Randall 1987).

On practical grounds, the status quo reference position is preferable in terms of the property rights structure. If an alternative is imposed by the blanket imposition of WTP formats in all CVM surveys, the result can be to create an unrealistic trade-off, hypothetical market bias and protest bids. Thus, rather than follow a generic prescription to always use WTP formats as a conservative estimate of values, the property rights prevalent in a given situation should be used as guidance. This reinforces the theoretical argument for using WTA to measure a loss and WTP for a gain (Knetsch 1994).

Dichotomous Choice versus Open-Ended Formats

The dichotomous choice format has been recommended because those supporting the approach regard a one-off yes or no decision as closer to a free market. This is debatable in itself with the yes or no decision being closer to a political referendum. There should be some concern for the rejection of such an approach in countries where prices are often discussed and argued about rather than given as fixed. Also, to bind the range of choices when conducting dichotomous choice, an open-ended CVM is required as a first step. This means that those advocating dichotomous choice must defend the open-ended CVM. Neither format is clearly superior on *a priori* grounds. However, the dichotomous choice format does suffer problems in practice. The "yea-saying" problem may be evidence of an anchoring bias and has raised questions as to the usefulness of the format. Desvouges *et al.* (1993) found dichotomous choice exceeded the open-ended format and had greater variability. The results are sensitive to the choice of bids by the analyst, and the choice of functional form for mean estimation adds to variability in results.

The NOAA Panel: A Comment on Generalized Guidelines

As the use of CVM has increased, so has the debate between supporters and detractors. Sagoff (1996) has critically attacked CVM and, in particular, what he terms the "Wyoming experiment" of the late 1970s and early 1980s. He sees the technique as economist venturing into the political realm, which he regards as totally separate. Applications to Kakadu National Park in Australia and the assessment of damages arising from the Exxon Valdez oil spill in Alaska created public controversy. In the Exxon case, one result was the suggestion that a specific set of guidelines for conducting a CVM should be followed.

A panel of experts was convened by the National Oceanic and Atmospheric Administration (NOAA) to fight pressure from Exxon coming via the Bush administration. The panel, which included Kenneth Arrow (Exxon consultant) and Robert Solow (State of Alaska consultant), gave qualified support for CVM. They produced guidelines which suggest there is one correct approach to conducting a "good" CVM study (i.e., methodologically similar to Cummings *et al.* 1986). Blind adoption of the NOAA guidelines has become a defense of the validity of specific work, although this ignores the variation in case study circumstances, such as whether property rights prescribe a WTP or WTA approach. In addition, merely quoting the use of NOAA guidelines seems inadequate defense and some regard for independent testing of the validity and applicability of both these guidelines and CVM results is required.

The extent to which CVM can be generalized is easily overstated. According to Cummings *et al.* (1986), CVM works best in only a limited range of circumstances. The most important rules are that respondents understand and be familiar with the commodity to be valued; that respondents have prior valuation and choice experience with respect to the commodity; that uncertainty about the operation of the hypothetical market is low; and that WTP is used in preference to WTA. However, the quantitative results of violating these conditions remain largely unspecified.

The NOAA panel guidelines include the use of WTP; in-house interviews on a random sample; full information on the resource change (including information on substitutes) and checks for understanding; closed-ended referendum formats (dichotomous choice); reinforcing budget restrictions; and careful pre-testing. They have also recommended reducing any resulting valuation, which raises questions over the derivation and credibility of this particular set of rules. In this regard, those using the guidelines should remember that the NOAA panel was politically appointed to adjudicate over the use of CVM in the USA as a result of the Exxon Valdez accident. The procedure for deriving the guidelines, with a Nobel laureate from each of the opposing camps on the panel, would be interesting to discover, along with the underlying justification for some of these rules.

A more general problem is the extent to which any one set of rules can dictate CVM research. The NOAA guidelines have not resolved the debate around CVM because they assume a technical solution regardless of the problem at hand. The rules try to impose a set behavioral model upon individuals (economic rationality) and reject divergent behavior (e.g., see the discussion of part-whole bias in Bateman *et al.* 1997). However, there can be general guidelines as to good practice rather than set formats for an idealised CVM survey that is universally applicable. Regard to bias problems, appropriate testing and conduct of the survey, and learning from past experience are obvious steps to adopt.

Designing the CVM for the Coral Reef Case Studies

Two separate CMV surveys were designed—one survey for Jamaica and one for Curaçao. The main difference between the surveys, besides geographical and institutional context, arose in the development of the biodiversity improvement scenarios and management options to achieve them. The Jamaican survey was designed and tested first and this informed the Curaçao survey, but feedback on the Curaçao experience was also possible before either of the final surveys. This resulted in some simplification of the information presented and the development of show-cards that could be used in either country.

Developing the Information Pack

The term "information pack" is used to summarize reference to all the descriptive materials included in a CVM survey to convey information about the environmental changes. Maps were sought to show the islands, the reefs by quality, mangroves, endangered or rare species, and main source points of pollution. This was to inform respondents as to the current areas of interest in terms of marine biodiversity, the threats to biodiversity, and the context for the proposed project. In addition, the area covered by the case study needed to be described along with some detail on what it would be protecting.

The final surveys included colour maps, descriptions to be read aloud by the interviewer, and show-cards for the interviewee to study. For each survey area, two maps were used. One showed the whole island and explained the location of the proposed project (i.e., the park) and identified other coral and marine resources (i.e., reefs, seagrass beds and mangroves), and, for Curaçao, the location of the endangered sea turtle. The second map detailed the use zones proposed within the parks themselves (e.g., recreation, fishing, multiple use, and shipping).

Institutional and Environmental Setting in Jamaica

For Montego Bay, Jamaica, background information was gained from available documents which allowed a characterisation of both the environmental quality and the institutional setting. The aim was to find a realistic scenario in which to describe a reason why the general public might need to pay for biodiversity improvement. The choice of an institutional setting was interconnected with the environmental problem that would be selected. There appeared to be several anthropogenic causes of reef damage that could be used in a CVM approach:

1. *Overfishing.* A policy would need to be presented which gave an institutional setting under which overfishing would be reduced. This would need to be combined with knowledge of the system of regulation to assess whether a realistic reason for asking the general public to contribute to such a scheme was feasible. Problems with this approach were the institutional setting, fishing being related to use values creating confusion when separating non-use values, and the difficulty of blaming one cause for marine biodiversity losses.
2. *Mining the reef.* This is an extreme scenario where the entire reef is lost. The difficulty was that the total value, rather than marginal quality change, in the reef in its present state would be estimated. The problems were the hypothetical nature (i.e., the creation of a problem which did not exist), the high probability of protests, and the failure to relate to the current institutional setting. In addition, WTA compensation as the appropriate measure of welfare loss would add another aspect of experimentation to the study.
3. *Waste treatment plant.* The need to improve water quality was the focus here. Problems arose in that many individuals were probably not connected to sewage systems and so would have no obvious payment mechanism. These individuals might resent paying for others' externalities. The institutional setting in terms of who pays and who benefits from wastewater treatment would have needed clarification. In addition, the extent to which the issue would be connected to coral reefs rather than human health was unclear and separating out the effects could be difficult.
4. *Trust fund for restoration.* This was realistic and could be given an institutional setting within the Montego Bay Marine Park. A range of management options for restoration could be outlined and their expected consequences described. Thus, the CVM survey would

outline expected biodiversity benefits related to Park provision. No one issue was needed as a cause to be blamed for reef decline; rather, a range of causes could be identified. There were no obvious problems with this option. However, the credibility of the trust fund was identified as a potential problem because it would be dependent upon whether, for example, the government or a non-government organization (NGO) was seen as most trustworthy to manage such funds. Similar funds in existence in Jamaica (e.g., Portland Environment Protection Association) implied this would be unproblematic.

The Montego Bay Marine Park (MBMP), which had already formed a point of interest in reef management, immediately had the advantages of an actual institution with a record of marine ecosystem management and provided a realistic context within which a WTP scenario could be developed.

Institutional and Environmental Setting in Curaçao

The best options raised for Curaçao were either: i) a trust fund to protect marine biodiversity to be used for the establishment and maintenance of a marine park along the south coast; or, ii) the improvement of the existing underwater park. The present underwater park, at the eastern end of the island, was deemed to be more substantive on paper than in fact. The site borders private property, effectively restricting access. Dive operators in the vicinity and the ecological institute (Carmabi/Stinapa) are the main users of the area. The limits on site access and the proximity of private property raised the following issues:

- The site might be seen as private property rather than a public good;
- Familiarity would be low;
- Use would be restricted, which would limit the survey more to indirect benefits; and,
- The possibilities for biodiversity improvement appeared limited.

At the time this project was being established (early 1997), a plan for a marine park along the whole south coast of Curaçao was developed by the agency responsible for the management of national parks (Stinapa). Thus, the best option was to base the CVM survey on this new plan. A major advantage was adopting an actual project proposal with an expected range of biodiversity improvements.

Information on the current state of Curaçao reef systems was gathered. There are very few mangrove areas and these are mainly surrounding inland lagoons. The main endangered or rare species identified were sea turtles, which have nesting grounds in one area of the islands. The main sources of pollution were industrial, primarily around the Willemstad refinery and the town itself. The main threat of physical damage was through the construction of artificial beaches. In terms of development, new tourist and population centers in the west and east were seen as potential threats.

Describing Marine Biodiversity

Biodiversity is a difficult concept to explain quickly and simply. Previous experience has shown the very term is often poorly understood by the general public and even among sub-groups with high education levels (Spash and Hanley 1995). However, people are quite often familiar with the ideas that lie behind the concept and these need to be brought out before any WTP questioning. The survey downplayed academic wording while portraying the same information.

Defining and Describing the Coral Quality Change

A major concern in designing the CVM survey was the characterisation of the environmental change and its cause and impacts on biodiversity. There was a period of consultation with marine biologists, ecologists and conservationists familiar with the sites and biodiversity degradation of coral reefs in general. Experts advised on the characterisation of the problem for the survey. On this basis, the Jamaican pre-test tried to explain the concept of coral reef abundance. Coral reef abundance was felt to be the best approximation to a measure of coral reef species diversity and health. The description of coral reef degradation and improvement in the WTP preamble and question was in terms of percentages from a maximum (100%). The general public was able to comprehend the idea of percentage changes from a hypothetical maximum without going into the detailed scientific reasoning. The aim was, therefore, limited to describing the environmental trade-off and the benefits from the proposed project.

The Benefit Payment Scenario

In order to design a payment scenario, the project being paid for must be described in enough detail to allow respondents to understand the net benefits. This requires an understanding of the current environmental status quo and the institutional context. The overall aim must be a realistic, if hypothetical, proposal. As explained above, environmental quality within the proposed parks was characterized to give a background picture.

In order to achieve a stated improvement in marine biodiversity, a set of management actions needs to be described. This requires some knowledge of the powers and jurisdictions of institutions so that management options attributed to the manager of the trust fund are realistic. For example, such things as tourist development projects and designation and enforcement of shipping lanes may be regarded as outside park management's jurisdiction.

The reduction of the nutrient and sediment loading onto the reef was seen as the main problem. This could be achieved through sewage treatment and industrial pollution control. However, a marine park is more likely to be involved in monitoring to determine whether such standards are being met and the occurrence of physical damage (e.g., due to anchors from fishing and diving boats). In these cases, the park is unlikely to be actually installing or running mitigating measures. However, the enforcement of the measures and provision of data and information to ensure the measures are enforced could be within park jurisdiction. The management options selected as examples for the survey were, in the end, found to be common to both the South Coast Marine Park in Curaçao and the Montego Bay Marine Park in Jamaica. These were:

- Planting mangroves and coastal plants to reduce impacts from run-off;
- Establishing monitoring of water quality, fish, plant life and mangroves;
- Establishing mooring buoys for fishers;
- Enforcing and patrolling use zones; and,
- Enforcing fishing regulations.

Several other possible management strategies were dropped as being outside of the jurisdiction of the parks:

- Treatment of sewage;
- New drainage systems for storm waters;
- Encouraging proper disposal of chemicals, garbage and other waste to improve water quality;
- Promoting higher industrial effluent treatment; and,
- Limiting inshore dumping by ships.

The current state of the reef system to be included in the park must be given and the expected improvements detailed. Knowledge of the existing situation can be used as the "business as usual" scenario and predictions made about the quality of the environment at some point in the future. This is then compared to the situation at that time with environmental measures in place.

In terms of environmental changes, the "business as usual" scenario is given by the current policy. The CVM survey could use the characterisation of reef quality to imply either stability of the reef system or, more realistically, degradation by a given percentage over a given period of years. The parks would then be described in terms of a "policy on" situation where degradation is avoided or coral abundance is increased. Thus, the management aim could be to either improve reef biodiversity or prevent biodiversity reductions and reef deterioration that would otherwise occur. In the survey, a mixed approach was felt to be most realistic. That is, the current situation of the coral reefs was estimated to be one of deterioration, but in both countries institutions had been identified which were working on reef maintenance. This allowed the current situation to be described as one in which the reef would deteriorate without any action, but that some action was already ongoing. This ongoing management would then allow the reef quality to be maintained at present levels, which had been characterized as degraded. The proposed project for which individuals would be asked to pay would increase the coral abundance from this level. The two scenarios were both for a 25% improvement.

Survey Sections and Questions

The layout for the CVM survey used here has been developed over several years. The design makes use of individual sections to separate a group of issues. In this instance, five main sections were included:

1. *Framing and background information.* The public policy context is described in terms of related issues that are of concern. That is, by a series of questions, the interviewees are made aware of a range of issues among which the environment is but one. They are asked to think about and reflect upon their own priorities. This also helps reinforce the concept of society having limited resources and there being a set of possible public policy issues requiring attention. The idea of framing is to place the problem of coral reef degradation within a broader context. Thus, the questions move from a very general level, with no mention of the environment, to environmental issues and the specific case study sites. Failure to frame the issues may be regarded as promoting one specific issue without any context and has been cited as a cause of embedding problems. Besides being concerned with framing the issue, this first section also gathers background information on the interviewees' knowledge of the site and provides information. The site information is given via maps and a short description. This aims to give all respondents a basic level of knowledge about the area and places it within a geographical context. Such information also acts as another framing device by showing other areas of coral reef and environmental habitat that may be regarded as substitutes. Background information on the interviewees' knowledge and use of the area is also gathered at this

stage. By the end, the context has been set and the interviewee has had to think about the coral reef case study area, their knowledge of the site, the benefits they gain from the coral reef, and their knowledge of biodiversity and, in particular, marine biodiversity.

2. *WTP into the trust fund.* The information forming the background to the WTP question has been described above. The scenario is to improve coral reef biodiversity by 25% given a set of management strategies to be adopted by a marine park. The park will have a trust fund set up explicitly for the purpose. Payment could have been on several bases, but a per annum payment for five years was felt to be reasonably realistic. Beyond five years, people are unlikely to regard actual payment as likely. The main alternative would have been to request a one-time payment and then try to estimate the time period or interest rate over which this might represent a discounted present value. This introduces unnecessary complications and, therefore, the per annum five-year payment mechanism was employed. The bid question was open-ended. Following the bid question, respondents were asked to explain the reason for their response. Tourists claiming no spare income had been noted to be an unusual group in the pre-test for Jamaica and interviewers were directed to probe these respondents. Probing was also requested in the case of those making extremely high bids. A coding table was developed for the zero bidders from the pre-tests. A separate question explores the embedding problem. The approach was to ask respondents whether they would increase their bid if a greater reef area were to be included in the project. Respondents should be prepared to do so unless they place no value on other reef systems. If they state that their bid was to cover all reefs, then a case of embedding has occurred. Subsequent questions probe indirect use values. Respondents are reminded of the uses they make of the area and the expected direct benefits of the project for them. Once the respondents are thinking of the uses they are asked to imagine leaving the island never to return. They are then asked whether this would lead to a reduction in their WTP and, if so, by what percentage. In the pre-test, a few respondents actually increased their bid despite being told their circumstances would be the same. In the final survey, the interviewer was requested to probe such respondents for their reasoning. Next, payment by volunteering hours was requested. This allows the unemployed and those on a low income to contribute to the project. In developing economies, payment by hours may be seen as more practical for many. The respondents were asked to make a commitment over five years, the same period as for the WTP question. The final question in this section was on the impact of information on the individual's preferences. The concern here was to see if the survey was informing the respondent, forming their preferences on coral reef degradation, or both.

3. *Rights and responsibilities.* This section had four questions. The first question splits the sample by the degree to which they attribute the right to be free from harm to five categories of potentially morally considerable groups. The five groups were: i) other humans now living; ii) future generations; iii) marine animals; iv) marine plants; and, v) marine ecosystems. Rights were attributed using a three-point scale with each point being associated with a position. The three positions can be summarized as: i) rights apply absolutely; ii) rights depend upon the circumstances; and, iii) no rights apply. Respondents could also answer "don't know". Those who responded by attributing a right under any category were then probed regarding their readiness to make trade-offs that might occur by the claimed attribution of a right. Thus, within the context of the park, the respondent was asked to agree or disagree with a personal responsibility to prevent harm regardless of the cost. They were then further probed to consider their answer. Those claiming such a responsibility were asked to reconsider if the cost was their current standard of living. Those rejecting the responsibility were asked to reconsider if their current standard of living was maintained. The final question asked how the individual thought the rights they had identified for the park should be protected.

4. *Socio-economics.* The collection of socio-economic data allows population statistics to be calculated and aids bid curve analysis. A set of standard questions was included to cover gender, age, education, and income. In addition, occupation was requested as a check on income and a few experimental variables added, namely dietary preference and religion.

5. *Interviewer response.* The interviewer was asked to give some feedback. The first question was whether others had been listening while the survey was conducted as this can lead to respondents saying what they think others want to hear and being reticent about their own beliefs. Next, the interviewer was asked to rank the difficulty the respondent had in answering each section. Finally, they were requested to note any specific questions that were found to create a problem for the respondent.

Pre-test Results and Survey Redesign

The survey was designed to derive estimates of non-use biodiversity values and test for the importance of a refusal to make trade-offs of money for environmental quality (i.e., the occurrence of lexicographic preferences). The survey for Curaçao was adapted from the Jamaican case study. This survey was pre-tested and updated prior to the survey being applied in Curaçao. Although the survey had already been pre-tested in Jamaica, the redesign and new cultural and geographic context meant a pre-test was also recommended for the Curaçao case study. Thus, survey pre-tests were conducted in both Jamaica and Curaçao.

The pre-test survey is a crucial stage in the development of a CVM survey and requires sampling the population from which the main test sample will be drawn. Typically, a pre-test is performed on 100 to 150 people with qualitative feedback being the central aim, rather than attempting to gain quantitative results. The aim of pre-testing is to identify any areas where the survey may be misinterpreted, where questions produce unexpected results, and, more generally, to identify areas requiring improvement. For example, misinterpretation can occur due to the use of excessively technical language in the description of environmental quality changes and probing a sample of the general public can make the analyst aware of divergence from the common use of language.

Both the interviewer and interviewee are important sources of feedback during the pre-test. Where survey design requires optional sections, the interviewers must be able to understand the sequencing of questions they are to relay. The CVM surveys used here required the design of questions to probe sub-samples and, therefore, were reasonably complicated and care was taken to re-design the format in light of interviewer comments. The pre-test was also a learning experience for the survey coordinators who were responsible for training the interviewers. This allowed the coordinators to revise the method of training and improve on the selection procedure for interviewers. In countries where market research companies, who are practiced in such matters, are unavailable, selection and training of the domestic coordinators takes on specific importance.

The results of the pre-test were used to make several improvements prior to the implementation of the main survey. Among the lessons for survey coordinators, which as mentioned above may be particularly relevant in the context of developing countries, are the following:

- Use older, more mature individuals able to understand the local language and probe the respondent when necessary;
- Increase the level of in-depth individual training of the interviewers;
- Increase the intensity and quantity of feedback given to the interviewers after surveys have been completed;
- Carry out the surveying over a longer period of time to allow quality control after a batch of surveys have been completed;
- Keep a close record of what each interviewer has received and done; and,
- Feedback the survey quota results to the interviewers to keep them informed.

In Curaçao, the survey required re-translation in selected areas. Changes were also made to the original translation in order to maintain direct comparability across different language versions. The administrators in each country selected and trained a set of interviewers (i.e., conducted sessions on familiarisation with the survey and an assessment of the interviewer as a competent but neutral purveyor of the survey information and questions). In addition, close quality control was undertaken to ensure at least 1,000 completed surveys were collected. The outcome was 1,152 surveys in Curaçao and 1,058 in Jamaica.

Detailed results of the main surveys for Jamaica and Curaçao (i.e., population sample statistics and data results for specific sections of the questionnaires) can be found in Spash *et al.* (1998). The remainder of this chapter will be concerned with the analysis of the WTP data and lexicographic preferences.

Lexicographic Preferences and WTP

One major difficulty with using CVM in the context of coral reef biodiversity is related to the existence of "lexicographic preferences". Stated simply, lexicographic preferences exist where decision-makers are unwilling to accept any trade-offs for the loss of a good or service. The literature demonstrates that, where such preferences are prevalent, CVM techniques are methodologically flawed. The first step of an applied CVM procedure should, therefore, be to determine the potential extent of such preferences. Recent work suggests that lexicographic preferences for biodiversity are exceedingly widespread in developed countries and that, moreover, the actual "definition" or "understanding" of biodiversity differs significantly among respondents. Under such conditions, the use of CVM techniques is questionable. Thus, this research tries to address the question of how to adapt CVM and test for refusal to make trade-offs in the context of coral reef valuation, taking account of possible lexicographic preferences.

Monetary valuation of the environment requires the definition of commodities in a way fundamentally identical to marketed goods and services. That is, when an environmental improvement occurs, an individual must give up some consumption of other commodities to maintain a constant utility level. This gives an individual's WTP amount, which can then be summed across all affected individuals to obtain an aggregate WTP figure. Similarly, the minimum quantity of other commodities demanded to accept a reduction in environmental quality is the WTA compensation. In this case, expenditure on other goods must be increased to compensate for the reduction in environmental quality, so maintaining the individual's initial level of welfare. Whether the other commodities are regarded in terms of a single numerate (i.e., money) or remain as a diverse set of goods and services is inconsequential.

The essential message of the normal indifference curve is that individuals are able to swap one bundle for another and can do so for a set of bundles without affecting their welfare level. As mentioned, a problem arises if, for example, an individual believes that aspects of the environment have to be protected without regard to the cost in terms of other commodities. That individual will refuse all money or commodity trade-offs that decrease what is regarded as an environmental commodity in the neo-classical framework. In theory, WTP to prevent the loss would be all the available commodities the individual could command (i.e., their income) and WTA compensation would be infinite. The respondent believes the aspect of the environment in question should remain at or above its current level in terms of either quantity or quality.

Such preferences mean that utility functions, including environmental aspects that are to be protected at all cost, are undefined for an individual (since the axiom of continuity is violated) and that indifference curves collapse to single points (denying the principle of gross substitution). These preferences are termed lexicographic by neo-classical economics because they give absolute priority to one commodity over all others and, therefore, imply a strict ordering as in a lexicon. The position described is, however, best regarded as extreme because its implications for the individual are total sacrifice for the environmental aspect to be protected (e.g., coral reef biodiversity). Economists have tended to regard the denial of continuity and violation of gross substitution as of little relevance because lexicographic preferences are unrealistic and unlikely to occur (Malinvaud 1972, p.20).

The extreme lexicographic position does indeed seem likely to be uncommon because of this overriding ranking of a good above even the individual's own life. The modified lexicographic position might be drawn-up in terms of first attaining a minimum standard of living prior to being prepared to defend the environment. Following Pigou (1920, p.759) this minimum might include, but not be restricted to, a defined quantity and quality of housing, medical care, education, food, leisure, sanitation and safety at work. Sen (1988), appealing back to notions of Adam Smith, goes further and defines functionings (the various living conditions we can achieve) and capabilities (our ability to achieve them) as essential parts of living standards rather than commodities. Such a living standard might be relatively materialistic in societies where being a functional member of society is defined in such terms (e.g., requiring ownership of a car and a television). As Sen (1988, p.17) states: "The same capability of being able to appear in public without shame has variable demands on commodities and wealth, depending on the nature of the society in which one lives". In this formulation, the concept of lexicographic preferences becomes more readily acceptable, but the definition for empirical purposes becomes far more difficult because the minimum living standard is expected to differ among social groupings.

Rights and Lexicographic Preferences

Lexicographic preferences are signified by a discontinuity in the preference function giving a single point, or bundle of goods, as the indifference set in goods space. The aim of the surveys reported here was first to identify the occurrence of such preferences and then see how far these might be indicative of a refusal to make trade-offs. This was achieved by direct questions on ethical beliefs that signify behavior incompatible with a continuous preference function, follow-up questions and consistency checks. The approach to dealing with lexicographic preferences taken here was based upon previous work (Spash 1993b, 1997, 1998c; Spash and Hanley 1995). The general approach to lexicographic preferences is reviewed next in light of the few key studies previously conducted.

The dominant economic theory of decision-making requires a fundamental philosophical assumption—namely, that individuals believe the net utility from the consequences of an action determines whether that action is right or wrong. Cost-benefit analysis and its tools, such as CVM, assume that individuals are able and willing to consider trade-offs in relation to the quantity and/or quality of public goods. Debates in environmental ethics have raised the issue of individuals refusing to make these judgments and so raised serious problems for the application of economic efficiency arguments (Sagoff 1988; Spash 1993a, 1994). One aspect of refusal can be a basis of belief in inviolable rights so that actions are intrinsically of value or deontological.

Neo-classical economists reject the notion of deontology because there is an assumed rationality attributed to the ability to make trade-offs, whatever the commodity, as long as enough compensation is offered in return. This can be summarized by the old colloquialism that everybody has his or her price. However, some individuals may treat certain aspects of the environment differently from the manner suggested by this theoretical framework. If an individual believes that aspects of the environment, such as wildlife, have an absolute right to be protected, then that individual will refuse all money trade-offs that degrade what is regarded as an environmental commodity in the neo-classical framework. Thus, the prevalence of the deontological position seems likely to be high among those who claim absolute rights to life for humans and other animals, future generations, trees or ecosystems. In contingent valuation, evidence exists in developed countries to suggest individuals express lexicographic preferences for wildlife (Stevens *et al.* 1991) and these relate to rights for animals, plants and ecosystems (Spash and Hanley 1995).

The Coral Reef Survey Results

Previous work on lexicographic preferences has relied upon a statement of belief in a position without consistency checks or developing a series of probing questions. In the current study, the survey instrument was designed to accommodate the presence of lexicographic preferences and to probe those claiming such a position more fully. This approach allows for the adjustment of a CVM survey instrument to detect the presence and extent of such preferences in the surveyed population, and also allows for the inclusion of variables reflecting those preferences for use in bid curve analysis. The methodology used had not been previously tested in a developing country context. Thus, among the results, the comparison between the tourist and local sub-samples is of interest as a reflection of the relationship between contexts and preferences and, in turn, their relationship to stated WTP.

The method used in the surveys takes a rights-based ethical position as signifying an ethical stance compatible with the lexicographic preference hypothesis. In the survey, respondents were asked to state the extent to which they saw rights as relevant to present and future generations of humans, marine animals, plants and ecosystems. These general attributions of rights were then probed further in the context of the marine park in question because a general discontent with trade-offs may disappear upon the specification of circumstances. Beyond this, respondents were asked to reflect upon the extent to which their refusal to trade was absolute by considering a potential conflict with their own standard of living. This allowed some refinement in the definition of various positions being adopted by the respondents and their stated acceptance of a position compatible with lexicographic preferences.

More specifically, respondents were initially asked to use the following categories in attributing or denying rights: an absolute right to be protected from harm applies to this case; a right applies that depends upon the circumstances and may, therefore, be withdrawn under certain conditions; or, no such rights to protection from harm applies to this case. The case where they had to decide which of these categories applied were: i) other humans now living; ii) future human generations; iii) marine animals; iv) marine plants; and, v) marine ecosystems. Respondents could answer that they just did not know, but only 0.2% in Jamaica and 2.1% in Curaçao found this necessary. Table 6.1 shows that almost all the sample are prepared to attribute rights to the first of these categories and that, for Curaçao, this declines moving from i) to v), while, for Jamaica, no decline occurs. More than just attributing rights, the respondents in the majority of cases are attributing an absolute right to protection from harm. Marine animals, plants and ecosystems are attributed these absolute rights by approximately 60% of the Curaçao sample and over 80% of the Jamaican sample.

People may fail to consider whether they are actually prepared to defend this position by making choices in their daily lives. Also, in over 60% of the cases, other people were listening while the interview was being conducted, which might stimulate a social norm. In order to address this issue, those who attributed a right to any of the five categories above were then asked a set of follow-up questions.

The follow-up questions were design to introduce the potential for needing to make trade-offs and to confront the respondent with a reasonably extreme case. The question was also made more specific and related to the marine park in question in order to give the rights-based position a context linked to the WTP questions. The respondents who had attributed any rights to one of the five categories were therefore initially asked whether, in the case of the relevant marine park, they believed the rights they had attributed meant a personal responsibility to prevent harm regardless of the cost. This is equivalent to reflecting that a duty for an individual would result from enforcing a right. The result was approximately 79% of the Jamaican and 68% of the Curaçao respondents answered affirmatively.

Next, respondents were channeled into two separate questions. Those affirming that they have a personal responsibility regardless of the cost were asked whether they would accept harm to the relevant island's marine life and habitat if trying to prevent it would threaten their current living standard. The other group of respondents, who had denied rights in this case, was also asked to reconsider

Table 6.1. Rights to protection from harm (% of total survey sample of 1,152 for Curaçao and 1,058 for Jamaica).

	Absolute right applies		*Right applies depending upon the circumstances*		*No right applies*		*Don't know*	
	Curaçao	Jamaica	Curaçao	Jamaica	Curaçao	Jamaica	Curaçao	Jamaica
Other humans now living	84	82	9	16	5	2	2	0
Future human generations	81	82	12	15	4	2	3	1
Marine animals	57	82	32	13	5	2	6	3
Marine plants	58	85	29	9	5	3	8	3
Marine ecosystems	60	84	25	10	4	3	11	3

given a more specific scenario. In their case, they were asked whether they would accept a personal duty to avoid harming the relevant island's marine life and habitat if their current standard of living would be unaffected. The outcome of these questions is to enable the sample to be split into four categories (in addition to those denying any rights to any of the five categories described earlier):

1. Those who attribute rights and accept a strong personal responsibility to protect marine life and habitats from harm even when their standard of living is threatened;
2. Those who attribute rights and accept a personal responsibility to protect marine life and habitats from harm only if their own current standard of living is unaffected;
3. Those who withdraw rights and any personal responsibility to avoid harm to marine life and habitats when the cost of doing so is in terms of their current standard of living; and,
4. Those who reject rights and any personal responsibility to protect marine life and habitats from harm regardless of whether their own current standard of living is unaffected.

The results for the two countries are shown for locals and tourists in Table 6.2. The two middle categories, 2 and 3 above, show a willingness to make trade-offs that is consistent with a modified lexicographic position (i.e., once a basic standard of living is obtained, a stronger ethical position for other species is adopted). A readiness to consider the trade-off circumstances and the subjectivity of the relevant standard of living means that individuals in these categories may be regarded as acting as utilitarians and weighing-up the trade-offs. The situation

Table 6.2. Personal responsibility to protect life and habitats in the marine park.

	No rights in this case	*No duty*	*Remove duty if cost high*	*Attribute duty if cost low*	*Strong duty*	*Total*
Curaçao						
Number of locals	2	91	262	120	173	648
Number of tourists	8	77	185	75	135	480
Total number	10	168	447	195	308	1128
Total (% of sample)	0.9	14.9	39.6	17.3	27.3	100[a]
Jamaica						
Number of locals	10	64	328	74	88	564
Number of tourists	0	46	342	34	70	492
Total number	10	110	670	108	158	1056
Total (% of sample)	0.9	10.4	63.3	10.2	14.9	100[a]

[a]Row may not add to 100% due to rounding errors.

for Jamaica shows a dramatic reduction in those attributing absolute or strong rights from 79% down to 14%. Similarly, although slightly less dramatic, for Curaçao the reduction is from 68% to 28%. Despite this large reduction, there is still a sizeable hardcore of individuals taking a position consistent with strong lexicographic preferences. This leaves the question open as to how these individuals expect to protect the rights they hold so strongly and how they would avoid having to make a trade-off decision, for example, where material goods are equated to the discharge of the moral duty being described. In order to try and address these issues, another set of follow-up questions was asked.

How to Protect Rights?

Those protesting in terms of a zero bid and a strong duty position are in favor of legal and educational approaches to increasing the quality of biodiversity in the marine parks. In Jamaica, 50% of these individuals opted for a purely legal approach, while in Curaçao, 53% wanted either a legal and/or an educational approach.

As mentioned earlier, both zero and positive bid strong duty holders are potentially signifying lexicographic preferences. The way in which this entire group, which is prepared to protect the marine environment at personal cost, believes the rights they have identified are to be protected is shown in Table 6.3. The biggest grouping of responses falls upon two methods for protecting the rights identified within the marine park. In Jamaica, 66.4% and, in Curaçao, 48.3% of respondents wanted rights to be protected by either a legal approach or education, or a combination of the two. Some of those holding a strong duty position felt the trust fund was also a good idea and would help in the protection of the rights they had attributed to the marine environment. Others gave responses combining more than one category. The miscellaneous category includes a variety of actions to be taken by various bodies or unspecified groups (e.g., NGO initiatives), unspecified schemes, and restriction of specific activities (e.g., harpooning, anchoring, creation of beaches, diving, allowing technology to prevent pollution, economic development).

The overall picture can be viewed as a proportion of these individuals externalising the cost to other parties or organizations. Alternatively, there may be a genuine failure to consider the cost of the proposed solution. The main category that avoids externalising the cost and maintains a position consistent with a strong lexicographic preference is that of the "lifestyle change". Education may also cover a range of activities that go beyond the

Table 6.3. How to protect a strong duty position (code method of protection: 1=legal enforcement, regulation and policing; 2=international community funded initiatives; 3=lifestyle and fundamental behavioral changes; 4=education, formal and informal (e.g., media); 5=user fees; 6=government responsibility and tax funded initiatives; 7=combined education and legal approach; 8=combined various approaches; 9=other miscellaneous approaches; 10=don't know).

	Method of protection by code total										
	1	2	3	4	5	6	7	8	9	10	Total
Curaçao											
Number of locals	51	2	12	30	17	14	8	12	8	19	173
Number of tourists	28	6	7	28	8	10	4	16	5	23	135
Total number	79	8	19	58	25	24	12	28	13	42	308
Total (% of sub-sample)	25.6	2.6	6.2	18.8	8.1	7.8	3.9	9.0	4.2	13.6	100[a]
Jamaica											
Number of locals	42	2	5	18	1	2	6	5	1	6	88
Number of tourists	20	1	5	15	1	4	4	2	10	8	70
Total number	62	3	10	33	2	6	10	7	11	14	158
Total (% of sub-sample)	39.2	1.9	6.3	20.9	1.3	3.8	6.3	4.4	7.0	8.9	100[a]

[a] Row may not add to 100% due to rounding errors.

classroom and remain consistent with the ethical position. However, given the limited extent of allowance for open-ended responses on the subject possible in the current survey, little more can be read into this.

The implication for stated WTP is that, in many cases, those holding a strong duty position are prepared to pay for a different institutional framework (e.g., a judicial approach) if required to do so. This, of course, creates a practical problem for a CVM survey that, as part of the design, selects one institutional approach to the problem at hand. In addition, there is the theoretical problem that, where respondents are prepared to pay for an institutional framework, this fails to be a reflection of the resource value, but is rather a contribution to a social construct. An extension to the current research would be to experiment with alternative institutions to see how WTP or WTA varies.

Internal Consistency of Responses

The characterisation of the change in biodiversity as an improvement also has implications for the trade-off. That is, the expectation of a lexicographic preference is that individuals will bid all their spare income in such a situation for even a small improvement. In fact, individuals may reject the institution that imposes such a condition upon them. This behavior has the advantage for the individual of avoiding acceptance of an institution, which may lead to a potential irreversibility. That is, if the improvement were reversed and the WTP bid had been made, the individual would now have no spare income to give a positive WTP and would then be classified as a zero bidder. The approach taken by Spash and Hanley (1995) was to identify zero bids for non-zero value reasons, identify protest bids and see how many of these were consistent with a lexicographic preference. The hypothesis was then that individuals protest against CVM and bid nothing rather than take part in a process which implicitly buys and sells improvements in what are seen as rights and duties. This approach is followed below and allows the results to be compared with the earlier work.

However, a qualification is necessary. We note that a positive bid by a believer in strong duties can still be consistent with a lexicographic preference. Such individuals are rejecting neo-classical choice theory but are acting in a way consistent with the expectations of mainstream economic theory by giving a WTP amount. If the less extreme modified lexicographic preference position is adopted, positive bids are expected to be the amount above a minimum standard of living. An additional complication is then that while the position seems more reasonable because it is less extreme, that lack of extremity means it is also difficult to identify. That is, positive bids may be given that reduce income to a subjective minimum living standard but this minimum is unknown. One way we try to address the positive bid issue is by using scaling and dummy variables in the bid curve analysis reported later.

First, consider the zero bids, which are taken as a rejection of a trade-off. The only data that is of interest with regard to the lexicographic position is taken to be that defined by the strong duty category. Note that this assumption may be questioned for a modified lexicographic model where a minimum living standard is defended first and, if threatened, takes priority. Positive and zero bids can split this category. The survey allowed for bids by both time and money as shown in Table 6.4. That is, the project gave the scope for including voluntary work to improve marine biodiversity and this was seen as an important alternative in a developing country context where many may be on a low wage or in a non-monetary economy. The impact of this approach is to reduce the zero bid category considered here beyond that of the monetarily defined. Remember, those who show a positive WTP in time and/or money may be indicating that they would be prepared to make a trade-off (indifference) or that they are giving up a substantive part of their current living standard (lexicographic). The zero bidders as a sub-group of strong duty holders are quite small in contrast to previous findings of 3.4% to 7.5%.

Next, the reasons for giving a zero bid are analyzed. These are divided into accepted economic reasons for a zero bid (i.e., income constraint or no value). The remaining reasons, shown in Table 6.5, are taken as indicating non-zero value. The outcome is to reduce the protest zeros, which are consistent with a strong lexicographic preference as defined by the strong duty, to 1.7% for Curaçao and 4.8% for Jamaica.

Bid Curve Analysis

Analysis of the determinants of WTP is particularly relevant to the purposes of the coral reef valuation project. The variables, which are hypothesised to determine variations in WTP, can be specified and studied via econometric analysis. In this section, bid curves are reported for the two case studies. The approach used in this section relies on a "tobit" analysis of the sample. Although many bid curve analyses rely on ordinary least squares (OLS) procedures, such techniques may be flawed when applied to data sets such as those generated by our surveys. The procedure is detailed in standard texts on limited dependent variables (e.g., Maddala 1983) and has been applied

Table 6.4. WTP of individuals holding a strong duty position.

	Zero bid	*Positive bid time*	*Positive bid money*	*Positive bid time and money*	*Total*
Curaçao					
Number of locals	38	19	82	34	173
Number of tourists	46	16	41	32	135
Total number	84	35	123	66	308
Total (% of sample)	7.5	3.1	10.9	5.9	27.3
Jamaica					
Number of locals	10	8	39	31	88
Number of tourists	26	7	29	8	70
Total number	36	15	68	39	158
Total (% of sample)	3.4	1.4	6.4	3.7	14.9

Table 6.5. Identifying reasons for non-zero bids by strong duty respondents.

Zero bidders by reason	*Curaçao*	*Jamaica*
Zero Economic Value Reason		
Low income or unemployed	20	13
Reef improvement unimportant	5	0
Non-resident	25	5
Total (% of sub-sample)	59	50
Non-Zero Value Reason		
Paying incorrect solution	6	1
Improvement will occur anyway	2	0
Mistrust marine park institution	3	2
Government is responsible	21	3
Could not place a money value	0	3
Other	2	6
Refused to answer or don't know	0	3
Total (% of sub-sample)	41	50
Total number	84	36

within the context of environmental economic household and individual choice decision models (e.g., Ruitenbeek 1996). A maximum likelihood estimation (MLE) procedure sets up a likelihood function and through iteration provides an efficient solution to the tobit specification. The procedures are analyzed based on the significance of individual explanatory variables (through t-statistics) and, when comparing models, through a likelihood ratio test based on a chi-square distribution. All tests of significance are reported at a 95% level of confidence.

WTP Determinants for Curaçao

A range of variables was available from the survey and those considered most important are shown in Table 6.6. A bid curve analysis, using a semi-log linear form, for Curaçao shows determinants of WTP as a set of standard socio-economic variables, knowledge and the position taken towards rights (i.e., a lexicographic type preference).[3] The socio-economic variables are gender, age and education. Income would be another standard variable expected to determine WTP, but is excluded here.

Table 6.6. Variable definitions and basic statistics for Curaçao.

Variable	*Mean*	*Min*	*Max*	*Valid number*	*Label*
TL	0.43	0	1	1152	Tourist (1) or local (0)
LANGDUTC	0.36	0	1	1145	Language Dutch
LANGENG	0.18	0	1	1145	Language English
LANGPAP	0.46	0	1	1145	Language Papiamentu
BENUM	1.41	0	5	1151	Number of benefit categories
VISITF	0.88	0	1	1152	Visit site in future
KNOWMBD	4.68	1	10	1152	Knowledge of marine biodiversity
PREFINFO	0.37	0	1	1152	Preference change and information effects
HARMMA	1.45	1	3	1078	Anti-rights to marine animals
HARMMP	1.43	1	3	1060	Anti-rights to marine plants
HARMME	1.38	1	3	1022	Anti-rights for marine ecosystems
RIGHTSEA	4.84	0	6	988	Marine animal/plant/ecosystem rights
NODUTY	0.16	0	1	1128	No rights/duty to marine environment
STRDUTY	0.27	0	1	1128	Strong duty
SEX	0.50	0	1	1152	Gender (male=0; female=1)
AGE	4.24	1	10	1151	Age by category (1=low; 10=high)
EDUC	2.86	1	5	1139	Level of educational attainment
INCOME	3.25	1	10	642	Level of gross income (coded)
WTPALL	49.16	0	2000	971	WTP (NAF)
LNWTP3	1.88	0	7.6	971	Natural log of (WTPALL+1)
PROBC	2.39	1	10	1149	Ease/difficulty with Section C of survey

This is because income is correlated with age and education and, therefore, little is added to the explanatory power of the equation if both sets of variables are included. In addition, the income variable only had 642 responses so that its inclusion would severely reduce the number of degrees of freedom in the estimation. Even the responses gained for income were suspected to be suffering from under-reporting, which is especially problematic when others are listening to the interview. The inclusion of a dummy variable for tourists versus locals was strongly insignificant, showing no difference. A set of dummies were also tried to test for the impact of language because the survey was translated into Dutch and Papiamentu, but these were also found to be strongly insignificant by the t-test. The final model results are shown in Table 6.7.[4]

The knowledge and use variables proved significant determinants of WTP. Knowledge of marine biodiversity (KNOWMBD) was derived from a survey question where individuals used a 10 point scale to signify their prior knowledge of the concept after having had a description. Greater knowledge increases WTP. This is also true for the use related variable, giving the number of benefits the individual derives from the marine park (BENUM; e.g., swimming, diving, site seeing, sunbathing).

A set of variables was also included to measure the ethical stance being taken by the respondent. First is the attitude of the individual towards rights. A seven point scale was developed from the questions of the survey covering the attribution of a right to be protected from harm to marine animals, plants and ecosystems (RIGHTSEA). The idea was to create a scale on the basis of the consistent attribution of rights. Respondents who answered "don't know" to any of the three groups were treated as missing data and so no position on the scale was given to these respondents. Those attributing absolute rights to all three aspects of the marine environment were ranked highest, and those denying rights in all three cases ranked lowest, with a graduating scale between these two extremes. As can be seen, rights for the marine environment are positively related to WTP, which means these individuals could be misconstrued as making an implicit trade-off of their rights position and this was implied earlier by the development of the "strong duty" category. Here, the data on personal duties is also incorporated in the equation.

Table 6.7. Preferred tobit model for Curaçao. The dependent variable is LNWTP3. Model has 463 limit observations (zero) and 508 non-limit observations. The predicted probability of y > limit given average x_i is 0.5868. The observed frequency of y > limit is 0.5232. At mean values of x_i, E(y)=1.5657.

Variable	*Normalised coefficient*	*Standard error*	*Asymptotic t-ratio*
SEX	-0.17322	0.073843	-2.3459
AGE	0.054646	0.018042	3.0288
EDUC	0.18416	0.039794	4.6278
KNOWMBD	0.051143	0.013414	3.8126
BENUM	0.18653	0.039808	4.6857
RIGHTSEA	0.15628	0.024749	6.3143
NODUTY	-0.31661	0.11346	-2.7904
STRDUTY	0.16615	0.080436	2.0656
PROBC	0.041131	0.019463	2.1133
PREFINFO	0.60101	0.074180	8.1020
CONSTANT	-2.0385	0.21111	-9.6561
LNWTP3	0.33092	0.011671	

The role of ethical positions is confirmed by the significance of the dummy variables on the personal duty to protect the life and habitats of the marine park. The dummy variables represent those respondents taking the strong duty perspective (STRDUTY) and those rejecting any duty (NODUTY). As can be seen, a strong personal duty, regardless of the cost, is positively correlated with WTP, while the rejection of this duty reduces WTP. This shows that WTP for biodiversity improvement is partially related to the ethical concern people show for marine animals, plants and ecosystems. Also, a variable on the difficulty found with these sets of survey questions was included in light of the results for Jamaica. This is also significant and positively correlated, which can be seen as supporting the no duty position in that these individuals care less about marine biodiversity and also find little problem in stating their lack of belief in rights. In contrast, those concerned about biodiversity improvement struggle with their precise ethical position and the extent to which duties are weak (tradable) or strong (lexical).

Thus, the overall results for Curaçao show a model of WTP being dependent upon standard socio-economic variables plus rights and duty-based variables. The RIGHTSEA variable is a recognition at an aggregate level of rights in the marine environment. The STRDUTY and NODUTY variables are specific to the marine park itself and the extent to which individuals are prepared to prevent harm at the risk of a loss in their own living standards.

In addition, a dummy variable called PREFINFO was included to account for whether individuals felt their preferences about marine biodiversity preservation had been changed by the survey. This variable was found to be highly significant and positive.

WTP Determinants for Jamaica

A similar semi-log linear form of model was developed for Jamaica with a set of socio-economic variables, knowledge and the position taken towards rights (i.e., a lexicographic type preference). The range of variables considered most important, along with some descriptive statistics, are shown in Table 6.8. The socio-economic variables, in this case, are gender and income. Income replaces the age and education variables of the Curaçao model. Income data for Jamaica was far more complete with 839 observations. This time, the inclusion of a dummy variable for tourists versus locals was strongly significant and negatively correlated with tourists. The final model results are shown in Table 6.9.

The knowledge and use variables again proved significant determinants of WTP. Knowledge of marine biodiversity (KNOWMBD) was found to be similar to that concerning reef degradation (KNOWCD) in terms of the equation and, in this case, the latter was used. This is derived from a survey question where individuals used a ten point scale to signify their prior knowledge of the causes of coral reef degradation after having had them

Table 6.8. Variable definitions and basic statistics for Jamaica.

Variable	*Mean*	*Min*	*Max*	*Valid number*	*Label*
TL	0.47	0	1	1058	Tourist (1) or local (0)
ENVIROAT	1.53	0	23	1058	Number of environmental concerns
VISITC	0.47	0	1	1058	Ever visited marine park
VISITF	0.88	0	7	1056	Visit site in future
KNOWCD	4.67	1	10	1058	Knowledge of coral degradation
KNOWMBD	3.29	1	10	1056	Knowledge of marine biodiversity
PREFINFO	0.19	0	1	1058	Preferences changed and informed
INFO	0.74	0	1	1058	Informed only
RIGHTSEA	5.51	0	6	1028	Marine animal/plant/ecosystem rights
NODUTY	0.11	0	1	1056	No duty to marine life/habitats
STRDUTY	0.15	0	1	1056	Strong duty marine life/habitats
SEX	0.56	0	1	1056	Gender (male=0; female=1)
AGE	3.63	1	10	1058	Age by category (1=low; 10=high)
EDUC	3.04	1	5	1058	Level of educational attainment
INCOME	3.47	1	10	839	Level of gross income (coded)
PROBC	1.83	1	10	1058	Difficulty with Section C of survey
WTPALLX	26.24	0	2866	833	WTP (US$)
LNWTP3	1.54	0	7.96	833	Natural log of WTPALLX

Table 6.9. Preferred tobit model for Jamaica. The dependent variable is LNWTP3. Model has 317 limit observations (zero) and 516 non-limit observations. The predicted probability of $y >$ limit given average x_i is 0.6544. The observed frequency of $y >$ limit is 0.6194. At mean values of x_i, $E(y)=1.4304$.

Variable	*Normalised coefficient*	*Standard error*	*Asymptotic t-ratio*
TL	-0.19667	0.083661	-2.3508
ENVIROAT	0.053173	0.024215	2.1959
INCOME	0.061696	0.015320	4.0273
NODUTY	-0.48570	0.13237	-3.6693
VISITC	-0.22942	0.076518	-2.9982
VISITF	0.47212	0.12543	3.7641
KNOWCD	0.038592	0.012067	3.1980
PREFINFO	0.36412	0.18868	1.9298
INFO	0.49011	0.17434	2.8112
PROBC	0.085788	0.028718	2.9872
CONSTANT	-0.81805	0.23137	-3.5356
LNWTP3	0.43953	0.014998	

described. As with KNOWMBD, greater knowledge increases WTP. This is also true for the positive likelihood of future use of the marine park (VISITF). Also, the relationship between WTP and having visited the park in the past is negative (VISITC). This result is not uncommon for such surveys in that it implies that, once an initial curiosity is satisfied, an individual's utility from subsequent visits will tend to drop off (this is consistent with decreasing marginal utility in individual preference functions).

In Jamaica, the set of variables on ethical stance were less relevant. However, some role for ethical positions is confirmed by the significance of the dummy variable rejecting any duty (NODUTY). This is also negatively correlated to WTP as was the case for Curaçao. The contrast with the results for Curaçao in terms of the role of ethical variables led to the inclusion of survey difficulty variables, and this showed a strong positive correlation with WTP. However, as this was then included in the Curaçao model and a similar result occurred, this alone seems unable to explain the difference in results.

Finally, PREFINFO is a dummy variable for whether individuals felt their preferences about marine biodiversity preservation had been changed by the survey. This was found to be highly significant and positive as in Curaçao. What was different here was the strong positive relationship of a second dummy representing the case of individuals whose preferences had remained unchanged but who felt they had been informed.

Thus, the overall results for Jamaica are in line with those for Curaçao, except in that the model lacks significant rights and strong duty variables.

Prediction of WTP

The expected WTP will depend on the location of the individual, their individual socio-economic characteristics, and their attitudes towards rights. Simulations using the preferred models were conducted to estimate WTP and the probability that they would return a non-zero bid. Results are shown in Table 6.10.

First, we note that at the sample means, WTP in Curaçao is about US$2.08, while in Jamaica it is US$3.24. This difference is readily explained through the differences in the mix of tourists and locals in the sample. Tourists generally had the same WTP in Curaçao and Jamaica—

Table 6.10. Predicted WTP for Curaçao and Jamaica as a function of individual characteristics. Local and tourist statistics taken at population means. For strong duty simulation (Curaçao): RIGHTSEA=6; NODUTY=0; STRDUTY=1. For no duty simulation (Curaçao): RIGHTSEA=0; NODUTY=1; STRDUTY=0. In Jamaica, the simulation turns on and off the NODUTY variable.

	Probability of non-zero bid (%)	*Expected WTP (US$)*
Curaçao		
Sample means—all	58.33	2.08
Sample means—typical local	56.18	1.85
Sample means—typical tourist	61.15	2.46
Locals with strong moral duties/rights	69.08	4.05
Locals with no moral duties/rights	17.82	0.19
Tourists with strong moral duties/rights	74.18	5.82
Tourists with no moral duties/rights	22.01	0.26
Jamaica		
Sample means—all	65.77	3.24
Sample means—typical local	68.49	3.75
Sample means—typical tourist	62.51	2.73
Locals with moral duties/rights	70.72	4.26
Locals with no moral duties/rights	52.37	1.66
Tourists with moral duties/rights	64.22	2.98
Tourists with no moral duties/rights	45.17	1.17

US$2.46 and US$2.73 respectively. Jamaicans, on the other hand, were willing to pay almost double their counterparts in Curaçao.

The importance of perceptions relating to rights and duties, however, is again seen in the WTP results. The tobit model simulations were conducted with the duty and right variables tuned to their highest and lowest possible combinations. The Curaçao set permitted a more extreme case because of the three variables, while the Jamaica is a "softer" comparison. The results show that people with some duty and rights perceptions are willing to pay approximately two to three times as much as those who have no such attachments; people with very strong perceptions will pay at least an order of magnitude more. Interestingly, in the Curaçao case, those with absolutely no moral attachment are expected to pay virtually nothing.

Conclusions

The goal of this study was to undertake a contingent valuation analysis of coral reef quality for amenity, biodiversity, and other values in Montego Bay, Jamaica, and reef areas along the south coast of Curaçao. Coral reef conservation benefits were to be valued in monetary terms with a view to identifying various economic and demographic characteristics of this valuation and its determinants (e.g., education, gender, and knowledge of biodiversity, local versus tourist). Although CVM is well developed and routinely used in assessing environmental benefits, two broad areas of innovation were part of the current study in the context of coral reefs. First, a rigorous developing country CVM analysis was undertaken of an environmental resource that had previously been neglected (i.e., coral reef quality); most developing country CVM studies having focused on other issues, such as water quality, or on specific urban locations. Second, and more significantly from a research perspective, the recent CVM literature had identified the existence of lexicographic preferences as one of a number of outstanding methodological questions associated with biodiversity valuation that required further analysis. The research addressed itself directly to this issue.

The lexicographic preference can be consistent with a positive or zero WTP. The expectation of protest responses associated with zero bids for reasons of non-zero value has been studied in a developed country context and has shown that around one fifth of respondents reject trade-offs when asked to pay to prevent environmental deterioration. A similar approach was adopted here in that the consistency of claiming a strong duty to protect the environment was contrasted with stated WTP in terms of a zero bid for reasons of non-zero value. In this case, WTP was for an environmental improvement.

Zero bid reasons were identified as those which are in accord with economic theory and those which are more problematic, representing a protest which cannot be taken as reflecting zero value. The combined result of all the reasons falling under the second category is to bias downward WTP because many of the respondents are concerned about biodiversity and place a positive value upon it. In the survey sample, this proved to be a substantial group with 32% and 27% of zero bids for Curaçao and Jamaica, respectively, reflecting non-zero values. This excludes those in the "other" and "refuse/unable to answer" categories who may also place a positive value on biodiversity improvement.

Those claiming a strong duty accounted for one third to one sixth of the sample, as shown in Table 6.11. When the data were analyzed for zero bids, in terms of time and money being given for reasons of non-zero value (which also excludes those unable to pay—the low income earners and the unemployed), the sub-sample falls to a few percent. There was no apparent difference between the tourist and local sub-samples as might be expected if the result was due to the developing country context. Another explanation may be that, because the study took the case of an environmental improvement, less controversy arose than if a WTP were asked for preventing an environmental deterioration (i.e., the low percentage of protests among zero bidders consistent with a strong duty). However, as Table 6.11 shows, the process adopted here for confirming respondents' adoption of a strong duty was also effective in reducing the proportion claiming absolute rights. Respondents claiming a strong duty to protect the environment were identified after probing questions confronted the respondent with a hypothetical trade-off in terms of their current living standard. The result contrasts with those attributing general but absolute rights to aspects of the marine environment, being two thirds or more of the sample.

While the finding of only a few percent of respondents in the protest-zero-lexicographic position does conflict with that of earlier studies, some caution should be taken in generalising the result. As mentioned, a positive bid for an environmental improvement can be consistent with a lexicographic position because any increase in the highly ranked good will increase welfare regardless of the loss of those goods ranked as inferior. A second improvement or a reversal of the improvement would both elicit a zero WTP because the individual has no income left (or no spare income under modified lexicographic

Table 6.11. Type and consistency of rights and duties for zero bidders.

	Curaçao		*Jamaica*		*Total*
	Locals	Tourists	Locals	Tourists	
Sample size	656	496	565	493	2210
Absolute marine rights (number)	322	251	385	441	1399
Absolute marine rights (% of sample)	58.9	56.9	71.8	89.6	63.3
Strong duty (number)	173	135	88	70	466
Strong duty (% of sample)	26.4	27.2	15.6	15.0	21.1
Strong duty and zero bid for reason of non-zero value (number)	20	14	6	12	52
Strong duty and zero bid for reason of non-zero value (% of sample)	3.0	2.8	1.0	2.4	2.4

preferences). This raises the interesting possibility that those refusing to bid more for the improvement of other reefs that were classified as showing part-whole bias (see Spash *et al.* 1998) may have lexicographic preferences. In addition, the rights-based position and implied duty does seem to influence bids as shown by the bid curve analysis. This result is very strong for Curaçao, but more limited for Jamaica. This Jamaican result led to consideration of the difficulty respondents may have had in answering the survey. In both countries, the levels of difficulty respondents were observed to have in answering the rights and duties section of the survey has a significant and positive influence on WTP. As this was an unexpected finding, explanations are purely speculative. However, one possibility is that people who dismiss rights and duties for the environment can answer quickly without problems and are also likely to give a low WTP bid. Those who are more concerned, with a higher WTP, struggle when confronted by the idea that they make trade-offs but, when pressed to do so, conform but still regard the language of rights as a more appropriate description of their actual position. Placing a set of right questions prior to the WTP question may, therefore, result in the respondents finding the bid section problematic rather than the ethics section.

In terms of the design of CVM, the study shows a methodology for classifying lexicographic type preferences. The second stage is then to develop checks for consistency in terms of WTP, and this was only partially achieved here because of the concentration on zero bidders and relative neglect of positive bidders in the analysis. However, the consistent results for the strong duty holders across the two countries shows they are in favor of alternative institutional approaches such as education, legal enforcement and, to a lesser extent, lifestyle changes. This poses a problem for CVM as currently practiced because it places the problem in a specific institutional setting when framing the WTP or WTA question and fails to allow for such alternatives.

Endnotes

1 Option value arises when there is uncertainty about the continued supply of a good or service and an individual is prepared to pay to keep a future option open for use of the good or service. Bequest value refers to the welfare from endowing future generations with goods and services. Existence value is more controversial and varies in definition in the literature, but essentially tries to capture the welfare related to knowing something exists; this welfare is independent of any use which might be made either directly or indirectly (i.e., by future generations).

2 A quota sample is conducted so as to take into account specified population characteristics such as the ratio of male to female respondents, age distribution, and income distribution.

3 Note in the table that to prevent estimation biases and provide a basis for conducting the tobit runs, the dependent variable is specified as LNWTP3, which is the natural logarithm of the WTP plus one. The addition of 1NAF introduces a bias of about +0.1% in the estimates but provides a truncation point on all of the relevant data (i.e., LNWTP=0 if and only if WTPALL=0).

4 Unlike OLS estimates, the estimators in this table cannot be used directly to derive a WTP through simple multiplication. Actual estimation of the WTP requires transformation of this function and application of density function for any given set of characteristics. This is most readily done in a simulation environment, dealt with later in this section.

Chapter 10

Development of the User Interface—Coral-Curaçao, Coral-Maldives, and COCOMO

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As described in previous chapters, the World Bank has been involved in several projects that aim to improve the protection and management of coral reef coastal systems. Results from each of the three case study sites (Montego Bay, Jamaica; Curaçao, the Netherlands Antilles; North and South Male, the Republic of the Maldives) has led to the development of a user-friendly computer-based application that incorporates a quantitative ecological economic model designed to assist in the formulation, evaluation and ranking of various cost-effective coastal zone management practises. The three integrated coastal zone management decision support models are:

- Coral-Curaçao, a decision support system for coral reef management in Curaçao;
- Coral-Maldives, a coral reef management model for the Republic of the Maldives; and,
- COCOMO, a model for management of COral reef COasts in MOntego Bay, Jamaica.

The models were developed with local input through workshops and meetings and have been tested in further workshops. They have been used successfully as training and education aids and it is hoped that they will be developed further so as to be used later as actual planning tools.

An accompanying CD-ROM contains the three decision support models that have been developed. The CD-ROM demonstrates decision support modeling for integrated coral reef management through realistic examples rather than abstract theory. The three decision support systems aim to create awareness for the integration of different coastal issues, as well as the formulation of integrated management plans. The CD-ROM can be used by stakeholders of the three study areas, as well as to illustrate application of the methodology to other coastal zones. The models are accessible for policy-makers and specialists from various disciplines, including those with minimal or no computer experience or scientific background, as well as a large percentage of the general public. The interface of the models is based primarily on graphic information to provide users with a quick overview with minimal use of text.

Framework for Analysis

Integrated coastal management is a complex issue crossing many disciplines and involving many stakeholders. There is often no clear-cut answer to the problems faced in managing such areas. Traditional sectoral approaches have failed to tackle the interrelated issues posed by user conflicts and interests within the coastal zone. This tends to be because problems are far from structured and objectives are unknown or unclear.

Solutions for such complicated problems can be found through a decision-making and management process that implies learning from other actors. Such an approach allows various stakeholders and decision-makers to explore and understand each other, the problem area and the different perspectives and interests that exist within it. Possible actions are found by learning and developing solutions, normally working in a cyclical, iterative way. When problem solving is approached as a learning process, the thinking processes need to be formally structured. The methodology is supplied by a framework and has been developed as a step-wise approach (Figure 10.1).

One of the components of a decision support system, which the models represent, is the user interface. The design of this will be instrumental in guiding the user through the decision. A step-wise approach is used, leading the user logically from problem definition to the evaluation of alternatives. This step-wise approach is based on a generic framework for analysis that has been developed over the last 10 to 15 years (Bower *et al.* 1994; Resource Analysis and Delft Hydraulics 1993; Rijsberman and Koudstaal 1989; Westmacott 1995). Practical applications of this approach to integrated coastal management issues are given by, for instance, Baarse and Rijsberman (1986, 1987) and Ridgley and Rijsberman (1992). Following this framework, the main steps in an integrated coastal management analysis within Coral-Curacao, Coral-Maldives and COCOMO are as follows:

- Problem identification;
- Definition of objectives and criteria as yardsticks to measure fulfillment of objectives;
- Definition of scenarios for uncertain, exogenous developments;
- Definition of management strategies in terms of their component measures;
- Analysis of the impacts of the strategies in terms of the criteria; and,
- Evaluation and selection of the most desirable strategy.

Modeling for Coral Reef Management

The cost-effectiveness methodology utilized in the modeling was initially developed for Montego Bay, Jamaica, and has been tested through two case studies: i) Curaçao, the Netherlands Antilles, where the methodology has been tested and validated in a relatively data-rich environment and a coral reef system with a high level of anthropogenic influence (Chapter 3); and ii) the Republic of the Maldives, where the coral reefs are in many areas still relatively undisturbed, but where development is rapidly changing these coral reef systems (Chapter 4).

In order to cope with the difficulties of assessing the benefits of improved coastal zone management, the modeling research presented on the CD-ROM has been limited to assessing the costs of coastal zone management, using a framework that focuses on four main steps: i) the specification of economic sector interventions; ii) the modeling of the changes of these interventions on production and consumption; iii) the quantification of the physical response of these in terms of the wastes and physical damage generated; and, iv) the modeling of the impact of the wastes and physical damage on reef health. The final cost of each of the interventions is then computed, taking into account potential negative costs (e.g., from production changes). This enables interventions to be formulated in such a way as to incur the minimum costs while retaining a certain quality of reef. Further research was carried out for the Jamaica and Curaçao case studies where the cost-effectiveness analysis was expanded into a full cost-benefit analysis with quantification of the value of benefits due to changes in reef health (see also Chapter 9).

Coral-Curaçao

Coral-Curaçao (see Chapter 3 and CD-ROM) is a computerized planning tool that is able to show the impacts of coastal developments and environmental protection measures on the economy, environmental and social situation in Curaçao. Development of the model started with a preliminary visit to Curaçao in April 1995 (Rijsberman *et al.* 1995a). A subsequent visit involved collection of data and information for the development of the model (Meesters 1995; Westmacott *et al.* 1995). The first version of the model was completed at the end of 1996 and is described in Chapter 3 (see also Rijsberman and Westmacott 1996).

The initial project aimed to develop a method to evaluate the cost-effectiveness of alternative coral reef management strategies. In order to achieve this, three sub-models were developed that linked together forming a single integrated model. The sub-models were an economic activity model, a water quality model and a reef health response model. As the models were developed, additional components were added to expand the focus to

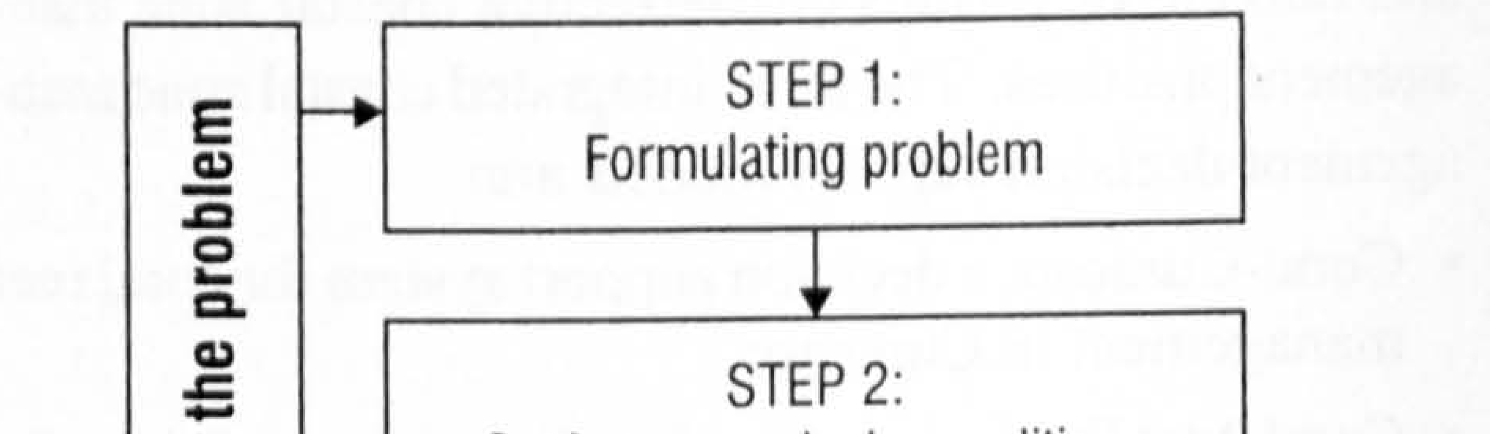

Figure 10.1. A step-wise framework describing a decision-making and coral reef management process.

cover a broad range of indicators, rather than simply cost-effectiveness. The aim was to achieve a user-friendly management model where users would input their ideas and plans for integrated coastal management for Curaçao and could analyze the impacts of the different plans in economic and environmental terms. Once developed, the Coral-Curaçao decision support model was presented to the different user groups in Curaçao, who were trained in its use.

Coral-Maldives

The Coral-Maldives decision support system (see Chapter 4 and CD-ROM) is structured in such a way that different users are able to explore a series of different coastal zone management options under varying assumptions for exogenous variables. The analysis allows the users to focus on the most cost-effective options for coral reef management and protection for the various economic development options. The impacts can be seen in terms of economic, social and environmental indicators that are selected at the outset of the analysis by the user. During the analysis, the user compares two situations: i) the reference situation; and, ii) changes in the reference situation as a result of the management options selected. In addition to the selected indicators, the user can explore more detailed information relating to the economy, reef health and coastal erosion. The final step of the analysis shows a score card of all the selected indicators. In addition, the user can use the cost-effectiveness analysis to rank the coastal zone management strategies.

The structure of the Coral-Maldives decision support system was developed and the data for the model collected during fieldwork in November 1995 (Westmacott 1996). The economic development and environmental protection options were also selected during this period through discussions with various government agencies involved in coastal zone management within the Maldives. The first version of the model was completed in 1997 and is described in Chapter 4 (see also Westmacott and Rijsberman 1997).

COCOMO

COCOMO (see CD-ROM) illustrates the relation between human activities and coastal problems in Montego Bay through a graphic user-friendly interface. It attempts to provide the information required to prioritize actions in order to preserve and improve the coastal environment. COCOMO is developed for policy-makers, specialists and anyone interested in coastal issues in Montego Bay. It provides information through maps, pictures, model calculations and texts. The model consists of three main parts:

- Background information on the objectives and coastal activities in Montego Bay;
- Information on the coral reef coast, including descriptions of the coral reefs and marine life, different coastal problems, and the values associated with the reefs; and,
- Calculation of the effects of different actions.

For a number of actions that will protect the reefs, the model estimates future coral reef health and the costs of the actions. The model also predicts the least expensive set of actions to realize a specified coral reef health and helps to evaluate the main causes of reef deterioration.

It is hoped that Coral-Curaçao, Coral-Maldives, and COCOMO will make significant contributions to the development of effective integrated coastal management programs and policies. The reader is encouraged to explore the use of these models through the CD-ROM included with this publication.

A Fuzzy Logic Model to Predict Coral Reef Development under Nutrient and Sediment Stress

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Abstract: *Coral reefs are highly complex systems characterized by mostly nonlinear relationships between biotic and abiotic components. Traditional models of reef dynamics often require unavailable data and precision, which limits their success and usefulness. We tested a new approach in coral reef modeling with fuzzy logic. Fuzzy logic has been applied successfully in modeling highly nonlinear systems in engineering, decision support systems, and ecology. As part of an integrated coastal zone management model, we constructed a coral reef model that predicts changes in coral cover and diversity under anthropogenic stress, namely nutrient enrichment and increased sedimentation. The model reflects our current knowledge of the fringing reefs of Curaçao, Netherlands Antilles. The seven input variables used were dissolved inorganic nitrogen and phosphate, suspended particulate matter, maximum colony size, substratum available for colonization, coral cover, and coral diversity. Each variable was divided into three triangular fuzzy sets reflecting low, medium, and high values. For each of the 2187 possible input combinations we estimated cover and diversity after 10 years. We consulted experts with a thorough knowledge of the local reef system and have automatically accounted for interactions between the variables described above. The model clearly shows how increases in nutrient and sediment inputs affect coral cover and diversity. Although the model can be refined continuously, it appears to reflect accurately the current knowledge of reef dynamics, making a beneficial contribution to education, management, and science.*

Modelo Lógico Indistinto para Predecir el Desarrollo de Arrecifes de Coral Bajo Estreees de Nutrientes y Sedimentos

Resumen: *Los arrecifes de coral son sistemas altamente complejos caracterizados por relaciones mayormente no lineales entre sus componentes bióticos y abióticos. Tradicionalmente los modelos de arrecifes de coral requieren de datos que no están a la mano, así como de precisión, limitando su éxito y su utilidad. Probamos una aproximación nueva en modelado de arrecifes conocida como modelo lógico indistinto* (fuzzy logic model)*. Este sistema ha sido aplicado satisfactoriamente en modelado de sistemas no lineales en ingeniería, en sistemas de soporte de decisiones y en ecología. Construimos un modelo de arrecife coralino como parte de un modelo de manejo integral de zonas costeras que predice cambios en la cobertura coralina y la diversidad bajo estrés antropogénico (enriquecimiento de nutrientes e incremento en sedimentación). El modelo refleja nuestro actual conocimiento de la franja de arrecifes de Curazao, Antillas de los Países Bajos. Las variables utilizadas fueron nitrógeno y fosfato inorgánico disuelto, partículas en suspensión, tamaño máximo de la colonia, disponibilidad de substrato para colonización, cobertura coralina y diversidad coralina. Cada variable fue dividida en tres juegos triagulares indistintos reflejando valores bajos, medios y altos. Estimamos la cobertura y diversidad después de 10 años para cada una de las 2187 combinaciones posi-*

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bles de datos. Las interacciones entre las variables descritas anteriormente fueron automáticamente tomadas en consideración utilizando expertos con un conocimiento meticuloso del sistema coralino local. El modelo muestra claramente como los incrementos en la entrada de nutrientes y sedimentos al sistema afectan la cobertura y diversidad coralina. Aunque el modelo puede ser refinado continuamente, aparentemente refleja con precisión el conocimiento actual de las dinámicas de arrecifes aportando una contribución benéfica para la educación, el manejo y la ciencia.

Introduction

Coral Reefs

Coral reefs are among the most diverse ecosystems on Earth. Relationships between the living and nonliving components are complex and often poorly understood. Coral colonies play a primary role in the construction and maintenance of reefs and provide support and shelter for the many other organisms that inhabit coral reefs. Because numerous reefs are experiencing unprecedented anthropogenic impacts including sedimentation (Bak 1978; Cortes & Risk 1985; Rogers 1990), eutrophication (Fishelson 1973; Tomascik & Sander 1985), and resource exploitation such as fishing (Munro 1983; McClanahan 1987; Hughes 1994), there exists an urgent need to understand the complex relationships between variables and processes that affect the long-term survival chances of coral reefs. Simulation of reef dynamics may provide a better understanding in the functioning of coral reefs.

Attempts to model the dynamic processes that take place on coral reefs have been conducted at various levels, ranging from modeling the effects on size distributions of single populations (Hughes 1984; Done 1987; Andres & Rodenhouse 1993) to modeling the productivity of whole reefs (Polovina 1984). According to systems theory, the precision with which a set of variables is measured decreases as the size of the system increases (Bosserman & Ragade 1982). Consequenctly, because coral reef ecosystems are large and complexly organized systems, many concepts and definitions are bound to be imprecise and exact data are often not available. Therefore the use of a modeling approach, such as fuzzy logic, that is by definition able to cope with this imprecision, seems attractive.

Using the case study of Curaçao fringing reefs, we constructed a model based on fuzzy logic which predicts reef development in response to anthropogenic perturbations.

Fuzzy Logic

In 1965 Lotfi A. Zadeh introduced fuzzy set theory, drawing on earlier work by Max Black and Jan Luckasiewicz (Zadeh 1965). Based on his experiences as an engineer and systems scientist, he concluded that traditional methods of systems analysis were unsuited to deal with systems in which relations between variables do not lend themselves to representation in terms of differential or difference equations or for which limitations of knowledge and/or data prevent precise definition of parameters. Such systems are the norm in biology, sociology, and economics.

Fuzziness, described by fuzzy mathematics or fuzzy logic, represents a type of deterministic uncertainty. Although it has some similarities to randomness, fuzziness is conceptually and theoretically distinct from randomness (Kosko 1990). Fuzziness results from the absence of precisely defined class membership and not from uncertainty concerning membership of an object in a set. A fuzzy set is a class with inexact boundaries. The transition from membership to nonmembership is gradual rather than abrupt. In this sense, the class of high mountains is a fuzzy set, as is the class of healthy reefs. The linguistic variable plays a key role in the application of fuzzy logic. Through its use the focus of attention is not on difference and differential equations but on fuzzy if-then rules in the following form: *if x is a then y is b*, where *x* and *y* are linguistic variables and *a* and *b* are their qualitative values (e.g., if pressure is high then volume is low). Such rules serve to characterize complex dependencies, enabling only imprecise descriptions, particularly abundant in biological systems.

The qualitative value of a linguistic variable is approximated by fuzzy sets. In a fuzzy set an exact value belongs by a certain degree to the given fuzzy set. This is measured by the membership function that maps exact values onto the interval [0,1] (Fig. 1). These membership functions have a predefined geometric shape. For example, the variable "coral cover" can be divided into three fuzzy triangular sets representing low, medium, and high cover (Fig. 1). Coral cover of 15% is a member of the fuzzy set medium (membership value 1). A value is often part of more than one set at a time; 7% cover is in both the fuzzy sets low and medium (membership values both 0.38).

Fuzzy rules are evaluated for their degree of truth; those that have some truth contribute to the final output state of the solution variable set (method of implica-

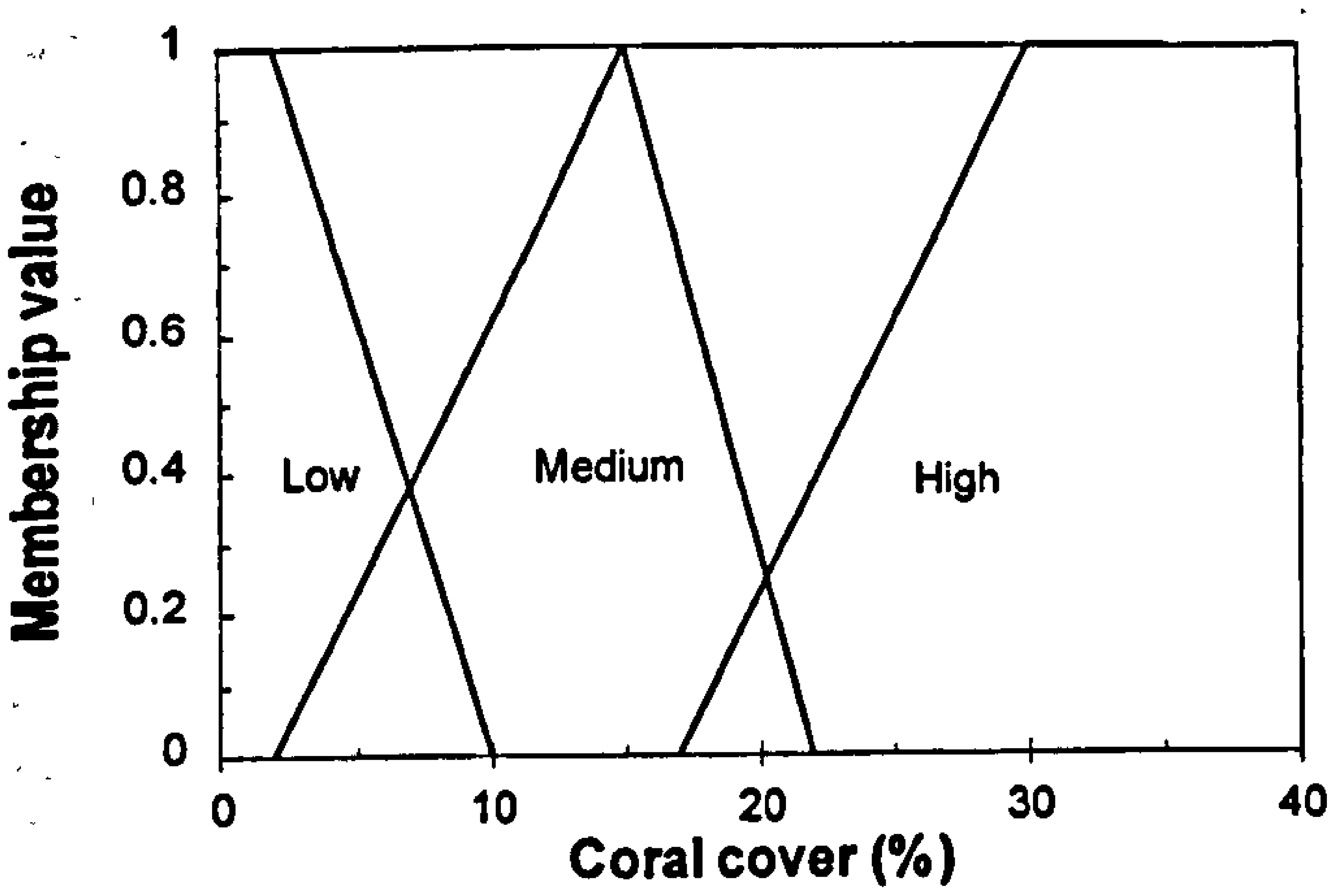

Figure 1. The variable coral cover divided into three overlapping fuzzy sets described as low, medium, and high and defined by the triangular membership function ranging from 0-1 as in Table 1.

tion). This set is then converted into an exact value. This is an important characteristic: the model uses fuzzy sets, but actual input and output values are exact. Methods of implication and "defuzzification" vary (for examples see Cox 1994).

An implicit assumption in fuzzy set theory is that the members of a fuzzy set are context dependent. For example, high nutrient concentrations for coral reefs are not equal to what specialists perceive as high concentrations in the North Sea. For practical reasons, most of the applications and successes of using fuzzy logic have been in the area of process and control engineering. Through fuzzy logic, manufacturers have reduced development time, modeled highly complex nonlinear systems, deployed advanced systems using control engineers rather than control scientists, and implemented controls using less expensive computer chips and sensors. But, fuzzy logic has also been introduced to environmental planning (Baas & Kwakernaak 1977; Yager 1977; Buckley 1985; Smith 1994) and the analysis of ecological data (Equihua 1990). We report the first results of an attempt to model reef dynamics through the use of fuzzy logic and fuzzy set theory. The study was undertaken in the framework of a larger project aimed at developing a methodology and model to carry out cost-effectiveness analyses for coral reef systems with case study sites in Jamaica (Montego Bay), the Netherlands Antilles (Curaçao), and the Republic of the Maldives.

Methods

Definition of Variables and Fuzzy Sets

Living cover of hard corals and species number were selected as the output variables because of their general ability to describe the condition of any particular reef as well as the availability of data. Increasing the number of variables increases at an exponential rate the number of rules to be defined. As a result, we restricted the number of input variables as much as possible while maintaining a reasonably accurate description of reef development over 10 years. This meant that other factors also of influence to the development of the reef (e.g., recruitment, fish stocks, grazing intensity) were not included in this version. It may become apparent through testing that these need to be included in more refined versions of the model. The final model structure was based on seven input and two output variables. The input variables can be separated into the impact variables of suspended particulate matter (SPM), dissolved inorganic nitrogen (DIN), and soluble reactive phosphorous (P) and the regulatory variables of diversity of hard corals (DIV), coral cover (COV), available substratum (SUBS), and maximum colony size (SIZE). For each output, we defined 2187 rules based on our knowledge of the fringing reefs of Curaçao, creating a fully saturated rule base. Through the definition of the rule base the interactions between the variables are implicitly taken into account. This means that the complex relationships between the variables do not have to be explicitly defined.

Although the model has been set up for the Curaçao application, the variables used are also applicable to other parts of the world. Consequently, the model may serve as a basis for describing other reefs as well.

Suspended Particulate Matter

Sedimentation is one of the most important factors threatening reefs globally (Ginsburg 1993). Traditionally, sediment traps have been used to quantify sedimentation, but high spatial and temporal variation of trap data (Pastorok & Bilyard 1985), as well as additional variation introduced through the use of different trap designs (Bloesch & Burns 1980), makes this variable unreliable. Trap height above the bottom is also critical because bottom sediment is resuspended in different concentrations to different heights at a fixed wave regime (Meesters 1995). This necessitated the use of a different variable to describe the sediment regime. Based on data from Curaçao (Meesters 1995) and Barbados (Tomascik & Sander 1985; Wittenberg & Hunte 1992), we decided to use suspended particulate matter (SPM). The SPM concentrations represent an instantaneous measure of the concentration of particles suspended in the water column, whereas sediment trap data measure the total downward flux of suspended particles. Because short-term increases, having a greater influence on trap data, are less deleterious to corals than chronic increases (Dodge & Vaisnys 1977; Bak 1978; Tomascik & Sander 1985), SPM is probably a better descriptor of long-term sediment effects on coral reefs.

Nitrogen and Phosphorus

In many coastal regions (e.g., parts of the North Sea, northern Adriatic Sea, Baltic Sea, Great Barrier Reef Lagoon, wider Caribbean, coastal areas of the U.S.) there is large-scale and in some cases chronic nutrient enrichment by nitrogen and phosphorus. In some regions the link between eutrophication and the destruction of an ecosystem is obvious, with excessive algae growth and water-column anoxia. In other cases, particularly in more fragile ecosystems, such as coral-reef and seagrass areas, the links are less obvious, yet the long-term effects of eutrophication in such regions can be devastating (Gabric & Bell 1993). The majority of the world's coral reefs thrive in relatively nutrient-poor waters, although corals in aquaria can survive under high nutrient concentrations (Atkinson et al. 1995). Many studies have demonstrated the detrimental effects of anthropogenic input of excess nutrients (Smith et al. 1981; Tomascik & Sander 1985; Cuet et al. 1988; Bell & Tomascik 1993), and alterations in reefs from coral dominance to algae dominance have been attributed to eutrophication (Littler & Littler 1984).

Maximum Colony Size and Available Substratum

Maximum colony size, measured as living surface area, is used here as an integrated measurement for disturbance intensity and frequency (Connell 1978; Done 1992). Small sizes reflect high-energy regimes in which colonies are frequently disturbed and do not attain large sizes (Done & Potts 1992). Large maximum sizes are interpreted as characteristic of more stable environments.

The amount of substratum available for settlement of coral larvae is defined as that part of the bottom not covered by sand, macro-algae, or dense stands of algae turfs. Space for recruitment and growth is generally limited in coral reef communities (Connell & Keough 1985). New settlement of recruits and growth of established colonies are necessary to offset natural losses in coral cover and diversity.

Coral Cover and Species Number

Coral cover is given as the percentage of the bottom covered by living scleractinian corals, including *Millepora* spp. because *Millepora* spp. constitute an important part of the reef fauna and contribute to reef formation through calcification. Boundary values of the fuzzy sets were set after we analyzed chain transect data collected for this purpose and compared it with published data (Tomascik & Sander 1987).

The number of species that will be encountered in line transects is an underestimate of total species richness. Species that are largely restricted to cryptic habitats and those characterized by small adult sizes will have less chance of detection. There are also large differences in coral diversity between Atlantic and Indo-pacific regions. For these reasons, we decided to use the variable species number (DIV) as a percentage of the maximum number that can be found in the geographical region under consideration (i.e., the maximum number at a number of pristine sites measured with the same technique).

Fuzzy Sets and Data Collection

Each variable was divided into three triangular fuzzy sets reflecting low, medium, and high values (Fig. 1). Boundaries for the fuzzy sets were determined by analyzing data collected specifically for this purpose and comparing it with data in the literature (Meesters 1995).

During a field survey of Curaçao reefs in August 1995 we sampled three control and two nutrient-enriched sites. The controls were situated in the area between Cornelis Bay and Lijhoek, the impact sites approximately at Hala Canoa and adjacent to the Avila Beach Hotel. At each site, 18 samples (chain transects) of the benthic community were recorded. A site consisted of a stretch of shore 150–200 m long. Perpendicular from the shore we laid out three long lines (50–70 m, depending on terrace width) at evenly spaced distances from 1 m depth to the drop-off. On each line, six perpendicular 10-m line transects were stretched out at randomly chosen points. Under each line transect a chain was rolled out; bottom characteristics and species under the chain were noted in terms of the number of links. From these we estimated species cover, number of species, available substratum, and maximum colony size.

Construction of the Rulebase

The rules that determine the behavior of the model are stored in a so-called rule base. With seven variables, each divided into three fuzzy sets, there are 2187 possible combinations for each output variable. Each combination forms, together with the expected output, one rule. We assessed every combination and estimated the development of the two output variables (coral cover and diversity) after 10 years. A period of 10 years was chosen as a compromise between the need for answers to pressing management problems and the normal time frame of coral reef processes, which can be substantially longer (Stoddart 1963; Pearson 1981; Rogers 1990). One such rule might be as follows: if SPM P, N, SIZE, SUBS, COV and DIV are low, then COV (in 10 years) will be low. We used the software program Fuzzy Systems Engineering (1994).

Table 1. The variables and boundary values of the membership function values of 1 and 0 used in the development of the fuzzy logic model of coral reef development in Curaçao.

	Low			*Medium*			*High*		
*Variable**	*1*	*1*	*0*	*0*	*1*	*0*	*0*	*1*	*1*
SPM (mg/L)	0	1.0	2.5	1.5	4.0	6.5	4.0	7.0	7.0
P (μmol/L)	0	0.04	0.07	0.05	0.09	0.12	0.09	0.15	0.20
DIN (μmol/L)	0	0.3	1.0	0.6	1.3	2.0	1.5	3.0	3.0
SIZE (m^2)	0	0.1	0.5	0.3	0.5	0.7	0.5	0.9	1.0
SUBS (%)	0	0	25	10	30	50	40	50	70
COV (%)	0	2	10	2	15	22	17	30	35
DIV (%)	0	25	50	25	50	75	50	75	100

**SPM, suspended particulate matter; P, soluble reactive phosphorous; DIN, dissolved inorganic nitrogen; SIZE, maximum colony size; SUBS, available substratum; COV, coral cover; DIV, diversity of hard corals.*

Results and Discussion

Fuzzy Set Boundaries and Rules

The boundary values of each fuzzy set (Table 1) were based on the collected data and literature. Variable ranges can easily be extended to incorporate the whole range found in the field, but this would greatly decrease the relative area in which most of the effects would be taking place. For example, nitrogen values above 3 μmol/L can be found in the field, but any concentration above this value is definitely high; in fuzzy terminology, the value would have the maximum membership value of 1 in the fuzzy set high. Consequently, the effects would not become stronger beyond 3 μmol/L, at least in the output of the model. The same reasoning applied to phosphorus and suspended particulate matter.

After surveying data of nutrient concentrations on the reefs (Gast et al. 1998) and in the literature (Tomascik & Sander 1985; Wittenberg & Hunte 1992), we set the boundaries of the fuzzy sets according to observed concentrations in the field. But the reported degrees of change in coral communities as a result of nutrient enrichment vary enormously, indicating that local community composition and abiotic factors are possibly of considerable influence. Also, data are lacking that would

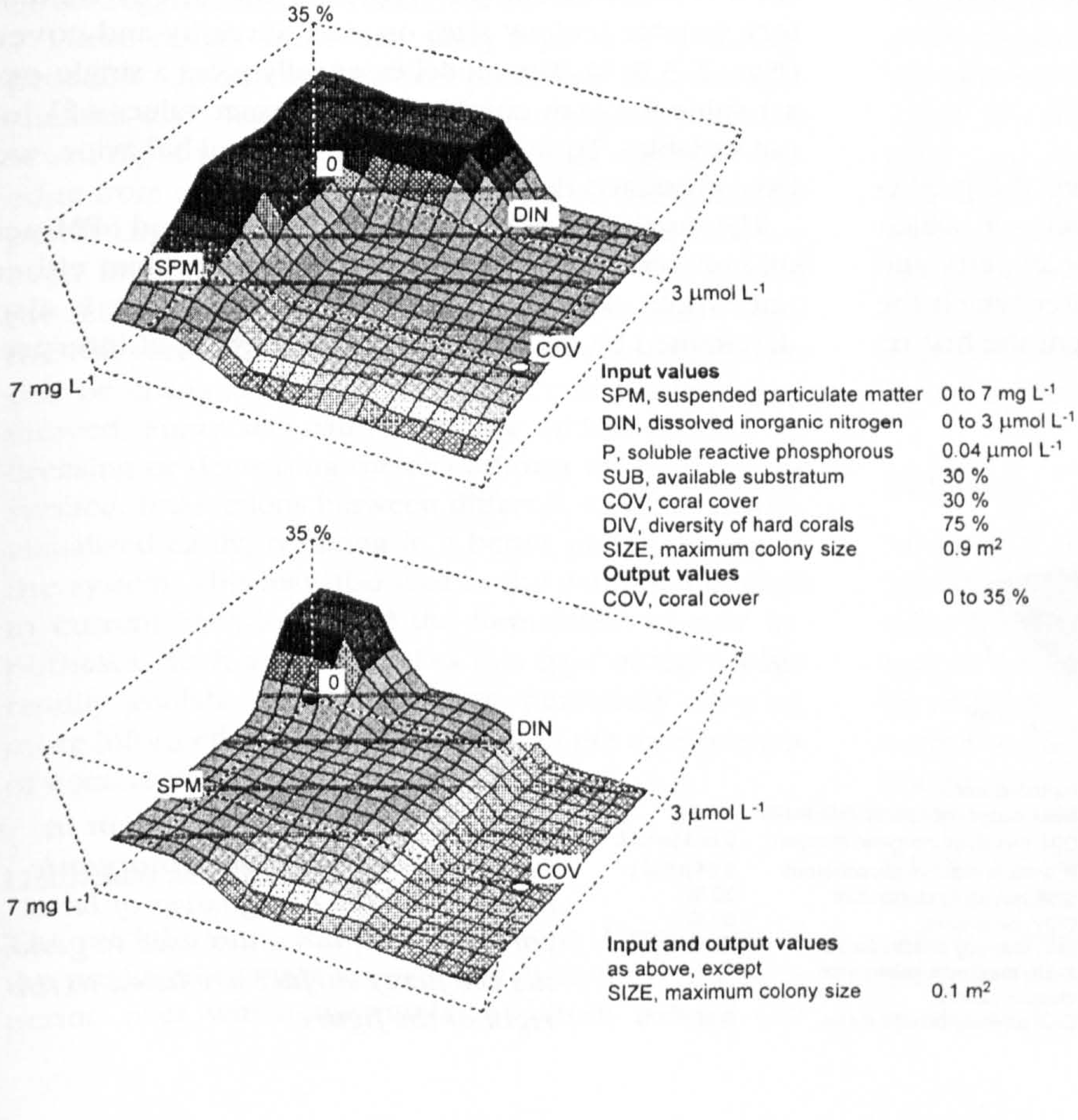

Figure 2. The effects of variations in suspended particulate matter (left axis) and dissolved inorganic nitrogen (right axis) on the living cover of hard corals (vertical axis) for two values of colony size. The input values used to generate the fuzzy surface are listed to the right of the figure.

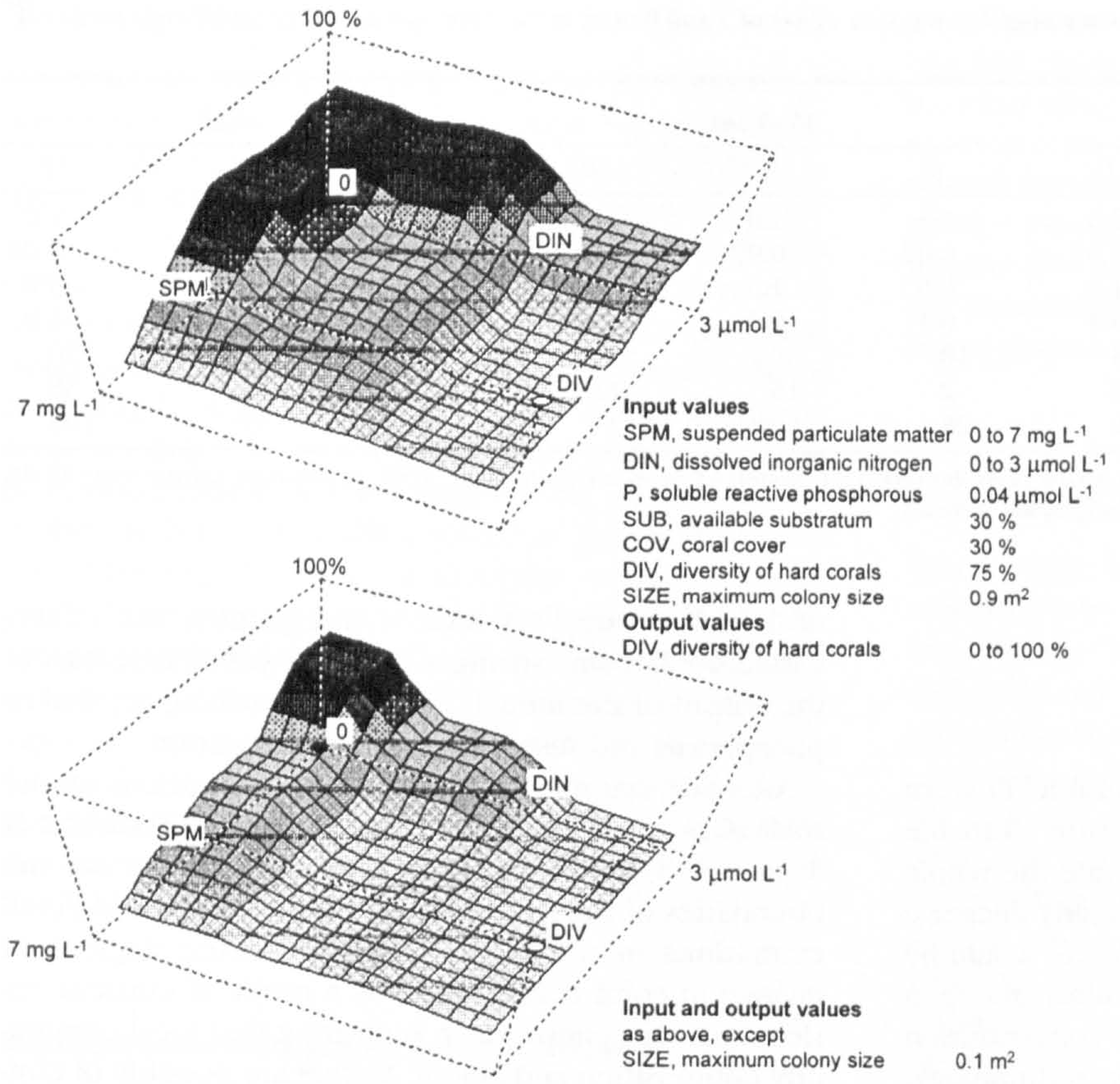

Figure 3. The effects of variations in suspended particulate matter (left axis) and dissolved inorganic nitrogen (right axis) on coral (vertical axis) for two values of colony size. The input values used to generate the fuzzy surface are listed to the right of the figure.

allow a clear differentiation of the effects of combined changes in nitrogen and phosphorus. Clearly, more research is necessary in this area.

Model Scenarios

After we defined the rules, we investigated the predictions of the model. This is an iterative process in which the model's predictions are evaluated by experts and compared with available case histories, after which the necessary adjustments are made. We present the first results, showing the combined effects of the impact variables (sedimentation and nutrients) and of one regulatory variable (colony size) on coral diversity and cover (Figs. 2, 3 & 4). The model essentially gives a single exact value for each combination of (exact values of) input variables. To show the model's general behavior, we have presented three-dimensional pictures.

The combined effects of increasing DIN and SPM act on coral cover at substantially lower levels than either one would alone (Fig. 2). The response surface is also determined by the other variables. For ease of interpre-

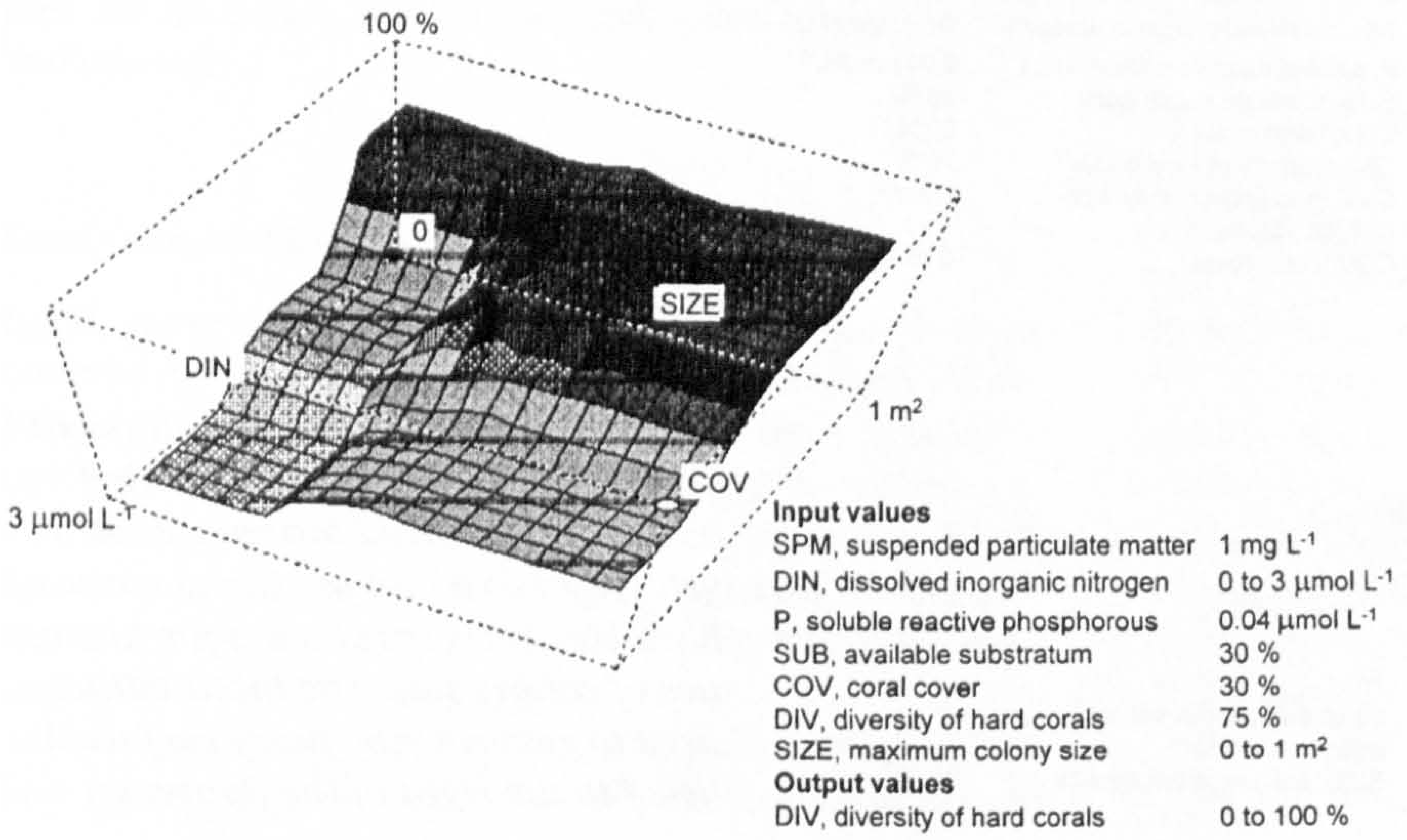

Figure 4. The effect of variation in colony size and dissolved inorganic nitrogen on the living cover of hard corals. The input values used to generate the fuzzy surface are listed to the right of the figure.

tation, values of the other input variables were chosen at their maximum membership value. In this case, phosphate concentration was set to the value with the maximum membership in the fuzzy set low (0.04 μM), substrate availability to medium (30%), and initial coral cover, diversity, and maximum colony size set to high (30%, 75%, and 0.9 m^2, respectively). The effect of increasing either SPM or DIN only becomes apparent when the impact level reaches one of the high fuzzy sets. After this threshold, coral cover starts to decrease to medium values. The combined effect of SPM and DIN occurs at lower impact levels, about half of the threshold level stated above.

If we decrease colony size from 0.9 m^2 to 0.1 m^2, leaving the other variables the same, coral cover is affected sooner (Fig. 2). This reflects the assumption that smaller colonies are more susceptible than larger colonies to overgrowth by algae and smothering by sediment.

Lower levels of SPM affect diversity sooner than the same levels of DIN (Fig. 3). As with cover, decreasing the maximum colony size to 0.1 m^2 (Fig. 3) shows the diversity to be more vulnerable to lower impact levels.

Next to the impacts of DIN and SPM, any other combination of variables can be chosen. The model was used to show the effects of DIN on coral cover for reefs with different maximum-size colonies (Fig. 4). Larger colonies will be less affected after 10 years than populations characterized by smaller colonies, except at very low concentrations of DIN, where there is no effect on coral cover regardless of the maximum colony size.

These results show that fuzzy logic is a useful approach to describing coral reef processes. The model visualizes and describes complex interactions between seven input variables and brings together expert knowledge from many sources. The accuracy of the model depends largely on the accuracy of the available data, but even in situations where data are scarce, this type of modeling could provide useful approximations. Once the rules are set, the boundaries of the various fuzzy sets can be changed and the performance of the model reviewed. Fuzzy sets can have more or less overlap, increasing or decreasing the smoothness of the response surface. Interactions between different variables can be visualized easily, resulting in a better understanding of the system. This may also lead to the definition of gaps in current knowledge and the formulation of new hypotheses. Such a model makes this type of knowledge readily available to nonbiologists, potentially allowing more informed decisions to be made in the management of coral reefs.

Limitations and Assumptions

The model has a number of limitations. Verification of the predicted changes in cover and diversity for the time period over which the model has been defined (10 years), as well as for any other time interval, is problematic because of a lack of data. Most studies are ad hoc, and information about the duration of increased nutrient or sediment values is almost always absent from reports on community change.

Information about interactions between variables is even less available. Available data strongly suggest that eutrophication has a negative effect on reefs, but in most cases reported, many confounding factors prevent identification of a clear cause-and-effect relationship. The effects of phosphorus and nitrogen, separately and combined, need to be studied in more detail with respect to their effects on whole reefs. Also, the effects on populations with different colony size-frequency distributions should be investigated.

Although the outcomes of the model are exact, the accuracy of these predictions need to be tested. The results of the model are, however, close enough to reality to indicate to managers and decision makers in what direction coral cover and diversity will change under certain development scenarios and, with a lesser degree of confidence, the size of this change. The model should find a place in coral reef management (after careful evaluation of local situations). Another important aspect is the educational value of the model. Processes can be visualized easily, variables changed, and their effects watched instantaneously.

The model was developed with the case study of Curaçao in mind. Curaçao reefs are under pressure from coastal development and overfishing, but, relative to other islands in the Caribbean such as Barbados (Tomascik 1991) and Jamaica (Hughes 1994; Andres & Witman 1995), the reefs are still in relatively good condition. Nutrient and sediment concentrations are not very high, and the island lies outside the hurricane belt. Also, overfishing of important grazers (Scaridae, Acanthuridae) is not yet a major problem, and the *Diadema antillarum* die-off (Lessios et al. 1983), which also decimated urchin populations in Curaçao (Bak et al. 1984), has not resulted in excessive coral death (Bak & Nieuwland 1995).

Refinement

The model can be improved on a number of points. More than three fuzzy sets can be used to define the variables. This would give more flexibility and detail in the output. Small changes in the input variables could then be addressed more precisely in the rules, the resulting output would be more accurate, and changes would occur gradually.

The amount of overlap between fuzzy sets can be increased. It depends on the underlying concept of the fuzzy set and the intrinsic degree of imprecision in the data associated with two neighboring states of the variable. More overlap in general results in smoother response surfaces. Fuzzy sets can also be represented by different shapes, such as a bell curve. This may give better results, especially because the object of the model is a living system, but in practice fuzzy models are not sensitive to these changes. Another possibility is the use of hedges. A hedge modifies the surface of a fuzzy set, causing a change in the membership function. A hedge thus transforms one fuzzy set into another. In linguistic terms, hedges are adverbs (with the fuzzy sets themselves being the adjectives) such as *very, extremely, about, near.*

More variables can be included, for example, time could also be a variable, as could grazing pressure or recruitment. A disadvantage is the exponential increase in the number of rules that need to be defined, but the model can be made "self-learning." Through the complementary use of neural network or cellular automata techniques, for example, it is sometimes possible to infer from empirical data rules not specified by the expert.

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Literature Cited

Andres, N. G., and N. L. Rodenhouse. 1993. Resilience of corals to hurricanes: a simulation model. Coral Reefs 12:167-175.

Andres, N., and J. Witman. 1995. Trends in community structure on a Jamaican reef. Marine Ecology Progress Series 118:305-310.

Atkinson, M. J., B. Carlson, and G. L. Crow. 1995. Coral growth in high-nutrient, low-pH seawater: a case study of corals cultured at the Waikiki Aquarium, Honolulu, Hawaii. Coral Reefs 14:215-223.

Baas, S., and H. Kwakernaak. 1977. Rating and ranking of multiple-aspect alternatives using fuzzy sets. Automatica 13:47-58.

Bak, R. P. M. 1978. Lethal and sublethal effects of dredging on reef corals. Marine Pollution Bulletin 9:14-16.

Bak, R. P. M., and G. Nieuwland. 1995. Long-term change in coral communities along depth gradients over leeward reefs in the Netherlands Antilles. Bulletin Marine Science 56:609-619.

Bak, R. P. M., M. J. E. Carpay, and E. D. De Ruyter van Steveninck. 1984. Densities of the sea urchin *Diadema antillarum* before and after mass mortalities on the Coral Reefs of Curaçao. Marine Ecology Progress Series 17:105-108.

Bell, P., and T. Tomascik. 1993. The demise of the fringing coral reefs of Barbados and of regions in the Great Barrier Reef (GBR) Lagoon: impacts of eutrophication. Pages 1-7 in R. N. Ginsburg, editor. Global aspects of coral reefs: health, hazards and history. Rosenstiel School of Marine and Atmospheric Science, Miami.

Bloesch, J., and N. M. Burns. 1980. A critical review of sedimentation trap technique. Schweizerische Zeitschrift für Hydrologie 42:15-55.

Bosserman, R. W., and R. K. Ragade. 1982. Ecosystems analysis using fuzzy set theory. Ecological Modeling 16:191-208.

Buckley, J. J. 1985. Ranking alternatives using fuzzy subsets. Fuzzy Sets and Systems 15:21-31.

Connell, J. H. 1978. Diversity in tropical rain forests and coral reefs. Science 199:1302-1310.

Connell, J. H., and M.J. Keough, 1985. Disturbance and patch dynamics of subtidal marine animals on hard substrata. Pages 125-151 in S. T. A. Pickett, and P. S. White, editors. The ecology of natural disturbance and patch dynamics. Academic Press, New York.

Cortes, N. J., and M. J. Risk. 1985. A reef under siltation stress, Cahuita, Costa Rica. Bulletin Marine Science 36:339-356.

Cox, E. 1994. The fuzzy systems handbook: a practitioner's guide to building, using, and maintaining fuzzy systems. Academic Press, London.

Cuet, P., O. Naim, G. Faure, and J. Y. Conan. 1988. Nutrient-rich groundwater impact on benthic communities of La Saline fringing reef (Reunion Island, Indian Ocean): preliminary results. Proceedings of the Sixth International Coral Reef Symposium 2:207-212.

Dodge, R. E., and J. R. Vaisnys. 1977. Coral populations and growth patterns: responses to sedimentation and turbidity associated with dredging. Journal of Marine Research 35:715-729.

Done, T. J. 1987. Simulation of the effects of *Acanthaster planci* on the population structure of massive corals in the genus *Porites*: evidence of population resilience? Coral Reefs 6:75-90.

Done, T. J. 1992. Phase shifts in coral reef communities and their ecological significance. Hydrobiologia 247:121-132.

Done, T. J., and D. C. Potts. 1992. Influences of habitat and natural disturbances on contributions of massive *Porites* corals to reef communities. Marine Biology 114:479-493.

Equihua, M. 1990. Fuzzy clustering of ecological data. Journal of Ecology 78:519-534.

Fishelson, L. 1973. Ecology of coral reefs in the Gulf of Aquaba (Red Sea) influenced by pollution. Oecologia 12:55-67.

Fuzzy Systems Engineering. 1994. Fuzzy knowledge builder. Fuzzy Systems Engineering, Poway, California.

Gabric, A. J., and P. R. F. Bell. 1993. Review of the effects of non-point nutrient loading on coastal ecosystems. Australian Journal Marine and Freshwater Research 44:261-283.

Gast, G. J., S. Wiegman, E. Wieringa, F. C. van Duyl, and R. P. M. Bak. 1998. Bacteria in coral reef water types: removal of cells, stimulation of growth and mineralization. Marine Ecology Progress Series 167:37-45.

Ginsburg, R. N., editor. 1993. Colloquium and forum on global aspects of coral reefs: case histories. Rosenstiel School of Marine and Atmospheric Science, Miami.

Hughes, T. P. 1984. Population dynamics based on individual size rather than age: a general model with a reef coral example. American Naturalist 123:778-795.

Hughes, T. P. 1994. Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. Science 265:1547-1551.

Kosko, B. 1990. Fuzziness vs. probability. International Journal of General Systems 17:211-240.

Lessios, H. A., P. W. Glynn, and D. R. Robertson. 1983. Mass mortalities of coral reef organisms. Science 222:715.

Littler, M. M., and D. S. Littler. 1984. Models of tropical reef biogenesis: the contribution of algae. Progress in Phycological Research 3: 323-364.

McClanahan, T. R. 1987. Overfishing and coral reef degradation: a preliminary report from East Africa. Conservation Biology 1:97-98.

Meesters, E. 1995. Cost-effectiveness analysis of coral reef management and protection: a case study of Curaçao. Report prepared for the Latin America and Caribbean Environment and Urban Development Division (LA3EU) of the World Bank. Resource Analysis, Delft, The Netherlands.

Munro, J. L., editor. 1983. Caribbean coral reef fishery resources. A second edition of "The biology, ecology, exploitation and management of Caribbean reef fishes: scientific report of the ODA/UWI Fisheries Ecology Research Project 1969-1973: University of the West Indies, Jamaica." Review 7. International Centre for Living Aquatic Resources Management (ICLARM) Studies, Manila, Philippines.

Pastorok, R. A., and G. R. Bilyard. 1985. Effects of sewage pollution on coral-reef communities. Marine Ecology Progress Series 21:175-189.

Pearson, R. G. 1981. Recovery and recolonization of coral reefs. Marine Ecology Progress Series 4:105-122.

Polovina, J. J. 1984. Model of a coral reef ecosystem. I. The ECOPATH model and its application to French Frigate Shoals. Coral Reefs **3**:1-11.

Rogers, C. S. 1990. Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series **62**:185-202.

Smith, P. N. 1994. Applications of fuzzy sets in the environmental evaluation of projects. Journal of Environmental Management **42**:365-388.

Smith, S. V., W. J. Kimmner, E. A. Laws, R. E. Brock, and T. W. Walsh. 1981. Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbation. Pacific Science **35**:279-395.

Stoddart, D. R. 1963. Effects of hurricane Hattie on the British Honduras reefs and cays, October 30-31, 1961. Atoll Research Bulletin **95**:1-142.

Tomascik, T., and F. Sander. 1985. Effects of eutrophication on reef-building corals. I. Growth rate of the reef-building coral *Montastrea annularis*. Marine Biology **87**:143-155.

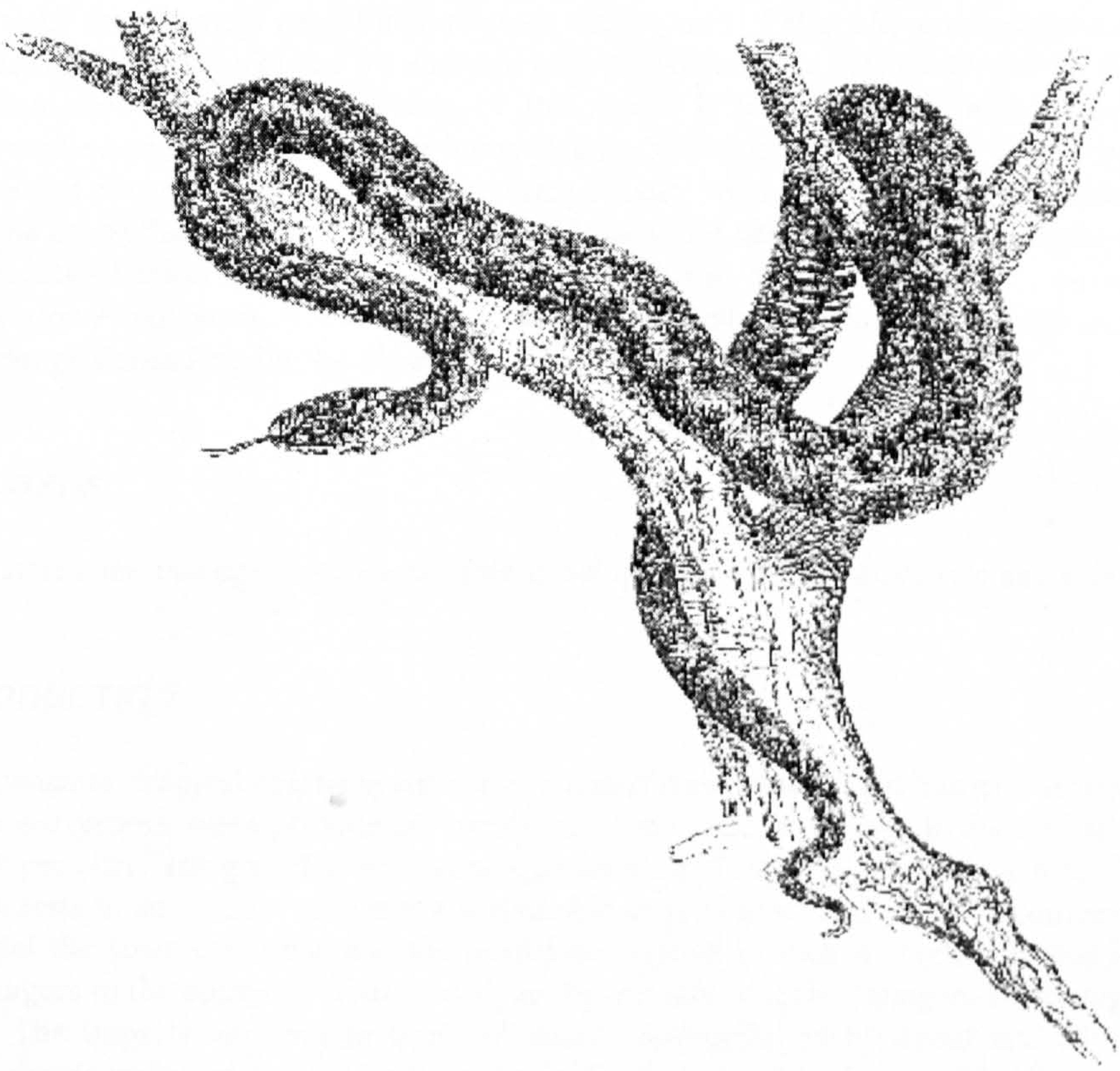
Tomascik, T., and F. Sander. 1987. Effects of eutrophication on reef-building corals. II. Structure of scleractinian coral communities on fringing reefs, Barbados, West Indies. Marine Biology **94**:53-75.

Tomascik, T. 1991. Settlement patterns of Caribbean scleractinian corals on artificial substrata along a eutrophication gradient, Barbados, West Indies. Marine Ecology Progress Series **77**:261-269.

Wittenberg, M., and W. Hunte. 1992. Effects of eutrophication and sedimentation on juvenile corals. Marine Biology **112**:131-138.

Yager, R. R. 1977. Multiple objective decision making using fuzzy sets. International Journal Man-Machine Studies **9**:375-382.

Zadeh, L. A. 1965. Fuzzy sets. Information and Control **8(3)**:338-353.



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CORAL,Coastal Management Model for the Sustainable Development of Coral Reef Areas

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ABSTRACT

CORAL is a coastal management model that assesses the impacts of alternative management strategies on the coastal zone. CORAL links socio-economic activities directly to reef health that is measured in terms of representative indicators. The core of the model is a cost-effectiveness analysis of the alternative interventions and combinations of interventions (strategies) with respect to reef health. This allows an assessment of the optimum strategy, in terms of cost, when considering sustainable coral reef management. The cost-effectiveness analysis is part of the wider coastal zone management model that assesses the impacts of these different management strategies in terms of economic, environmental, social and institutional indicators. These criteria can then be used in the selection of the most suitable management strategy depending on the objectives selected for analysis.

KEYWORDS

coral reefs, coastal zone management, sustainable development, cost effectiveness analysis

INTRODUCTION

Coral reefs are valuable, tropical coastal systems that support many natural and human functions. These functions of the ecosystems often provide the backbone of the local economy. Reefs around the world are under heavy pressure. Integrated coastal zone management (CZM) is one approach to balance the multitude of interests in an attempt to achieve sustainable development and use of resources. CORAL attempts to model the socio-economic and the ecological system in such a way as to enable decision makers and managers in the coastal system to analyze the impacts of their management strategies on the coastal system. The impacts are seen in terms of social, economic, institutional and environmental indicators. The development of the CORAL model is divided into four stages. The first stage is the problem identification and initial contacts, the second stage is the field work and data collection, the third stage is the model development and the final stage is the testing and calibrating phase. This paper is a progress report describing the model that is currently in the third stage of development.

The CORAL model presents a new and innovative approach to the modelling of reef management plans. Firstly, the CZM framework for analysis is combined in an interactive and graphic user-interface that structures and guides the user through the decision making process. Such an interface makes the model applicable for the decision making process. The second aspect is the modelling of the impacts that pollutant loadings have on reef health. This is done through the formulation of a model based on fuzzy logic. This type of modelling captures expert knowledge, modelling the impacts in a qualitative manner. Reef 'health' will be used as a proxy for coral ecosystem health, and will be expressed through several relatively simple indicators. Those selected are coral cover and diversity, measured in terms of number of species as a percentage of the potential number of species. The third aspect attempts to link the level of reef health directly to the activities occurring in the socio-economic system. Linking the economic and ecological sub-modules allows a cost-effectiveness analysis to be undertaken where the 'least-cost' interventions to maintain or restore a level of coral reef 'health' are able to be identified. This has been detailed in Huber et al. (1994). The desired level of reef health is defined by the user in a similar way to water quality standards. Set in a CZM framework it can also be analyzed as a trade off against other objectives.

For CORAL, the cost-effectiveness analysis will be the major component of the computational core. The structure of this cost-effectiveness analysis can be seen in figure 1.

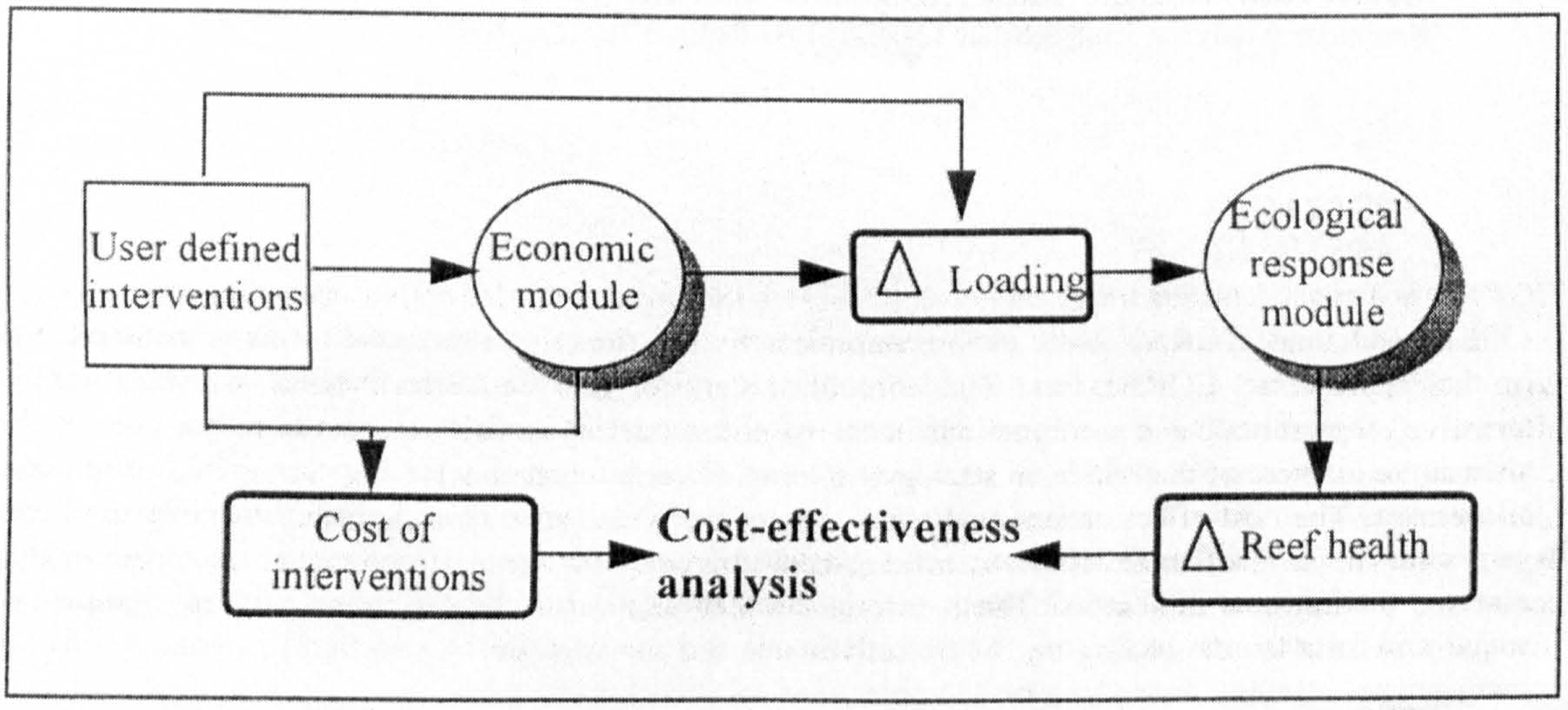

Figure 1 Cost-effectiveness modelling core

When examining the effects that these interventions have on a region, there are certain exogenous factors that should be accounted for. These are, for instance, demographic, economic and long term climatic changes. Often these factors are uncertain and therefore the analysis needs to be carried out for a range of scenarios. The objectives of the various stakeholders living and operating in the coastal zone can be represented in the analysis by proxies, or indicators. These indicators are, as far as possible, quantifiable and together allow an evaluation of a future state of the coastal system. Indicators should represent the interests of as many of the coastal zone stakeholders as possible.

APPLICATION OF CORAL IN CURAÇAO

The CZM framework used in the CORAL model as applied to Curaçao can be seen in figure 2, where the opening screen of the computer application is displayed.

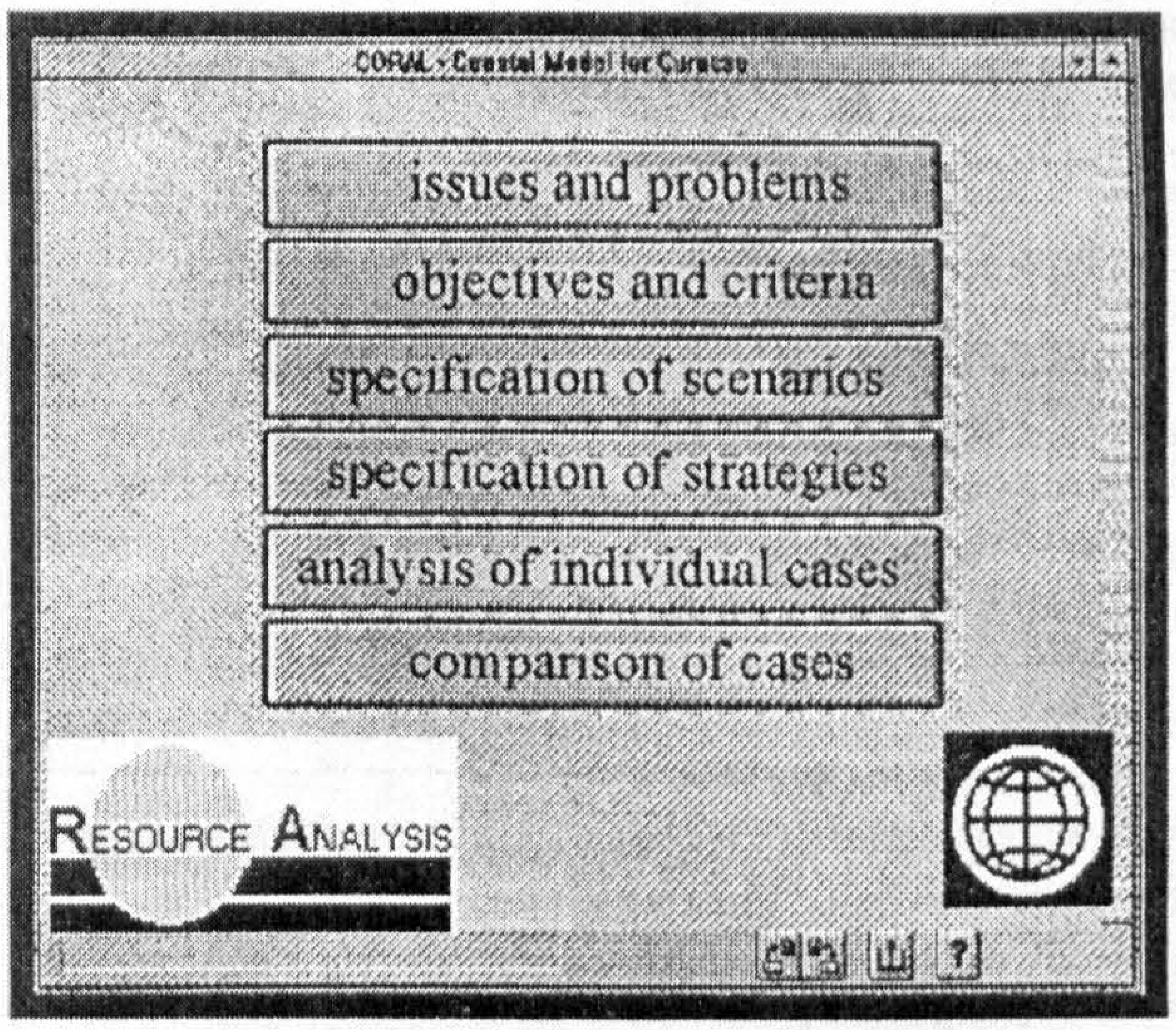

Figure 2 CZM framework used in CORAL

The selection of the issues to be included into the CORAL model for Curaçao involved cooperating closely with the local decision makers and experts in order to shape the final product into a tool that can be used for actual decision making in the region. During a first site visit, contacts were made and cooperation established with key local decision makers, scientists and stakeholders. These, and other organisations that were approached during stage two, had a crucial contribution in advising the project, participating in the fieldwork, and providing a perspective on CZM objectives, problems and relevant interventions. This type of involvement is instrumental in starting the process of education, participation, awareness building and cooperation with the local community.

During the field data collection interviews were held with 20 different governmental departments as well as non-governmental organisations. These interviews identified the major issues that such a model should include and identified the different objectives present in the coastal zone. Criteria measuring the achievement of these objectives were also identified along with possible management actions to achieve these objectives.

Coastal Zone of Curaçao

The major issues to be included in the model are those of water pollution through municipal and industrial waste water discharges, the rapid expansion of both tourism and residential areas along the shoreline, the construction of artificial beaches and the ability of the institutional structure to cope with the complexity of the issues. These issues lead to the degradation of the coastal ecosystems, in particular the coral reef, restrict the access to the coastline and create conflicts between the government and stakeholder groups (Westmacott et al., 1995).

Stakeholder Objectives and Indicators

Interviews held during the field work identified the different objectives of coastal zone management. An overall objective to improve the management of the coastal resources could be subdivided into economic, environmental, social and institutional objectives. Economic objectives aimed to produce a growth in the economy. Environmental objectives focused on improving the reef health, the water quality, reducing habitat loss and preventing the dumping of garbage on land and in the sea. Social objectives were based on the preservation of coastline access for beach recreation and fishing. Institutional objectives were to increase cooperation between stakeholders, political and financial feasibility of plans and public awareness towards the environment. In order to access the level of achievement of the objectives a series of criteria were identified. These are listed in box 1.

economic indicators	Contribution of coastal activities to GDP (Mln NAf) Contribution of coastal activities to employment (# jobs)
environmental indicators	Reef health index (diversity, coral cover) Water quality (# E. coli) Areas of mangroves (ha) Reduction of illegal dumping sites (%)
social indicators	Number of public beaches
institutional indicators	Level of co-operation & responsibility for government departments (+/-) Political feasibility (+/-) Cost of public investments (mln NAf)

Box 1. Indicators used in the CORAL model for Curaçao

Interventions

CORAL models both hard and soft interventions. The model allows the user to see the impact of setting taxes and imposing permits, e.g., for pollution, as well as hard engineering solutions such as the construction of treatment plants, outfall pipes and sediment traps. The interventions modelled in the CORAL model are related to the development of the economy as well as environmental preservation and institutional strengthening. Development of tourism and port facilities can be selected where planning restrictions can be made to maintain access to the coastline. Pollution reducing measures focus on industrial discharges and municipal discharges and will include permits and taxes as well as the construction of traditional treatment plants. Interventions relating to the marine park are also included where the level of monitoring and patrolling can be set as well as the length of coastline brought under legal jurisdiction of the park. Other interventions relating to awareness raising and participation will be included which, if omitted in the formulation of strategies, could lead to poor feasibility levels.

STRUCTURE OF THE MODEL

The coastal management model will cover the southern coastline of Curaçao where the reef health ranges from virtually pristine to heavily impacted. One major advantage of this site is that it has been intensively studied by researchers based at the ecological institute CARMABI for more than 20 years (eg., Bak & Nieuwland, 1993; van Duyl, 1985). The model is divided into three modules. These are the economic module, the ecological response module and the wider CZM framework.

The economic model

The economic model computes the impacts of the user defined interventions on the economy. The model enables the user to see the impact of soft interventions such as changes in input prices and taxes placed on inputs and outputs as well as the more usual hard engineering constructions. Changes in the economy produce different levels of activity within each sector thus producing changes in the pollutant loadings. Certain interventions focus only on reducing the pollutant loadings such as the construction of sewerage systems and waste water treatment plants. The changes in the loadings are then input into ecological sub module.

For each intervention a cost estimate is made in terms of initial investment costs and annual running costs. For the interventions that change the economic structure or behavioural patterns the cost is computed as the change in productivity. This may as likely be a positive as a negative cost.

Ecological response module

The ecological response model works through fuzzy logic to track the impact that changing pollutant loadings will have on the reef health. The pollutants modelled are nitrogen, suspended particulate matter and phosphate. These pollutants are widespread along the coastline and have been chosen as representative. Other pollutants such as oil and heavy metals also affect reef ecosystem although the impact is much less known and the effects are very localised. The indicators of reef health are diversity measured in number of species and coral cover as a percentage of total bottom area. These indicators are chosen due to their understandability to the non-biologist. They are also considered good indicators of reef condition.

The fuzzy model captures expert knowledge through a series of qualitative rules. The rules link different levels of loadings and a series of reef parameters to the outputs, diversity and coral cover. The levels are defined by fuzzy sets, which are ranges in the categories of high, medium and low. These categories and ranges are pre-defined in the model by the expert. The model computes the changes to the reef health after a period of 10 years.

The CZM framework

The CZM framework includes the modelling of criteria outside the two submodules described above. This allows a wider analysis to be carried out where the gains or losses in terms of costs and reef health can be seen against other CZM criteria. One aspect is the modelling of the institutional factors. These are modelled in qualitative terms where the user can define different levels of awareness building programmes and cooperation levels. This is then combined in a look up function that assesses feasibility on the grounds of these levels of awareness and cooperation interventions and the ability to implement the other measures selected. Other issues such as beach access are modeled through simple simulations where development interventions depending on the selected site and the set-back policies imposed will reduce the level of access to the shoreline.

THE COST-EFFECTIVENESS ANALYSIS

This allows the costs of the different interventions to be compared to the gains or losses in reef health. As one of the results a cost-effectiveness curve can be constructed that shows the gain of reef health versus the cost for each intervention or combinations of interventions. The user can define an acceptable level of reef health which must be achieved through the application of different interventions. Where the reef health falls below this level, the interventions are not acceptable. In this case new combinations must be defined. The model allows the user to compare the costs of each intervention or combinations of interventions against the gains in reef health. This eventually will allow the users to assess the cost effectiveness of each intervention/ set of interventions in relations to reef health.

The usefulness of such an approach to assessing the effectiveness of management strategies is formulated in the framework of coastal zone management where additional criteria are used to illustrate the impacts of the strategies on the coastal zone and the achievement of the objectives seen and identified as important by the various stakeholders.

Testing and calibrating will be done by means of workshops in Curaçao.

ASSESSMENT AND CONCLUSIONS

CORAL will provide a tested and validated model able to identify the least-cost interventions to maintain or restore coral reef health that can be used, or adapted, for coral reef systems in Curaçao and elsewhere. The cost-effectiveness analysis provides the decision maker with an additional tool that allows a direct ranking or comparison to be made with cost of the strategy and reef health. Setting this type of analysis in a CZM framework allows the user the invaluable opportunity to see the other tradeoffs necessary for the sustainable management of coral reef areas. The model is flexible enough to include the objectives of all the stakeholder interests and allow the different users to see the impact of their chosen management strategy.

Involving the local community directly in the formulation stage of the model and the evaluation stage has provided and will provide a valuable contribution towards increased awareness and participation among stakeholders concerning coastal issues in Curaçao.

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REFERENCES

Bak, R. P. M. and G. Nieuwland. 1993. Twenty years of change in coral communities over deep reef slopes along leeward coasts in the Netherlands Antilles. *Proceedings of the Colloquium on Global Aspects of Coral Reefs, Health Hazards and History, University of Miami.* pp. 154-159.

Duyl, F.L. 1985. Atlas of the living reefs of Curaçao and Bonaire, Netherlands Antilles. Publ. *Foundation Scientific Research Caribbean Region.* 117:1-13

Huber, R.M., S. Dollar, S.C. Mathur, H.J. Ruitenbeek. 1994. *Cost effectiveness analysis in integrated coastal zone management: A least cost model for coral reef environments in the developing tropics.* Research proposal to the World Bank/IFC/M.I.G.A.

Westmacott, Susie; Pavel Klinckhamers, Leanne Fernandes & Frank Rijsberman. 1995. *Cost-effectiveness Analysis of Coral Reef Management and Protection. A Case Study of Curaçao. Phase 2 Field visit project report.*