SMR rapport

Integrated Coastal Zone Management in Central America

Applications to the tropical coastal systems of Golfo Dulce, Costa Rica

SMR-report 19/95

UNIVERSITETET I BERGEN
SENTER FOR MILJØ- OG RESSURSSTUDIER

ISSN 0803-7132

Report from an international workshop,
November 1993 and follow-up meetings in 1994,
San José, Costa Rica

Integrated Coastal Zone Management in Central America

Applications to the tropical coastal systems of Golfo Dulce, Costa Rica

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ISSN 0803-7132

Centre for studies ent and resources

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Rapport no.
SMR 19/95

Distribution:
OPEN

Report title	Date
Integrated Coastal Zone Management in Central America. Applications to the tropical coastal systems of Golfo Dulce, Costa Rica	24.5.1995
	No pages 119
Author	**Project leader:**
David N. Barton and José Antonio Vargas	Ulf Lie

Contractors

University of Bergen, Norway. CIMAR, Universidad de Costa Rica, Intergovernmental Oceanographic Commission (IOC). Center for Tropical Marine Ecology (ZMT). Swedish Agency for Research Cooperation with Developing Countries (SAREC)

Abstract

The report is a summary of keynote speeches, discussions and conclusions from an international workshop and follow-up meetings in 1993 and 1994 in Costa Rica. The report and the contributions by experts in their respective fields consider different ecological and economic approaches to integrated coastal zone management (ICZM) of tropical coastal systems. The aim of the first workshop was to select a Costa Rican study site and define an agenda for an inter-disciplinary and international research programme in ICZM that would serve as an example for other initiatives in Central America.

The Golfo Dulce and its catchment basin on the south Pacific coast of Costa Rica were selected based on the potential threats to its unique pristine condition, and the feasibility of implementing a coastal area management plan. The report also gives examples of work currently in progress in defining practical ecological management indicators for the Golfo Dulce systems that are relevant to economic uses and can be locally monitored.

Keywords
coastal zone, management, tropical, ecology, economics, Costa Rica

Project leader

Administration

Acknowledgement of sponsors

The international workshop of 22-28 November 1993 and the follow-up meetings in 1994 were organised by the Centre for Studies of Environment and Resources (SMR), University of Bergen and the Center for Marine Research and Limnology (CIMAR), University of Costa Rica. We are grateful to the Norwegian Research Council (NFR) for providing basic funding for the workshop.

In addition to the organisers, the initial workshop was co-sponsored by the Intergovernmental Oceanographic Commission (IOC), the Center for Tropical Marine Ecology (ZMT) of Bremen, and the Swedish Agency for Research Cooperation with Developing Countries (SAREC). Without their support the workshop would not have provided the basis for the successful development of the international research programme now taking place between the associate universities.

Table of Contents

I. Keynote addresses (cont.)

Dixon, J.A., "Economic Analysis of Coastal Zone Development Options: Linking Economic and Ecological Models", Environment Department, World Bank

Costanza, R., "Integrated Ecological Economic Modeling of Coastal Systems", Maryland International Institute for Ecological Economics, Center for Environmental and Estuarine Studies, University of Maryland

Vargas J.A. and R. Soto, "Coastal Systems Management Problems and Research in Golfo Dulce, Costa Rica - A Summary of Present Knowledge", CIMAR, University of Costa Rica

Cortés, J., "Research on Coral Reefs of Costa Rica", CIMAR, University of Costa Rica

Hviding, E., "Isomorphism or disparity? On "Scientific" and "Folk" Models of Coastal Resources and their Managment", Department of Social Anthropology

II. Other written contributions and presentations

Huber, R., "Economic Analysis of Coastal Zone Management Planning in the Caribbean", Latin America and the Caribbean Environment Division, World Bank

Kjerfve, B., "Flushing Half-Life of a Hypersaline Coastal Lagoon", Belle W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina

Padilla J. , "Towards the bioeconomic analysis of tropical fisheries: summary of a conceptual paper", International Center for Living Aquatic Resources Management (ICLARM)

Malcolm O. Hendry, Marine Resources and Environmental Management Program (MAREMA) , University of the West Indies, Barbados

Ron Johnstone, Swedish Agency for Research Cooperation with Developing Countries (SAREC)

III. Working group reports

IV. Programme of the workshop

V. List of participants

Acronyms

ACOSA - Osa Conservation Area (MIRENEM)
CAM - coastal area management
CBA - cost-benefit analysis
CELLS - coastal ecological landscape spatial simulation model
CMT - coastal marine tenure
CRM - coastal resources management
EIA - environmental impact assessment
ICZM - integrated coastal zone management
ICM - integrated coastal management
MCA - multi-criteria analysis
MEY - maximum economic yield
MIRENEM - Ministry for natural resources, energy and mines (Costa Rica)
MSY - maximum sustainable yield
OSY - optimum sustainable yield
REA - rapid ecological assessment

I. Integrated Quantitative Analysis and Tropical Coastal Zone Management.

Report from the international workshop, 22-28 November 1993, San Jose, Costa Rica.

1. Introduction

The initiative for the workshop was taken by the co-organisers, the University of Bergen (UoB) and the University of Costa Rica (UCR) as a first step in developing an inter-disciplinary and international research programme in Marine and Coastal Sciences in Central America.

The inter-disciplinary workshop and research programme were justified for several reasons. Little information is available on coastal marine systems in Central America and few, if any, scientifically guided management plans are actually in operation in the region. A focus on tropical coastal ecosystems was chosen for its relevance to coastal zone management in developing countries in general. Finally, the focus on integrating ecological and economic quantitative analyses examined ways in which natural and social sciences could cooperate in providing coherent information relevant to addressing coastal management problems.

The concrete aim of workshop was to define a specific site for a research programme in Costa Rica where experience from integrating ecological and economic analyses would have general applicability to the coastal management problems of the Central American region. Based on the site proposal, the workshop then outlined a research programme framework that is now being developed by the associates to the programme.

The site recommended by the participants of the workshop was the Golfo Dulce, enclosed by the Osa Peninsula on the southern Pacific coast of Costa Rica. The site was amongst others chosen because of the potential resource conflicts arising due to current rapid development along the gulf coast, the high biodiversity in the tropical forest watershed, as well as for its unique oceanographic characteristics resembling a temperate fjord, one of only three such sites in the tropical world.

The research programme entitled - "*Integrated research for the sustainable development and environmental management of the coastal systems of Golfo Dulce, Costa Rica*" - aims at understanding and modeling the interaction between the coastal systems of the Golfo Dulce and its watershed and their individual ecological components. In addition, understanding the socio-economic forces that drive long-term change of these systems will serve as a basis for proposing strategies for coastal management of the area.

Since the workshop a number of other joint activities have been undertaken by the universities associated to the research programme. In 1993-1994 a marine research expedition was conducted to the Golfo Dulce and Osa Peninsula by the scientific ship RV Victor Hensen, organised by the University of Bremen and the University of Costa Rica. Amongst others, the expedition gained valuable baseline information on the processes that link mangrove forests with tidal flats and subtidal nearshore basins (ZMT 1994)[1].

Following the initial workshop subsequent meetings were also organised between the University of Bergen and the University of Costa Rica during 1994 on the topic of, "*Ecological and economic indicators for the integrated coastal management of the Golfo Dulce and adjoining areas* ". In this follow-up, Costa Rican natural and social scientists, and local resource managers from the Osa Conservation Area of the Ministry of the Environment (ACOSA-MIRENEM) identified ecological indicators that could be used to monitor coastal zone development in the area.

2. Summary of keynote addresses and discussions

The following summaries include principle points from the keynote speeches and ensuing discussions, followed by the written keynote contributions. In addition, participating scientists made shorter presentations and written contributions of ongoing work in the field of coastal marine science and mangement that may be found in the annex.

The workshop was organised around the idea that coastal marine research in developing countries should be defined by the resource management problems that arise with the human use of coastal marine systems. The focus on management´s needs for different kinds of scientific information is hopefully reflected in the following presentations in this report.

[1]RV Victor Hensen Costa Rica Expedition 1993/1994 Cruise Report, eds.M.Wolff (ZMT) and J. Vargas (CIMAR, Costa Rica), ZMT Contribution 2 - Center for Tropical Marine Ecology (ZMT) 1994.

2.1 Integrated coastal zone management in the tropics - interdisciplinary challenges and management needs

Keynote address: "Interdisciplinary Challenges and Management Needs for Qualitative Analysis" by **Dr. James E. Maragos**, Programme on Environment, East-West Center.

For largely unexplored coastal zones or island areas, qualitative surveys are needed first to define the status, distribution, and needs of resources in the coastal zone. Then these qualitative surveys can point out specific issues and problems that may be better addressed using more quantitative procedures and analysis. Given the limited budgets that normally are available for coastal management, and the limited availability of experienced coastal scientists, it is usually impossible to conduct quantitative scientific surveys and analysis that cover broad coastal regions, such as those which surround islands and fringe other countries [..] The trade-off between qualitative and quantitative analysis is not difficult if one perceives both as necessary and as part of a phased scientific research programme.

Dr. Maragos discussed some of the procedures and products related to using largely qualitative ecological surveys such as "rapid ecological assessment" (REA) to aid in the design and implementation of coastal planning and management programmes in the tropics. The presentation was based on experiences from in the insular tropical Pacific, with the Palau Islands as a case in point.

A short history of the development of **coastal zone management approaches** revealed three key acronyms and concepts ; coastal resource management (CRM), coastal area management (CAM) and integrated coastal management (ICM). In the CRM concept the focus is on the resources found within a country's whole coastal zone. For scarce financial means to be directed to managing the allocation of these resources, a definition and delimitation of the coastal zone is necessary. For small island states the whole land area is essentially a coastal zone. As a newer concept, the essence of CAM is to choose a pilot area of the coast for which a large scale management plan can be developed. Research resources are initially concentrated in the pilot area, and successful management techniques used as templates for other areas of the country at a later stage. Integrated coastal management (ICM) can be applied in both cases and essentially refers to an interdisciplinary approach being followed to support management. ICM is a process that presents particular challenges for researchers involved. As an example, conclusions from political analyses may run counter to those of all other disciplines involved in elaborating the management plan.

The **phasing of qualitative and quantitative analyses** is due to lack of baseline data. In addition, limited scientific resources justify an extensive rather than intensive approach when commencing studies of an area. Rapid ecological assessment (REA) is an economical and efficient methodology developed through trial and error to address these issues. For a resume of the elements of the approach see Dr. Maragos keynote paper (pp. 8-10).

The output of an REA comes in the shape of inventory reports, atlases and maps. Rapid ecological assessment basically gives a static, "snapshot" description of biomass in the study area. Dynamic relationships between resource uses and the environment are revealed through aerial surveys and later confirmed on the ground. These surveys lay the foundation for the prioritising of different quantitative analyses that later serve as a basis for more detailed management plans. An REA approach is in certain cases necessary in order to flag potential problems to managers and politicians in coastal areas undergoing rapid change. However, it was pointed out that REA, because it is quick, might confuse variation in natural baselines with anthropogenically induced variation. Quantitative analysis and long term monitoring would be needed to uncover such dynamic problems.

Interest was expressed in the **research resources needed to conduct an REA** in the tropics. Using Palau as an example, an approximate cost of \$200 000 was needed to survey 180 sites using 25 scientists, all contributing their time gratis. Sites were surveyed over a total of 9 weeks, with about six man months of synthesis being required as a follow-up. This will make Palau´s ecosystems one of the best documented in the Pacific (Maragos, pp.13-14). The next step is to develop a CZM master plan for Palau and to initiate a review process amongst local communities and government.

On the topic of the **general social applicability of REA** across coastal areas, the case was made that urban type problems of immigration are as relevant in small Pacific islands as they are in larger developing countries. Uncovering trends in migration was seen as a key part of the social component of an REA. Furthermore, much emphasis was placed on the integration of traditional knowledge of ecological links and stock assessment (e.g. fish aggregation sites) into REA. A related methodological question is whether traditional knowledge obtained through socio-cultural observation is verified by natural science methods in an REA. Apart from the recording of traditional knowledge being important in its own right, verification of social information pertaining to natural systems should be conducted, time and resources permitting.

Finally, the burden of proof in doing environmental assessments should be shifted from the public authorities to the developer. An environmental bond scheme where developers would be reimbursed the bond if they could prove that the development was within accepted limits would give incentives to privately funded research. This may solve some of the problems of the prohibitively expensive quantitative analysis that often need to follow REAs.

2.2 Economic analysis of coastal zone development options

Keynote address: "Economic Analysis of Coastal Zone Development Options: Linking Economic and Ecological Models" by **Dr. John A. Dixon**, Environment Department, World Bank

More so than for most ecosystems, the economic analysis of tropical coastal zones requires collaboration between economists and natural scientists. Because of the pervasive nature of economic and ecological externalities, partial analysis is rarely adequate to address the problems and provide realistic policy options [..] The analytical question is how to model and analyse the economic and ecological processes that determine how resources are used and how decisions are made.

Based on case studies presented from Palawan in the Philippines, Bonaire in the Netherlands Antilles, and Bintuni Bay in Indonesia, Dr. Dixon presented the following general lessons learned from work on integrating economic and ecological models:

- the results justify the effort required to work interdisciplinarily
- a high degree of uncertainty will remain for integrated analyses
- there has been very limited progress to date in formally linking ecological and economic models.
- economic valuation techniques can increasingly be used to value many goods and services found in the coastal zone, but many others will have to continue to be handled qualitatively

The point of departure was a conceptual model for the economic analysis of the uses of mangroves. Economic goods and services being valued are divided into four categories depending on their location on- or off-site in relation to the study area, and whether they are marketed or non-marketed. The approach is general enough that it has application to other ecosystems is feasible. Two case studies, from Palawan and the Bonaire, were then discussed in depth using the logic of this approach as a framework. For further details see the keynote presentation.

With reference to the case studies some methodological and policy questions were raised by the participants. The **Palawan study** concerned the analysis of an optimal logging policy based on the observation that forestry induced erosion was affecting coastal water quality, coral reef cover and fish stocks. This in turn was reducing income of in-shore fisheries and SCUBA diving-based tourism in the area. Based on this hydrological linkage between resource users, a total logging ban vs. a "business as usual" scenario were subjected to a simplified cost-benefit analysis of the gross revenues from each of the three sectors.

Questions raised pertained both to natural systems, economic and management aspects. It was pointed out that other **management scenarios** might have been evaluated that also looked at modified logging techniques. In determining rates of erosion it was found that the shock to the hydrological system came more from the logging roads than from the logging itself. In the same line of thought, it was asked whether the approach used in the Palawan study could be used to determine an optimal rate of logging taking into account a corresponding amount of water quality degradation. In fact, the analysis presented only allows for the evaluation of a binary management option - either continued logging at previous levels or a total ban. Optimising logging with respect to total gross income would require an ecological economic model that formally linked the resource uses through the hydrological system. Logging rate control variables could then theoretically be managed at a level that optimised gross tourist, fishing and logging income.

A main obstacle to an optimal control problem is the lack of **natural systems data**. Furthermore, there is considerable difficulty in taking into account **non-linear variables** describing the natural system. In this case stochastic events such as storms and substantial residual sediments in the hydrological system mean that linkage functions are anything but smooth. On the economics side, it was difficult to obtain sufficient information on the economic profits of the different users involved.

General conclusions to be drawn from the Palawan study were that despite simplifying assumptions, cost-benefit analysis (**CBA**) has broad applicability as a management tool . For relatively modest **research costs** important recommendations can be made concerning environmentally determined trade-offs between economic uses. Considering the research costs involved, quantitative analyses can also be well managed by for example post-graduate students, as was the case in Palawan.

The **time available for analysis** and management recommendations is the main limiting factor in determining the amount of quantitative analyses needed. In the Palawan case, recommendations came too late to prevent serious loss of coral reef cover. However The approach is applicable to other areas where recommendations can still be incorporated in management plans. Important **political rents** connected to natural resource uses in developing countries, such as logging, can be a major obstacle to the implementation of otherwise well-documented recommendations.

With the case study in mind areas in Costa Rica were briefly discussed as possible sites for a similar type of analysis. In the Osa Peninsula considerable logging has begun as a result of new roads into the area. At the same time only small fishing and tourist interests are represented in the Golfo Dulce watershed, although potential for tourist development is substantial. Samara-Carillo also has heavy logging in its watershed with a potential for tourism development. In both cases, logging whether sustainable or not in itself, only enters into conflict with potential other users and therefore does not inspire immediate political interest.

The **Bonaire Marine Park (BMP)** study concerned an evaluation of the ecological thresholds to the economic activity of SCUBA diving on coral reefs in the park. The state of the reefs is seen as a function of diver numbers, skills and land and water management variables. Economic benefits are a function of diver numbers, expenditure per diver and the local economy's ability to capture diver generated revenue. Ecological surveys included evaluating coral cover and species diversity across a number of dive sites. Economic surveys included determining diver related revenues as well as a survey of willingness to pay a park user fee. An extension of the analysis is to develop a dynamic economic model that explicitly links ecological constraints to selected economic goals, such as maximising income subject to reef stress thresholds. (Dixon, pp.4-5, in annex I).

Based on these ecological and economic analyses the long term viability of the BMP was evaluated. Maintaining **ecological viability** of reef use can be achieved through (1) diver education (2) limiting the number of visits (3) shifting dive loads between sites and (4) charging a "congestion tax". In addition to such a tax, the **economic viability** of BMP could be assured through (1) greater revenue retention in the local economy (2) increasing revenue from each diver.

Methodological questions to the study included the following. As time series data was lacking a **static analysis** was made of coral cover and diversity across dive sites of different diver loadings. It was pointed out that reef sites would have to be similar from the point of view of the level of natural "disturbances", such as wave action, for anthropogenic impacts to be identified with any accuracy.

In reference to the **market structure and management** of multiple users, it was pointed out that considerable debate was related to whether a concentrated or competitive industry was most beneficial in maintaining environmental quality. In the Bonaire case the multiple users belong to the same diving industry . On the one hand it has generally been considered that greater competition leads to larger supply of the environmental good/service in question, lower prices and greater degradation. On the other hand the adage that "the monopolist is the environmentalists best friend" may not be true if one takes into account the considerable political rent often associated with maintaining large but unsustainable monopoly profits.

With reference to the general debate on ecological economic analysis, questions were raised as to the **acceptance of cost-benefit analysis as a management criterion.** Especially considering the high level of information aggregation and the frequent heroic assumptions that have to be made. In reply it was underlined that benefits that cannot be quantified with reasonable reliability should be left out of the analysis. By making all assumptions explicit, CBA should be seen as a source of dialogue across social and natural science disciplines in better understanding quantitative relationships between economic and ecological systems.

A further discussion concerned to what extent CBA should be used alongside other **qualitative non-monetary management criteria**. How, for example, should local culture and indigenous priorities be traded off against monetary benefits? A possible qualitative tool referred to was multi-criteria analysis (MCA). A major drawback of such methods however is that the decision-maker is always confronted with an ultimate and subjective trade-off of the type "apples and oranges". The incorporation of environmental "intangibles" into decision-making is often not even attempted and remains a major methodological challenge.

2.3 Quantitative coastal ecosystems analysis

Keynote address: "Integrated ecological economic modelling of coastal systems" by **Dr. Robert Costanza**, Maryland International Institute for Ecological Economics, Center for Environmental and Estuarine Studies, University of Maryland

The presentation was based on a number of papers distributed at the workshop which have not been included in this report for lack of space. The focus of the presentation was on integrating process based, spatial articulation models for, on the one hand, ecological succession of landscape types, and on the other, economic land-use decisions. Preliminary results are based on a model being developed for the Patuxet River Drainage Basin, Maryland and are summarised in the following paper.

- "Ecological Economic Modeling and Valuation of Ecosystems" by Nancy Bockstael, Walter Boynton, Robert Costanza, Ivar Strand, Maryland International Institute for Ecological Economics (MIIEE) (forthcoming)

The broad structure of the integrated model can be seen in figure 1. of Dr. Costanza´s presentation. Previous landscape modelling exercises have included human impacts only as exogenous to the ecological model. In the Patuxet case valuation and decision sub models are to be endogenous to the model and will influence what uses landscape is put to.

The case of the Atchafalaya/Terrebone wetlands in Louisiana, was also presented as an example of a purely ecological model. Using a process-based coastal ecological landscape spatial simulation model (CELSS), one can examine long-term natural changes to the wetlands and also exogenously determined human impacts. The CELSS model is built up as a large number of cells where each one represents a certain landscape type. Each cell is described by a number of state variables, material/energy inflow or outflows, auxiliary variables and information flows as depicted in figure 2. Different ecosystem types have different parameter values, and following a rules-based approach cells will change landscape types when parameters (such as salinity) cross some threshold level due to natural and human forcings.

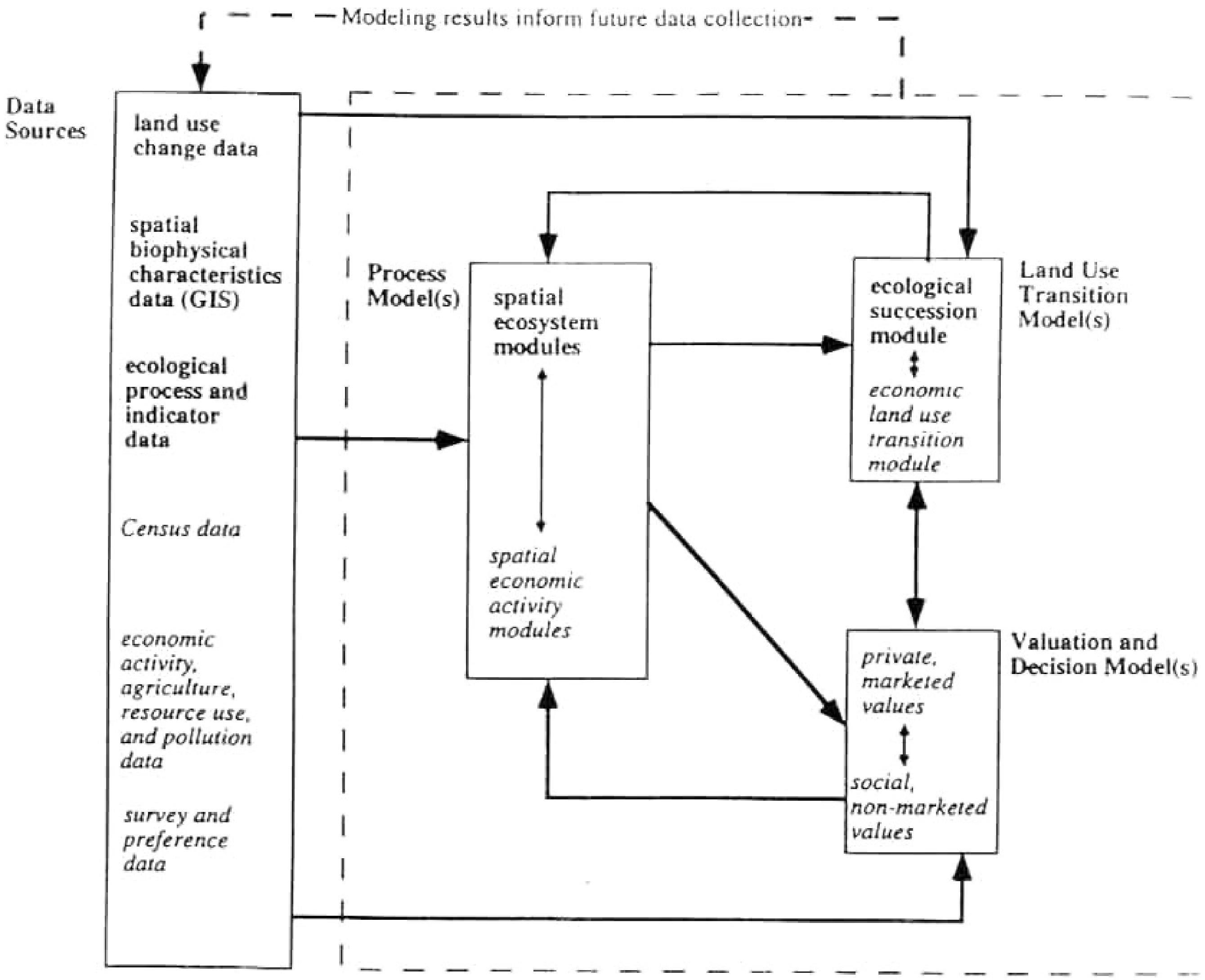


Figure 1 Integrated ecological economic modeling and valuation framework. Modules in **bold** are already included in the Patuxet Landscape Model (PLM). Modules in *italics* are to be added as part of our ongoing project.

Source: Bockstael, Boynton, Costanza, Strand. "Ecological Economic Modelling and Valuation of Ecosystems", Maryland International Institute for Ecological Economics, Center for Environmental and Estuarine Studies, University of Maryland. Draft 10/27/93 presented during keynote address, San José, November 1993.

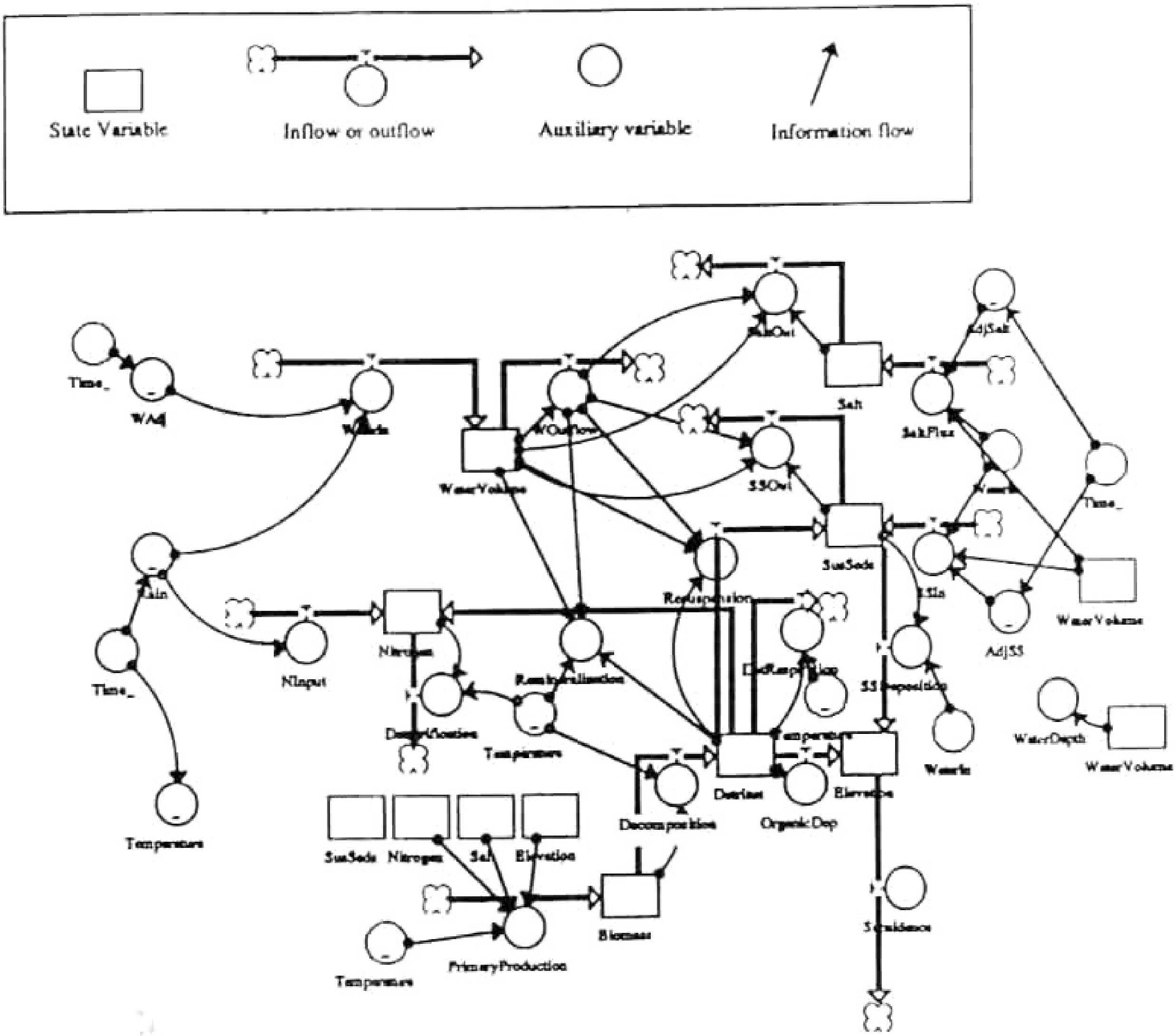


Figure 2 Diagram of typical unit cell model in the CELSS landscape model.

Source: Costanza, Sklar, White. "Modeling Coastal Landscape Dynamics". Bioscience, February 1990. Vol.40 No.2.

Further details of the model can be found in the following paper.

- "Modeling Coastal Landscape Dynamics" by Robert Costanza, Fred H. Sklar, Mary L. White, Bioscience Feb. 1990, Vol. 40 No.2,

Some general lessons learned from integrated quantitative modelling exercises are presented below.

Appropriate science - requirements of modelling

Elements of an extensive and **comprehensive systems approach** to modelling include;

- **conceptual pluralism**, and
- **problem driven** research
- **multiscale** problems - the aggregation of microcosm to meso- and macrocosm models is not straightforward and is the subject of a separate field of research.
- **integrated** models are required in order to address systems related problems

Furthermore, it was underlined that no branch of science is value free and that **links with policy** should be made explicit within research. In the research and decision-making process modelling is important;

- as a **consensus building tool**. An important product of the modelling process is sharing information across disciplines.
- to **communicate uncertainty** . The traditional approach to uncertainty is using sensitivity analyses of **parameter** uncertainties and their effects on model output. More work needs to be done on analysing overall **model structure** uncertainty. **Data** uncertainty is a further area that requires attention. A system of grading database quality is needed in order to determine where efforts are to give the best improvement in model certainty. By making uncertainties explicit the researcher also raises the question of the best policy and institutional strategies to deal with them.

The integrated ecological economic model of the type being developed for Patuxet confronts a number of general methodological issues common to understanding dynamic interaction between social and natural systems.

- **multiple purposes and criteria** in its problem oriented approach. Model design therefore necessitates conceptual pluralism and furthers consensus in understanding complex phenomena.

- **scale and hierarchy** issues. Experimental ecosystem modelling research is currently looking at the multi-scaling of models from microcosm to meso-, macro- and multi-cosm levels and how this affects model output. Choice of model scale is a trade-off between various factors as depicted in figure 3.

- **fractals and chaos theory**

- **resolution and the limits of predictability.** Model and data predictability determine the optimal level of model resolution. The modeler has to adopt a cost-benefit approach to weighing the trade-off between the two. This is presented in figure 4.

- **Evolutionary approaches as distinct from optimisation.**

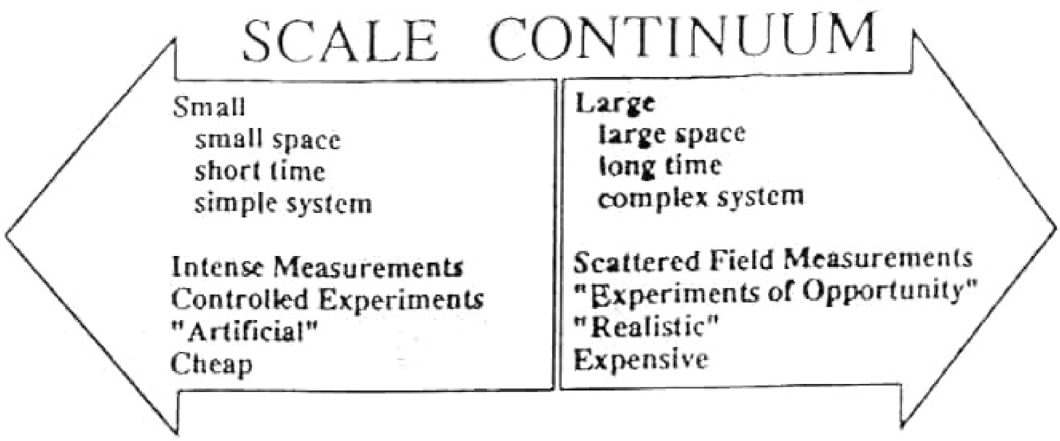
Questions were raised concerning how the **land value sub model** functioned relative to the ecological model of the CELSS type (see figure 2). In reply, both are based on rules-based successional algorithms. The economic and ecological rules for parameter switching values of the landscape cells are clearly different. Land values depend both on direct use and amenities values. The Patuxet model will allow the study of the consequences of excluding social values from land-use decisions in a watershed. Another fundamental difference from traditional economic modelling philosophy is the emphasis on describing spatial economic activity in an evolutionary context. Traditional economic modelling has not been concerned with spatial issues and has been focused on problems of optimisation rather than dynamic evolution.

Technical capabilities and data needs

Recent advances in PC-technology have made the modelling tools employed in these studies widely accessible. The Achafalaya/Terrebonne model was constructed using an icon-based programme called STELLA which can be used on personal computers. GIS systems are needed to handle remote sensing data, and computation of the model must be run on a connection machine or super computer. It was pointed out that research infrastructure in most developing countries does not permit the use of such systems. Furthermore, the US case studies presented build on some 30 years of baseline environmental data - information that is not available in many developing countries.

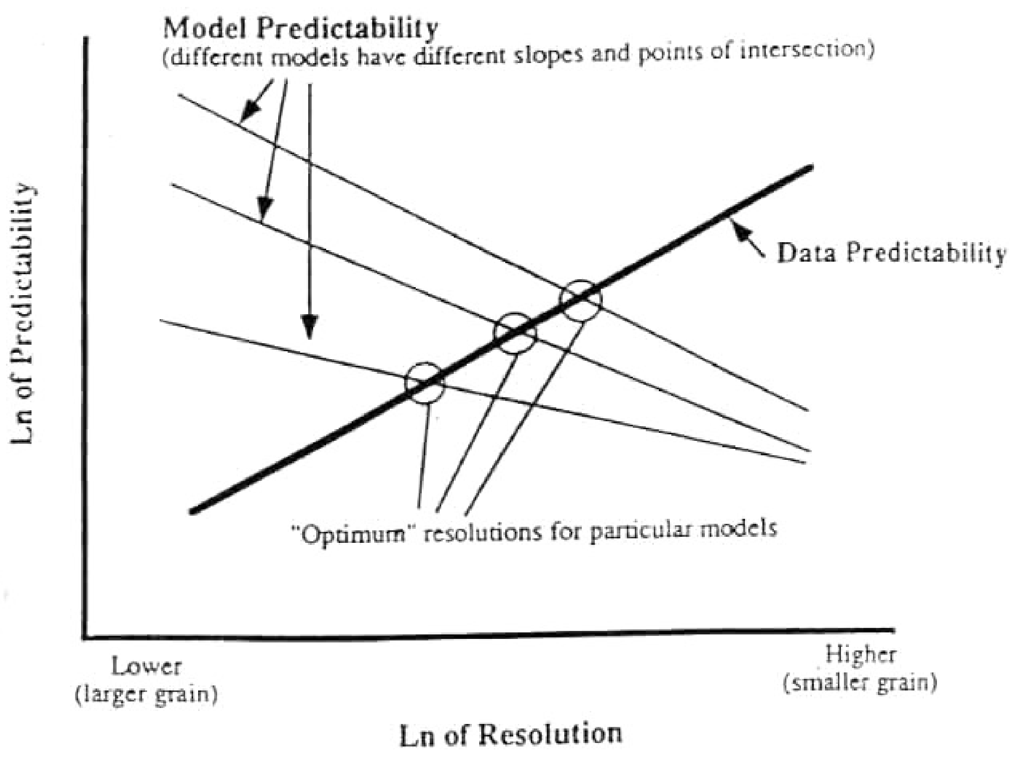
Concerning software and hardware access in developing countries Dr. Costanza pointed out that these tools would be available within a few years over collaborative networks such as INTERNET. In the process of data assembly for modelling he made clear that more effort should initially be devoted to uncovering historical trends than to mapping current environmental status. Model scale should be chosen to tackle relevant policy problems, but for the modelling exercise itself it is less important at what level of hierarchy on starts. For understanding the effects of model (dis)aggregation, however, a research programme should specify further scales of analysis in order to conduct a comparative study.

Figure 3



Source: Costanza. "Integrated Ecological Economic Modeling of Coastal Systems". Keynote address, San José, November 1993.

Figure 4



Source: Costanza and Maxwell. "Resolution and Predictability: an Approach to the Scaling Problem". To appear in Landscape Ecology 1993.

2.4 Selection of coastal systems in Costa Rica for research programme development

Keynote addresses by scientists at CIMAR, University of Costa Rica:

Dr. Jorge Cortes:	Coral Reef Ecology
Prof. Jenaro Acuna:	Marine Pollution
Prof. Ricardo Soto:	Mangrove Ecology
Dr. Jose Antonio Vargas:	Multivariate Statistics in Benthic Research

Presentations were made of the principle coastal systems of Costa Rica, their location and economic uses. The ensuing discussion turned to which of the ecosystems and geographical areas presented would be suitable as a research programme site for the coastal marine sciences.

Selecting a study site

The choice was narrowed down to the areas the Gulf of Nicoya and the Golfo Dulce and their related watersheds. The criteria for site selection revealed during the discussion are instructive for similar exercises elsewhere in the region. Committing scarce research resources to one study site in a developing country often means foregoing the development of science-based management plans for other coastal areas. Selection criteria reflected in the debate were

- existence of coastal zone management plan, other management regimes
- number of political stakeholders, ownership of management plan
- expressed political support for development and enforcement of a management plan
- diversity of uses - current and potential resource user conflicts
- expected rate of coastal conversion and development
- level of resource and ambient environmental quality degradation
- coastal ecosystems and species diversity represented
- availability and types of data from the study site

The **Gulf of Nicoya** is the area currently most developed of the two and has experienced large scale degradation of coastal habitats such as mangroves and depletion of commercial marine stocks. There is no operational coastal zone management plan for the area. Among the activities affecting the Nicoya area are large tourist beach developments, urbanisation, over fishing, aquaculture, mariculture, salt ponds, water contamination from e.g. inland leather tanneries and agriculture. Based on current needs for management it was felt that Nicoya was of greatest importance as a site for research. The area has about 12 years of research data already available.

On the other hand, several factors also weigh heavily in favour of selecting the **Golfo Dulce** site. Compared to the Gulf of Nicoya it is known that terrestrial biodiversity is much greater and large areas of the watershed remain in near pristine condition. However, rapid development of non-artisanal activities in the Golfo Dulce is just beginning and resource use conflicts are starting to surface. The immediate prospect of large scale tourism development in the area would argue for the rapid development of a coastal management plan to preempt degradation.

Second, Golfo Dulce has a less complicated jurisdictional structure and fewer institutional and political stakeholders governing its use. Approximately 80% of the Osa Peninsula around the Golfo Dulce is covered by some form of protection in national parks or reserves. This should make the acceptance, implementation and enforcement of a coastal management plan less difficult than in the Nicoya area where close to 20 public agencies have a jurisdictional mandate in the coastal zone.

Third, although under rapid development, the pattern of resource uses is seen as less complex in Golfo Dulce and would be easier to model in an integrated ecological economic framework. A case was made for the opportunity to start data collection for the purpose of integrated analysis whereas existing data on the Nicoya area had generally not been collected with such a purpose in mind. In the Golfo Dulce area a largely qualitative rapid ecological assessment (REA) has so far been carried out for the coastal terrestrial environment, and a marine REA is pending. The opportunity of new data collection would, however, seem to apply equally to both areas. See also CIMAR papers in annex for an overview of available data. Several participants warned, however, of the unmotivated collection of data and the compilation of expensive "coastal profiles" without the research being problem oriented from the outset.

The phasing of different analyses was also raised in connection with the prioritisation of research resources. A comparative analysis between the two gulfs was thought to be particularly interesting as they were in different stages of development. While the Gulf of Nicoya is in need of larger scale socio-economic analyses, environmental baseline studies are the priority in the Golfo Dulce. While this approach has theoretical merit, scarce research resources in Costa Rica would prevent social and natural science from working together in both gulfs simultaneously. By concentrating efforts on one study area an integrated ecological-economic and problem oriented approach would be the focus from the outset.

In the opinions of Costa Rican experts who knew both areas, the Golfo Dulce was preferred for the possibility to develop an operational coastal area management plan (CAM) that could serve as a pilot for similar initiatives in other areas of the region. For any degree of success to be achieved with a managed plan it was felt that tackling an area of less socio-economic and political complexity was preferable to begin with. At the same time, participants called for a national/regional level survey of existing coastal management and environmental information and the development of a priority list of areas that could benefit from the conclusions from the Golfo Dulce research programme.

2.5 Alternative management criteria

Keynote address: "Isomorphism or disparity? On "scientific" and "folk" models of coastal resources and their management" by **Dr. Edvard Hviding**, Institute of Social Anthropology, University of Bergen

"Scientific and folk" models of management have fundamental similarities on the level of form - isomorphism. Successful management plans such as those of the Great Barrier Reef Marine Park Authority (GBRMPA) bear considerable similarities to regimes in, for example, the coral reefs and lagoons of the South Pacific islands, where Dr. Hvidings examples were taken from. Similarities (isomorphisms) refer to e.g general use zones, reef appreciation areas, seasonal closure areas, replenishment areas etc. as found in the GBRMPA. For further details see his paper in annex I. A general conclusion of the presentation was that "folk" models and "scientific" models of management while being alternatives are not necessarily incompatible.

Similarities in management regimes and customary tenure are built on **similar forms of analysis**. Any model is initially qualitative in that a relational basis has to be drawn up before any attempt is made at quantifying flows, linkages and causalities. Both scientist and local resource users must make assumptions about qualitative linkages and complex relationships among and between human groups, ecological zones and specific organisms. There is often an acute awareness among coastal peoples of systemic relationships and regularities in the environment, and to systemic sets of regulations on human uses of the coastal environment. People's subjective views of ecosystem linkages ("cognised environment") are just as significant as the linkages per se ("operational environment") because they govern resource use. Understanding resource use motives, which are by no means always economic, is therefore central to any successful CZM plan.

Elaborating on his paper, Dr.Hviding pointed out the **traditional awareness** among pacific island villagers of hydrological linkages between upland-downland. In these societies women are the prime bearers of such knowledge as they are the ones to work in closest contact with the natural resource (e.g. through shell collection in the mangroves). In the Solomons upland-downland linkages are also "matched" by cultural distinctions between inland and coastal inhabitants resource use rights. Customary sea use rights make no distinction between ownable and unownable areas. Zoning of uses is related to social groups such as the ones described above. Sometimes the system of customary marine tenure (CMT) is even given recognition in the country's legislation.

In relation to economic **valuation of the environment**, the point was made that existence and intrinsic value may have very little relevance in traditional cultures where the biological resource is solely subject to direct use, i.e. as a source of nutrition or artisanal materials. To the extent that one has seen local action to protect habitats, this has been directly related to assuring the level of extractive uses of the resource. Totemistic or religious values relating to e.g the magic powers of certain species, is the closest one may get to "observing" existence values in traditional cultures.

Social-anthropological analysis raises important questions concerning the **objectives of coastal zone management** that is constructed on purely quantitative economic and ecological analyses. What are key management "state variables" and which of them should the policy-maker be attempting to optimise through CZM? A number of management criteria are non-quantitative by nature, such as "optimal way of life", or otherwise difficult to model and culture specific, such as "optimal employment levels". Objectives that cannot be operationalised in quantitative models are nonetheless an essential part of management criteria. In reference to the "cognitive environment", the key question is to determine what variables/concerns local resource users are trying to maximise.

In reference to Costa Rica and the area of **Golfo Dulce**, an important empirical question regarding how much local "traditional" knowledge exists upon which to build a "modern" CZM plan ? Although concerned with the development of their fish stocks, most local artisanal fishermen have only been working the area for 20-30 years and have little in the way of "folk" knowledge in comparison to the Pacific islands. Many are immigrants from inland or ex-plantation workers from the area. There are therefore no immediately visible forms of Customary Marine Tenure (CMT) or community based management, as discussed in Dr. Hviding´s paper.

A major task for anthropological studies in the Golfo Dulce area would therefore be to discover what local knowledge is available, how resource users perceive qualitative linkages in their environment, and what traditional management (if any) is internally regulating resource use.

As a general conclusion it was underlined that moving management blueprints from one area to another was seldom, if ever, a success. Lessons could, however, be learned from ways of tackling problems common both to "traditional" and "modern" management systems. Building social-anthropological analysis into the CZM exercise is a matter of building on knowledge that is already available locally, a central tenet also of rapid ecological assessments (REA).

3. Summary of the working group recommendations

Following the plenary presentations of the "state of the art" in quantitative analysis of tropical coastal resources and environments and alternative approaches, the workshop divided into two groups.

- Working group 1 : "Aims of a research programme - CZM needs for integrated cost-benefit analysis".
- Working group 2 : "Conceptual model - key ecological-economic variables of importance in the tropical coastal zone and systems information flow".

Workshop goal achievement

The original focus of the workshop on the integration of quantitative ecological models with social-economic cost-benefit analysis was hard to maintain as the majority of participants present were unfamiliar with the economics methodology. Regarding the development of a conceptual model for integrated analysis and systems information flow, the workshop recommended using existing conceptual models for the development of the research programme. Such management models would include flow diagrams indicating information gaps and guiding a research programme in identifying necessary expertise and co-sponsors/associates.

The following is a synthesis of the working group recommendations for the components of a research programme. The full working group reports can be found in annex III.

Recommendations:

1 The research programme should be concentrated in the **Golfo Dulce and its watershed**.

2 **Hypothesis testing of coastal zone management policy** should be conducted for the Osa-Dulce area: Is the present management regime in the area in accordance with primary normative policy objectives for Costa Rica's coastal zone?

3 Co-ordinate management policy objectives with key agencies and local communities, with the aim of **achieving concurrence** and/or **support for policy objectives** of a possible coastal area management plan (CAM).

4 Analyse **institutional and jurisdictional context** and boundaries in project area and regulation of resource users. Evaluate the administrative, judicial and financial potential for enforcement of a possible CAM plan.

5 **Analyse and synthesise existing information** on;
a) terrestrial habitats
b) hydrometeorological system
c) marine systems

6 Determine **criteria for further data collection**; what management issues have little supporting ecological and economic baseline data? Evaluation of these databases for their suitability to test the normative policy objectives listed in the report of working group 1.

7 Analyse and synthesise information on **key ecosystems processes**; develop descriptive and quantitative systems models.

8 Analyse and synthesise information on **socio-economic systems**; development of qualitative and quantitative models.

9 Develop **linkages** between natural systems models and socio-economic models. Identifying long-term changes of the system.

Time did not permit addressing all points in the terms of reference for the two working groups. The **unaddressed terms of reference** below should be seen as the possible subject of subsequent meetings in the context of the research programme.

- phasing of qualitative and quantitative analysis. Determining the steps from rapid ecological assessment to social economic cost benefit analysis, and policy proposals for CZM in the Golfo Dulce and watershed.

- determining variables to be optimised in an integrated ecological-economic analysis of a multiple resource user problem. The management objectives presented in the report of WG1 should be structured according to those that are operational concepts for quantitative modelling and those that need to be evaluated using qualitative criteria. (see follow-up meetings).

- identification of key management / technological "control variables" for the Golfo Dulce area. What are the regulations that institutional / jurisdictional actors can apply to natural resource use in the area?

- development of a quantitative model structure for (parts of) the Golfo Dulce and its watershed and its users. Assess overall integrated modelling structure. Assess uncertainties of the model (parameter, data, overall system).

II Economic and ecological indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas.

Report from follow-up meetings of July and October 1994, San José, Costa Rica

1. Introduction

Part II of this report summarises the results of two meetings held as a follow-up to the workshop in November 1993, "Integrated Quantitative Analysis and Tropical Coastal Zone Management". The meeting brought together scientists from the University of Costa Rica, the University of Bergen and functionaries and professionals familiar with resource management around the Golfo Dulce and the Osa Peninsula.

1.1 Objectives

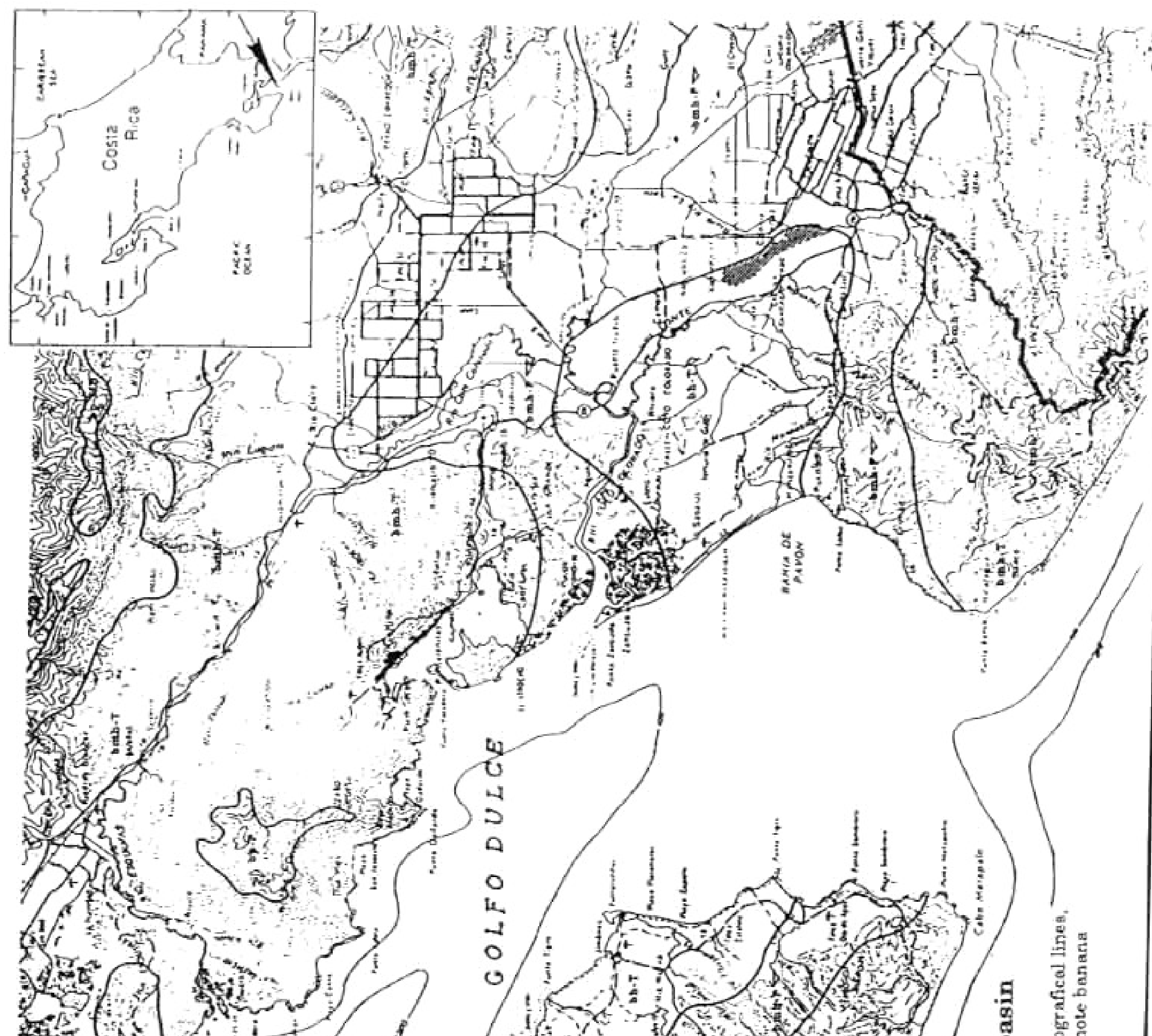
One of the principal challenges of the research programme deliniated by the initial workshop was the focusing of research towards satisfying management needs for the waters of the Golfo Dulce, its watershed, its natural resources and ecosystems.

The aim of the two follow-up meetings was therefore to define a limited number of ecological and economic indicators that would be of simultaneous use to integrated quantitative studies, as well as be relevant to the resource managers within the Osa Conservation Area (ACOSA).

The meetings succeeded in defining a limited number of long-term ecological indicators that would serve as important priorities for upcoming natural science research within the programme. The definition of economic indicators for monitoring purposes was less successful due to the diversity and rapid changes of resource uses patterns in the area, and a limited experience of using economic indicators in resource management in Costa Rica. The second follow-up meeting therefore focused on the identification of resource use conflicts within the area with a view to further definition of useful indicators at a later date.

1.2 Definition of relevant study area for management and research concerns

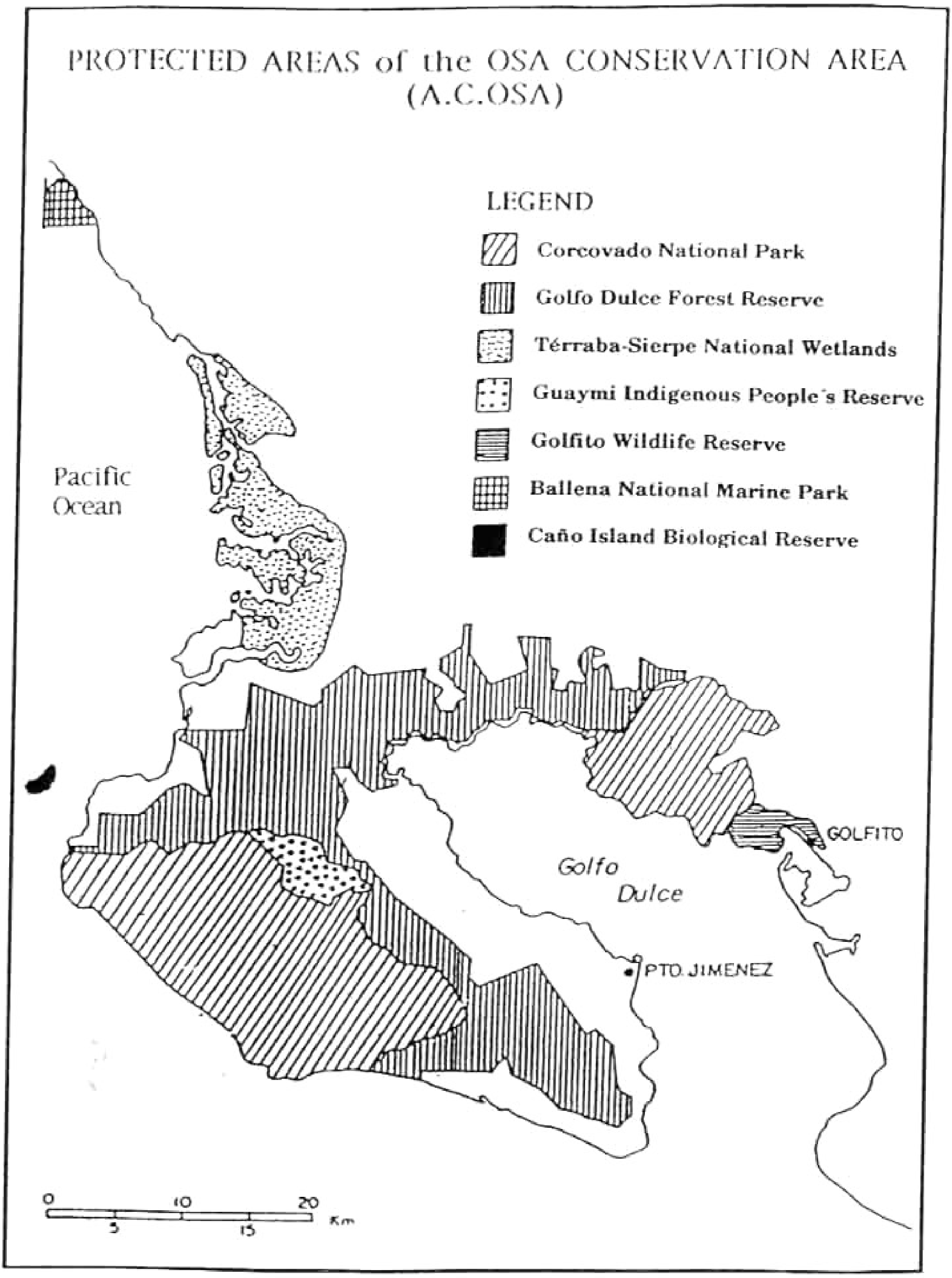
One of the goals of the research programme is also to generate information that may serve as a basis for an integrated coastal area management plan (CAMP) for the Golfo Dulce and its catchment basin (map 1). However, ACOSA includes the management of resources and ecosystems on the whole of the Osa Peninsula (map 2), a considerable portion of which lies outside the catchment basin of the Golfo Dulce .



Map 1 - Golfo Dulce and catchment basin

Note: Map denotes life zones (bmh, bp), bathymetry and topografical lines, principal rivers, roads and towns. Rectangles to the East denote banana plantation infrastructure.

Map 2



Source: Area de Conservación Osa (ACOSA) - Ministerio de Recursos Naturales,Energía y Minas (MIRENEM)

In discussions with functionaries of MIRENEM it became clear that many current coastal management problems of ACOSA lie outside the Golfo Dulce, such as the Caño Island Biological Reserve, the Ballena Marine Park and the Térraba-Sierpe National Wetlands. In these areas, such as the Térraba-Sierpe mangroves, some of the more intensive resource extraction takes place, while Caño Island, for example, recieves the highest visitation rates in the area for SCUBA-diving related tourism.

A compromise was sought between the focus of ecological research on the Golfo Dulce and potential management issues to be found in the hydrografical system, and the current social and economic priorities of ACOSA outside the catchment basin. The focal study area was therefore defined as the embayment and catchment basin of the Golfo Dulce, while the area of influence was defined as including the whole of the Osa Conservation Area, because of the jurisdictional boundaries and socio-economic linkages on the Osa Peninsula.

2. A methodology for the selection of ecological and economic management indicators

2.1 Resource use conflicts

With a view to addressing potential resource use conflicts in the area a number of factors should determine which socio- economic activities and issues should receive priority attention within the research programme:

- A large number of persons affected by a resource or environmental dispute.
- Important short-term environmental impacts on other resource users off-site.
- Potential long-term environmental impacts, although currently not a source of conflict.
- Environmental impacts where the distribution of external costs fall unevenly on different social and income groups within the area.
- Local traditional resource users affected.

On the basis of these points a number of resource users were identified within the study area that had historically been in dispute with oneanother or had a potential to do so in future. The sectors are also listed in figure 2 at the end of this report.

1. Protected areas vs. excluded traditional uses

The establishment of protected areas, such as national parks, biological refuges and reserves within ACOSA (map 2) has led to the expropriation or limitation of tradtional resources users in the area (gold mining, forestry, small-scale agriculture. livestock farming). The establishment of these protected areas implies an opportunity cost of lost production that needs to be compared to, for example, the increased economic benefits from tourism, and the non-use values derived from conservation of endangered species within the protected area.

2. Tourism sector and land speculation vs. traditional uses

Social conflict is also arising between the local population and foreign investors, such as tour operators, due to the large scale purchase of lands near the protected areas. Economic issues of importance are land-tenure disputes; the opportunity costs of lost traditional production; the degree of substitution of traditional employment by the tourism service sector jobs; the expatriation of profits generated by foreign operators.

3. Infrastructure and transport vs. conservation and tourism

Growing infrastructure, such as increasing the access of the road to Puerto Jimenez, the expansion of the port of Golfito for forestry purposes by Ston Forestal, change the sceenic features of the Golfo Dulce coastline and its watershed. Issues of interest are increased income from better tourist and industrial access to the area versus benefits from the conservation of sceenic beauty and biodiversity in the area. Due to erosion infrastructure such as roads have also had an impact on marine water quality and the health of coral reefs.

4. Logging and mining vs. downstream activities

Logging and mining has had an economic impact on other activities downstream through sceenic changes, impacts on fresh water quality and marine sedimentation. Potential conflicts existing in the area today lie particularly with tourism and also with the quality of local populations´ drinking water.

5. Freshwater and marine pollution vs. other uses

At present pollution of the Golfo Dulce is limited to dumping of municipal wastes and urban sewage, as well as some agricultural run-off of pesticides. Potential large scale conflict exists with the increased sewage problems of coastal tourism development and population growth. Some concern has also been expressed as to possible spills from maritime transport to and from the port of Golfito.

2.2 General normative management objectives

With a view to addressing the conflicts above, normative management objectives need to be selected in order to then define their related indicators. Based on suggestions in the literature[2] , three general management objectives were proposed as suggested guidelines for environment and resource

[2] Daly, H. E. and K. N. Townsend, "Valuing the Earth. Economics, Ecology, Ethics". Massachusets Institute of Technology 1993

management within ACOSA (see also a listing of possible normative objectives working group one's report in part I).

1. Sustainability of ecosystems and their natural resources
2. Efficiency in the allocation of scarce resources
3. Equity in the distribution of benefits from ecosystems and their resources

The indicators related to the ecological sustainability of the coastal ecosystems and resources in Golfo Dulce were given priority and detailed further. The social economic efficiency and equity objectives were not developed further due to the complexities involved in dealing simultaneously with;

- many resource users and social groups with different interests in the area
- limited experience of using economic indicators in resource management in Costa Rica
- ethical and political considerations related to the limited role scientists within the research programme should play in determining local and national coastal management priorities.

The broad steps then followed are outlined in figure 1 below. The normative objective of ecological sustainability was then detailed further as several objective "functions" which could be described by a set of indicators and their related parametres. Ecological objective functions were also sought that had a parallel economic interpretation. Maintaining or increasing productivity, resilience and stability[3]. of coastal systems within the study area were agreed upon as necessary functions of ACOSA for achieving ecological sustainability.

1. Productivity
Biological productivity can be measured by for example net primary productivity, or by rates of resource extraction that take into account human and technological effort. This has been the most common indicator used in environment and resource management and economic policy.

2. Resilience
This refers to the elasticity or capacity of the system to recuperate in environmental and biological terms to its previous state (e.g. productivity) after having been submitted to external impact and stress.

3. Stability
Refers to the variability in time of key indicators of ecosystem health, or in economic terms, the variation of production, income and welfare derived from natural resources and the environment.

[3]based on Conway (1985) Agroecosystem analysis. Agricultural Administration no. 20

2.3 Criteria for selection of indicators

The process of defining ecological indicators was guided by a number of criteria in order to assure a common approach to gathering data from the different coastal systems within ACOSA, provide accessible management information and facilitate the later development of integrated ecological and economic models. The following criteria were used during the process of indicator selection:

- **linkage to human activity.** The ecological indicators (biological, chemical, physical) should preferably use units of measurement that can also be employed in economic valuation and natural resource accounting excercises.

- **no more than 5-9 indicators** should be used to describe the state of each coastal system. It has been shown that this is the greatest number of different information categories that can be considered by the decision-maker when choosing between alternative policies[4]. This limitation reduces the danger of information saturation, in cases where quantitative models that can deal with multiple trade-offs between alternatives are not available.

- **the indicators should be of long-term relevance.** Monitoring programmes for ecological indicators should concentrate on long-term variation of the coastal systems rather than changing data collection proceedures according to the needs of economic users present at any one time.

- **efficiency in the relationship information quality and management utility / data collection costs.** Although measurement methods were not discussed in the workshop, indicators were chosen that were generally obtainable with available equipment in Costa Rica.

- **identify natural background effects** that may influence the ecological indicators selected and mask anthropogenic impacts.

- **identify current availability of information** and institutional sources for each indicator selected.

2.4 Other methodological issues of data collection

The local personell of ACOSA and local NGO´s interested in participating in the programme should be contacted in order to define which indicators can be measured with the local technical capacity and which need support from the universities involved. The cost of monitoring and sampling will be a principle

[4]van Pelt, M.F.J., "Sustainability-oriented project appraisal for developing countries. Ph.D. Thesis, Wagenigen Agricultural University, 1993

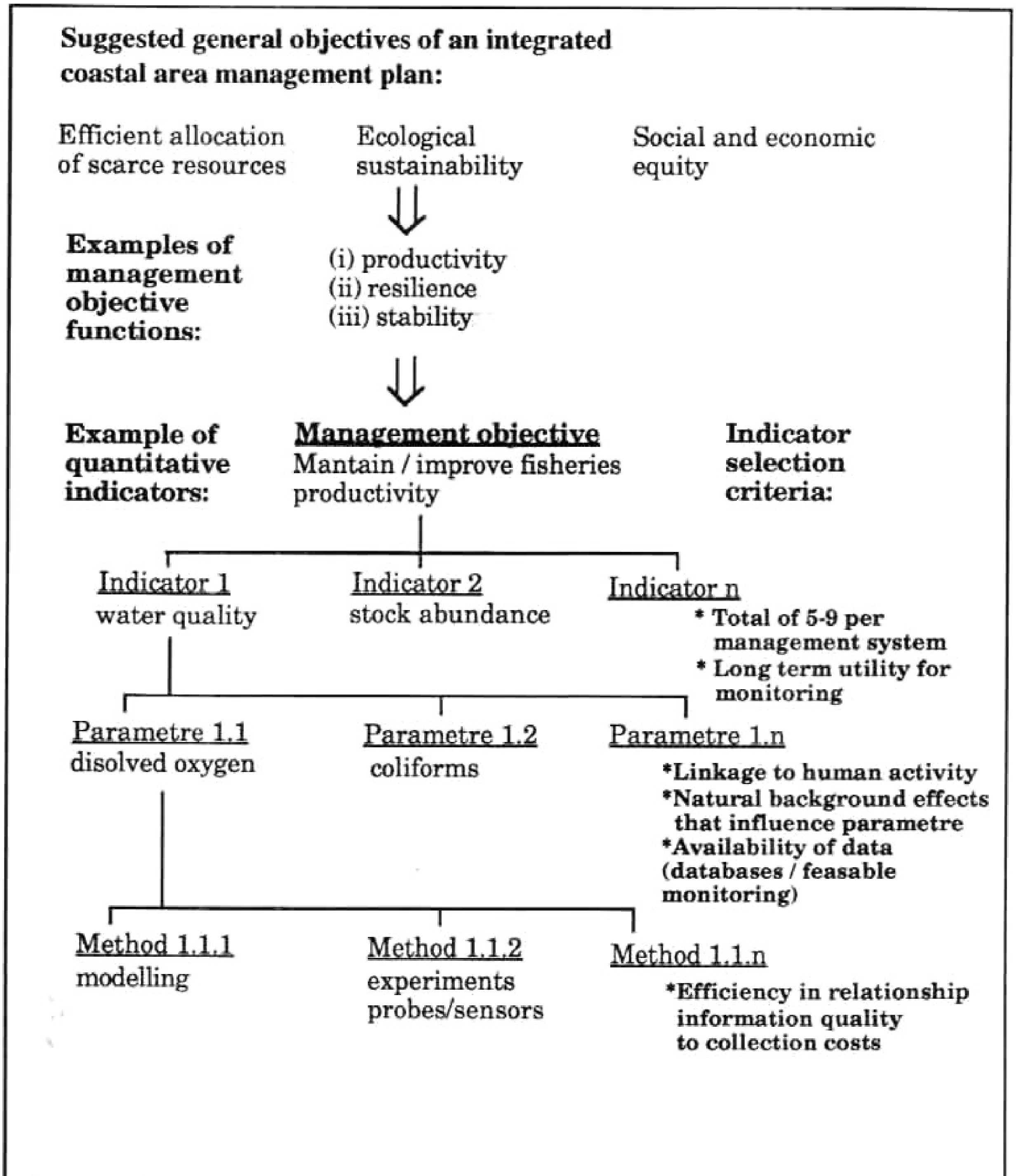
criteria and one of the aims of the programme is to identify international sources of financing for the more expensive monitoring tasks.

Indicators common to all the coastal systems should be identified as candidates for rational collection of data by one single monitoring programme. Frequency and periods for monitoring or of occasional sampling should then be determined. Candidates for occasional sampling are, for example, the more expensive chemical pollution studies where continual monitoring is not feasible.

A priority list of the selected indicators should be developed according to the gravity of environmental and resource problems currently affecting the study area. The selection of indicators and their measurement sites within each system should take into account the linkages to other neighbouring coastal systems. For example, the decision on whether or not to monitor the fresh water quality of a particular river in the watershed should depend on the importance of drinking water supply, mangroves, coral reefs, and fish spawning grounds downstream. As another example, the measurement of marine water quality could be defined by the risk of impacts on human health near recreational areas.

In addition to the system specific indicators, a it was agreed that there was a general need for more reliable basic meterological and oceanographic data than currently available (wind, precipitation, humidity, temperature, currents etc.).

Figure 1. Schematic outline of criteria for selecting management indicators

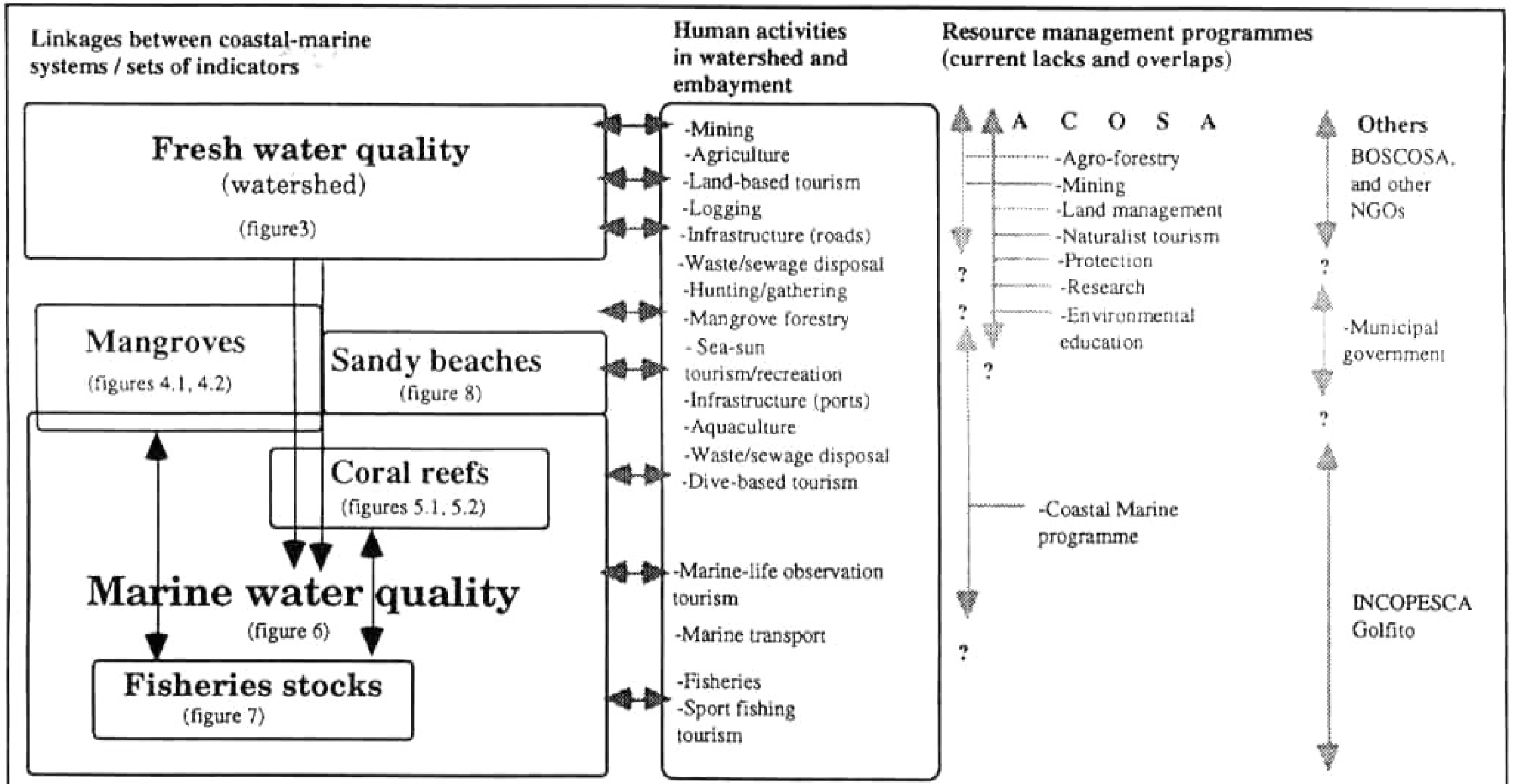


Source: adapted from Carpenter and Maragos, eds., "How to assess environmental impacts on tropical islands and coastal areas", South Pacific Regional Environmental Training Manual, Environment and Policy Institute, East-West Center (1989)

3. Suggested ecological indicators for the coastal environment and resource management of the Osa Conservation Area (ACOSA)

Figures 2-8

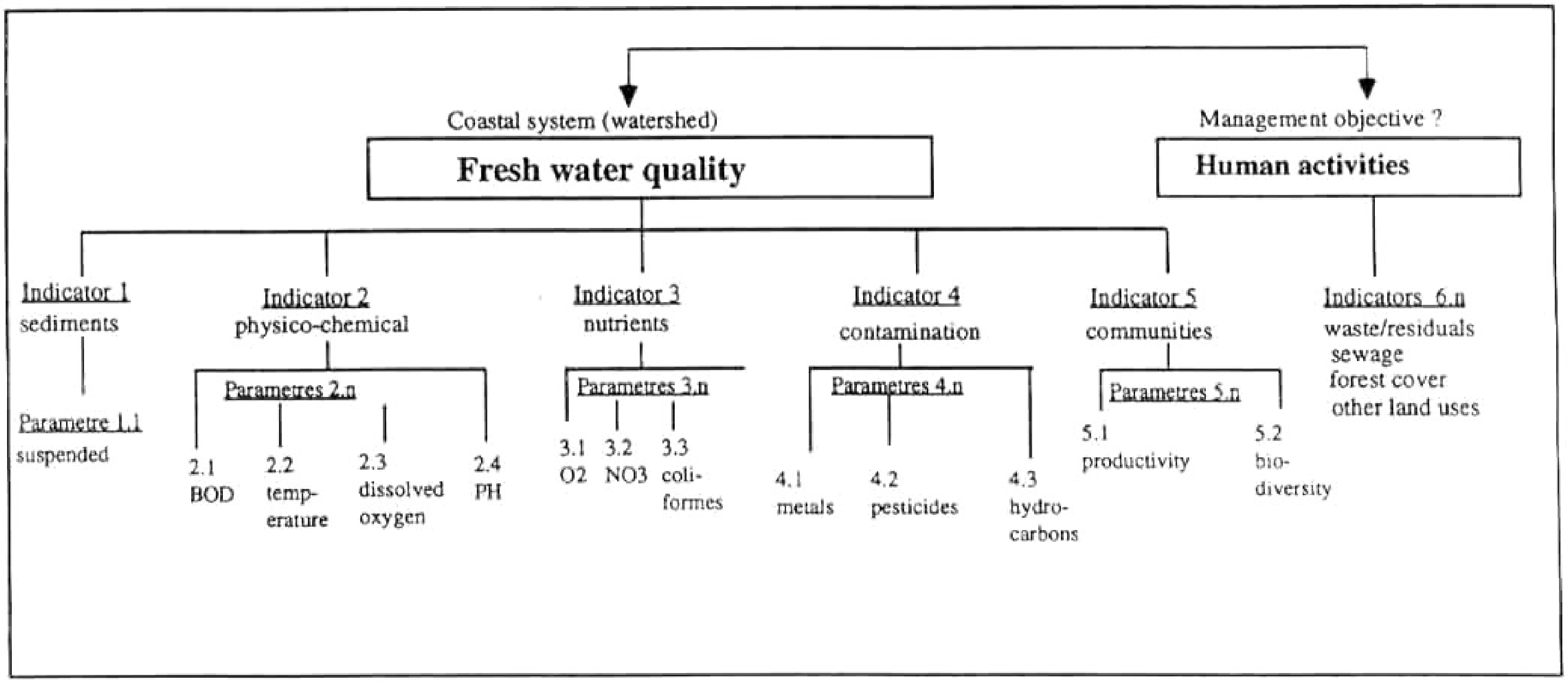
Figure 2. Linkages between systems of ecological indicators, human economic activities and resource management initiatives within the Osa Conservation Area (ACOSA)



Note: hydrological and/or food-chain linkages between the principle coastal systems within ACOSA (conceptual)
resource and environmental user linkages (examples)
jurisdictional, planning and implemenation horizons of resource managers in the study area (examples)
Question-marks (?) denote the need for coordination and/or possible extension of existing natural resource management programmes in Golfo Dulce and its watershed.

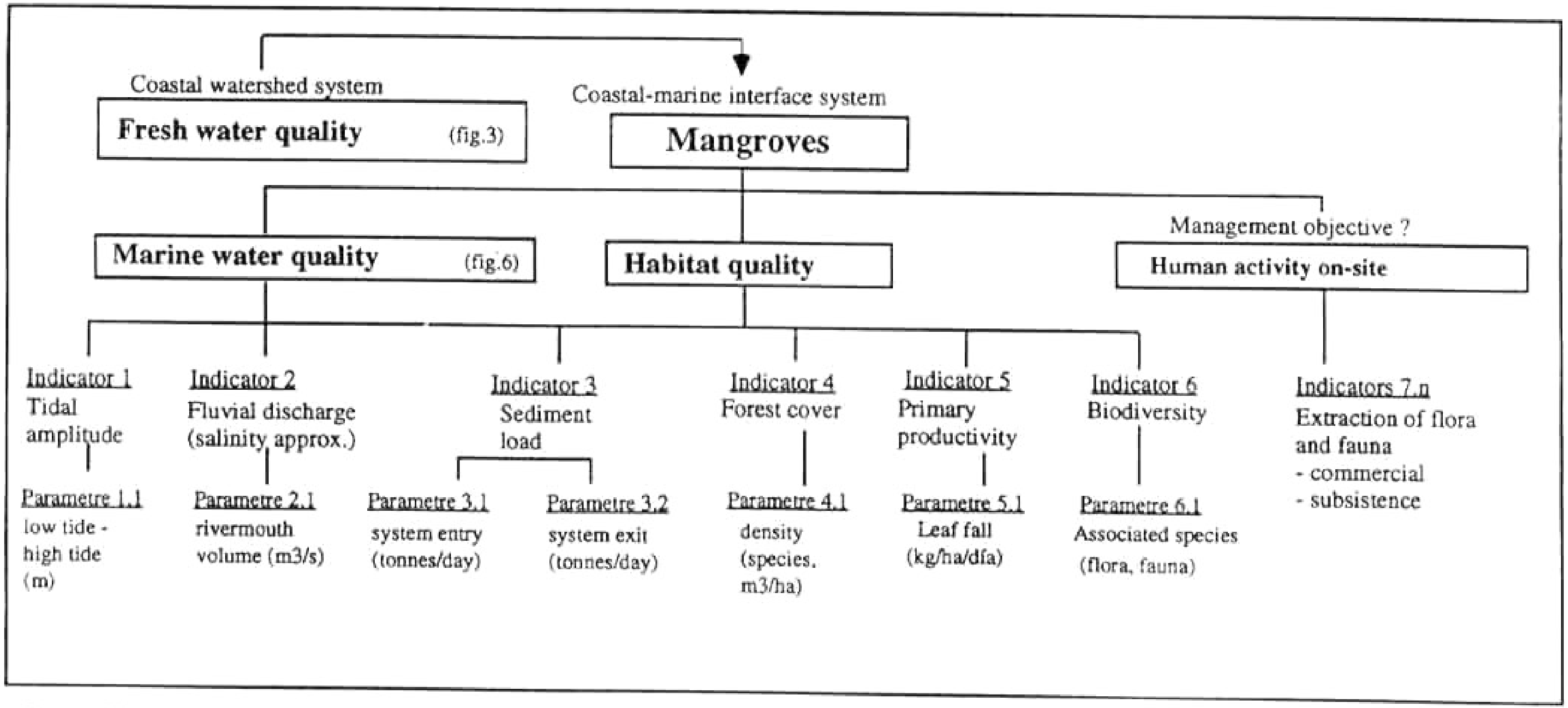
Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas

Figure 3. Fresh water quality - suggested ecological indicators for environment and resource management within the Osa Conservation Area (ACOSA)



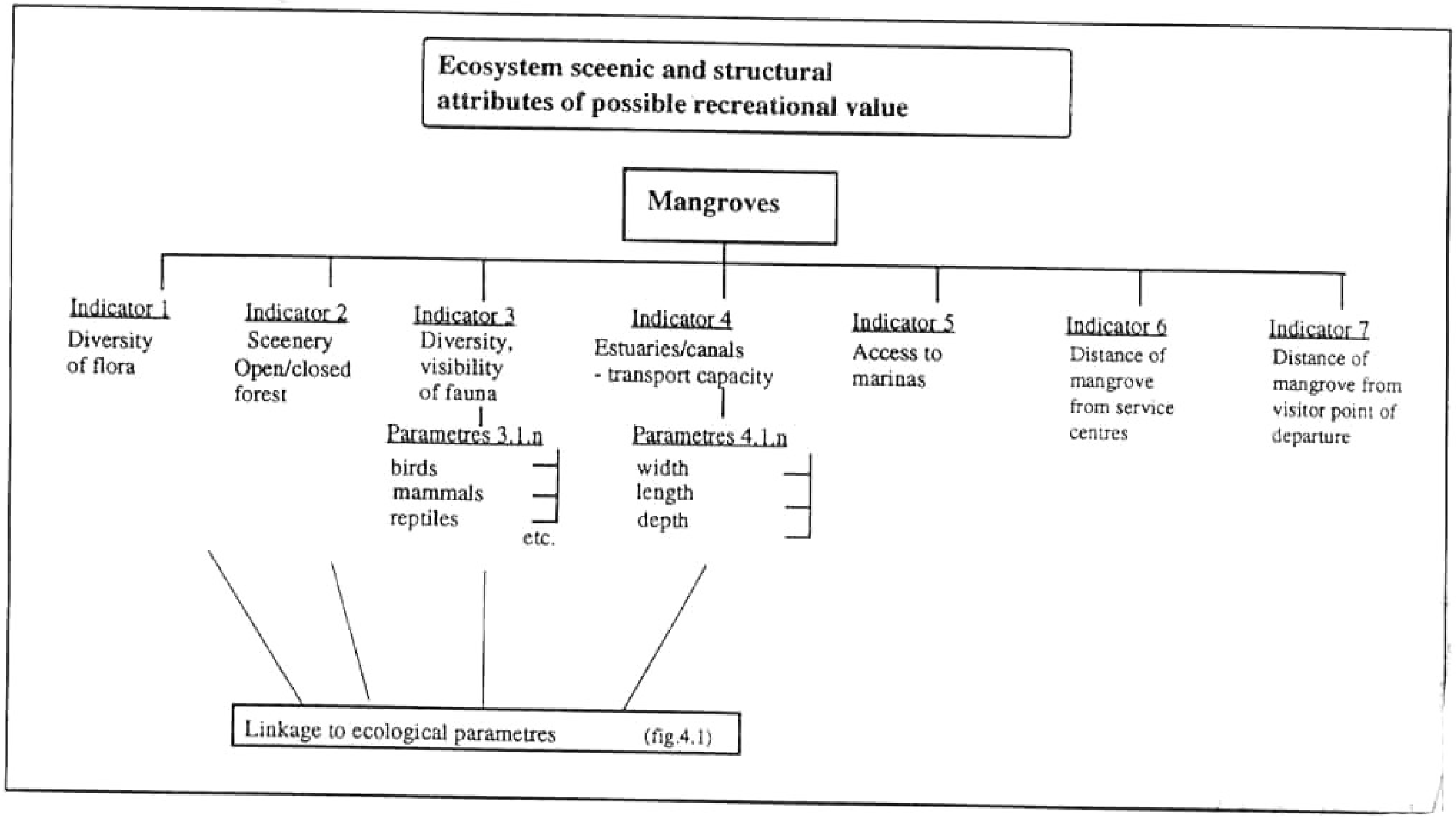
Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas. CIMAR, University of Costa Rica - SMR, University of Bergen, Workshop July 1994, San José.

Figure 4.1 Mangroves - suggested ecological indicators for environment and resource management within the Osa Conservation Area (ACOSA)



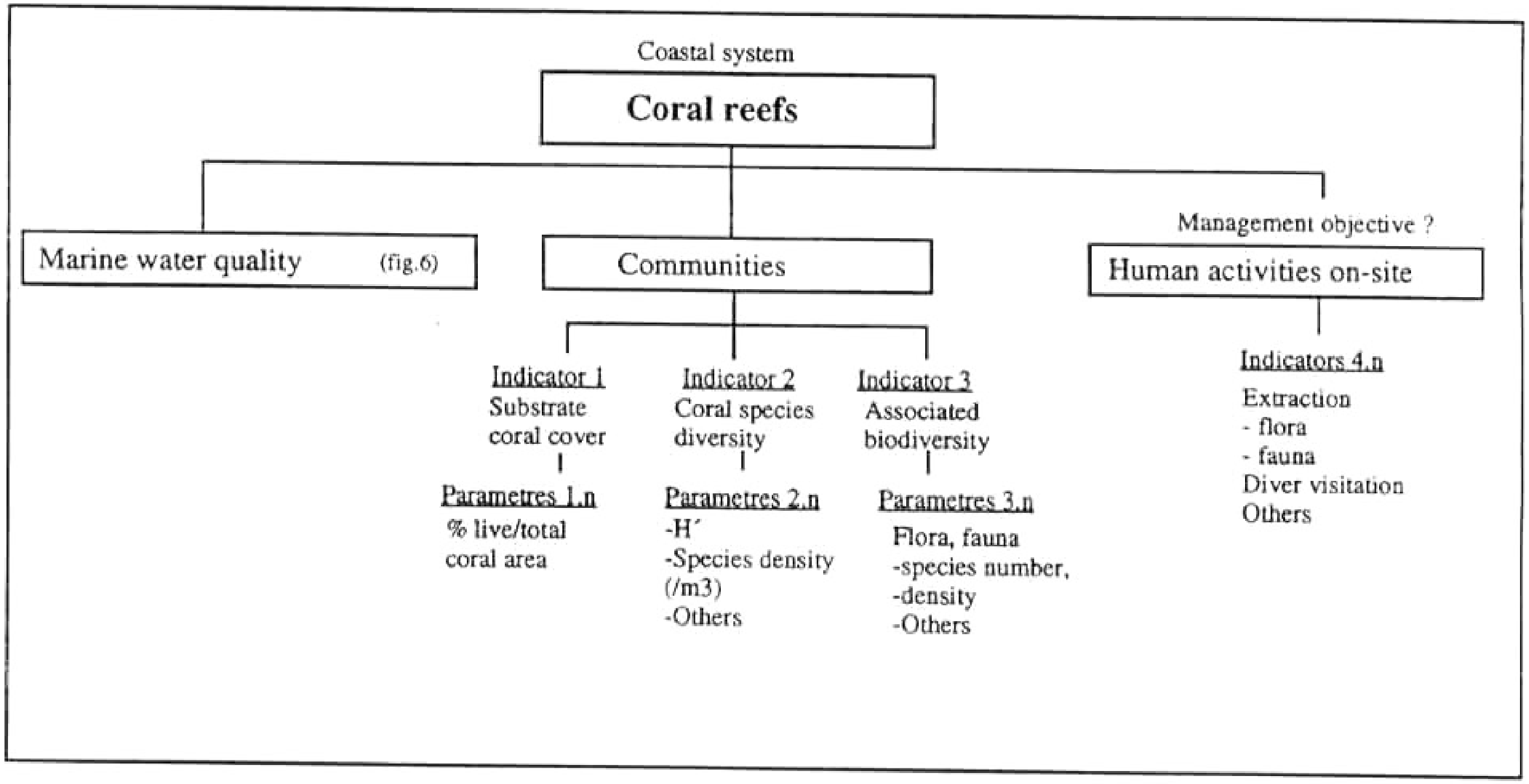
Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining systems. CIMAR, University of Costa Rica - SMR, University of Bergen, Workshop July 1994, San José

Figure 4.2 Mangroves - suggested ecological indicators for the environment and resource management within the Osa Conservation Area (ACOSA)



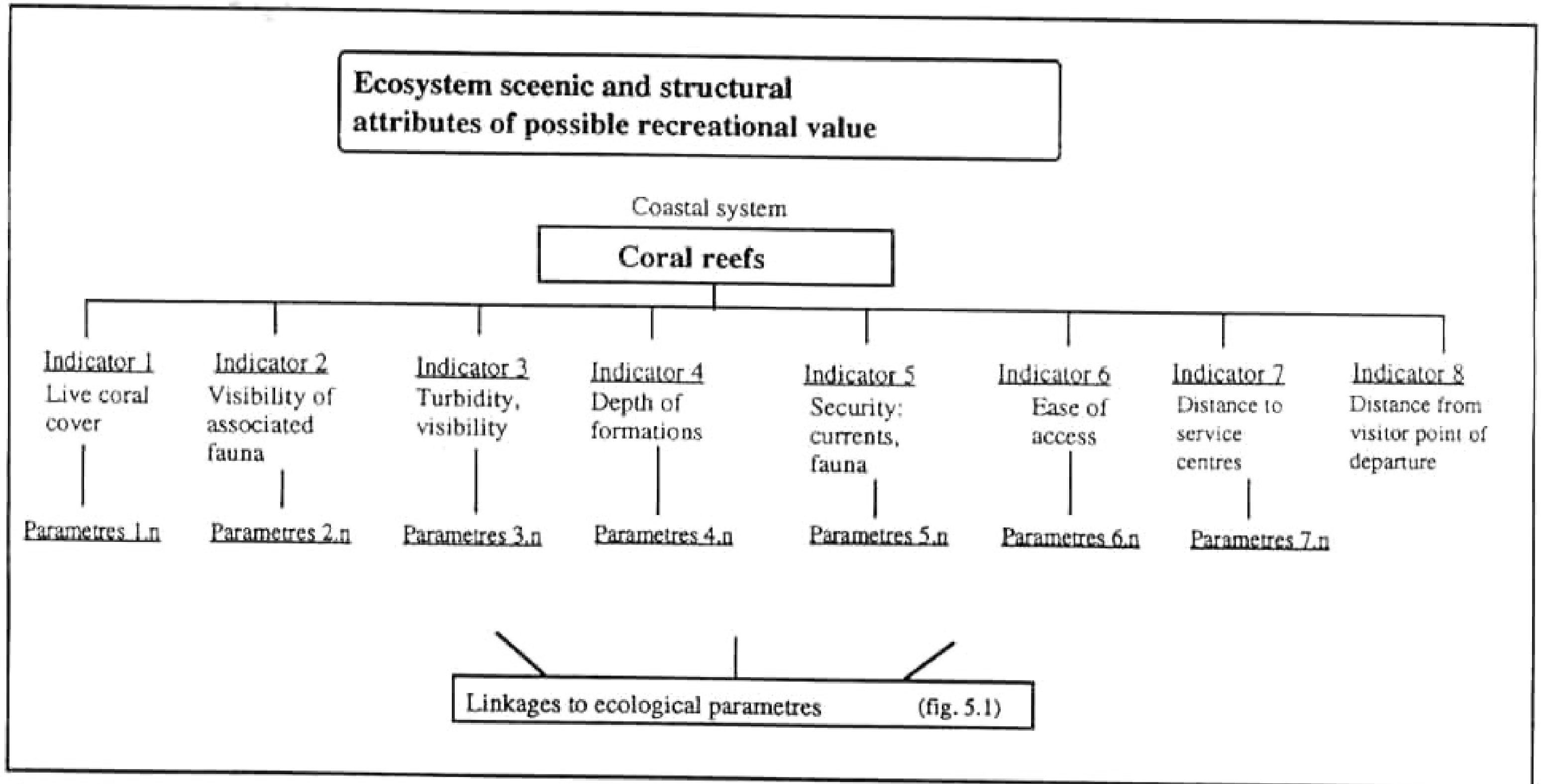
Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas. CIMAR, University of Bergen. Workshop July 1994, San José

Figure 5.1 Coral reefs - suggested ecological indicators for environment and resource management within the Osa Conservation Area (ACOSA)



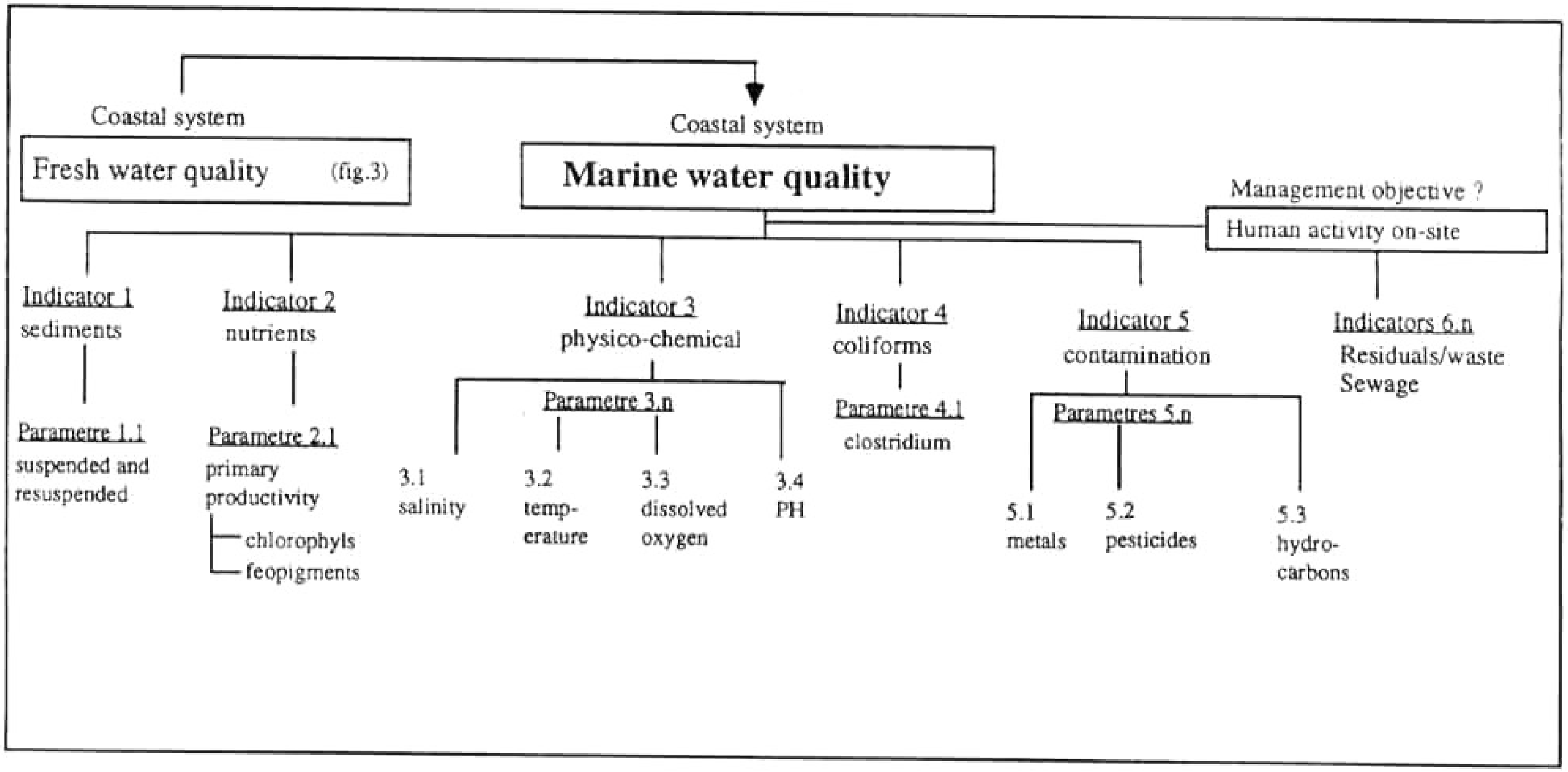
Source: Ecological economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas. CIMAR, University of Costa Rica and SMR, University of Bergen, Workshop July 1994, San José.

Figure 5.2 Coral reefs - suggested ecological indicators for environment and resource management within the Osa Conservation Area (ACOSA)



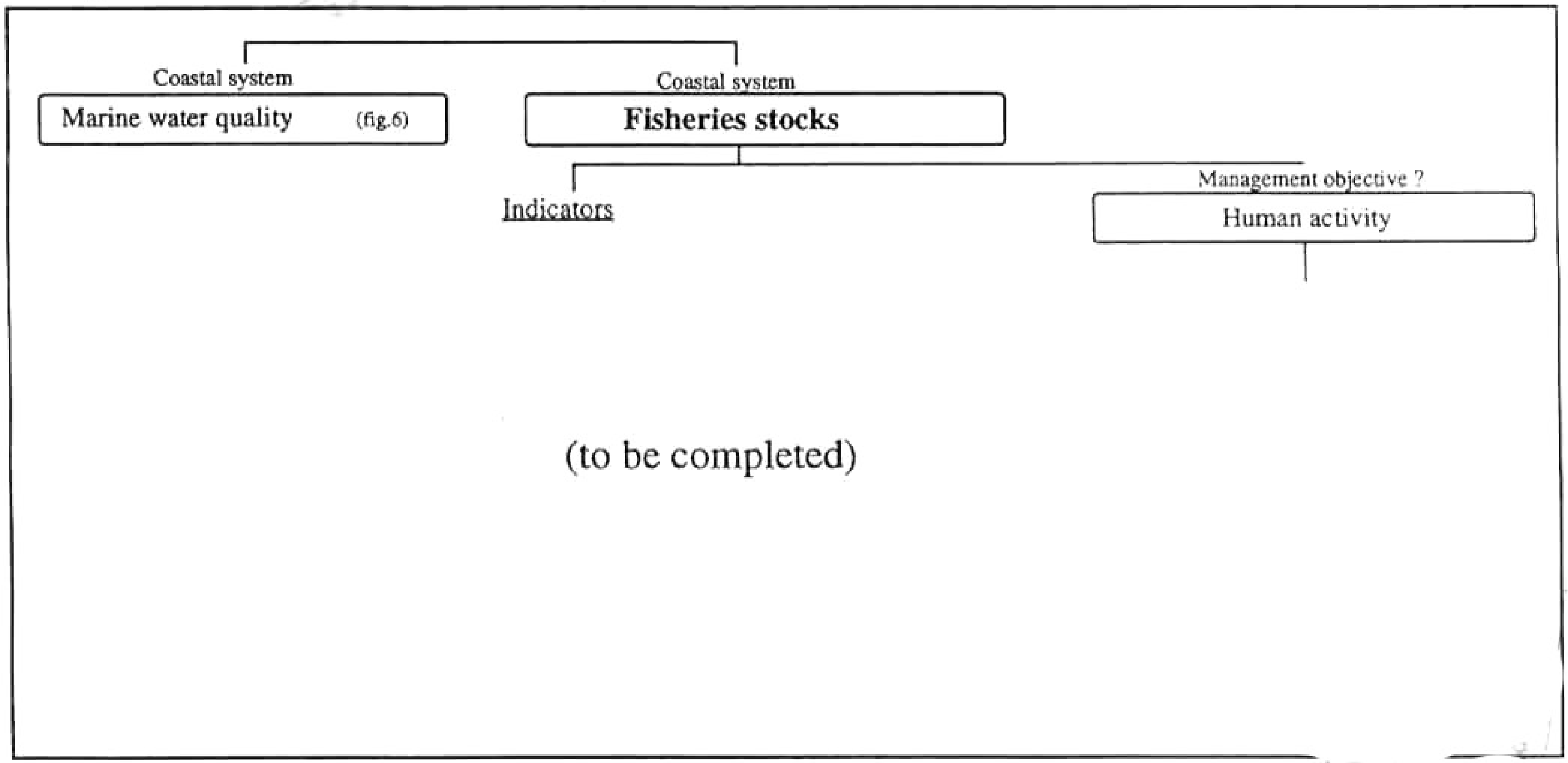
Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas. CIMAR, University of Costa Rica -SMR, University of Bergen, Workshop July 1994, San José.

Figure 6. Marine water quality - suggested ecological indicators for the environment and resource management within the Osa Conservation Area (ACOSA)



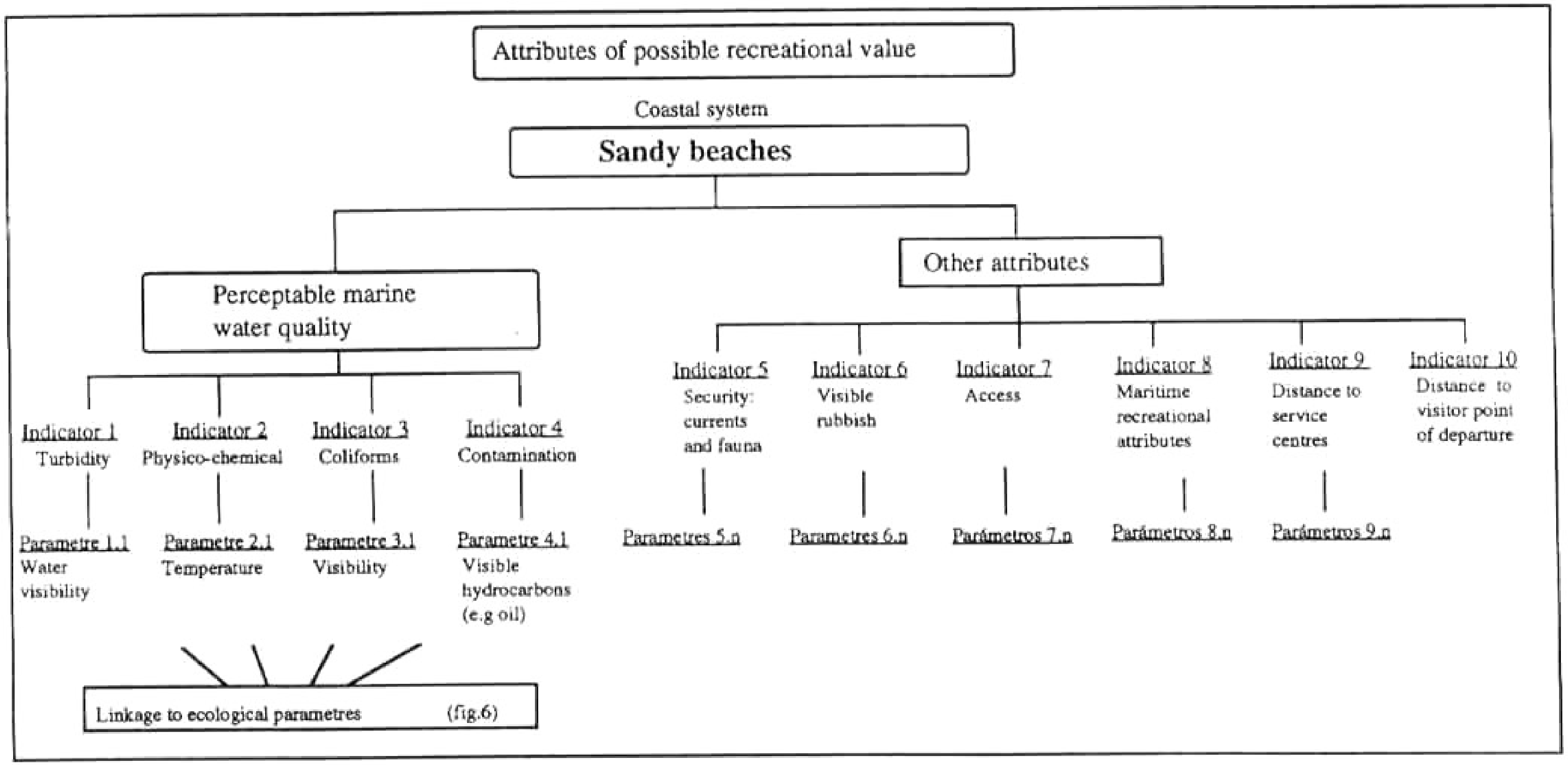
Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas. CIMAR, University of Costa Rica - SMR, University of Bergen, Workshop July 1994, San José.

Figure 7. Fisheries stocks - suggested ecological indicators for environment and resource management within the Osa Conservation Area (ACOSA)



Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas. CIMAR, University of Costa Rica - SMR, University of Bergen, Workshop July 1994, San José.

Figure 8. Sandy beaches - ecological indicators for environment and resource management within the Osa Conservation Area (ACOSA)



Source: Ecological and economic indicators for the integrated coastal zone management of the Golfo Dulce and adjoining areas. CIMAR, University of Costa Rica - SMR, University of Bergen, Workshop July 1994, San José

ANNEXES

Annex I Keynote addresses

INTEGRATED COASTAL MANAGEMENT IN THE TROPICS: INTERDISCIPLINARY CHALLENGES AND MANAGEMENT NEEDS FOR QUALITATIVE ANALYSIS

by

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Abstract

For largely unexplored coastal zones or island areas, qualitative surveys are needed first to define the status, distribution, and needs of resources in the coastal zone. Then these qualitative surveys can point out specific issues and problems that may be better addressed using more quantitative procedures and analysis. Given the limited budgets that normally are available for coastal management, and the limited availability of experienced coastal scientists, it is usually impossible to conduct quantitative scientific surveys and analysis that cover broad coastal regions, such as those which surround islands and fringe other countries. This report discusses some of the procedures and products in using largely qualitative ecological surveys to help design and implement coastal planning and management programs in the tropics, based upon experience gained in the insular tropical Pacific. The tradeoff between qualitative and quantitative analysis is not difficult if one perceives both as necessary and as part of a phased scientific research program.

Evolution of Modern Coastal Zone Management

The United States was the first country to enact comprehensive national legislation on coastal management with passage of the U.S. Coastal Zone Management Act of 1972 (CZMA). Historically the U.S. constitution gave the states the right for land use planning and management. However, in the 1960's the national government recognized the need for intervention to address increasing levels of conflicts, challenges, and crises involving unplanned use and abuse of the coastal zone. The need for coastal zone management emerged as a national priority; upland sources of pollutants and soils were washing down into coastal ecosystems including wetlands; beaches were disappearing due to encroachment of structures; ports and energy generation plants needed to expand but were faced with increasing public opposition; public access and recreational opportunities in the coastal zone were being foreclosed by special interests; the cost of coastal lands was skyrocketing; commercial fisheries were being threatened from over-harvesting; coastal recreation threatened from pollution and overdevelopment; and marine ecosystems were also being degraded. The CZMA provided financial support to states that developed coastal zone management (CZM) plans consistent with national guidelines, and states were provided additional federal funding to operate approved CZM plans. This "incentive" approach sidestepped constitutional challenges and enabled the national government to intervene and assist state governments in developing CZM.

The major requirements of the CZMA included the following:

1. Designation of a geographic coastal zone
2. Designation of areas of particular concern for CZM
3. Establishing policies and regulatory procedures for development in the coastal zone
4. State level endorsement or commitment to CZM via passage of counterpart legislation and/or executive orders, and
5. Development of procedures to ensure that federal activities achieved consistency with federally approved state CZM plans

In the subsequent 2 decades, the national and state level CZM programs in the U.S. have been successful in achieving comprehensive management and use of the coastal zone. The programs have also helped to sort out major use conflicts, enhanced public awareness and effectiveness, improved long range planning, and have promoted more orderly development and conservation initiatives. On the negative side, bureaucratic mechanisms and approvals are often cumbersome, and there is often great disparity in the nature of CZM programs between adjacent states. Some programs are stronger than others, confusing national level appraisals of the effectiveness of the CZMA. Also national level oversight of state programs has been weak, and ineffective. Finally from a scientific perspective, many state CZM plans have often failed to inventory and evaluate resources and values of the coastal zone prior to setting priorities on their management. Although the CZMA was the first initiative, the subsequent two decades of experience in implementing it have led to adjustments and improvement that can potentially benefit other countries interested in establishing their own CZM programs.

Emergence of Coastal Resource Management

The initial U.S. experience was oriented to a large continental nation with clear distinctions between inland and coastal regions. The need to define a coastal zone is essential under such circumstances to ensure that limited financial and institutional resources were concentrated in the coastal zone. However in small tropical countries and islands, the distinction between the coasts and inland areas is less clear. For example, in Hawaii, one of the larger island archipelagoes in the Pacific, the maximum distance between the land and sea is only 47 kilometers. In small island states virtually all land is coastal. In response to this reality, island governments devoted more attention to defining the specific coastal resources and values warranting management and less energy towards defining a coastal zone: hence the concept of coastal resource management became vogue among several Pacific island governments. For example the U.S. territories of Guam, Northern Mariana Islands, and American Samoa have designated certain ecosystems as areas of particular concern warranting the utmost concern for coastal management: forests, coral reefs, seagrass beds, wetlands,beaches, lagoons, historic sites etc. Coastal resource management is particularly beneficial in helping island states focus on resources of importance, such as those threatened from overdevelopment or vital to future economic growth or natural resources conservation. Island states are clearly more fragile because their coastal resources are smaller; once mistakes are made there are rarely second chances to correct them.

Coastal Area Management

Coastal area management (CAM) has emerged as the newest concept, especially in nations outside the U.S. sphere of influence. As I understand it, CAM involves the selection of specific representative and important coastal areas in a country where coastal management activities are intensified and practiced to serve as a model or template for later expansion into other comparable areas of the country. In this circumstance CAM concentrates on large scale pilot projects; outside of the project areas, remaining coastal zone resources are not initially subject to coastal management. Based upon the success stories and lessons learned from the pilot projects, the host governments can elect to extend coastal management to new areas. This approach is being pursued in the tropical Pacific and Asia by International Center for Living Aquatic Resources Management, the University of Rhode Island, and other institutions, with much of the funding derived from the U.S. Agency for International Development and the Asian Development Bank. Target countries include Thailand, Sri Lanka, Indonesia, Philippines, and Ecuador.

The most successful example of CAM to date in the tropical Pacific is management of the Great Barrier Reef Marine Park of Queensland Australia by a partnership of national state agencies and scientific institutions. A special federal agency, the Great Barrier Reef Marine Park Authority is the lead responsible agency but works closely with the Queensland Dept. of Wildlife and National Parks for day-to-day management, enforcement, research and other activities. Zoning plans were developed for each of several regions in the Park and a full range of development and other resource use activities are regulated through a permit process, including dive boats, floating recreational platforms, recreational fishing, commercial fisheries and shrimp trawling, commercial navigation, research monitoring, enforcement and planning for new additions to the park. The management agencies benefit significantly from the close associations with nearby universities, the Australian Institute of Marine Science, and museums which provide senior scientists and students for research and technical evaluation of development proposals. The Great Barrier Reef Marine Park is an excellent example of coastal area management carried out in a very large region, the largest national park in the world.

Third World Initiatives: CZM in other insular tropical Pacific Areas

Despite the impressive degree of support for coastal management, by the U.S., Australia, New Zealand, and international aid organizations, few other countries in the tropical Pacific have access to the technical resources needed to embrace and adopt coastal management. Several states have demonstrated the political will for coastal management by passing enabling legislation (such as Fiji, Marshalls and Kosrae State in the FSM), but implementation of procedures and regulations is daunting due to the technical expertise required. For example, the Republic of the Marshall Islands passed a Coast Conservation Act in 1988 but has yet to prepare regulations and implement the act. As an atoll nation, the Marshall Islands are vulnerable to global climate change, population crowding, sand mining, damage to properties from national hazards, limited water supply, and other constraints imposed on low lying coral island environments. Considerable outside expertise however is needed to conduct coastal surveys and develop the plan, including attorneys, ecologists, engineers, social scientists, and public involvement and educational specialists.

The lack of relevant, simple, and successful models to follow from other island regions hampers progress. Coastal and small island states can be the first to recognize the need, but with limited resources and populations, can be the least equipped to implement coastal management. A complicating factor is widespread distrust by Pacific Island governments over the concept of land use zoning and controls. Some actually fear that land use planning is the latest sinister ploy by westerners to deprive island landowners and authorities of their rights to unrestricted and traditional use of their lands and resources. Traditional customs and controls have worked for thousands of years in many of these countries, but the advent of modern construction practices, cash economics, "western" educational systems, and improved health care have exacerbated over population, encroachment of structures into the coastal zone, increased pollution, and promoted excessive harvesting of coastal fish and shellfish, and have undermined traditional controls and authorities. A vacuum now occurs in many island states where eroded traditional controls over coastal resources have not been replaced or strengthened by as yet untested westernized approaches. Landowners and reef owners will continue to exert traditional rights and controls over unrestricted use and access of their resources until public education and demonstration can convince them of the need to adopt holistic, integrated and long range management of coastal resources. Clearly new approaches and strategies ar needed.

Quantitative Data and Analysis for Coastal Management

In a perfect world scientists should be playing a major support role for countries starting out in coastal management, for example, in conducting technical evaluation of the status of renewable resources, water pollution, rare species and ecosystems, and cultural and socio-economic resources etc. An inventory of the value and status of all potentially important coastal resources should be conducted before decisions are made on their management. Scientists are also key figures in modeling and understanding complex biological, chemical, geological, and physical processes in the coastal zone. In actuality scientific expertise has been insufficient or under utilized in helping to establish coastal management programs. Many scientists tend to be "introverted", focusing on individual species or the dynamics of smaller habitats and communities. Many scientists don't want to assess more extensive regions and interactions for fear of not being able to defend findings to their peers in the broader scientific community. This basic science or academic approach normally cannot benefit planners and managers needing early feedback on the status of broader ecosystems and regions of a coastal zone. The need for planning and management can't wait for scientists to get organized to support broader surveys, and coastal management programs will often move forward without adequate scientific input.

At the other extreme "applied" scientists conducting more qualitative and extensive surveys are not recognized by their academic peers as contributing to the advancement of scientific knowledge and inquiry. However the situation is now changing rapidly in that aid organizations and governments are now sponsoring applied scientific research in direct support of coastal planners and managers. A whole new generations of scientists are now being educated and poised to support the technical needs of coastal management.

For example, the Great Barrier Reef Marine Park Authority uses scientists extensively to support applied research such as monitoring of construction projects, monitoring of corals and other reef organisms being used as environmental indicators, ecosystem restoration projects, assessment of visitor use and damage to park natural resources, broad-scale qualitative inventories of candidate additions to the park, etc. In these situations the scientists and managers work together to achieve acceptable compromises that both responds to management's needs and which is also rewarding enough research for reputable scientists. Only in this manner will established or senior scientists be willing to give up some of their "basic" scientific interest to assist in coastal management.

Rapid Ecological Assessments

In the tropical Pacific and Southeast Asia there is over 30,000 islands and accompanying reef ecosystems. Less than one percent of these have been the subject of basic or reconnaissance level surveys. There is a clear shortage of scientific expertise to accomplish a systematic overview of the coastal zones of the islands and reefs of this broad region, even if all able scientists were available and willing to contribute. Initially what is needed is a broad scale semi-quantitative survey by teams of scientists to assess the "big picture" - the status and values of the coastal zone in broad regions, islands, and archipelagoes. Theoretically these surveys could help direct coastal planners, managers and scientists to identify areas where more intensive attention is needed. For example, broad-scale surveys could address the following issues or needs:

- Sites of important commercial or subsistence fisheries
- Habitat for rare species and communities
- Areas potentially popular for tourism, parks and recreation
- Historic sites of importance to indigenous cultures
- Areas where many species new to science have yet to be described
- Appropriate sites for ports and transportation corridors
- Important polluted or degraded ecosystems warranting restoration
- Ecosystems or coasts, subject to natural catastrophes that warrant long term monitoring,
  etc.

Broad-scale scientific surveys over short periods of time to address specific questions (such as those listed above) are often called rapid ecological assessments (REA). The ultimate goal of REA is to maximize the efficiency of limited scientific input over broad regions to address specific management or planning needs. REA can be carried out both in terrestrial or aquatic coastal zone regions. I've spent much of the last 15 years devising means to accomplish REA for tropical island and coastal areas in the Pacific. A combination of "office" and "field" procedures is common to many rapid ecological assessments:

1) Review of available scientific and other literature for the target area
2) Review of large scale maps to define and begin to map ecosystem types
3) acquisition and analysis of aerial photography (low and medium altitude color and false-color infrared imagery is most useful, but for very broad regions satellite and high altitude imagery may be needed)
4) Interviews with local historians, cultural leaders, natural scientists and village elders
5) Additional interviews with planners, politicians, and other government "decision makers"
6) Reconnaissance - level field surveys over broad areas involving senior or experienced scientists to verify opinions gained from interviews and analysis of imagery and to uncover additional information of value to coastal management, and
7) Portrayal of information on maps, in reports and via video and photographs to promote understanding.

Using trial-and error experience, I've participated in about 20 REA's and have attempted to improve the quality and utility of REA's by applying new technologies and procedures. In all cases teams of scientists varying from four to twenty have been involved in the various aspects of each REA.

Table 1. Coastal resource atlases and inventory reports prepared in the tropical Pacific between1978-1993 sponsored by the U.S. Army Corps of Engineers unless otherwise noted.

Island Group	Island	Atlas	Report	Notes
State of Hawaii				
	Oahu Island	Yes	Yes	
	Maui Island	Yes	Yes	
	West Hawaii	Yes	Yes	
	Kauai Island	Yes	Yes	
	Molakai Island	Yes	Incomplete	
American Samoa				
	Tutuila Island	Yes	Yes	Mostly sponsored by NOAA
	Aunu'u Island	Yes	Yes	Mostly sponsored by NOAA
	Ta'u Island	Yes	Yes	Mostly sponsored by NOAA
	Ofu Island	Yes	Yes	Mostly sponsored by NOAA
	Olosega Island	Yes	Yes	Mostly sponsored by NOAA
Republic of the Marshall Island				
	Majuro Atoll	Yes	Yes	
	Arno Atoll	Yes	Yes	
	Kwajalein Atoll	Yes	Incomplete	
Federated States of Micronesia				
	Pohnpei Island	Yes	Yes	
	Kosrae Island	Yes	Yes	
	Yap Island	Yes	Yes	
	Moen Island	Yes	Yes	
	Chuuk Lagoon	In progress	In progress	Mostly sponsored by the FSM National government

Coastal resource atlases and inventories

During my term with the U.S. Army Corps of Engineers in the tropical Pacific, 17 coastal resource atlases and inventory reports were completed for islands and atolls in Hawaii, American Samoa, the federated States of Micronesia, and the Republic of the Marshall Islands. In a few cases other sources of financial assistance was also received (table 1). The atlases and reports documented REA findings for the islands and atolls.

The earliest atlases and inventory reports were accomplished for islands in Hawaii. For Oahu and Maui new maps were produces for the atlases. For West Hawaii, Kauai, and Molokai, the atlases maps were prepared from aerial photos to which were coastal resource information and place names. The atlases for American Samoa and Moen Island involved production of new maps.

Remaining atlases have relied on using existing high quality large scale maps prepared by the U.S. Army Map Service (for the Marshall Islands) and the U.S. Geological Survey (for other areas). Copies of the original negatives for these maps were obtained from these agencies. Using the existing high quality maps as base maps for the atlases greatly reduced costs associated with map production and increased the quality and popularity of the atlases.

The most recent atlas for Chuuk lagoon is relying on computer aided or "digital" cartography rather than manual cartography as used in all earlier atlases. Army Map Service maps were digitized using Intergraph™ and Map Info™ based software customized by Aspect Consulting Inc. and Corial, two private firms. The atlas base maps for Chuuk lagoon have been downloaded on personal computers so that resource information, place names and symbols can be easily added. The Chuuk atlas will be produced in hard copy as with the other atlases, but will also be available on diskette for use by resource agencies and scientists having personal computers with Windows™ installed. Digital production of the Chuuk atlas has greatly reduced the cost and will revolutionize the production of future coastal resource atlases.

The coastal resource atlases have been very popular in the tropical Pacific because of the manner in which resource information is portrayed. Large scale "thematic" maps (varying between 1:6,000 to 1:25,000) are produced for each coastal segment of an island or atoll, and a variety of information and resource uses are portrayed using descriptive symbols. For example the following types of information are shown via using the resource symbols:

Sea turtle nesting and feeding areas
Cultural and historic sites
Shipwrecks
Rich coral areas
Important fish aggregation sites
Marine mammal aggregation sites
Giant clams and other clams concentrations

Mangrove crabs and coconut crabs
Lobster, octopus and shrimp grounds
Special fishing techniques
Aids to navigation
Bird nesting and feeding grounds, etc.

Traditional map symbology is also used to depict reef lines, shorelines, seagrass beds, passes, channels, mangroves, other wetlands, topography, bathymetry, place names, scales, north arrows etc.

The atlases are produced and displayed in a form useful for many scientists, planners, engineers, and resource managers. They often serve as a catalyst for additional research and development of coastal management plans in countries which have not yet embraced coastal management. Cost of the atlases varied between $50,000 to $100,000.

Rapid Ecological Assessment for the Republic of Palau

The most advanced and comprehensive of the REA's completed to date in the tropical Pacific was accomplished in 1992 for the entire archipelago of Palau. The principal sponsors of the Palau REA included the Palau National Government, the U.S. Dept. of Interior, and The Native Conservancy. All major islands, reefs, and atolls in Palau were surveyed as a part of 4 separate scientific expeditions during 1991-1992. In addition, color aerial photography was flown at scales of 1:4,000 to 1:20,000 for all islands and reefs in 1992. The photographs proved to be essential for mapping important ecosystems, selecting fields sites, and identifying polluted areas, important ecosystems, the status of construction and land clearing activities, shoreline erosion etc.

The purpose of the Palau REA was very specific- to identify the most important ecological areas in Palau so, that they could be considered for protective, status as part of a National Economic Development Master Plan process now underway. The REA reports were completed in early November 1993 and copies will be brought to the conference. Essentially the normal procedures were used to complete the REA including; review of literature, maps, interviews, aerial photography, underwater photography and videography, field work, map production and report preparation. Maps for the REA were digitized and added to the reports, substantially enhancing the value and utility of the reports. The cost of the Palau REA was about $200,000. Half of the funds were used to fly the aerial photography and reproduce the nearly 900 color aerial photo prints. Remaining funds were spent to sponsor selected consultants, cover field expenses, and report and map preparation. Most scientists agreed to participate without compensation for their time although travel and field expenses were covered. Over 180 marine sites were surveyed and together with other applied scientific surveys recently conducted, Palau's ecosystems now rank as among the best studied of the tropical Pacific countries. Information collected from the REA and other technical scientific reports will be used to complete the master plan, eventually produce a coastal resource atlas, and possibly help develop a coastal management program for Palau.

Trade-off between qualitative and quantitative scientific procedures

Experience has shown that both qualitative and quantitative studies are needed for coastal management, and that it is never a choice between one or the other. It is more a matter of phasing and a progression of scientific inquiry starting off with qualitative and extensive surveys during early "pioneering" work in coastal zones, and gradually moving to more intensive quantitative approaches to address specific questions for specific resource or sites. In most of the countries in the tropical Pacific, there is very little useful baseline information or scientific reports of value in inventorying coastal resources as part of a planned coastal management initiative. Under such circumstances it is entirely appropriate to begin with broad brush, mostly qualitative reconnaissance type surveys (such as REA) in order to get the "big picture"; for the whole coastal zone. Based upon the results of the qualitative studies, specific research questions or scientific inquiries may emerge to justify more quantitative research or experimentation; but for the most part this research is applied in nature, to be of direct value or utility in helping coastal zone managers and planners accomplish their jobs more accurately. Given the trial-and-error experience gained in the tropical Pacific, it is now possible to tailor and design large scale surveys to address specific needs for coastal management that are efficient and economical.

ECONOMIC ANALYSIS OF COASTAL ZONE DEVELOPMENT OPTIONS: LINKING ECONOMIC AND ECOLOGICAL MODELS

by

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More so than for most ecosystems, the economic analysis of tropical coastal zones requires collaboration between economists and natural scientists. Because of the pervasive nature of economic and ecological externalities, partial analysis is rarely adequate to address the problems and provide realistic policy options. The case of mangroves is particularly well known (e.g. see Hamilton and Snedaker, 1984; Hamilton, Dixon and Miller, 1989; Ruitenbeek, 1992) but other costal zone systems (and they are systems, including economic, social and ecological components) share similar attributes.

The analytical question is how to model and analyze the economic and ecological processes that determine how resources are used and how decisions are made. Over the past 15 years or so there has been an increasing amount of work on quantifying and integrating physical phenomena into economic analysis of natural systems. (We assume, perhaps naively, that social concerns are already integrated into the economic processes reflecting the perceptions of different resource users.)

A major focus of earlier work was watershed management and how one can identify and quantify the benefits and costs of different policies affecting soil use and soil erosion (see Easter, Dixon and Hufschmidt, 1986; Dixon and Hufschmidt, 1986; Doolette and Magrath, 1990). Upstream/downstream linkages and impacts were identified and quantified. The incidence of benefits and costs of different management alternatives were estimated and appropriate tax and/or subsidy programs were designed to more closely align social and private actions. Many of these approaches can be applied in the case of coastal resources.

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The Location and Valuation of Impacts

One approach that has proved quite useful for analysis of coastal zone development is a simple 2 x 2 matrix that grew out of work on mangroves. As seen in Figure 1 this matrix divides the goods and services produced by a mangrove (or any other ecosystem) into 4 quadrants depending on both the location of the good or service (on-site or off-site) and whether or not it is bought and sold in a market. Quadrant 1 goods and services are those that are usually included into an economic analysis -- they are found on-site (e.g. in the mangrove, or in the coastal zone being studied) and they are bought and sold in the market. With easily identified impacts and market prices, it is fairly straight forward to quantify the impacts.

For other quadrants the analytical process is more difficult. Quadrant 2, for example, consist of those goods and services that have market prices but are found outside of the project or study area. Off-shore fisheries that are partially dependent on the mangroves are a classic example. These resources can be identified and valued but considerable scientific work is needed to correctly identify the cause-effect link between sectors: e.g., in this case, the role of the mangrove in supporting the coastal fishery and the potential impact of destruction of the mangrove, or part of it, on the fishery. Once these relationships are identified, however, the economic analysis is not overly difficult.

Quadrants 3 and 4 pose more problems -- market prices are not readily available and there may be considerable scientific uncertainty about the links between the project and/or study site and the related off-site effects. This is particularly true for Quadrant 4 goods and services, that are often neither easily measured nor valued in monetary terms. (On-site non-marketed goods and services are usually easier to identify -- e.g. collection of medicinal plants, certain recreational uses, biodiversity benefits, and ecological services such as water filtering by a mangrove. Valuation may not be very easy, however, although some of the Quadrant 3 items, such as recreational or tourism uses, may be valued in monetary terms.)

As should be clear, this broader framework for analysis places increasing importance on understanding the physical as well as the economic systems. The use of ecological models is becoming increasingly important to the correct economic analysis of such systems. (Some of the earliest work along these lines was done in the US for the Delaware River system by scientists at Resources for the Future in Washington; see Spofford, Russell and Kelley, 1976.) Applications in developing countries have been fewer but have produced interesting results. I will cite three studies that I have either been involved with or have reasonable knowledge of: the Bacuit Bay study by Hodgson and Dixon (1988, 1992); the study of Bintuni Bay in Irian Jaya by Jack Ruitenbeek (1992), and the study of the Bonaire Marine Park by Scura and van't Hof (1993), and Dixon, Scura and van't Hof (1993).

Figure 1 **Relation between Location and Type of Mangrove Goods and Services and Traditional Economic Analysis.**

Valuation of Goods and Services		Location of Goods and Services: On-site	Location of Goods and Services: Off-site
	Marketed	**1** Usually included in an economic analysis (e.g., poles, charcoal, woodchips, mangrove crabs)	**2** May be included (e.g., fish or shellfish caught in adjacent waters)
	Nonmarketed	**3** Seldom included (e.g., medicinal uses of mangrove, domestic fuelwood, food in times of famine, nursery area for juvenile fish, feeding ground for estuarine fish and shrimp, viewing and studying wildlife)	**4** Usually ignored (e.g., nutrient flows to estuaries, buffer to storm damage)

Source: Hamilton and Snedaker, eds. (1984).

The Bacuit Bay, Palawan Study.

This study examined the links between forestry in a watershed surrounding Bacuit Bay on the island of Palawan in the Philippines, and the fishery and resort diving industry dependent on the coral reefs and fish population in the Bay. The study linked ecological models of soil erosion and sedimentation, and its impact on the reefs done by a zoologist (Hodgson) with an economic analysis (Dixon) of the implications of two differing management options - continued logging or a logging ban - on the three different resource users.
Figure 2 presents the physical model of soil erosion and ultimate impacts on the coral reef. Submodels examined the interaction between levels of sedimentation and coral cover, and coral cover and fish biomass. The economic model was a simple present value calculation of the gross revenues generated under the two scenarios (continued logging or a logging ban) and used plausible assumptions about economic outcomes based on the results of the ecological models.[6] Note that the two models were not formally or mathematically linked. The ecological model results defined the outcome scenarios for the economic analysis. There may be greater precision in the ecological models since they are based on actual observations in the affected and in control areas. The economic model, on the other hand, depended on assumptions about how individuals would react to actual changes in the coastal environment -- reasonable assumptions were made, but actual behavior can always vary greatly. In hindsight, we were half right and half wrong -- the physical damages predicated occurred, at least in certain areas, but the predicted decrease in SCUBA tourism appears not to have happened yet. Follow-up analysis is needed to reassess cause-and-effect and the assumptions in our models.

The Bintuni Bay, Irian Jaya Study.

This study, carried out by H. Jack Ruitenbeek (1992), a resource economist, developed a series of outcome scenarios for different management options for Bintuni Bay based on identification of biophysical and socioeconomic linkages between mangrove use and ecological and economic outcomes. Table 1 and Figure 3 present the hypothesized linkages between mangrove components (Table 1), and, in Figure 3, the general case and a specific example (lower land taxes) of macro-economic policy linkages.

This study used a more intuitive approach to identification and quantification of the biological linkages, but built the assumptions into the economic model. Similar to the Palawan study, the Bintuni Bay study examined a number of mangrove forest management options and evaluated them both for their direct profitability (e.g. Quadrant 1 effects) but also in terms of their impacts on other parts of the ecosystem. A series of "linkage scenarios" examined the connections between mangrove conversion (destruction) and other parts of the ecosystem: offshore fishery production, traditional uses of the mangrove, and

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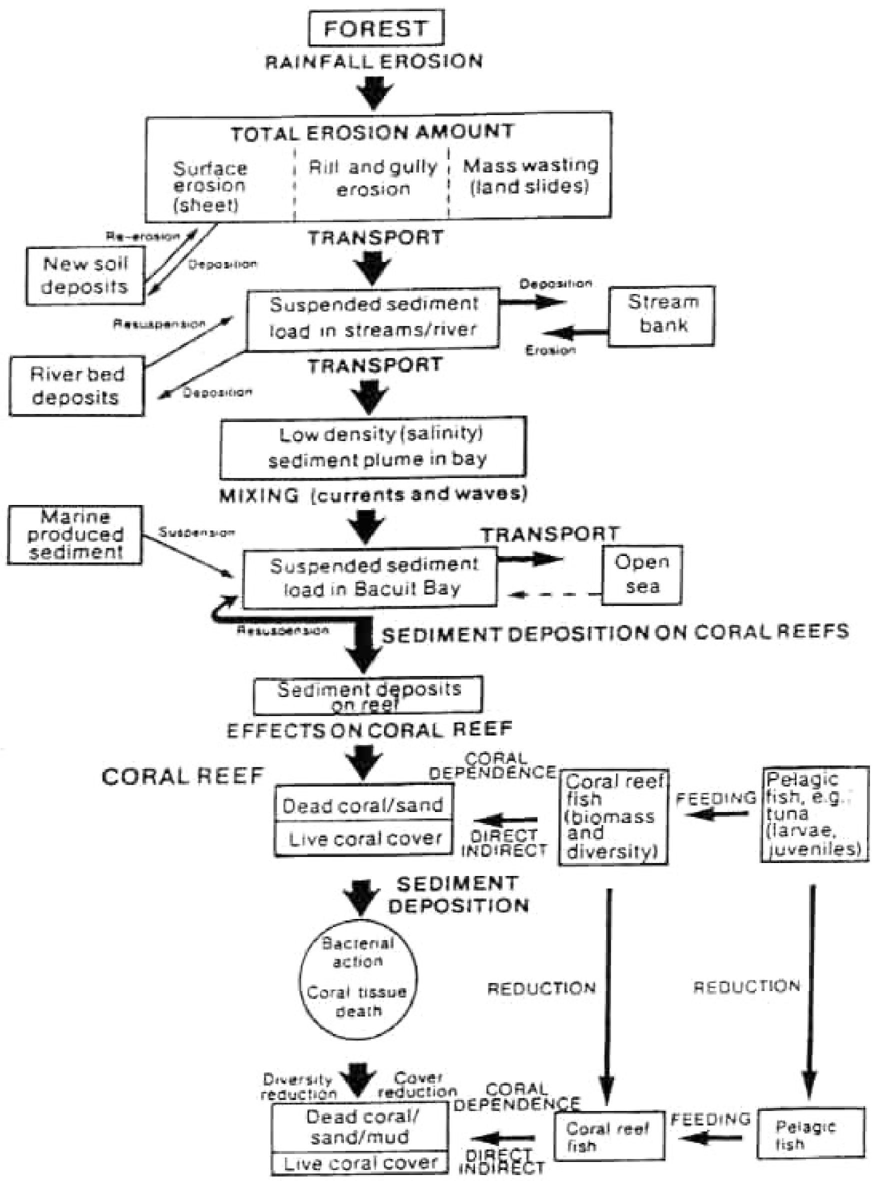
6 Note that this is not a traditional benefit-cost analysis; since it was not possible to obtain cost information from the logging firms or resort operators, we used a modified benefit approach that focussed on the generation of gross revenues under the different scenarios.

Figure 2 Soil Erosion Impact Model for Bacuit Bay, Palawan, Philippines



The predicted pathway of soil eroded from the forest floor as it passes to the sea. Note the many locations where soil can be temporarily stored and then later rejoin the transport process. Upon reaching the sea, sediment settles to the bottom. If coral reefs are present, the living corals may be damaged by sediment deposition. Since fisheries are linked to the coral directly and indirectly, they will be reduced by losses of living coral cover.

Source: Hodgon and Dixon (1988).

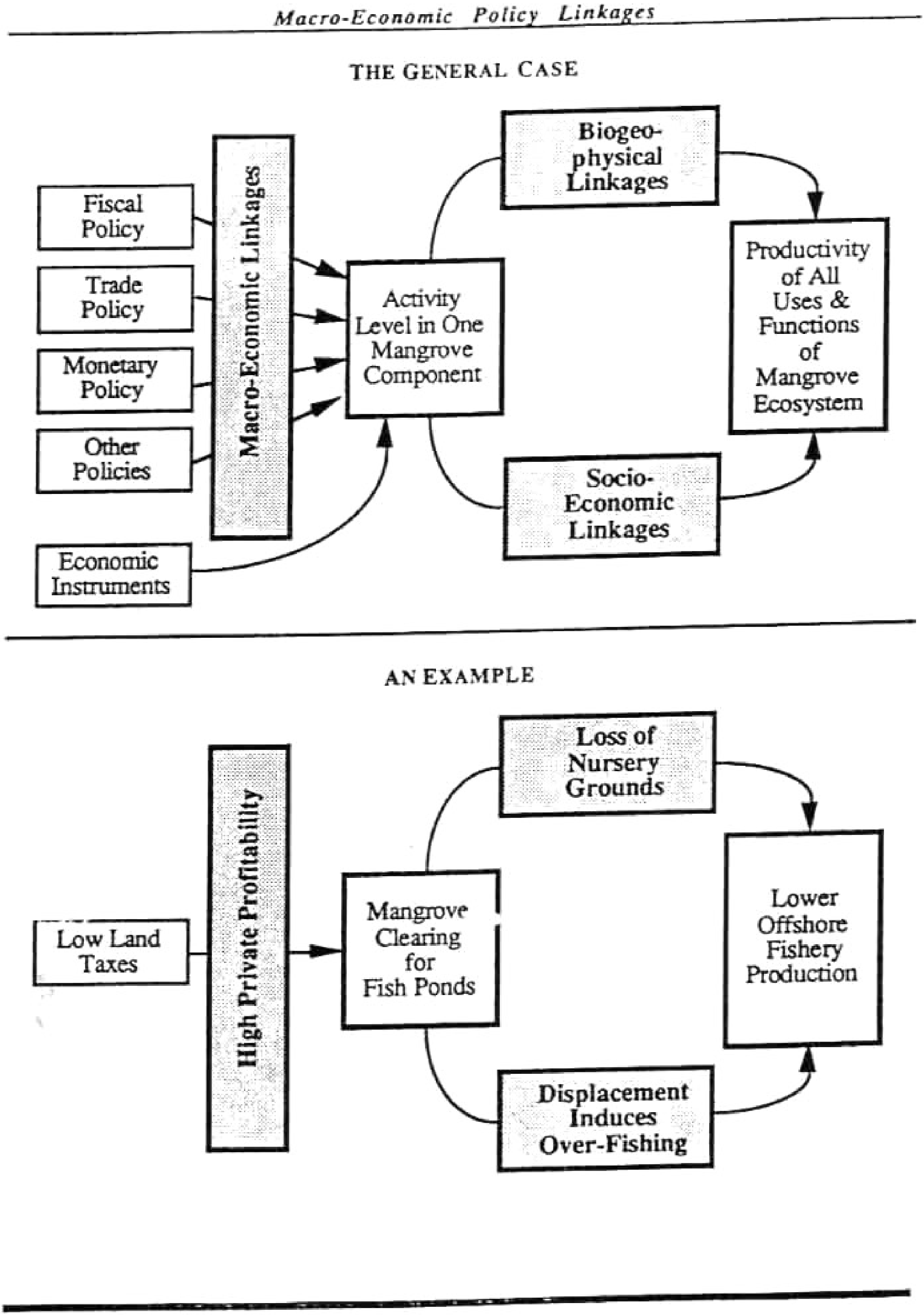
Table 1 Examples of Linkages between Mangrove Components in Bintuni Bay, Irian Jaya

Examples of Linkages between Mangrove Components

TYPE	NATURE OF IMPACT	EXAMPLE
BIOGEOPHYSICAL LINKAGES	DIRECT PRE-EMPTIVE USE	One mangrove use immediately pre-empts other use because they are incompatible uses which share same land area: Conversion to fishpond pre-empts land for sustainable wood production.
	INDIRECT PARTIAL OR DELAYED IMPACT	Activity in one component of mangrove partially affects productivity of some other system component: Conversion to fishpond increases erosion which, over a number of years, increases siltation and destroys coral reef habitat offshore.
	INDIRECT LINEAR IMPACT	Activity in one component of mangrove has immediate affect on productivity of some other system component: Conversion to fishpond destroys nursery ground and reduces offshore fishery production in proportion to lost area of mangrove.
	INDIRECT CATASTROPHIC IMPACT	Activity in one component of mangrove irreversibly destroys critical ecosystem component: Conversion to fishpond of a critical area of breeding ground causes collapse of offshore fishery.
SOCIO-ECONOMIC LINKAGES	ACTIVITY SUBSTITUTION OUTSIDE MANGROVE ECOSYSTEM	Availability of external income causes changed local use patterns of mangroves: Expanded wage economy reduces traditional reliance on mangrove harvesting.
	ACTIVITY SUBSTITUTION INSIDE MANGROVE ECOSYSTEM (ECONOMIC DISPLACEMENT)	Change in availability of one mangrove component causes local substitution for other mangrove component: Loss of onshore productivity for hunting and gathering due to mangrove conversion forces increased reliance on offshore fishing.

Source: Ruitenbeek (1992).

Figure 3 Macro-economic Policy Linkages in Bintuni Bay, Irian Jaya



Source: Ruitenbeek (1992).

the benefits of erosion control and biodiversity maintenance functions. Using a benefit-cost analysis framework, Ruitenbeek examined the economic sensitivity of the results to delayed ecosystem linkages, and identified a scenario with a 25% conversion (with linear but delayed linkages of 5 years) as the optimal management strategy. This study used social welfare, and the generation of net economic benefits, as the criterion for selection.

The Bonaire Marine Park Study.

The Bonaire Marine Park study, like the Palawan study, benefitted from having both natural scientists (van't Hof) and economists (Scura and Dixon) involved. The question posed was the following: What level of SCUBA diving within the marine park was compatible with the twin goals of resource conservation (an ecological goal), and revenue generation (the economic goal). The study used a combination of ecological and economic research to answer these two questions. van't Hof carried out extensive underwater photographic surveys to identify the extent and cause of reef damage from diver use. He was able to identify a relationship between diving intensity and coral cover and coral diversity, and a stress threshold level (represented graphically in Figure 4).

This information was then linked to the economic analysis of the generation of revenues by diving tourism, and the potentials for both increasing revenues per diver as well as increasing the number of divers over time. Again, the two models were not formally linked, but provided a critical connection between the economic and ecological analysis. This linking is seen in Figure 5: the potential for increasing diver use (and revenues) while respecting ecological limits of the marine ecosystem (a carrying-capacity type argument) is dependent on both improved park management (movement from level A to level B), and diver education to reduce the impact of each additional dive (a shift from line ON to line ON'), thereby allowing increased diver use and revenue generation.

We hope in the next few months to develop a dynamic economic model that explicitly links the ecological constraints to selected economic goals: the model will maximize income subject to reef stress threshold levels and consider the use of different fee or tax systems to balance income with stress. The general case will consider Bonaire as one site, and the disaggregated model will allow diver switching between the 86 dive sites theoretically possible.

Lessons from Linking Ecological and Economic Models

A number of lessons can be drawn from this review of some limited attempts to combine formal economic and ecological models of coastal resource development.

First, the results justify the effort required to work interdisciplinarily. It is never easy to work with other disciplines; the richness and reality of the results that can be obtained when this link is made, however, fully justifies the expense and effort required in the case of coastal resource management.

Figure 4 Relationship between Coral Cover, Species Diversity, and Stress in the Bonaire Marine Park.

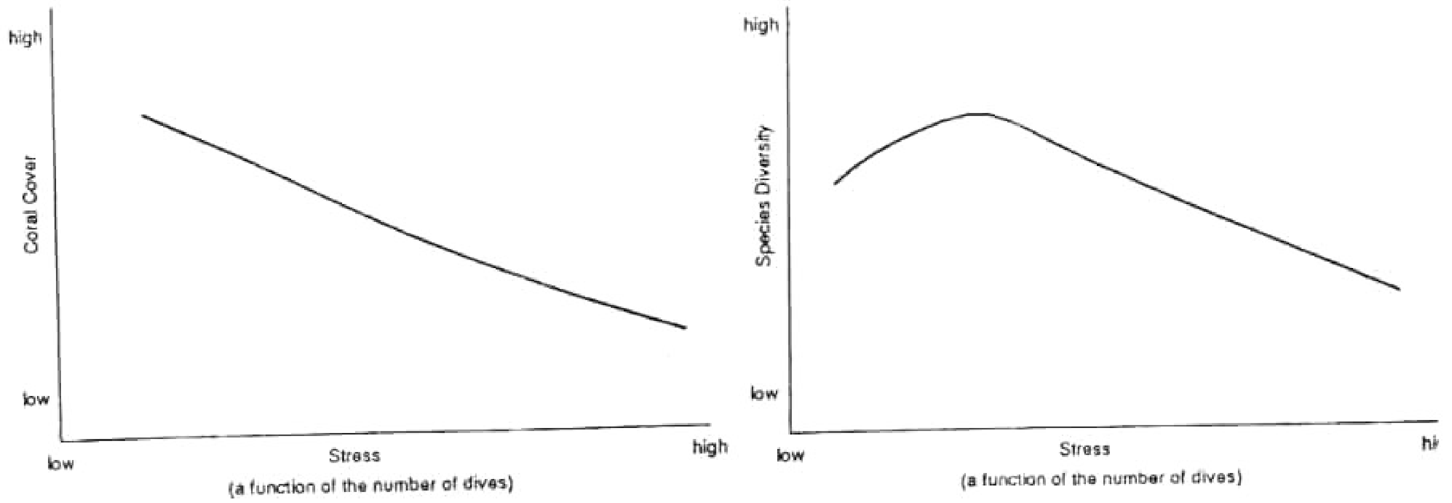
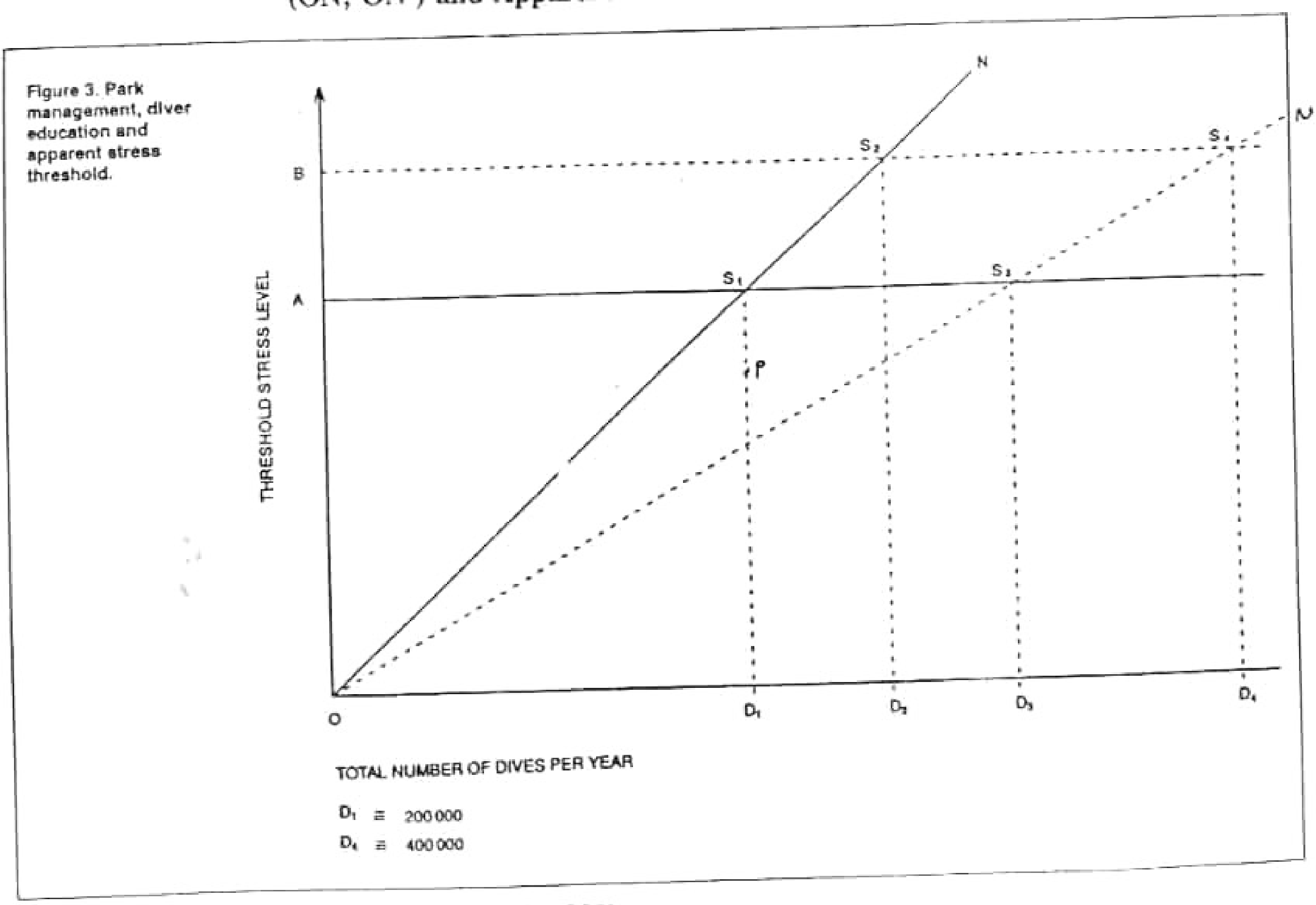


Figure 5 **Relationship between Park Management Levels (A, B), Diver Education (ON, ON') and Apparent Stress Threshold in the Bonaire Marine Park.**



Source: Dixon, Scura, van't Hof (1993).

Economic analysis without the ecological checks can easily lead to unrealistic maximizing without realizing the important, and sensitive ecological links between different components of the system. Similarly, ecological analysis without the economic dimension usually leads to unrealistic policy prescriptions that ignore the pressing economic reasons that lead to resource degradation, and that must be addressed if pareto improvements are to be obtained.

Second, a high degree of uncertainty will remain. The combining of both economic and ecological models, both of which have numerous assumptions and uncertainties in them, only increases the level of overall system uncertainty. This means that sensitivity analysis is very important, and that all assumptions should be clearly laid out so that others can examine and question the underlying assumptions.

Third, there has been very limited progress to date in formally linking ecological and economic models. This result is not unexpected, and should not discourage researchers in this area. It merely points out the difficulty in formally linking two quite different analytical approaches. As more is learned, and as economists and natural scientists become more comfortable working together, one expects that more formally linked economic/ecological models will be developed, and hopefully the robustness of the economic predictions will increase. This should be a "growth industry" that promises to yield exciting results.

Finally, economic valuation techniques can increasingly be used to value many goods and services found in the coastal zone, but many others will have to continue to be handled qualitatively. As seen earlier, those goods and services that are physically measurable and that have market prices associated with them are readily handled in the economic analysis. Even recreational and tourism benefits are increasingly being measured by the use of selected valuation techniques including the travel cost approach, and the various survey-based approaches collectively referred to as contingent-valuation methods (CVM).

Biodiversity benefits, however, are poorly handled by economic analysis and diffuse ecosystem maintenance benefits are similarly difficult to value. Fortunately these can be addressed by other means, including the use of safe-minimum standards (SMS) and either cost-effectiveness analysis or least-cost analysis to evaluate different ways to preserve or protect important natural resources.

The possibilities for future work in the broad area of integrated quantitative analysis of tropical coastal zone management are exciting. The basic approaches are known, and there is a wealth of technical expertise available. What is needed is increased efforts to work across disciplines and design research efforts that draw on the disciplinary strengths that exist, but that also build on the synergies possible when work is done across disciplines.

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