THE CONCEPT OF INTEGRATED MANGROVE RESEARCH AS A TOOL FOR THE DEVELOPMENT OF MANAGEMENT STRATEGIES

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ABSTRACT *Mangroves and mangrove ecosystems are often regarded as wastelands of little or no value. In many places of the world mangroves increased their value when converted to shrimp ponds. This approach however is based on a failure to recognize the natural values of mangrove ecosystems that are expressed as a variety of products and services. The value of the mangrove resources in terms of its marketed products can be expressed in economics terms. Other services such as storm protection, erosion control, wastewater cleanup and a variety of educational and leisure activities are more difficult to measure. Integrated coastal zone management project however try to consider the economic and social well-being of coastal communities and its many economic regional and national activities that are dependent on the continued viability of mangrove ecosystems.*

The nature of the material transported to the coastal environment is controlled by the landscape and the biogeochemical processes that take place at the land-sea interface. Such external processes are responsible for the maintenance and renewing of mangroves. Another often stated reason for rehabilitating mangrove ecosystems is its importance to coastal fisheries. There is still a significant lack of well establishes quantified relationships between fish yields and area of mangrove. To answer these questions the integration of economic and physical/ecological studies are essential in order to estimate changes in value associated with specific environmental changes. The joint German/Brazilian project on Mangrove Dynamics and Management (MADAM) is an integrated concept to study the scientific basis for a multipurpose use of the system without sacrificing ecosystem integrity. Given adequate knowledge of what the resource consists of, how it is currently being used, and what the future demands are likely to be, rational management of the resource can be undertaken within the context of national land-use planning.

1. General Goals

1.1. Mangrove characteristics:

Mangroves and mangrove ecosystems have been studied extensively but remain poorly understood. With continuing degradation and destruction of mangroves, there is a critical need to understand them better. Aspects of mangrove biology have been treated in several recent reviews. Tomlinson

(1986) described the basic botany of mangroves. Snedaker and Snedaker (1984) reviewed earlier mangrove research and made recommendations for further research. An overview of tropical mangrove community ecology, based primarily on Australian work, can be found in Robertson and Alongi (1992). Li and Lee (1997) reviewed many Chinese mangrove literatures published between 1950 and 1995. Schwamborn and Saint-Paul (1996) and Ellison and Farnsworth (2000) have recently published a general review of mangrove ecology.

Mangroves are distributed circumtropically, occurring in 112 countries and territories. Global coverage has been variously estimated at 10 million hectares (Bunt, 1992), 14-15 million hectares (Schwamborn and Saint-Paul, 1996), and 24 million hectares (Twilley *et al.*, 1992). Spalding (1997) gave a recent estimate of over 18 million hectares, with 41.4% in South and Southeast Asia and an additional 23.5% in Indonesia. Mangroves are largely restricted to latitudes between 30^0 north and 30^0 south. Northern extensions of this limit occur in Japan ($31^0$22'N) and Bermuda ($32^0$20'N); southern extensions are in New Zealand ($38^0$03'S), Australia ($38^0$45'S) and on the east coast of South Africa ($32^0$59'S) (Spalding, 1997; Yang *et al.*, 1997).

Mangrove distributions within their ranges are strongly affected by temperature (Duke, 1992) and moisture (Saenger and Snedaker, 1993). Large-scale currents may also influence distributions by preventing propagules from reaching some areas (de Lange and de Lange, 1994). Individual mangrove species differ in the length of time that their propagules remain viable, in their establishment success, in their growth rate, and in their tolerance limits. These factors, which appear quite consistent around the world, interact to produce characteristic distribution ranges for most species (Duke *et al.*, 1998).

Mangroves are salt-tolerant forest ecosystems that grow at the interface between land and sea in tropical and sub-tropical latitudes where they exist in conditions of high salinity, extreme tides, strong winds, high temperatures and muddy, anaerobic soils. There may be no other group of plants with such highly developed morphological and physiological adaptations to extreme conditions.

Because of their environment, mangroves are necessarily tolerant of high salt levels and have mechanisms to take up water despite strong osmotic potentials. Some also take up salts, but excrete them through specialized glands in the leaves. Others transfer salts into senescent leaves or store them in the bark or the wood. Still others simply become increasingly conservative in their water use as water salinity increases. Morphological specializations include profuse lateral roots that anchor the trees in the loose sediments, exposed aerial roots for gas exchange and viviparous water-dispersed propagules.

Mangroves create unique ecological environments that host rich assemblages of species. The muddy or

sandy sediments of the mangal are home to a variety of epibenthic, infaunal, and meiofaunal invertebrates. Channels within the mangal support communities of phytoplankton, zooplankton, and fish. The mangal may play a special role as nursery habitat for juveniles of fish whose adults occupy other habitats (e.g., coral reefs and seagrass-beds).

Because loose sediments surround them, the submerged mangroves roots, trunks, and branches are islands of habitat that may attract rich epifaunal communities including bacteria, fungi, macroalgae, and invertebrates. The aerial roots, trunks, leaves and branches host other groups of organisms. A number of crab species live among the roots, on the trunks or even forage in the canopy. Insects, reptiles, amphibians, birds and mammals thrive in the habitat and contribute to its unique character.

1.2. Use of mangroves:

The uses of mangroves fall into two categories, firstly the use of the mangrove ecosystem as a whole or its conversion to other uses, and secondly, the use of products from the mangrove ecosystem.

Ecologically mangroves are important in maintaining and building the soil, as a reservoir in the tertiary assimilation of waste, and in the global cycle of carbon dioxide, nitrogen, and sulfur. The protection against cyclones is a "free" benefit. Yet hidden benefits from mangroves, especially in marginal areas, may even be more important than the obvious ones. They play a significant role in coastal stabilization and promoting land accretion, fixation of mud banks, dissipation of winds, tidal and wave energy.

Transplanting salt marsh vegetation is an alternative erosion control method which is relatively inexpensive and proven to be effective on some shorelines. The aerial plant parts dissipate waves, act as a living groin by accumulating sediment and the tough mat of roots and rhizomes stabilizes the substrate. They trap sediments and thus contribute to land building and prevent excessive shifting of coastline sand. These so formed beaches are material to a relatively recent commercial use of recreation and ecotourism.

The uses of mangroves are many and varied. A fundamental function of all forests has been to supply timber for cooking, heating and constructing dwellings, and mangrove forests are no exception (Watson, 1928; FAO, 1982). Traditionally, people have used mangroves for the benefit of the local community, but increasing populations have led to an increasing non-sustainable abuse of the resources.

Mangroves have been exploited for timber for building dwellings and boats and fuel-wood for cooking and heating. Palm species are used, especially in Southeast Asia and Brazil, to construct jetties and other submerged structures because they are resistant to rot and to attack by fungi and borers. *Rhizophora* and, to a lesser extent, *Avicennia* woods have a high calorific value and are excellent fuels for the boilers of trains in Pakistan. In Indonesia, commercial exploitation of

mangroves for charcoal is reported from 1887. In Central America, the direct use for charcoal production and the extraction of tannin has been responsible for large-scale mangrove removal and degradation. Large-scale conversion of mangroves for wood chip production began in East Malaysia and Indonesia during the 1970s. Mangrove wood chips are still a major export from Kalimantan.

Mangroves are used in flavoring agents, textiles, mats, paper, housing, baskets, boats and tapa cloth and also used as staple food.

In Malaysia, where mangroves occur in profusion, an important cottage industry is the manufacture of shingles for roof thatching from the fronds of *Nypa fruticans*. Basketry, corks and floats are obtained from the pneumatophores. *R. apiculata* has been exported from the Philippines to various parts of the world for utilization in the textile industry and extracts of stilt roots exhibited mosquito larvicidal activity. In Sri Lanka, *Cerebera manghas* is used in making masks for many traditional cultural activities. Pulp for paper, matchsticks, household utensils, agricultural implements and toys are some other products produced from mangroves. In Japan, propagules of *Rhizophora* and *Bruguiera* are planted in pots and make good decorations when germinated.

The tender leaves of *Acrostichum*, the hypocotyls of *Bruguiera*, are the staple food of some Papua New Guineans. Leaves of *Osbornia octodonata* are flavouring agents. Fibres, mats, paper and tapa cloth are products of *Hibiscus tiliaceus*, *Thespesia populnea* and *Pandanus* spp.

A local industry in the Sundarbans of Bangladesh and India is the production of honey and, in Bangladesh, a large number of people including wood and thatch cutters, honey and wax collectors and fishermen are directly dependent on the mangroves. Fruits of *Avicennia marina* are universally used as vegetables. The fruits of *Kandelia candel* and *Bruguiera gymnorrhiza* contain starch and if sliced, soaked in water to rinse out tannins and then ground to a paste can make excellent cakes.

The indigenous people of Australia and Sri Lanka use extracts from mangrove plants as valuable sources of dyes. "Sagu" is taken from the mangrove palm tree *Metroxylon sagu* found in Southeast Asia where the hypocotyts of *Bruguiera* are also an accepted food item. Intoxicating drinks are made from the sap of the "coconut" of *Nypa* and *Borassus*. The common *Nypa* plant, in addition to sugar, provides a diversity of products, including thatch from the leaves and alcohol and vinegar obtained by distillation of the fermented sugary phloem sap. Cooking oil and cigarette wrappers are also products obtained from many species of mangroves. Extracts of the heartwood of *A. alba* and *A. officinalis* have tonic properties. It is reported that some mangrove plants and extracts are used as incense, perfumes, hair preservatives, condiments and aphrodisiacs. Edible

jelly and a kind of salt are made from the ashed leaflets.

Among the coastal lagoons along the West Coast of Africa, the villagers produce salt by using a technique of boiling brackish water placed in a clay bowl over a fire made from *Avicennia*. On the west coast of Sri Lanka twigs and branches, mainly of *R. mucronata*, *R. apiculata* and *Lumnitzera racemosa*, are used to form "brush piles" or "brush parks" in a specially devised fishing method. The gathering of mangrove leaves (e.g. *Suaeda* and *Porteresia*) for animal fodder remains widespread in the Near East and South Asia, and for feeding camels in Iran and India. To a limited degree, the indigenous people of Australia and Sri Lanka use extracts from mangrove plants as valuable sources of dyes.

The importance of bark tannins has declined in many Asian countries, but mangrove tannin is still used in India and Bangladesh for leather curing. In Sri Lanka tannin is used traditionally in curing fishnets. The tannins comprise two groups of phenolic constituents, hydrolysable and condensed, which are important economically as agents for the synthesis of certain medicines.

Their potential value as cytotoxic and/or antineoplastic agents and as antimicrobial agents has been demonstrated. Mangrove plants are rich sources of saponins, alkaloids and flavonoids. Plant saponins have been shown to have interesting biological activities such as spermicidal and molluscicidal activity. The extraction of natural chemical compounds, in addition to those already known to the pharmacopoeia of the people, continues to this day and among the latest additions are an array of substances from glues to alkaloids and saponins and many other substances of interest to modern industry and medicine.

An alternative source of wealth in the mangroves is the exploitation of the fish, mollusks and crustaceans, which are abundant in mangrove areas. In Vietnam, farmers complement their income by collecting and sorting shells from the mangrove mud flats. The exploitation and value of aquatic products from mangrove ecosystems is of great significance today.

Use of mangroves as natural sewage-treatment plants has been considered. Mangroves trap sediments and so contribute to land building, preventing erosion and excessive shifting of coastlines.

A relatively recent commercial use of mangroves is for recreation and ecotourism. In Australia, mangrove habitats play a significant role in programs of conservation, recreation and researching methods of establishing nature reserves, sanctuaries, national parks and biosphere reserves.

1.3. Mangrove destruction:

Living at the interface between land and sea, mangroves are well adapted to deal with natural stressors (e.g., temperature, salinity, anoxia, UV). However, because they live close to their tolerance limits, they may be particularly sensitive to disturbances like those created by human activities. Because of their proximity to

population centers, mangals have historically been favored sites for sewage disposal. Industrial effluents have contributed to heavy metal contamination in the sediments. Oil from spills and from petroleum production has flowed into many mangals. These influences have had significant negative effects on the mangroves.

Habitat destruction through human encroachment has been the primary cause of mangrove loss. Diversion of freshwater for irrigation and land reclamation has destroyed extensive mangrove forests. In the past several decades, numerous tracts of mangrove have been converted for aquaculture, fundamentally altering the nature of the habitat. Measurements reveal alarming levels of mangrove destruction. Some estimates put global loss rates at one million ha per year, with mangroves in some regions in danger of complete collapse. Heavy historical exploitation of mangroves has left many remaining habitats severely damaged.

These impacts are likely to continue, and worsen, as human populations expand further into the mangals. In regions where mangrove removal has produced significant environmental problems, efforts are underway to launch mangrove agroforestry and agriculture projects. Mangrove systems require intensive care to save threatened areas. So far, conservation and management efforts lag behind the destruction; and there is still much to learn about proper management and sustainable harvesting of mangrove forests.

2. Perspectives for MADAM III

Superficially, the gross physiognomy of mangrove forests appears no different than other low-elevation tropical forests in similar climates. Mangroves however, are adapted to very different habitat conditions, including but not limited to sediment anoxia, salinity, a marine-tide drives hydrology help to create a high dynamic geomorphic setting. Each of these factors also acts as stressors that modify forest dynamics. To achieve a better understanding of its dynamics, research during MADAM III should continue to focus on both short-term and long-term processes. As mangrove forest dynamics operate on different temporal and spatial scales, advances techniques in remote sensing in combination with the further development of the forest model KiWi are considered to be the principal tool that integrates diverse research interests and supports decisions for management tools.

The MADAM project has analyzed during the last two periods the relationship between the rural population in the Caeté Bay and the mangrove ecosystem (Fig. 1). An extended interim reports, annexed to the present proposal, has been presented summarizing the principal results of MADAM I and II. From the results it is possible to conclude that preservation of mangrove ecosystems in the region is fundamental to the maintenance of the household's quality

of life. Over recent decades, this forest system has been increasingly exploited. Unfortunately, not enough is known whether the use of mangrove resources in the study area is sustainable. The use of those resources has been taking place for many generations and yet, there are indications that some mangrove products have decreased in number and size. The mangroves provide the subsistence products for nutrition, housing and fuel, as well as commercial products from which income is generated for the rural population of the Bragança municipality. In some cases the subsistence income is higher than the commercial income, indicating a strong connection between the population and the ecosystem. Therefore mangroves are a strong factor in poverty alleviation. The reduction of mangrove area can result in significant economic loss for the local households, which lack any other income source. Impacts of global change and sea-level rise on coastal areas are still unknown.

Despite these now more recognized benefits and their curious attributes, mangroves are facing destruction by a growing amount and variety of human activities, not only specifically in the Bragança area, but also worldwide. This is why we are convinced that MADAM results are of importance for and transferable to other mangrove areas around the tropics. Detailed knowledge on past sea-level changes during glacial and Holocene periods may help in understanding future alterations. However, a sensible coastal area management plan is only possible if based on scientific data.

In its third phase MADAM will focus consequently on fisheries economy and the development of management strategies for a sustainable resource management.

The Handbook of Mangrove Area Management published by Hamilton and Snedaker (1984) outlines management priorities as follows:

- To prevent further destruction of mangroves by halting all unjustifiable conversation activities.
- To provide for traditional and contemporary human needs while ensuring that the diversity of plant and animal life is adequately protected.
- To manage mangroves as a renewable resource on a sustainable-use basis for direct and indirect products as well as the free environmental services they provide.
- To view mangroves as an integral part of the coastal zone rather than as an ecosystem surviving in isolation. Decisions concerning the use of mangroves should be made in the context of their dependence on the adjacent water catchments land use and their important interrelationships with adjoining coastal waters and any associated tidal marshes, sea grass beds, and coral reefs.

Consequently MADAM will focus during its third phase on the following two focal subjects, which are supplemented by activities of overall

interest, such as communication and data bank management

- Synoptic analysis of the surface structures on both a local and a regional level.
- Natural resource management and its linkages to natural, economic, and social systems with special emphasis on *Ucides cordatus*, the mangrove's outstanding resource.

The projects related to the first focus area are presented in two chapters one dealing with "Analysis of mangrove forest dynamics" and the other one with the " Influence on inundation regime on systems features". The chapters 3.3 and 3.4 are dealing with aspects of resource management with special emphasis on crabs and fish.

Additional so called associated projects are summarized in a special chapter.

An interdisciplinary overview of the network is given in figure 2 and 3.

Each sub-project will be linked to these networks and will help to create a better understanding of the complex interrelationships between natural and anthropogenically influenced parameters in regional ecosystems, and to make recommendations for safeguarding and improving the quality of life for the Bragança population on the basis of the knowledge gained.

Development is rarely encapsulated by a single problem fitting nicely into one of the disciplinary boxes that have emerged from the academic division of labor. Technological innovations require functioning markets and a favourable legal and political environment. Introducing new forms of governance may create subtle economic and budgetary consequences or lead to long-term natural resource degradation. And finally an economically efficient mode of allocating natural resources through carefully introduced market mechanisms may entail political costs too high to make the option feasible.

Environmental research geared toward these goals can only be successful and deliver sustainable results if it is conduced in a multidisciplinary fashion in accordance with state of the art technology. A central focus of integrated environmental research is the often very complex issue of trying to come up with a solution suitable for both "partners" on the earth: the environment and humankind. This does not mean necessarily that such project have to focus on crosscutting interdisciplinary themes. Especially on tropical issues, in both terrestrial and marine environments, there is still a significant lack of basic knowledge.

By the end of MADAM III detailed knowledge of mangrove structure and dynamics and its resources will be available and can be used for the development of a mangrove management plan with the general objective to conserve the mangrove resource in a sustainable way for maximum benefit to humans. Experts of the MADAM project together with the users and the decision makers in administration and policy have to develop the plan while

the implementation has to be done by Brazilian authorities.

3. German/Brazilian cooperation in the Bragança region

MADAM was planned and has been executed since its beginning as an integrated project and stands therefore for mangrove dynamics and management. As mangroves are not isolated ecosystems but are strongly linked to the region and its population on a social, cultural, economic, and ecological level, other activities on the field of scientific, technical and financial cooperation have to be considered for ongoing planning activities.

Following an overview is given on cooperation projects in rural Pará, and their specific objectives are outlined. Their linkages are visualized graphically.

3.1. PRORENDA (Programa de Renda Familiar):

Smallholder families are driven into a vicious circle of environmental destruction and poverty by their economic weakness and by an insufficient access to technical knowledge of agriculture. In response, these families migrate to the forest borders and to the rapidly growing slums of the Amazonian cities or try their luck as Garimpeiros (gold diggers who work under very primitive conditions). These problems are characteristic of the situation in the Northeast of Pará. The state offers agricultural credits, but the smallholder businesses carry a substantial risk, since neither the ecological sustainability of the cultivation of new crops nor their future markets are ensured. Additionally, the existing smallholder cooperations are badly organized and relatively isolated.

GTZ supports the PRORENDA program through the GFA to reduce poverty and promote self-help in urban and rural areas. This program promotes self-help initiatives among small farmers, micro-entrepreneurs, and low-income inhabitants of urban fringe areas.

The project purpose is to implement a sustainable increase of profits for smallholder enterprises in several regions of Pará. The project is implemented by the state government of Pará, represented by the Ministry of Planning and Agriculture, research institutes and many NGOs and trade unions. For this purpose, they will establish a Project Council. The implementation will be supported through GTZ experts. The consultation focuses on state entities in the agricultural sector, which are to be qualified to provide better services for smallholder families.

The overall goal in this context is to improve the living conditions of these families through the development of sustainable methods of cultivation. PRORENDA is designed as a pilot program and as an associated bilateral project within the planned PP-G7 sub-program “Rehabilitation of Degraded Soils".

Target group for this Project are the smallholder family businesses in the Northeast of Pará, in the five municipalities Bragança, Capanema,

Ourém, Peixe Boi and Nova Timboteua. These families typically have access to 25-100 ha of land, of which only 1-3 ha are planted with so called "white" crop (manioc, corn, rice, beans). The share of women in the production process is usually very high.

The Project is connected with the following projects and initiatives:

- University of Gottingen collaborates with the Brazilian Agricultural Research Corporation EMBRAPA / CPATU;
- Project POEMA, connected with the federal university UFPa;
- A number of NGOs;
- German Volunteer Service (DED) supports its partner (NGO FASE)
- MADAM project for the Bragança area

3.2. PP/G7 (Pilot programme):

The destruction of the Amazonian rain forest has generally led to an international discussion concerning sustainable development and protection measures. The German government is participating through the International Pilot Programme for Preserving the Tropical Rain Forest in Brazil, which was begun after the 1992 World Environmental Summit in Rio. The objective of this programme is to sustainably preserve the rain forest from the continuing process of destruction while at the same time formulating appropriate use concepts together with local population groups.

3.3.PD/A(Projetos Demonstrativos tipo A):

The project purpose is to support local communities in the Amazon and the Mata Atlântica region in their research and development of innovative models for sustainable development and conservation of natural resources. It will support their capacity to develop, test and communicate innovative methods for a sustainable use of resources. Trade unions of smallholders and fishers, small cooperatives, indigenous representations and church-initiatives are examples of groups that are increasingly interested in environmental topics and a sustainable use of resources. At the moment, there is a need for information on small-scale projects successfully implemented by NGOs, community groups, and state entities, which could be adopted by other institutions.

The target group, which is directly affected by the project are NGOs, community groups and state entities in both regions. These are supported in their implementation of individual environmental measures through information and financing. The indirect target group is the general population which is to participate in these measures and which is directly affected by them.

Main objectives of the PD/A "Água e mangue: manejo e desenvolvimento agro-pesqueiro do estuário do rio Caeté" linked to the MADAM program are:

- to determine the fishing methods to be used to guarantee ecological and economic sustainability of fishery.
- to develop pilot experiences of alternative income sources in order

to reduce pressure on natural fish stocks in danger of overexploitation.
- to create instruments like local associations for general discussion, conflict management, and decision-making.
- to improve environmental awareness of the local communities in order to foster ecological issues for regional development aiming at an integrated and participatory administration.

3.4. FASE (Federação de Órgãos para Assistência Social e Educacional):

The regional program *Amazonia* supports the sustainable use of natural resources by advising and training small-scale farmers in methods of locally appropriate farming techniques thus improving their income. Farmers will be organized to improve their influence on local policy and decision-making.

FASE consultants (DED) are involved in projects such as sustainable forest-management, agro-forestry systems, commercialization of agricultural and forest products (Wood and non-timber-products), or land tenure conflicts.

3.5. Technical, financial and scientific cooperation linkages for Bragança region:

The most substantial cooperation exists between the research project MADAM and the GTZ-project PRORENDA Rural Pará in the context of a demonstrative project (PD/A) in Bragança focusing on aquatic resource management. An overview is given in Fig. 4.

In addition to the above-mentioned cooperation, MADAM is additionally supported by the following agencies:

- The Brazilian partners were recommended by the Brazilian Research Council (CNPq) for an integrated project (*Nucléo de Estudos Costeiros*) to create a "Center on Integrated Coastal Studies" at Bragança coordinated by Horacio Schneider. Several other universities and research institutions are cooperating. This is the only project from north Brazil being approved in this CNPq millennium edition.
- Victoria Isaac is participant of a second CNPq Millennium award on "Use and Management of Coastal Living Resources", coordinated by Jorge Pablo Castello from the FURG. Several other universities and research institutions are cooperating.
- Both projects are strongly linked to the MADAM project with the participation of scientists from both countries.
- The Brazilian Research Council (CNPq) is supporting the Brazilian scientist with mobility funds and research grant for scientists, students of all levels and technicians.
- The responsibility of the International Bureau is to support the German Federal Ministry for Education and Research (BMBF) in the international cooperation in the fields of education, scientific research and technological

development. For the MADAM project the International Bureau provides mobility funds for scientists and a very restricted funding for some low cost equipment.

- The German Agency for Academic Exchange (DAAD) is granting several Brazilian Ph.D. students.
- UNESCO financed part of the field work of a study on "Understanding, modeling and valuing the linkages between local communities and the mangroves of the Caeté River Bay (PA-Brazil)".
- The Seidel foundation is granting the Ph.D. thesis on "Foraging ecology and habitat use of wading birds and shorebirds in the mangrove ecosystem of the Caéte Bay, north-east Pará, Brazil".

This survey shows clearly, that since the beginning with initial funding restricted to the BMBF and the CNPq during the first phase a significant amount of additional funding was acquired. Especially the CNPq support through the Millennium Edition will help to establish a *Center of Excellence on Integrated Coastal Research* in the North of Brazil. This, together with the recently established master and Ph.D. program at the UFPa nucleus in Bragança, will help to turn out Bragança to an internationally recognized competence center in the field of marine tropical ecology for both scientists and students.

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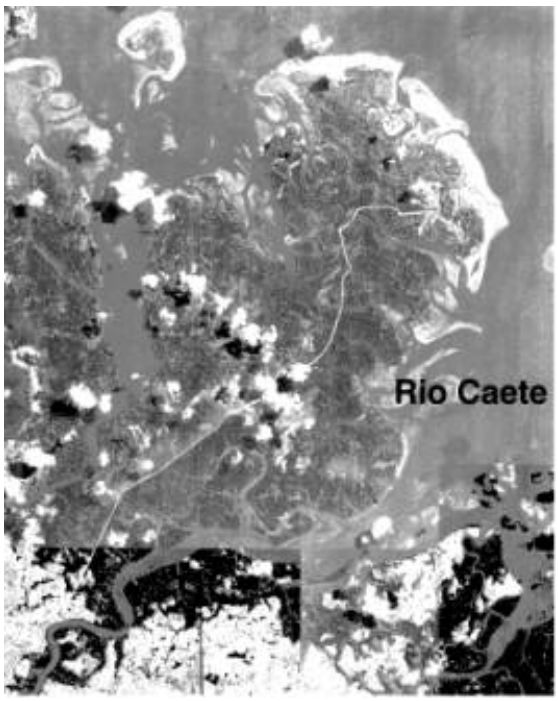

Fig. 1: **Research area of the MADAM project, the Bragança peninsula**

Which factors and processes determine the vegetation structure of a mangrove forest?

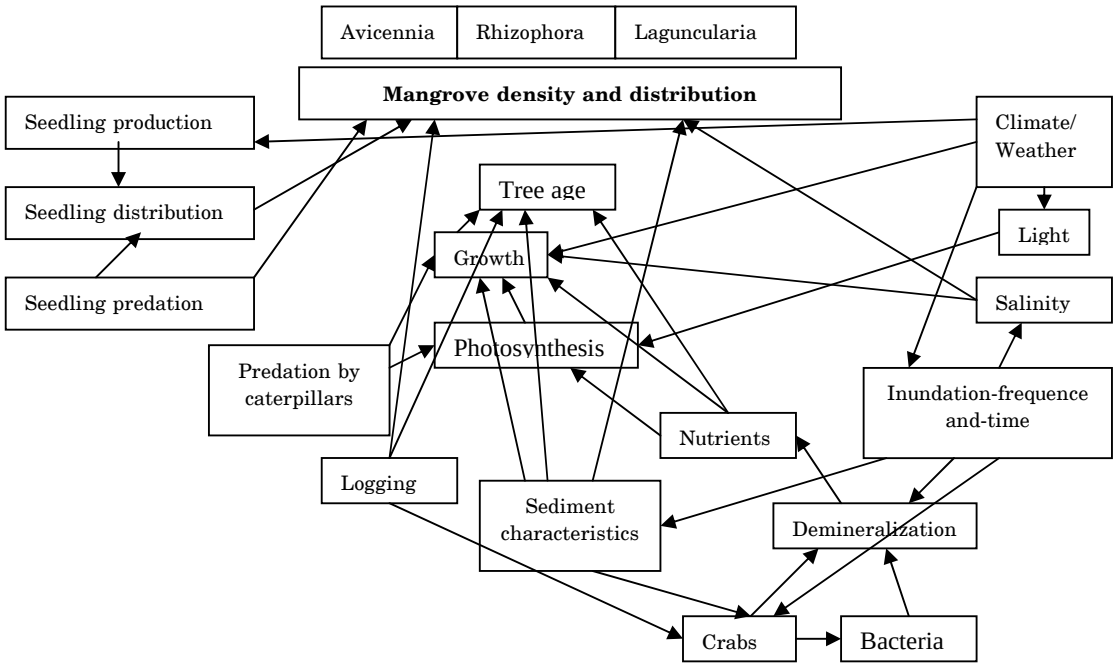

Fig. 2: **Causal diagram for mangrove density and distribution**

Which factors and processes are of importance for a sustainable management of *Ucides cordatus*?

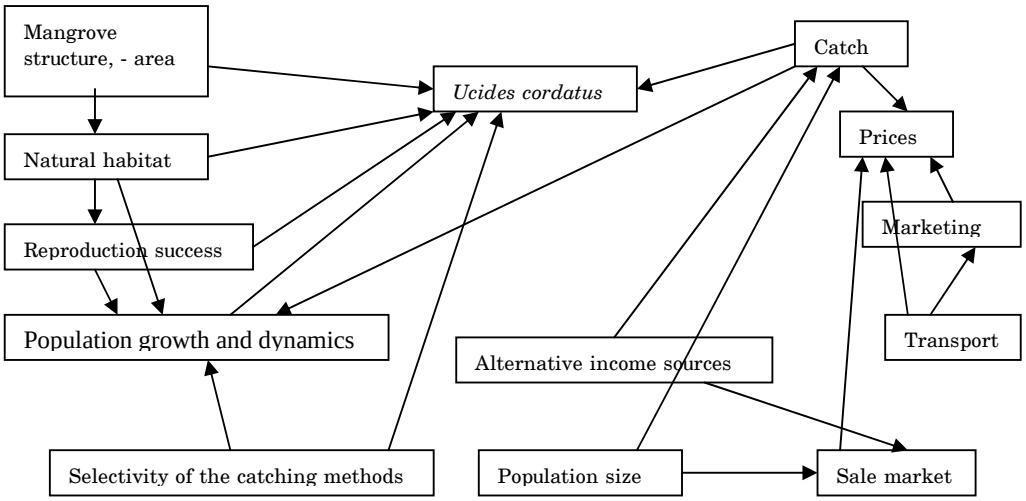

Fig. 3: **Causal diagram for *Ucides cordatus***

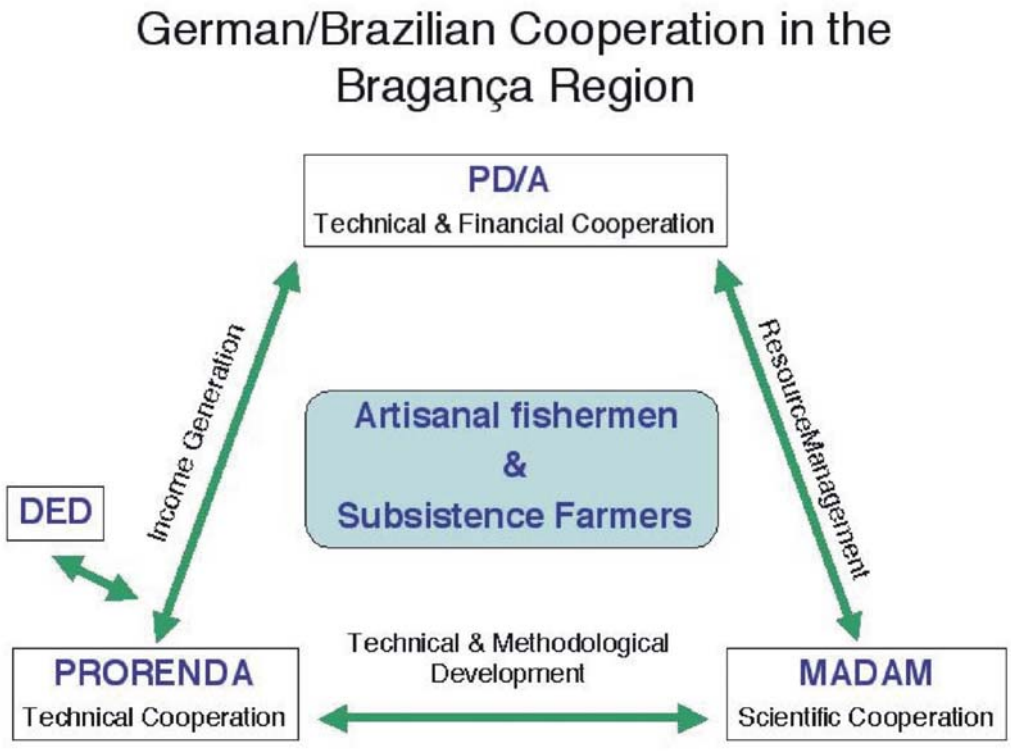

Fig. 4: **Linkages between technical, financial and scientific cooperation in the Bragança region**