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LARGE MARINE ECOSYSTEMS CONCEPT APPLIED TO MANAGING OFFSHORE ZONES AND MARINE RESOURCES: KENYA'S CONTRIBUTION

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Background

Large Marine Ecosystems (LMEs) are large areas of global exclusive economic zones -- greater than 200,000 sq. km -- characterized by unique bathymetry, hydrography, productivity, and community trophodynamics. On a global basis, nearly 95 percent of the biomass yields from the oceans are produced within the currently identified boundaries of LMEs. Economically important activities ranging from fishing to coastal tourism are dependent on the maintenance of robust biological diversity and sustained health of these ecosystems.

LMEs are becoming increasingly stressed from pollution, over-exploitation of living resources, and natural environmental perturbation. In addition, LMEs experience regional effects of global problems associated with atmospheric increases in the levels of greenhouse gases and decreases in the ozone layer. Against this background, scientists and resource managers have identified LMEs as the appropriate regional units for the implementation of monitoring and management actions leading to sustained and predictable development of marine resources.

Monitoring and management based on units of LMEs (i.e., based on ecological principles) are more economically efficient than monitoring and management based on politically-bound management units. Most LMEs are international in scope, such that water and economically important living marine resources move freely throughout the ecosystem regardless of political boundaries. Overfishing, coastal habitat degradation, and pollution in any of these countries' waters has negative impacts on the resource sustainability and biodiversity of the entire ecosystem. To ensure the sustainability of these shared, economically important resources, it is advantageous for all LME-adjacent nations to cooperate in ecosystem-wide monitoring and management. The LME approach also avoids costly duplication of effort by the individual countries in marine monitoring, research management, and enforcement and fosters international cooperation.

At present, the LME in the Kenya-Somalia area is not adequately monitored. This has led to a situation in which coastal habitats (e.g., mangroves, coral reefs) are degraded, living marine resources are overexploited, and pollution levels increase, while inadequate data are collected to characterize impacts on natural resources and biodiversity. The problem is particularly acute in LMEs such as the Somali Current where rising human populations as well as unchecked coastal development threaten extensive damage to adjacent LMEs.

Development Problems

Kenya is experiencing significant and widespread environmental degradation as a result of increasing pressures due to human population growth and expansion and intensification of land use. A primary result of this degradation is the changes induced by altered sediment flux in coastal areas. This causes the disappearance of species, ecological communities, and the genetic diversity they contain.

The Kenya coast represents one of the most unique biotic regions of the world, containing a wide variety of ecosystems: mangrove forest, seagrass, coral reef, and open sea. A rich diversity of plants and animals, many endemic, are found within these ecosystems. Kenya's coastal biodiversity resources, both economic and environmental, are of critical value to Kenya and to the global community.

Continued loss of biodiversity forecloses opportunities for future generations to benefit from the many known and potential values in increases of biodiversity. The maintenance of biodiversity is essential to meet present and future development needs. The ecological integrity of natural communities, particularly Kenyan ones rich in diverse marine wildlife, represents an important prospective and actual economic value through tourism and marine wildlife utilization.

What is Known About the Western Indian Ocean

Information on the biomass yields of the LMEs of the Indian Ocean has been largely limited to the reports of the Food and Agricultural Organization (FAO) of the United Nations.

Very little is documented on the abundance of zooplankton, by species, for the Somali Current. This makes it difficult to determine which species of copepods, euphausiids, salps, and doliolids dominate the shelf and oceanic zooplankton assemblages of the Western Indian Ocean. Within the coastal upwelling zone off Somalia, the dominant calanoid species found during the upwelling season (southwest

monsoon) include the large copepods *Calanoides carinatus*, *Eucalanus elongatus* and several species of smaller copepod genera including *Paracalanus*, *Clausocalanus*, *Centropages*, *Temora*, and *Acartia* (Fleminger and Hulsemann, 1973; Smith, 1982). Most of the taxa persist throughout the northeast monsoon as well, with the notable exception of *C. carinatus*. There seem to be no striking differences in abundance of copepods between the northeast and southwest monsoon (Smith, 1982; 1984) nor in the total zooplankton biomass. In addition to this list, a species that is probably important in warmer coastal regions and offshore waters is *Undinula vulgaris* (Binet, 1977).

The food chain of the Somalia LME is peculiar. During oligotrophic periods, bacterial production is high and the biomass of zooplankton is much too high for the observed primary production, using ratios of the Sargasso Sea as a standard (Smith, 1982). During the July-September monsoon period, one species of zooplankton, which is absent in oligotropic periods, blooms and dominates the biomass, supplying intense grazing pressure on phytoplankton (Smith, 1982). Biomass of fish is dominated by myctophids. A short and well-coupled food chain could accelerate the flux and cycling of carbon and nitrogen in this LME.

Comparison of zooplankton biomass estimates from upwelling areas including the Somali Current, southern African waters, west Africa, South America, and the Oregon region reveals that all of these productive areas have similar biomass. The biomass of the Somali area is 4 g dry weight per square meter (all of the biomass data refer to total zooplankton biomass composed primarily of crustaceans). It is possible to estimate the relative contribution of euphausiids systems. Probably euphausiids make up 25 percent of the total biomass, and copepods make up most of the remainder. As for contribution of salps and doliolids to total biomass, there is no information whatsoever.

The anchovy-sardine complexes that characterize the world's coastal upwelling systems, *Engraulis*, *Sardinops* and *Sardina* spp., are replaced in warm productive water by different genera: the anchovy (*Stolephorus* spp.) and sardine (*Sardinella*). There is a substantia' fishery for the oil sardine, *Sardinella longiceps*, along the Kenyan anc Somalia coasts from September through December. This is a coasta pelagic fish and is almost certainly a key species in terms of control ling the biomass of phytoplankton and copepods in the coastal zon It is not known how far this fish ventures to sea, but given its hig growth rates, and thus high metabolic requirements, it is probab restricted to the coastal zone. Aspects of the fishery and biology of t oil sardine have been summarized by Longhurst and Wooster (199(

As in other coastal upwelling systems, scombrids are prominent in the Western Indian Ocean, with the Kingfish Barracuda (*Scomberomorus commerson*) and Indian mackerel (*Rastrelliger kanagurta*) being the dominant forms. There is a strongly seasonal pattern of fishing activities in the region, with the lower effort in June to August, the southwest monsoon period, and with peak landings from October through January. Large pelagic fish comprise about 35 percent of total landings and include the tunas, barracuda, kingfish, large jacks, and an array of rare species. All are voracious apex predators and many are migratory, in response to seasonal production. It is well known that in tropical ocean environments most of these species require about 5 to 20 percent of their biomass per day to grow and thrive (Longhurst and Wooster, 1990).

The United Nations Environment Programme and the FAO Fisheries Department are involved in joint studies with the maritime nations around the Indian Ocean rim fostering research and management programs aimed at implementing a balanced strategy for ensuring sustained yields of the living marine resources within the regional LMEs.

In the attempt to piece together a global map of marine productivity Cushing, Krey, and Rao in Zeitschel, (1973) show that the intensity of primary, secondary, and tertiary production all reach their regional maximum in the Arabian Sea. Production reaches a temporal maximum during the southwest monsoon, reflecting some aspect of that persistent circulation or the changes it induces in the upper ocean. The causes are unknown in details. The southwest monsoon seems set to change with global warming.

Though we are unsure of the mechanism that connects the production maximum of the Arabian Sea with the southwest monsoon, and even less sure of its future course, the productive significance of this area justifies the initiation now of a sufficient effort in plankton monitoring to establish the baseline against which the effects of climate change may be detected and with which the mechanism of change can be understood.

Concerned Parties/Target Beneficiaries

The problem of monitoring LMEs in general has been well defined and outlined in the world conservation strategy (FAO/WWF/IUCN). The inextricable linkage between environment and development is now universally acknowledged by the development assistance community of which UNDP is a partner.

Direct beneficiaries include the Government of Kenya through Kenya Marine and Fisheries Research Institute (KMFRI), Kenya training and education Institutions, and relevant non-governmental organizations. Other government and non-governmental agencies responsible for development, and the global community at large, directly and indirectly benefit from the conservation of biodiversity.

Pre-Project and End-Project Status

At present in Kenya there are the Kenya Marine and Fisheries Research Institute, local universities, Kenya National Museums, Kenya Wildlife Services, and the Fisheries Department that provide capacity for LME. These departments and research institutes are designated with specific responsibilities to develop the capacity to protect biodiversity. There are a few individuals with technical training relevant to the protection of LME.

Overall, national efforts to develop LME strategies and to implement integrated, national-level programs to protect LME are severely constrained by a lack of essential financial support.

As a result of this project, a number of incremental improvements are expected to result in a permanent strengthening of institutional and human resource capacities, at both the national and regional levels. These include:

a. establishment of effective LME conservation planning units to coordinate with ministries responsible for planning and finance;
b. improvement of educational, training, and research facilities for professionals who study marine wildlife; and
c. improvement of survey, monitoring, and data processing capabilities.

What Can Kenya do to Support the LME Concept

Kenya lays an important emphasis on the sustainable exploitation and conservation of her aquatic resources in marine waters. Such meaningful sustainable exploitation and conservation requires management that is banked with scientific research and training. Apart from KMFRI, marine research in Kenya is also carried out by national universities, Kenya Wildlife Services, the National Museums of Kenya and the Fisheries Department. Given funds, Kenyan scientists can monitor Large Marine Ecosystems in the Western Indian Ocean (Kenyan portion).

Kenya Marine and Fisheries Research Institute

The Kenya Marine and Fisheries Research Institute was started in 1979 out of the defunct East African Marine Fisheries Research Organization (EAMFRO) and the East African Freshwater Fisheries Research Organization (EAFFRO), which were established in 1984 and 1950, respectively, as International Service Organizations to serve the East African countries. The main objective of the Institute is to promote and develop genuine local expertise by propagating general research activities in both freshwater and marine ecosystems.

The Institute is a governmental para-statal organization and is currently under the Ministry of Research, Science and Technology. It is managed by a Board of Management appointed by the Minister. It has two main divisions, the Marine Science Division housed at the headquarters in Mombasa and the Inland Waters Division with laboratories in Kisumu on the shores of Lake Victoria, Kalokol on Lake Turkana, at Lake Baringo, Sangoro on the river Miriu, Kegati, Lake Naivasha, and Nairobi.

Staff

The Institute started in 1979 with only five Kenyan scientists and a small supporting staff. Today, however, KMFRI has 120 scientists who carry out research in both fresh and marine waters. Of all these scientists, only two have Ph.D. degrees, 33 have Master of Science degrees, and the rest hold Bachelor of Science degrees. To date the Institute has a supporting staff of about 1,300 people.

Research Programs

There are several research programs that the laboratory in Mombasa undertakes.

One of these is in the field of fisheries research in which the goals are to assess the stocks of commercially important fin fishes and shellfish and to study the ecology of coral fishes. The fact that Kenya's coastline has several sites suitable for rearing of fish means that research oriented to mariculture is very important. Currently research on the culture of prawns, oysters, and algae as well as finfish is underway. There are also attempts to integrate salt mining activities with the rearing of the brine shrimp, *Artemia*.

Kenya has a long history of a strong interest in preservation and conservation of her wildlife resources and protection of critical habitats through the creation of parks. Coastal marine parks in Kenya are also a major attraction to tourists. Kenya has also gained financially in creating parks as thousands of tourists and local visitors are

attracted by the high diversity of life in the parks. As regards health, there is every need to monitor pollution in order to avoid diseases and possible elimination of intolerant species.

The environmental programs deal with problems that range from increased sediment loads from the land to the sea, sewage and solid waste disposal from urban areas, overexploitation of reef resources, overcutting of mangroves, oil pollution, and wastes disposed from industries.

Kenya has many species of marine organisms that could be used as a source of active ingredients of pharmaceutical and nutritive value. These extractions could be beneficial to the country in saving lives and generating foreign exchange. However, studies on extraction of active ingredients from marine organisms are scanty and still at the rudimentary stages. Crustacean shells, easily available from crabs, lobsters, and prawns, could be used as a source of chitin. The reef flats support rodophytes from which agar could be extracted. There are also harvestable quantities of echinoderms and sponges from which various active ingredients can be extracted.

There is also a program on food science and technology dealing specifically with the problem of spoilage of fish. The conventional methods of curing fish are under study with a view to find alternative ways of reducing fish spoilage. The laboratory is also active in oceanographic research covering the biological and chemical as well as the physical aspects of our marine waters. Finally our marine geologists are involved in a comprehensive study of the geology of the Kenya coastal systems, especially the relationship between the distribution of mangrove areas and oceanographic processes.

Attempts to Model a Mangrove Ecosystem in Kenya

On the Kenya coast at Gazi Bay, various parameters are measured on a monthly basis or even at shorter intervals with a view to understanding the structure and function of this mangrove ecosystem. To achieve this aim, research groups studying nutrient and nitrogen fixation, production, phytoplankton and sea grasses, mangrove primary production by their litter fall and decomposition, fisheries productivity, and hydrodynamics have been established at the Institute in Mombasa. These teams are multi-disciplinary, and it is hoped that all the data will be brought together and a meaningful model for this mangrove ecosystem will be produced.

This is a collaboration program, and the institutions involved are KMFRI (Kenya), University of Nairobi (Kenya), Free University of Brussels (Belgium), State University of Ghent (Belgium), Delta Institute for Hydrobiological Research (Netherlands), Catholic

University of Nijmen (Netherlands), University of Florence (Italy), and Center for Study of Tropical Faunistics and Ecology of Italy.

Cooperation in Marine Research

The Kenya Government encourages bilateral and multilateral cooperation in marine science research with other countries. Cooperation such as this minimizes duplication of efforts and is instrumental in training Kenya scientists in various marine research techniques by experienced experts. This approach has proved really useful and must be encouraged in the region and especially among local scientists.

One of the oldest and most successful of such bilateral projects in marine science research is the Kenya Belgium Project (KBP). It was started in 1985 and its main objective is to link training, research, equipment, and marine science literature. In this project research is carried out in the country by Kenyans and by visiting Belgian scientists and studies. Under the auspices of the project, too, the Belgian government provides fellowships for Kenyans to go abroad for specialized training in marine sciences and research. While initially the cooperation was between KMFRI and the Free University of Brussels (VUB), it has expanded to involve other universities and institutions in Belgium, the Netherlands, and Italy as well as Nairobi and Kenyatta Universities in Kenya.

The success of the KBP attracted other relevant marine science activities in Kenya. As mentioned earlier, the Kenya-EEC Project, whose aim is to describe structure and function of mangrove ecosystems along the Kenya coast, came into being in 1989 as an offshoot of the KBP cooperation in marine sciences. In 1989 also the Regional Cooperation in Scientific Information Exchange in the West Indian Ocean (RECOSCIX-WIO) was initiated by the IOC with the KMFRI-KBP computer section as the Regional Dispatch Center (RDC). It is currently funded by the Belgian government through the University of Limburg. The main objective of the project is to promote communications between marine scientists in the West Indian Ocean and amongst them with the international community of marine scientists, institutions, and organizations. It should be noted that in the two years of its existence, RECOSCIX-WIO has satisfied the needs of marine scientists by responding to their requests for information. Indeed RECOSCIX-WIO has opened channels of communication that have encouraged exchange of information between scientists in an area geographically so wide that traditional communication, as in most developing countries, is slow, difficult, and expensive.

If the achievements of the RECOSCIX-WIO can be seen as beneficial, other IOC regional bodies may wish to initiate activities along similar lines.

The Kenya-Dutch expedition on the Indian Ocean started on 13 June 1992 from Mombasa, Kenya. One part of this expedition on board the Dutch ship, *R.V. Tyro*, will be to study the effects of the monsoons on coastal ecosystems in Kenya. The other part will study the mangroves, seagrass, and coral reef ecosystems on the coastal fringes of Kenya from a land-based camp on the south coast of Kenya.

Kenya will also participate in the Coastal and Marine Research in Africa (COMARAF) project and will from 1992 to 1996 undertake research into the ecology of coral reefs along the Kenya coast. To fit into the objectives of the COMARAF project, the Kenya research will focus on describing the range of coral reefs with respect to and in comparison with the other coastal ecosystems, the taxonomy of the various groups, as well as the effects of human and natural aggression on coral and suggested steps to limit their consequences.

Kenya participates fully in the East African Action Plan, which was started by a joint mission of UN agencies in 1991 to the eight states of the region. KMFRI has received an atomic absorption and a gas chromatograph under the auspices of the regional project on Assessment and Control of Pollution in the Coastal and Marine Environment of the East African Region (EAF 6) as part of the aims of the East African Action Plan.

The Regional Committee for the Cooperative Investigations in the North and Central West Indian Ocean (IOCINCWIO), at its second session in Arusha, Tanzania (December 1987) approved the development of a regional component of the Global Sea-level Observing System (GLOSS). Since then, four extra sea-level stations have been established to fully support the GLOSS program. A workshop on causes and consequences of sea level change in the Western Indian Ocean was held in Mombasa in 1991. The theme of this workshop was to promote the use of sea level data and products in the IOCINCWIO region.

The Swedish Agency for Research Cooperation in developing countries (SAREC) has supported the development of marine research in East Africa directly. In 1990 SAREC concluded an agreement with the IOC for a joint regional program in whose light SAREC and SAREC/IOC have recently organized seminars, workshops, and training courses to which Kenyans have actively participated.

Besides research linkages made at the government-to-government level in UN bodies, individual researchers who have their research grants and skeletal equipment can be allowed to undertake their research at KMFRI and use the latter's facilities for their research purposes. Some foreign researchers who have already established professional links with their counterparts in Kenya, find it cheaper to undertake joint research with their Kenya counterparts rather than to bring groups from abroad to assist them. This also enhances professional links and speeds up the buildup of confidence of local researchers with their foreign counterparts. Cases of affiliations of research individuals to KMFRI are therefore also encouraged. One such current project is the "Coral Reef Conservation International." The foreign scientist works with a total of six Kenyan researchers, some of whom receive academic training and are drawn from KMFRI, Kenya Wildlife Service, and University of Nairobi.

Although all of the above-cited assistance provides important support, the nature and scale of donor involvement is still insufficient to meet all critical needs related to biodiversity conservation in Kenya. It is expected that the proposed project will complement and significantly enhance existing and proposed activities in this area and will fill important gaps to ensure the conservation of biodiversity in the region.

Design of a Monitoring Strategy

At a recent meeting to design strategies to provide information on which to base marine resource stress mitigation and development action, a core monitoring program was devised consisting of two modules: (1) productivity and population monitoring using continuous plankton records (CPRs), and (2) fish community surveys using vessel survey charters (VSCs). CPRs are towed behind ships-of-opportunity collecting phytoplankton and zooplankton and measuring up to eighteen biological, physical, and chemical parameters including temperature, salinity, turbidity, dissolved oxygen, chlorophyll, primary productivity, nutrients, and petrogenic hydrocarbons. The CPR system is user-friendly, downloads easily to a computer database, and is inexpensive to operate because minimal dedicated ship time is required. VSCs augment the CPR module by providing a means for measuring important fish trends in other economically important population levels, habitat conditions, and changes in other economically important populations. This module utilizes stratifed sampling strategies, acoustics, and satellite technology. When combined, the two modules provide an inexpensive means whereby developing countries

can monitor conditions in their LMEs, with obvious implications for improved management.

LME Core Monitoring Strategy

Information will be required on the temporal and spatial scales of variability of selected ecosystem components if progress is to be made in understanding the processes controlling the structure and functioning of marine ecosystems. This necessitates the monitoring of the key components of LMEs on a long time scale and on a large spatial scale.

The core monitoring strategy includes:

a. A continuous plankton recorder/undulating oceanographic recorder (CPR/UOR) sampling strategy to measure variability in LME health. Such a program will provide useful knowledge on marine pollution, fisheries, and coastal zone management.
b. The CPR/UOR sensor package with components for measuring:
   (1) zooplankton species composition, biomass, biodiversity, and size;
   (2) phytoplankton species composition, biomass as chlorophyll, a pump and probe sensor for productivity, diatom/flagellate ratios, and size;
   (3) salinity;
   (4) temperature;
   (5) hydrocarbons;
   (6) light;
   (7) oxygen;
c. A small, coastal vessel sampling program using nets acoustics to:
   (1) measure species abundance, biodiversity, and stock levels;
   (2) gather data on fish age, growth, size;
   (3) gather data on predator-prey interactions from stomach sampling;
   (4) make observation on gross pathology;
   (5) obtain simultaneous measurements on gross pathology;
   (6) obtain simultaneous measurements of temperature and salinity;
   (7) sample for pollutants and photograph macrobenthics on an opportunistic basic.
d. Use of satellite images for characterizing water mass movements and use of chlorophyll and temperature data for satellite intercalibrations.

For monitoring inshore-offshore extension of nutrients and eutrophication, systems of towed CPRs should be deployed and where

possible, moored buoys for collecting chlorophyll and productivity data.

Regional Coordinating Centers are proposed to be established at KMFRI, staffed facilities will serve as a center for training, sample processing for center staffs in plankton identification and processing will occur at the Sir Alister Hardy Foundation Laboratories in Plymouth, England and at NOAA facilities in the United States. An international advisory board comprised of ecosystem scientists, managers, and host country representatives will oversee all project activities.

The training component will be strengthened and opportunities for expanded LME coverage explored through the cooperation of IUCN (the World Conservation Union). IUCN will provide the staffing needed to establish the LME networks.

The Somalia Current LME

The justification for monitoring plankton changes across the global production center of the Arabian Sea has been described in IOC/INF-869 UNESCO (1991). The need is to lay down a system capable of recognizing the ecosystem effects that are expected to arise through climatic modulation of the southwest monsoon.

One route has been selected which runs from East Africa to the Persian Gulf (Figure 1). This route offers the following benefits: it is a frequently travelled and therefore easily-worked shipping route; it transects the Somali current and the Arabian Sea; it provides both the large-scale context and the "open ocean" contrast for one of the likely key sites of the Large Marine Ecosystem study (the East African-Somali Current Domain). There are already a small but sufficient number of CPR tows from this route to confirm the validity of the CPR survey technique in these waters.

Kenya Conference on LME

As follow-on to the Monaco conference, scientists in Kenya and Belgium are collaborating in "twining" activity between a developing and developed country to organize a symposium on the LMEs of the Indian Ocean to be convened during August 1992 in Mombasa, Kenya. The symposium will contain workshops that will inform participants on the methodology of the LME approach, demonstrate the use of modelling and identify scientific data needs for LME studies.

Project Objectives

The development objective is to strengthen the capacity of the participating country (Kenya) for sustainable use and conservation of LME. This holds true in both the context of protecting marine parks and reserves from effects of isolation and surrounding development and of developing areas for fisheries, mining, and other economic activities. This development objective will be achieved through the following immediate objectives:

a. support to Kenya Marine and Fisheries Research Institute and marine science research in local universities;
b. institutional support to programs in LME conservation;
c. provision of field and laboratory equipment to survey and monitor elements of LME and to organize biological, physical, and chemical oceanographic data and technical assistance as needed to ensure the best use of data of field and laboratory equipment; and
d. the establishment of effective LME conservation planning units to coordinate with ministries responsible for planning and finance.

Rationale for Funding

The government of Kenya has set up Marine National Parks and Reserves. This shows that the government of Kenya has already demonstrated that its strong commitment to conserve biodiversity can thus be expanded to cover the EEZ within its borders. The Western Indian Ocean can be approached as an LME on a regional basis. Under existing projects alone, attainment of adequate conservation standards is not possible in most existing protected areas over the next three years because of resource and staff constraints.

Without additional funds, the development of the capacity to manage and conserve species, habitats, and genetic diversity unique to the Western Indian Ocean (Kenya coast) will not be possible.

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