GLOBAL CHANGE
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REPORT No. 33

LOICZ
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Land-Ocean Interactions in the Coastal Zone

Implementation Plan

The International Geosphere-Biosphere Programme: A Study of Global Change (IGBP)
of the International Council of Scientific Unions (ICSU)
Stockholm, 1994

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Executive Summary

The Land-Ocean Interactions in the Coastal Zone (LOICZ) is one of seven Core Projects which comprise the International Geosphere-Biosphere Programme: A study of Global Change. The overall aim of the IGBP is "to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in the system and the manner in which they are influenced by human actions."

As its name implies LOICZ is that component of the IGBP which focuses on the area of the earth's surface where land, ocean and atmosphere meet and interact. The overall goal of this project is to determine at regional and global scales: the nature of that dynamic interaction; how changes in various compartments of the Earth system are affecting coastal zones and altering their role in global cycles; to assess how future changes in these areas will affect their use by people; and to provide a sound scientific basis for future integrated management of coastal areas on a sustainable basis.

The project commenced in 1993 with the establishment of the Core Project Office at the Netherlands Institute for Sea Research, and the Office is financially supported by the Netherlands Government. Like all IGBP projects, LOICZ is scheduled to run for 10 years. This Implementation Plan lays out the scientific goals and objectives and charts a course towards their achievement based on the co-ordination of nationally funded research. This co-ordination will require the continued leadership of the International Scientific Steering Committee and strong management on a day to day basis through the Core Project Office. Over 400 scientists were involved in developing the Science Plan published in 1993 and this network has already been extended to 1,000 scientists in 124 countries who have provided inputs to the development of this Implementation Plan.

In comparison with the relatively uniform environment of the sunlit zone of the open ocean, or the rapidly mixed environment of the atmosphere, the spatial and temporal heterogeneity of the world's coastal zones is considerable. There are as a consequence considerable methodological problems associated with developing global perspectives of the role of this compartment in the functioning of the total Earth system. Identifying and quantifying this role and developing scenarios of change in the coastal compartment of the Earth system under anthropogenic and geocentric driving forces of change will require a considerable body of research.

The Activities and Tasks described in each Focus chapter, provide a blueprint for the design of individual and national research, contributing to the overall goals of the LOICZ Project. The Framework and Integrative Activities are designed to provide the mechanisms for co-ordination of these efforts and modalities for co-operation and consolidation of the results of such research (Figure 1). The nature of necessary project management actions are described in the Programme Management chapter and the various Appendices.

The financial requirements and justification are provided in some detail since it is recognised that to successfully meet the goals and objectives of the project as a whole, substantial new research funds must be appropriated. Unlike many of the other Core Projects of the IGBP, LOICZ deals with a specific domain rather than a process and that domain is spatially extremely heterogeneous. To achieve the overall goals and objectives a truly global network of coastal scientists must be developed and the active participation of scientists from developing countries is vital to the ultimate success of this project. Financial and other support must therefore be provided through the Core Project to foster the research envisaged as being undertaken in such countries since their coastlines encompass the bulk of the world's tropical shores and are areas where the rates of anthropogenically driven change are considerable.

Whilst the objective of LOICZ is not to undertake coastal zone management, a clearly articulated objective is to provide a sound scientific basis for the future sustainable use and integrated management of these environments, under conditions of global change. Adequate funding of the research agenda outlined in this plan would, over the course of the ten year life span of the project, provide models and data that would enhance the prospect of realising these wider goals of sustainable use and integrated management of coastal areas.

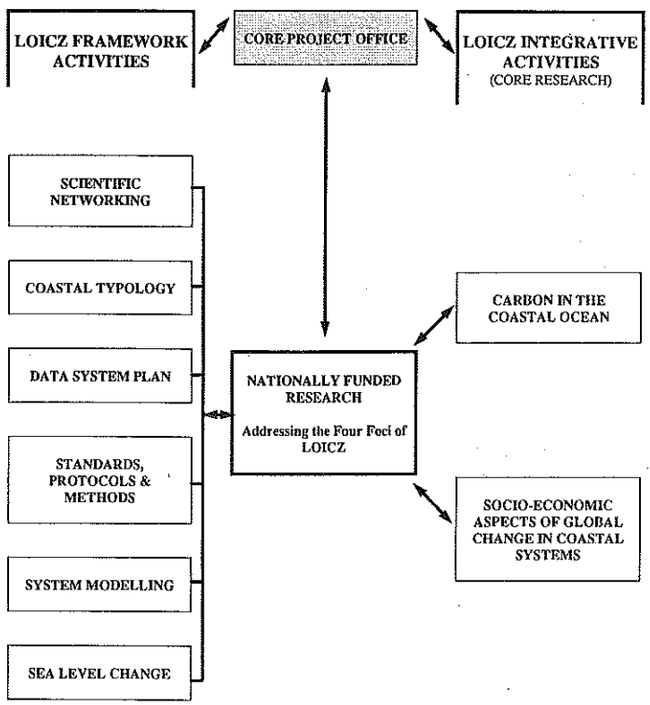


Figure 1. Relationship between the LOICZ Core Project Office, LOICZ Framework Activities, Nationally funded research and LOICZ Integrative Activities (Core Research).

Introduction

The Earth System & IGBP

Planet Earth is not a steady state system: its forcing functions change continually. Externally, cyclic and long-term alterations in the energy output of the sun, the concert of orbital periodicities, and episodic cometary impacts serve to modulate the flow of energy available to fuel the Earth system. Internally, decay of radioactive elements, inherited from the planetary nebula, produces heat, which provides the energy driving plate tectonics, shifting continents and uplifting rocks into volcanic edifices and mountain ranges. This heat is ultimately dissipated to space by conducted and convected geothermal heat flux. From the perspective of its geological history, Earth is experiencing a relatively warm and climatically stable period, called the Holocene which globally is about 2°C warmer than the Last Glacial. The Holocene started about 11,000 to 11,700 years before Present, when the last cold period, the younger Dryas, ended within a few years, possibly in less than ten years. We still do not know what happened exactly, but shifting ocean currents in the North Atlantic seem to have played a key role. In consequence the northern hemisphere heated rapidly, eventually triggering the melting of vast continental ice sheets, the consequent rise of global sea level by about 100 m, and drastically changed the trace gas composition of the Earth's atmosphere. This climatic change event was a natural shift, unlike anything that has happened since then. It must be remembered however, that the term "Last Glacial" is euphemistic, and that the "Next Glacial", on geological time scales, is just around the corner.

During the Holocene, a certain primate, our own species, developed a large, technologically based society, which uses energy, and moves material within the Earth system at rates comparable to or surpassing the natural rates of biogeochemical cycling. As a consequence, the Holocene quasi-steady state conditions have been changed, with possible serious consequences for climate and biosphere, or more precisely for the state of the climate and biosphere under which this society has developed. Should the climate undergo another drastic shift, just as happened 10,000 years ago, then large sections of humanity will suffer severely. At present, science cannot predict the extent to which the Earth system can be stressed before a sudden climate shift may occur. In addition, there are other sources of environmental change which represent areas of concern to the human species, including basin scale changes in ocean currents and in the rate of ocean turnover, such as the El Niño-Southern Oscillation; the rise in sea level; the loss of biological and genetic diversity; the spread of deserts; the loss of agricultural soil through erosion; the accumulation of nitrate in the fresh water pool; and, a general shortage of potable water of an acceptable quality, to name but a few.

The International Council of Scientific Unions (ICSU), through its International Geosphere-Biosphere Programme (IGBP), strives to advance our scientific understanding of the Earth system in the light of ongoing changes. One of the areas of the Earth's surface in which humanity is most concentrated and which we can least afford to damage is the coastal zone (Figure 2), the object of study of the IGBP Core Project LOICZ (Land-Ocean

Interactions in the Coastal Zone). The LOICZ Science Plan (IGBP, 1993) defines for the purposes of this Core Project, the coastal zone as:

> *"extending from the coastal plains to the outer edge of the continental shelves, approximately matching the region that has been alternately flooded and exposed during the sea level fluctuations of the late Quaternary period."*

In the context of global change impacts in the coastal zone, sea level rise has received considerable attention from the international community and public media. Eustatic sea level rise is however, relatively small (1-2 mm a^{-1}) at present, and even with a warming and expansion of the mixed ocean surface layer and the melting of temperate land-based glaciers, global mean sea level will not rise more than a few decimetres in the next century. Of more immediate concern however, is the subsidence and recession of certain coastlines through natural or anthropogenically caused processes. The mining of oil, gas and water from deltas, and the sediment starvation of rivers through the world-wide increase in the number of reservoirs, and large scale irrigation and water diversion projects, causes regional, relative sea level changes which are an order of magnitude higher than eustatic sea level rise. Many highly productive and densely populated low-lying lands are currently threatened by such changes. Undisturbed coastlines counteract such recession by building beaches, sand spurs or coral platforms and filling lagoons with mangroves, peat or marsh. These interactions are the subject of biogeomorphological research which forms the topic of LOICZ Focus 2.

As a consequence of the flooding of the continental shelves by sea level rise at the end of the Last Glacial, the continents are surrounded today by shallow seas, some of them over 1,000 km wide. Many of the inland seas, like the Baltic Sea and the Hudson Bay, did not exist 10,000 years ago, or like the Black Sea have become filled with salty water. The Black Sea, during the Pleistocene was the largest fresh water body on Earth, surpassing by far all the freshwater existing on land today. This fringe of shallow sea serves as a reaction vessel for all the material delivered both naturally and anthropogenically to the ocean, which in times of lower sea level, were discharged almost directly from land to the open ocean. In shallow water, nutrients, for example, can be recycled many times, before becoming finally fixed in the sediments or being exported to the open ocean. Therefore, a far higher productivity is maintained in the shallow seas of continental margins, than in most of the open ocean with positive effects on the harvest of fish and other *frutti di mare*. Annually, roughly 0.4 gigatons of organic carbon in dissolved and particulate form, reach the ocean via river discharge and may be partly or totally respired, thus forming a potential natural source of CO_2 for the atmosphere. How much is actually respired is unknown, since apparently much of the riverine carbon (specifically the dissolved organic carbon) is highly inert and is mixed into ocean water conservatively. Furthermore, the anthropogenic input of nutrients (nitrate and phosphate) to the coastal sea via rivers and through direct waste discharge can now produce more biomass and may therefore constitute a new, additional sink for atmospheric carbon of the order of 0.07-0.12 Gt C a^{-1}. Many of the uncertainties in global carbon flow models may represent unquantified processes occurring in the coastal zone.

Observations show that over the past few decades highly eutrophicated coastal seas, such as the North Sea, have significantly increased their seasonal amplitude (i.e., the difference between the winter and summer conditions) for almost all ecological and carbon cycle related parameters. The coastal seas are of prime interest to mankind since not only do

they play an important role in the global carbon cycle (disturbed and undisturbed), but also their internal behaviour affects their high productivity. The amplitudes of natural cyclic processes cannot be increased indefinitely and it must be recognised that there may be a critical threshold, beyond which the system shifts suddenly to some other mode of functioning. If high rates of production occur during summer, for example, organic matter can accumulate on the seafloor, where it is respired, until all the oxygen is depleted. At this threshold the system shifts from oxic to anoxic respiration, and sulphate is used as an oxygen donor. In this process H_2S is generated, which kills all higher life in and on top of the sediment and in bottom waters as well.

Another threshold occurs when rapid photosynthesis draws the free CO_2 from the water, increasing the carbonate ion concentration and the pH. Again, certain parts of the marine biota cannot tolerate such conditions and disappear from the water column, giving rise to the opportunity for massive blooms of a few species such as flagellates. The ability to effectively produce calcium carbonates is lost at too high a pH in many biomineralising organisms thus, potentially the narrow balance of alkalinity, supersaturation and total dissolved carbonate can be disturbed, with possible severe consequences for reefs, shell producing invertebrates and calcareous plankton. The processes involved, the cycling of carbon and nutrients, and the global significance of the coastal seas for the carbon cycle, are therefore the primary research targets of LOICZ Foci 1 and 3.

Land-derived carbon, nutrients, freshwater and sediments all enter the coastal zone at point inputs, the river mouths. Changes in these inputs have major consequences not only for the mixing zone between fresh and sea water, the estuary in the wider sense, but also for the entire sediment, carbon and nutrient balance of the coastal sea, down current of the river mouths. Understanding the mechanisms which mobilise these materials in the catchment basin is a natural task of LOICZ, and in Focus 1 (Activity 1.1) one of the aims will be to build a model linking the continental water discharge with material transport. This will be based on a similarity analysis of river discharge behaviour, seasonally and inter-annually and will involve assembling a large data base of GIS-based river networks, long-term discharge curves, and material transport. As a start, LOICZ is already assembling basic river data in a databank GLORI (Global Land-Ocean River Input).

In addition to developing a typology of river catchment behaviour, coastal zones themselves must be discriminated into classes of high similarity, in order to later sum the results of total carbon budgets, or to construct box or dynamic models to serve as modules for a future Earth system model. This task will be taken up through the LOICZ Core Project Office (CPO) as an initial major scientific effort. LOICZ will conduct and encourage modelling of coastal zone processes at all levels: from process models, which investigate ecosystem reactions to physical and chemical forcing; to budget models, which try to elucidate the mass balances in specific geographic regions and time frames; to system models, which couple advanced regional general circulation models with biogeochemical, sedimentological, or meteorological process models (Focus 1, Activity 1.4). For most of these models, carbon will be the major currency, alongside sediments and the macronutrients nitrate, phosphate and silicate.

Because of the central importance of the coastal zone for humanity and the ICSU policy of fostering co-operation between natural and social scientists, LOICZ Focus 4 has been designed as a forum for collaboration between IGBP and HDP (Human Dimension of Global Environmental Change Programme). The experience of the first three foci will be

used to develop scenarios of coastal zone development under changing climate, changing river inputs and changing biogeochemical and biogeomorphological forcing functions (Activity 4.1). This information will be used to investigate possible feedback on coastal populations and environment (Activity 4.2). Finally, LOICZ will assess the extent to which scientific understanding of coastal zone changes could contribute to the formulation of integrated management strategies for sustainable use of coastal environments and resources (Activity 4.3).

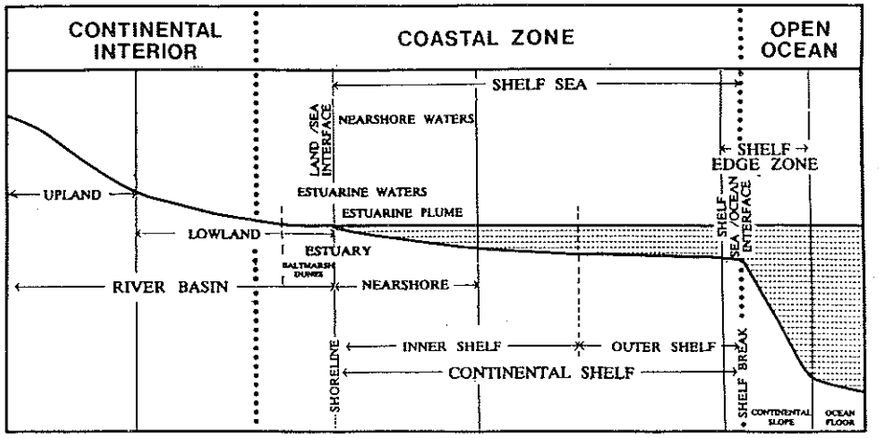


Figure 2. Diagrammatic representation of the coastal zone, continental shelf and other features of the Land-Ocean boundary. The relative size and proportions of these components show considerable geographic variability.

Global Change and the Coastal Zone

What is Global Change ?

During the 1970's the social sciences community adopted the term "global change" to refer to changes in international social, economic and political systems, particularly with regard to concerns about international insecurity and decreases in the quality of life. The first use of the term was essentially therefore anthropocentric.

During the 1980's a geocentric use was adopted by the natural scientists to encompass *global environmental changes* - changes in the earth's atmospheric, biological, geological and hydrological systems. This geocentric view of Global Change appears to involve two separate but related usages :

Systemic changes are those which occur throughout a global compartment of the Earth system, with the often quoted examples of: rising CO_2 in the atmosphere and global warming; global mean sea level rise; and, depletion of stratospheric ozone.

Cumulative changes are those which take place at discrete locations around the globe but when combined have "global" importance; often quoted examples are acid rain, deforestation, desertification and other processes leading to changes in the biosphere which alter its capacity to store CO_2. A coastal example of such a change, would be eutrophication leading to changes in carbon flow and sequestration with consequences for the global carbon cycle.

As its name suggests the International Geosphere-Biosphere Programme (IGBP) takes a primarily geocentric and systemic view of global change although LOICZ represents *par excellence* a Core Project addressing cumulative changes in a defined spatial domain. IGBP measures the "global importance" of cumulative changes in deciding whether or not a topic deserves inclusion in the core projects by assessing the feedback between the actual change and the global system. The observable decline in marine, bony fish biomass, or increasing contamination of coastal waters with heavy metals, Polychlorinated Biphenols (PCB's), and pesticides, whilst they have undoubted local impacts, are anthropogenically driven changes which cannot be demonstrated at this point in time to have a feedback on the "Earth system". They are therefore not topics included within the IGBP research agenda.

Systemic and cumulative change

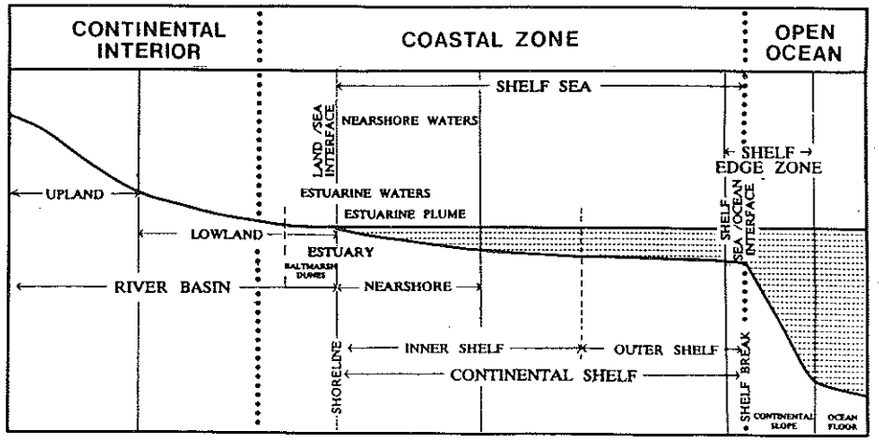
The separation of so-called systemic changes from cumulative changes is merely one of temporal and in some instances spatial distance which separate the cause and the effect. Feedback from the geocentric perspective is measured on temporally limited and spatially defined scales. Ozone depletion is actually a cumulative change, in that it results from release of Chloro Fluoro Carbonates (CFC's) at discrete locations around the globe but its impact on the Earth system is observed in a single environmental compartment - the stratosphere - within a short period of time - years - hence it is for the purposes of these definitions, systemic. The short time lapse between cause and effect in this example reflects the comparatively rapid mixing and diffusion processes in the atmosphere, and its comparative uniformity and homogeneity when compared with the oceans, which are highly stratified, physically divided into compartments of different scales, (ocean basins, semi-enclosed seas, abyssal depths, and continental shelves, amongst others) and in which the mixing and diffusion processes are much slower, decades to centuries. Demonstrating cause and effect when the two are separated by long time periods is clearly more difficult than in the case of short term reactions of the Earth system to anthropogenic forcing. Nevertheless the importance of such longer-term interaction cannot be ignored, as recognised by the climate modelling community in its current endeavours to build coupled ocean-atmospheric Global Circulation Models.

The overall aim of the IGBP is:

"To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions."

Central to the theme of the IGBP therefore is the interaction between chemical, physical and biological processes. Most biological sub-systems are relatively complex in that they contain numerous individuals, species and populations each with their characteristic metabolic rates, life styles and life expectancies. Changes in one species affect changes in

used to develop scenarios of coastal zone development under changing climate, changing river inputs and changing biogeochemical and biogeomorphological forcing functions (Activity 4.1). This information will be used to investigate possible feedback on coastal populations and environment (Activity 4.2). Finally, LOICZ will assess the extent to which scientific understanding of coastal zone changes could contribute to the formulation of integrated management strategies for sustainable use of coastal environments and resources (Activity 4.3).



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"To describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment that it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions."

Central to the theme of the IGBP therefore is the interaction between chemical, physical and biological processes. Most biological sub-systems are relatively complex in that they contain numerous individuals, species and populations each with their characteristic metabolic rates, life styles and life expectancies. Changes in one species affect changes in

other species in the same community to varying degrees depending on the relationships between the species concerned. Changes in the abiotic environment affect different species differently, hence altering the balance between the different species in the biotic community as a whole, and from the geocentric view of global change, altering the role of the biological sub-system in biogeochemical cycles. The buffering capacity of biological systems in terms of the slowness of their response to chronic or low levels of external forcing, delays, or may even mask, the overall system response, and non-linear responses are often characteristic of biological sub-systems. The difficulties of modelling in the oceanic realm are also compounded by the truly three dimensional universe which marine biota exploit compared with the more two dimensional universe of terrestrial organisms.

Our capacity to model the processes in biological systems is extremely limited, hence our capacity to predict how changes in physical or chemical limiting factors will affect the biological compartment directly and alter its role in global cycles is correspondingly limited, as is our ability to predict the impact of changes in one biological compartment due to human use of that compartment. We cannot say definitively therefore that the present decline in teleost biomass in the world's coastal oceans does not feedback on global geochemical cycles and hence the Earth system as a whole. Equally we cannot prove that it does. The Scientific Committee of the IGBP has placed lower priority on resolving this uncertainty than on addressing other more pressing scientific issues. Nevertheless, this does not mean that such issues are unimportant, merely that they are beyond the remit of IGBP-LOICZ.

Given that the anthropogenic inputs of nutrients, particularly nitrogen and phosphorus to the oceans, are now equivalent to and in some areas exceed the natural rates of transfer from land to ocean, and given also that the main limiting factors for primary production in the marine environment are generally nitrogen and phosphorus, changes to the rate of carbon fixation in coastal waters and hence temporary and perhaps permanent sequestration of carbon must be occurring, or are they ? The question cannot be definitively answered at present simply because data concerning the role of coastal oceans in the undisturbed carbon cycle are inadequate to provide a baseline against which to measure changes in the coastal carbon cycle. Hence "global change" due to these changes in the role of the coastal sub-system in the global carbon cycle cannot be quantified. We do not know whether the world's coastal oceans are being changed from systems with predominantly internal cycles of production and consumption (the presumed pre-industrial condition) to systems which are based more on external inputs of organic carbon. This is one of the process issues which is to be addressed by LOICZ and hence has been given priority by IGBP (Figure 3).

Humans as driving forces of global change and geocentric change as a driving force for social change

The geocentric view of global change views humans as a driving force of change, hence for example CO_2 emissions are calculated in relation to human population numbers and fossil fuel consumption, thus providing input data to the models of the anthropogenically disturbed carbon cycle. The anthropocentric view of global change considers environmental or Earth system changes as one of many drivers of social and economic change, for example deforestation or desertification are measured in terms of changes in land quality and productivity and hence as driving forces of social and economic change and migration.

LOICZ CARBON FLOW MODELLING

Carbon flow models of the world's coastal zone will be developed under LOICZ. These models will be aquatic models that will include water, sediment and nutrients as well as various forms of carbon. They will include internal dynamics as well as important exchanges across boundaries. The tasks (in parentheses) indicate where each activity is located in the draft LOICZ Implementation Plan.

Development of a coastal typology system (Task F.2.1.)
The typology will be used to determine regions for which models and model output are needed, and for developing global syntheses and models.
This Task will be undertaken by the CPO.

Development of a strong, centralised framework for LOICZ modelling activities (Task F.5.1.)
This Task will provide the overall framework for co-ordination and communication and provide guidelines for model development. This Task will be led by the CPO with strong inputs from the modelling nodes when established.

Development of improved methods for assimilating fine scale models into large scale models (Task F.5.2.)
This Task links hydrodynamic models to biogeochemical models, and involves scaling up from local to regional models and from regional to global models. This Task will be led by the CPO with strong inputs from the modelling nodes when established.

The development of new local and regional carbon flow models (Task 1.4.1.)
Building on existing data this Task involves constructing new budget and system models following recommended guidelines. Budget models will be developed first followed by system models for sites and regions identified through the typology exercise. An on-going activity which will continue as new data become available, this activity will primarily be undertaken as part of national/regional programmes with LOICZ co-ordination.

Evaluation and validation of carbon flow models (Task 3.1.4.)
Under this Task models of similar coastal units and contrasting coastal units will be compared and generic sub-models of key biogeochemical processes will be developed which have wider applicability. New models will be validated using new field data. Where possible models will be used to explore the effects of different scenarios on regional carbon flows. Undertaken primarily as part of national/regional programmes this will require strong LOICZ co-ordination.

Global synthesis of regional carbon flow models (Integrative Activities (Core Research))
Dependent upon all the above activities, especially the typology exercise and scaling up techniques. Using available regional models, develop carbon flow models for the world's entire coastal zone. Feed the results of coastal carbon flow models into Earth system models. Where possible, models will be used to explore the effects of different scenarios on global carbon flows. Led by the CPO this Task will require strong input from the modelling nodes and regional research networks when established.

Figure 3. Activities related to the development of global syntheses and models of carbon in the coastal ocean, envisaged under LOICZ.

But the two views (the natural and social sciences perspectives) as exemplified by the IGBP and the HDP are merely the two halves of a feedback loop which cannot be considered, analysed, or understood independently of one another. IGBP and HDP are jointly trying to address this issue of mutual feedback, through the development of a co-sponsored core project on land-use and cover change, LUCC. This planned Core Project aims to address both sides of this relationship, whilst recognising the importance of humans as drivers of change since this direction of forcing is dominant at this point in human history. The impact of changes in vegetation cover, as a consequence of anthropogenic changes in land-use, on the Earth system is apparently a "given" since it is assumed that these changes alter the biospheric storage of carbon. The systemic basis for inclusion of LUCC in IGBP is therefore obvious.

LOICZ Focus 4 represents another arena in which the interplay: between the natural and social sciences; between HDP and IGBP; between anthropocentric and geocentric; and, between systemic and cumulative views of global change is occurring. The logic for the inclusion in an IGBP project of what is, in the view of many natural scientists, essentially a social sciences focus, is however flawless being based on the importance of coastal zones both to human populations and to global biogeochemical cycling.

The coastal domain (Figure 2) from 200m above to 200m below sea level:

- Occupies 18% of the surface of the globe
- Is the area where around a quarter of global primary productivity occurs
- Where around 60% of the human population lives
- Where two thirds of the worlds cities with populations of over 1.6 million people are located
- Supplies approximately 90% of world fish catch

The coastal ocean accounts for:

- 8% of the ocean surface
- <0.5% of the ocean volume
- Around 14% of global ocean production
- Up to 50% of global oceanic denitrification
- 80% of the global organic matter burial
- 90% of the global sedimentary mineralisation
- 75-90% of the global sink of suspended river load and its associated elements/pollutants
- In excess of 50% of present day global carbonate deposition

Recent estimates concerning various characteristics and properties of the coastal zone (Box) demonstrate quite clearly the global importance of the coastal domain for both humanity and for geochemical cycles, despite its comparatively small surface area and volume.

Research on change in coastal zones

Regarding changes in the coastal zone that are driven by changes to the Earth system, theory suggests that global warming will result in a rise in global mean sea level hence coastal areas will be impacted by potential changes not only to the climate system but to sea level. The potential impacts of environmental changes on humanity may therefore be greater in this compartment of the geosphere-biosphere system than in many other areas of the surface of the globe since the range of geocentric drivers of change includes not only climate change in the broadest sense of changes in temperature, rainfall and wind regimes but also includes changes in ocean climate, storminess, flooding and inundation.

At the same time, anthropogenically driven change is arguably more intense in coastal areas than elsewhere on the surface of the globe since:

- That is where the majority of people presently reside, resulting in comparatively high existing population densities
- Rates of growth in coastal populations are usually greater than rates of growth in inland areas due to migration of permanent residents
- Most international tourism is coastal
- 90% of land-based pollution including sewage, nutrients and toxic materials remain in the coastal ocean
- Much of the fertile agricultural land in tropical countries is coastal, hence land-use and cover change are most intense in coastal margins
- Earlier this century the anthropogenically driven flux of sediment from land to ocean exceeded natural rates of flux
- On continental scales the rates of sediment flux is now considerably reduced, due to dam construction and large scale irrigation schemes (a reversal of previous trends)
- The anthropogenic flux of dissolved nutrients from land to coastal ocean is now equal to and in some areas greatly in excess of the natural flux

We must conclude therefore that the primary driving forces for immediate change (years to decades) in the coastal domain are direct anthropogenic influences, but that longer term changes (decades to centuries) may be driven by environmental system changes (climate and sea level). Furthermore we cannot quantify at regional or global scales, the impacts of anthropogenically driven change in coastal systems and hence cannot describe the scale and in some instances the actual direction of changes to the Earth system which result from anthropogenically driven cumulative changes in biosphere-geosphere elements of the coastal domain. Hence the obvious need for LOICZ to be involved in the scientific investigation of anthropogenically driven coastal changes and their implications for global Earth system functioning. It is in this area of LOICZ research in general and Focus 4 in particular, that some confusion exists concerning the more specific objectives of LOICZ within this arena of the research agenda. This confusion arises from the fact that the *science of anthropogenically driven change* is often confused with the issue of *the management of the immediate consequences of these changes*. LOICZ research is concerned with the science of anthropogenically driven change in coastal systems.

The argument is often advanced that research on the anthropogenic driving forces of change belongs to the domain of the social sciences rather than as a component of the LOICZ Project which is primarily concerned with biogeochemical processes and the role

of coastal systems in these processes. The corollary of this argument is that LOICZ should merely take the output of appropriate social sciences research in coastal environments and use this as input data for models of coastal change and hence scenarios and projections of change in the Earth system as a whole. The converse of this argument is that the social scientists should take the outputs of the LOICZ natural sciences research on geocentric change and use this as input data for their models of social change.

Whilst these arguments are superficially attractive in that they simplify the lines of responsibility and place defined limits on the research domain of each community, they are in reality specious, since the temporal scales over which the two driving forces of coastal change operate are different, the spatial scales are different, and the whole is almost certainly greater than the sum of the parts. In reality, the way in which natural and social sciences data are collected and models constructed independently of one another, precludes their easy integration or assimilation by each research community. There is therefore a need to engage both research communities simultaneously if the spatial and temporal domains of both datasets are to be congruent and if coupled natural and social sciences models are to be developed.

A real intellectual challenge exists therefore in developing coupled inter-disciplinary models which fully integrate both types of data in describing and ultimately predicting the nature of change in coastal systems. The entire feedback loop must be examined, analysed and described if we are to understand the role of coastal systems in the Earth system as a whole (the IGBP and LOICZ natural sciences objective), or to understand the way in which environmental change affects society (the HDP and LOICZ social sciences objective), or to manage human activities in the coastal zone with a view to halting or slowing the present rates of change, and avoiding or mitigating the adverse consequences of global changes, (the IPCC and management objective).

Development of the LOICZ Project and LOICZ Implementation Plan

The goals of LOICZ

The goals of the LOICZ Project as stated in the Science Plan (IGBP, 1993) and approved by the SC-IGBP are as follows:

(i) To determine at global and regional scales:

a) The fluxes of material between land, sea and atmosphere through the coastal zone
b) The capacity of coastal systems to transform and store particulate and dissolved matter
c) The effects of changes in external forcing conditions on the structure and functioning of coastal ecosystems

(ii) To determine how changes in land use, climate, sea level and human activities alter the fluxes and retention of particulate matter in the coastal zone, and affect coastal morphodynamics

(iii) To determine how changes in coastal systems, including responses to varying terrestrial and oceanic inputs of organic matter and nutrients, will affect the global carbon cycle and the trace gas composition of the atmosphere

(iv) To assess how responses of coastal systems to global change will affect the habitation and usage by humans of coastal environments, and to develop further the scientific and socio-economic bases for the integrated management of the coastal environment

The development of the LOICZ Core Project of the IGBP

The IGBP was established by ICSU at its General Assembly meeting in Berne, in 1986 and subsequently a series of Core Projects have been developed and adopted by the Scientific Committee of the IGBP (SC-IGBP). In 1990 a Scientific Planning Committee for the LOICZ Project was established by the SC-IGBP, which over the course of two years.and several meetings developed the Science Plan (IGBP-Report No 25). The Science Plan was adopted by the SC-IGBP at its 5th Meeting in Durham, New Hampshire in December 1992. At this point the LOICZ Project became the sixth Core Project of the IGBP and the formal offer of the Government of the Netherlands to host the Core Project Office for LOICZ was accepted by the IGBP. The development of the Science Plan, which outlines the issues and uncertainties concerning the role of the coastal sub-system in the total Earth system and the possible nature of changes which might be expected under scenarios of future change, was assisted by a network of over 450 scientists who contributed ideas and material through meetings, workshops, discussions and correspondence.

Following publication of the Science Plan in early 1993 an Open Science Meeting was convened at Raleigh, North Carolina at which National representatives of twenty two IGBP participating countries met with scientists to discuss the implementation of the LOICZ Science Plan. In total some 70 scientists participated in this meeting which also served as the venue for the first meeting of the newly appointed LOICZ Scientific Steering Committee (LOICZ-SSC, see Appendix 1 for the present membership) under the Chairmanship of Dr Patrick Holligan. The Open Science Meeting and first LOICZ-SSC meeting initiated the process of developing the Implementation Plan for LOICZ.

The Core Project Office officially opened at the *Nederlands Instituut voor Onderzoek der Zee* (Netherlands Institute for Sea Research, NIOZ) on the Island of Texel, in November 1993 following the appointment of the Core Project Manager, and the second LOICZ-SSC meeting was held at the Office in December of that year. To assist in the development of the Implementation Plan, a series of small workshops and informal meetings were held during 1993 and 1994 to draft various sections and consolidate ideas concerning the implementation of the Foci and Activities described in the Science Plan. Draft materials were considered during the third LOICZ-SSC meeting held in the CPO in June 1994 and these were subsequently revised, expanded and despatched for wide review and comment to the LOICZ networks which by September 1994 exceeded 1,000 active scientists involved in natural and social sciences research in coastal zones and global change, in 124 countries.

The Implementation Plan for LOICZ

The purpose of this document is to provide guidance to the scientific community having interests in research in global change and the coastal zone concerning the nature of research that is urgently needed to address the issues and uncertainties surrounding the role of the coastal sub-system in the total Earth system and the nature of the responses which may be expected from this sub-system to the anticipated climate and other changes over the next several decades. The document is not intended as a proscriptive listing of topics which must be undertaken, rather it amplifies through examples the nature of research Tasks and Activities which, if undertaken in a co-ordinated and collaborative manner, could contribute to the resolution of the issues and uncertainties originally outlined in the Science Plan.

IGBP research is conducted through nationally funded activities, which it is recognised, particularly in the field of coastal research, are likely to encompass goals and objectives outside those of the IGBP and LOICZ. This is not necessarily seen as counter-productive, or detracting from the global objectives; rather it provides a rich tapestry from which to draw experience, data and approaches in addressing the wider perspective. The Activities, Tasks and Sub-tasks described in the following chapters provide examples of the kinds of research endeavours which can be undertaken by individuals, institutions or national research groups as contributions to the project as a whole.

To achieve the global goals of the IGBP and address the regional and global objectives of the LOICZ Core Project will however, require strong co-ordination and collaboration and significant investment in these activities through the Core Project Office. The Framework Activities provide an outline of the nature of centrally co-ordinated actions which are seen as necessary supporting structures to provide a matrix for interaction and a framework on which the tapestry must be woven, whilst the section on Programme Management provides an outline of the way in which the project is envisaged to function as an evolving entity.

Attempting to construct global syntheses and models from national level research alone is unlikely to prove successful even with adequate investment in Framework Activities and Programme Management, since many of the issues and uncertainties discussed in the Science Plan are beyond the interests or capacity of single nations to address. It is foreseen therefore that in certain fields, core research or Integrative Activities that are broad and inter-disciplinary in content and wide in spatial domain, will need to be conducted and this will require significant investment of new research money. Two Integrative Activities are outlined in the present document and it is envisaged that other activities will be developed in collaboration with international partners and funding agencies in the future. These activities will provide a substantial research frame of reference within which more spatially limited studies can be integrated and which will bring further insight and understanding to national level research.

Science evolves as knowledge and understanding improve, and static research plans represent evolutionary dead ends. Although this Implementation Plan has been prepared on the basis of a ten year life span, it is anticipated that it will evolve and change during the implementation of the project. The opportunity for regular review, redirection and change will be provided through Open Science Meetings which will be convened by the international Scientific Steering Committee of LOICZ. Figure 4 which lists the LOICZ Foci

and Research Activities described in this Implementation Plan represents a stage in this evolution since the Activities have been grouped slightly differently from their presentation in the Science Plan. The Activities, Tasks and Sub-tasks outlined in the following chapters are not intended as a proscriptive listing of "LOICZ Research", rather they provide a starting point for addressing the research issues and uncertainties surrounding global change and the coastal zone. Although examples of specific coastal ecosystems, or geomorphic types are used in detailing the nature of the research that is required, similar research can and should be designed to address the same scientific issues and uncertainties in other ecosystems and geomorphic settings. This diversity of research activities is necessary if regional and global scenarios and models of change are to be developed and if we are to understand the role of the world's coastal zones in the functioning of the Earth system.

Focus 1: The Effects of Changes in External Forcing or Boundary Conditions on Coastal Fluxes

Activity 1.1 Catchment basin dynamics and delivery
Activity 1.2 Atmospheric Inputs to the Coastal Zone
Activity 1.3 Exchanges of energy and matter at the shelf edge
Activity 1.4 Development of coupled models for coastal systems

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Focus 2: Coastal Biogeomorphology and Global Change.

Activity 2.1 The role of ecosystems in determining coastal morphodynamics under varying environmental conditions
Activity 2.2 Coastal biogeomorphological responses to anthropogenic activities
Activity 2.3 Reconstruction and prediction of coastal zone evolution as a consequence of global change

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Focus 3: Carbon Fluxes and Trace Gas Emissions

Activity 3.1 Cycling of organic matter within coastal systems
Activity 3.2 Estimation of net fluxes of N_2O and CH_4 in the coastal zone
Activity 3.3 Estimation of global coastal emissions of Dimethylsulphide

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Focus 4: Economic and Social Impacts of Global Change in Coastal Systems

Activity 4.1 Evolution of coastal systems under different scenarios of global change.
Activity 4.2 Effects of changes to coastal systems on social and economic activities
Activity 4.3 Development of improved strategies for the management of coastal resources

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Activity 1.4 above encompasses activities 1.4 and 1.6 of the LOICZ Science Plan.

Activity 2.3 above encompasses activities 1.5 and 2.3 of the LOICZ Science Plan.

Figure 4. The Research Foci and Activities of LOICZ, and their relationship to those outlined in the LOICZ Science Plan.

The Research Plan

LOICZ Framework Activities

Background

The IGBP Core Projects, whilst global in scope, are necessarily dependent on research conducted at a smaller spatial scale, and the IGBP as a whole relies on nationally funded research to achieve its programme goals. Most of the research that will contribute to the specific goals of LOICZ will be funded and implemented through national mechanisms and agencies and will include specific national objectives, which may not coincide with those of the LOICZ Core Project. To ensure co-ordination of results and the active participation of coastal scientists in contributing to the preparation of global syntheses and models, LOICZ will engage in diverse networking activities designed to both provide service to researchers and to ensure their continuing contribution to the work of the project.

In developing global syntheses and models, covering aspects of the role of the coastal sub-system in the Earth system, strong co-ordination of the results from research conducted in more narrowly defined spatial domains will be vital. Classically such co-ordination would have necessitated the development of a centralised facility for data management, storage and modelling however, in the context of modern information technology such a centralised management system is unnecessary. The overall philosophy for the development of the co-ordination functions within the LOICZ Core Project will place strong emphasis on networking, dis-aggregated data storage, and the use of modern information technology, where appropriate.

The LOICZ CPO will provide the focus for co-ordination of Framework Activities, and Integrative Activities (Core Research), components of which will be implemented through other designated centres that will include research and regional nodes (see Programme Management).

LOICZ Framework Activity 1 - Scientific Networking

Introduction

A considerable body of scientific research has been, and continues to be undertaken in the world's coastal areas, through individual, national, regional and international programmes and activities. Since the coastal zone as defined by LOICZ encompasses both the land margin to an approximate altitude of 200m above sea level and the coastal waters out to the edge of the continental shelf, the community of natural scientists currently conducting research in this domain encompasses marine, terrestrial and freshwater specialists. In addition, LOICZ interests in analysing the feedback between change in coastal zones and the human driving forces of, and changes in, atmospheric and open ocean boundary conditions, will necessitate the involvement of specialists from the social

sciences, and from the atmospheric and open ocean, natural sciences community. In order to meet the objectives of LOICZ in producing global scenarios of change in the coastal zone, and elucidating the role of the coastal sub-system in the functioning of biogeochemical cycles, it will be necessary for LOICZ not only to seek the active input of such wider research communities into this work but also to supply these diverse research communities with the coastal information and data that they require in order to meet their own objectives.

The LOICZ research community of scientists, both natural and social, directly involved in executing national, regional and global studies within the overall framework of the LOICZ Project will need to be provided with mechanisms for the regular exchange of news and information concerning research results and developments during the life-time of the project.

Overall objectives

The overall objectives for the networking framework activity of LOICZ are to:

- Facilitate access by LOICZ researchers to the information and data needed to further develop understanding of the processes involved in global change and coastal zones
- Facilitate access by other national, regional and international coastal zone programmes to LOICZ research, data and information

The LOICZ approach

The LOICZ approach will involve networking at three semi-independent but related levels, namely those of: the individual scientist; the IGBP National Committees; and, international organisations and programmes including other Core Projects of the IGBP. At the level of the individual scientist LOICZ networking functions will be designed to: keep participating scientists abreast of overall developments within the LOICZ Core Project on a regular basis; put individual scientists in contact with other members of the LOICZ and IGBP global networks having similar research interests or involvement in on-going projects; provide access to information concerning data sources and where appropriate to facilitate such access; and to provide appropriate fora for the regular exchange of views concerning cutting edge developments in the field of global change and coastal zones.

At the level of the National IGBP Committees LOICZ, through the CPO and the Scientific Steering Committee will provide: regular information on developments in the LOICZ Project; guidance concerning the nature of activities which may be seen as contributing to the overall goals of LOICZ; assistance in categorising nationally funded research through the development of appropriate criteria for distinguishing Core, Regional, National and Relevant LOICZ research (see Appendix 2); and, information concerning the nature of research activities conducted through other relevant, national global change research programmes.

In terms of networking at the international level the LOICZ CPO will provide a focus for the exchange of information and data concerning on-going research conducted within the

framework of LOICZ and other international research programmes concerned with global change and the coastal zone, and will, where appropriate, develop linkages to facilitate the access of LOICZ researchers to other global and regional databases, networks, and research activities, and *vice versa*.

In executing these functions neither the LOICZ-SSC nor the CPO envisage that LOICZ will function as a data bank, rather it will facilitate information and data flow and only when required by the specific objectives of identified LOICZ Activities and Tasks will the CPO and LOICZ-SSC become involved in the compilation and assembly of specific databases. Nevertheless it is clear that some database activities will require the direct involvement of the CPO and LOICZ-SSC and these are outlined below (Framework Activity 3).

The modality of operation of LOICZ networks will involve the transfer of information and data using various media, depending on the most appropriate mode of transfer, determined on a case by case basis, between individuals, designated nodes, institutions and organisations

Task F.1.1 Establishment of LOICZ research networks

Rationale

To accomplish the Activities and Tasks envisaged in this Implementation Plan will require the adoption of an integrated and comparable approach to different scientific issues and questions by individual scientists working in different countries and different environments. Harmonisation of these different approaches will only be achievable through close collaboration and rapid transfer of information between involved individuals.

Specific objectives

- Establish an overall network of LOICZ scientists and ensure appropriate linkages between individuals and institutions engaged in addressing similar scientific issues and problems relating to global change and the coastal zone
- Establish, as appropriate, regional and specialist research networks of active coastal zone researchers

Implementation

This task will be closely co-ordinated by the CPO and will be accomplished through the establishment of initial mailing lists of scientists involved in research in global change and the coastal zone. An initial listing of 1,000 corresponding scientists from 124 countries has been established and this network has received copies of the draft Implementation Plan for review. Periodic directories of LOICZ scientists and research projects will be produced for distribution throughout the network. Specialist networks will be established where appropriate in conjunction with the development of LOICZ research and regional nodes, (see programme management). LOICZ National Focal Points established by the National IGBP Committees (Appendix 3) will be provided with regular, but *ad hoc* information concerning developments in the LOICZ Project for dissemination to the community of coastal change scientists in the country concerned. Since the IGBP at present has National Committees in only 72 countries, and more than twice that number of countries are coastal

or archipelagic, a considerable body of research is currently being undertaken of relevance to LOICZ which is outside existing IGBP networks. The LOICZ CPO will address this problem through establishment of networks of individual scientists in such countries undertaking research in global change and the coastal zone, and through close collaboration with other international organisations such as the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Oceanographic Commission (IOC), the United Nations Environment Programme (UNEP), the World Conservation Union (IUCN) and the UNESCO-Man and the Biosphere Programme (MAB) which already have established networks of coastal scientists in such countries.

Outputs

- Functioning networks of active coastal researchers organised around LOICZ research Foci and Activities
- Periodic directories of LOICZ researchers and research projects

Task F.1.2 LOICZ publications

Rationale

Once the LOICZ project becomes operational and projects and research activities are initiated by the LOICZ-SSC or are approved at a national level, there will be an increasing need for rapid transfer of information within the LOICZ research community concerning on-going projects and results.

Specific objectives

Short-term

- Provide a forum for the regular transfer of synoptic information concerning LOICZ plans, research activities and results amongst the LOICZ research community

Long-term

- Provide a forum for the exchange of reviews of LOICZ science and metadata concerning research on global change and the coastal zone

Implementation

In executing this task the LOICZ CPO will organise, publish and distribute a series of publications including a regular newsletter, a Workshop Report series and a Reports and Studies series.

Initially the newsletter will be produced by the CPO, with the assistance of the LOICZ-SSC and will be based on inputs from participating scientists, national IGBP Committees and partner organisations. In the first instance the newsletter will be produced in hard copy form only and air-mailed to individual scientists, national IGBP Committees and collaborating institutions and organisations. The problems of electronic information transfer to developing countries will require continuation of the newsletter in hard copy form for the anticipated ten year life span of the LOICZ project although the development of regional centres and electronic mailing facilities through the START Framework Activity of the IGBP will progressively reduce the need for hard copy production over the

life of the project. It is anticipated that an "electronic" version of the newsletter will be produced before the end of 1995, thus reducing the extent of the hard copy mailing as the network of LOICZ scientists grows. This development will be closely co-ordinated with the similar developments planned by the IGBP Secretariat for the IGBP as a whole.

Whilst it is anticipated that the substantive outputs of LOICZ research, and the scientific results of specific workshops, will be formally published in the internationally refereed scientific literature and in the form of contributions to the IGBP Cambridge University Press Series, it is also anticipated that the record of discussions and decisions undertaken in LOICZ workshops will be of immediate interest to scientists participating in LOICZ research. The LOICZ CPO will, therefore, organise the informal publication and rapid distribution of technical meeting reports to scientists within the LOICZ networks having interests in the topics of the workshops concerned. In addition, it is anticipated that topical reviews of various scientific issues; agreed methods and research protocols for LOICZ activities; and some databases, will need to be published promptly, and widely disseminated for discussion and/or adoption by the scientific community. The LOICZ Reports and Studies Series will therefore be published by the LOICZ CPO on an *ad hoc* basis to meet these needs as they arise.

Outputs

- Quarterly hard copy newsletter distributed to the LOICZ research network, IGBP National focal points, collaborating organisations and institutions (5,000 copies)
- Coincident production of an electronic version of the newsletter
- LOICZ Meeting Report series
- LOICZ Reports & Studies series
- Contributions to the IGBP Book Series to be published by Cambridge University Press

Task F.1.3 LOICZ Annual Open Science Meetings

Rationale

The SC-IGBP has charged the Scientific Steering Committees of its Core Projects to organise regular, annual Open Science Meetings at which the results of on-going research and developments within the Core Projects can be presented to, and discussed amongst, the widest possible groups of scientists.

Specific objectives

- Stimulate wide international participation in the LOICZ Core Project
- Provide a forum for potential funding agencies to evaluate the results of LOICZ Research and possible areas for future support
- Provide a forum for the dissemination and discussion of the planning, implementation and results of LOICZ Research
- Provide the opportunity for wide participation by the scientific community in formulating strategies for LOICZ Research
- Ensure periodic review and redirection, as appropriate, of the aims and objectives of LOICZ Research

Implementation

The LOICZ CPO will take responsibility for the organisation and management of annual open scientific meetings, whilst the LOICZ-SSC will be responsible for the development of the scientific programme. These meetings will be convened at different locations in order to maximise contacts between LOICZ and the global scientific community. It is envisaged that each meeting will focus on particular areas and priorities of LOICZ Research. These areas and topics will differ from time to time according to the results of on-going research, new developments, findings and insights in the field of global change and the coastal zone. In addition, the meetings will serve to acquaint the LOICZ research community with developments in methods, standards and protocols developed by workshops during the intervening period, and to publicise the developments of the LOICZ Framework activities as a whole. In accordance with the philosophy of the IGBP, these meetings will be open to the global scientific community and the IGBP National Committees will be encouraged to nominate and send representatives where appropriate.

Outputs

- Periodic review and revision of priorities for specific areas of LOICZ Research
- Publication of proceedings, as appropriate
- Publication of volumes of research results, as appropriate
- Improved information flow and collaboration between LOICZ scientists
- Regional and global syntheses of LOICZ results

LOICZ Framework Activity 2 - Development of a Coastal Typology

Introduction

Financial and human resources to carry out LOICZ are finite and those available can be used more efficiently if they are focused in key geographic coastal regions. It is not necessary to conduct empirical studies in every coastal area of the world in order to develop global scenarios and predictive models since large areas of the coastal zone have similar properties. One of the most important initial tasks for LOICZ is to establish a global coastal zone classification system or typology based upon available scientific information, both descriptive and dynamic. This system will subdivide the world's coastal zone into a number of discrete, scientifically valid units on the basis of natural features and processes. The typology will be used as the basis for encouraging new research projects in coastal types which are under-represented in current research activities and for analysing and reporting results on a regional and global basis.

Overall objectives

The overall objective of this framework activity is to categorise the world's coastal zone on the basis of natural features, into a realistic number of geographic units, which will serve as a framework for:

- Overall co-ordination and planning of LOICZ research activities
- Organisation of data bases

- Selection of regions for extensive studies (remote sensing, long term monitoring)
- Selection of appropriate sites for new local and regional coastal zone field and modelling studies
- Scaling local and regional models to regional and global scales
- Analysis, compilation and reporting of LOICZ results in the form of regional and global syntheses
- Interfacing with the regional research nodes

The LOICZ approach

This task will be initiated immediately and make full use of recent advances in Geographic Information Systems (GIS) technology. The first step will be to review existing coastal classification schemes and to determine the best approach to meet the LOICZ objectives. This approach is likely to parallel modern numerical taxonomic methods of classification by similarity using *inter alia*, distance statistics, discriminant function and cluster analysis.

While the priorities for LOICZ research will in part depend upon the initial results, this activity must be considered as on-going, dynamic, and subject to evolution in both methodological and output terms. It will proceed on an iterative basis and the boundaries between different coastal units and the definition of representative coastal unit types will probably change as the project evolves and more data become available. The results of the typology exercise will be used to determine the organisation of LOICZ data bases (see Activity F.3) and by each LOICZ focus according to its specific requirements. For example, the classification will provide the basis for selection of specific coastal zone units in which empirical and modelling studies are needed to ensure global coverage of the variability displayed by the world's coastal subsystem as a consequence of its high spatial and temporal heterogeneity. Without a rational framework for classifying the world's coastal zones, the appropriate weighting for data from each coastal type cannot be determined and accurate global syntheses of the role of the coastal sub-system in the Earth system cannot be prepared.

Assuming that the World's coastline is of the order of 600,000 kilometres, division into segments of approximately 1,000 km would result in 600 units. Efforts will be made to reduce the number of units to an optimum number for practical application in the framework of LOICZ activities.

Task F.2.1 Development of a system for formulating LOICZ global coastal typologies

Rationale

The global scope of LOICZ and the constraints of human and financial resources, necessitate the development of an objective typology of coastal units to serve as a sampling framework and to determine the appropriate weighting for preparing global syntheses, scenarios and models on the basis of limited spatial and temporal research data.

Specific objectives

Short-term

- Develop a framework global coastal zone typology based upon existing scientific information
- Use the typology to guide the development of the LOICZ Core Project

Long-term

- Refine and develop the typology according to the evolving needs of the Project and the individual Foci
- Apply the typology in preparing regional and global syntheses, and in developing scenarios and models

Implementation

This task will be conducted primarily by the CPO in collaboration with the LOICZ-SSC. Work will begin by reviewing current classification systems and determining in consultation with the LOICZ-SSC the best approach to adopt in meeting the goals of the LOICZ Project. Once the approach is agreed the appropriate available information will be assembled and a first draft of a typology produced. Factors to consider for inclusion at this stage will include *inter alia*: geography (shelf width, shoreline configuration, bathymetry, etc.); catchment area and characteristics including land-use and freshwater runoff; sediment and nutrient input; rainfall; salinity; tidal range; exchanges at the shelf edge; type of seasonal boundary conditions; areal extent of important habitat types (mangroves, saltmarshes, intertidal flats, reefs, macrophyte beds, banks, ledges, etc.); seabed sediment characteristics; levels of primary production; fisheries production; and demographic and socio-economic characteristics.

On the order of 100-200 divisions of the world's coastal zone are anticipated, many of which will have similar properties, such that they can be assumed to be identical in function from the Earth system perspective. By grouping similar units, it is expected that a more limited number of key functional coastal types will be recognised (e.g. wide shelf with strong boundary current, narrow shelf with heavy freshwater and sediment input, etc.). The results will then be used by the CPO and LOICZ-SSC to guide the further development of the LOICZ Core Project. Throughout the development of this activity, results will be reported and discussed at LOICZ workshops and meetings and ultimately published in an appropriate format. Once established, the typology will be used by the LOICZ CPO as a basis for organising data bases of LOICZ research results and for preparing regional and global scenarios and models.

Outputs

- Functional typology of the world's coastal zone
- Framework for the selection of sites for LOICZ research activities
- Framework for the compilation of regional and global syntheses of data, scenarios and models of the role of the coastal sub-system in Earth system functioning

LOICZ Framework Activity 3 - Data System Plan

Introduction

As noted in IGBP Report No 30, each Core Project will need to develop its own data system plan, incorporating guidance on data quality and availability, management, exchange and application in global syntheses and modelling activities. As detailed elsewhere in this Implementation Plan, LOICZ modelling activities will be undertaken at a variety of scales and will involve a wide diversity of data types which will need to be interfaced at various different levels and for varying purposes. The development of the LOICZ Data System Plan will therefore form a fundamental and critical activity on which the ultimate success or failure of the LOICZ Core Project as a whole will depend.

National level research will form a fundamental component of the implementation and execution of the LOICZ Core Project and hence it will be important for LOICZ to establish strong working relationships with national IGBP Committees and LOICZ Focal Points, where these have been identified by the National Committees, in developing agreed procedures for the acquisition, storage and transmission of data generated by national activities as a contribution to the LOICZ Project. Much of this data will be synoptic since the integrative nature of LOICZ activities and the need to describe and model coastal processes at regional and global scales will, in combination with the financial and manpower constraints of the project management as a whole, limit the capacity of the LOICZ CPO and research nodes to handle complex, detailed datasets.

Overall objectives

- Identify existing sources of data required for LOICZ hence obviating the need for *ab ovo* data collection in some instances
- Assemble the necessary datasets from existing sources, on-going national and regional LOICZ research which are required to address the overall goals of LOICZ (see for example Activity 3.1)
- Prepare regional and global syntheses of data needed for modelling at different scales
- Prepare and distribute directories of existing data and information where these exist and are required for LOICZ research activities within the different Foci
- Facilitate the access of LOICZ researchers to data held in existing international systems for purposes of modelling and synthesis within the context of LOICZ

The LOICZ approach

Except in specific instances, identified as being priority needs by the LOICZ-SSC and where it can be demonstrated that such data sets do not already exist, LOICZ will not be involved in the *ab ovo* assembly of new global data sets based on specific observations. The approach of LOICZ will be to use in novel ways, existing international datasets wherever possible and to apply a georeferenced approach to the storage of coastal data of differing types, enabling them to be manipulated and applied in models of differing scale and complexity, and for specific LOICZ research activities.

The precise nature of the data required to answer the scientific issues and uncertainties outlined in the LOICZ Science Plan is staggeringly complex, ranging from remotely sensed data concerning rates of change in coastal morphology, land use and vegetation, through regional and global coverage of *in situ* measurements of chemical and physical parameters. Clearly, assembling the total data required to address all issues and questions will be beyond the logistic capacity of the CPO, the LOICZ networks and the scientific community within the ten year life span of LOICZ. The LOICZ Data System Plan will therefore be developed to clearly delimit priorities for dataset development in parallel with the development of research activities.

Task F.3.1 Development and publication of the LOICZ Data System Plan

Rationale

The development of global syntheses, models and scenarios are key activities of LOICZ, which are data dependent. To achieve the long-term goals of LOICZ a clearly formulated plan for data acquisition, quality control, management and exchange is required.

Specific objectives

- Identify the specific, remotely sensed and *in situ* data sets required by LOICZ research activities
- Identify existing data sources that meet the needs of LOICZ research activities
- Formulate guidelines for the acquisition, quality control and exchange of data within the project
- Determine, in close collaboration with IGBP-DIS and with other international agencies currently involved in the acquisition and archiving of relevant data, the appropriate mechanisms for LOICZ acquisition and manipulation of such data sets as are required from time to time
- Outline the nature of the overall databases required in support of the preparation of global syntheses and LOICZ models
- Determine the nature of appropriate products in relation to the users of the system

Implementation

The LOICZ CPO will, in close consultation with the LOICZ-SSC and the IGBP-DIS, develop a LOICZ Data System Plan encompassing *inter alia:* identification of the information and data needs of the Project as a whole; the need for data quality assurance in relation to identified data sets; proposals concerning the mechanisms which need to be developed to ensure the required data quality and standards; the need for new datasets as envisaged by the global syntheses and modelling activities outlined in this Implementation Plan; priorities for development of such new datasets; the need for metadata and catalogues providing the LOICZ Research network with the information required concerning data availability; plans for the archiving of new datasets developed during the lifetime of the project; the need for and mechanisms to establish external co-operative linkages with agencies and organisations such as the IODE of the IOC for access and exchange of data. In addition the system plan should contain an initial outline of the LOICZ data policy regarding access and exchange with individuals, institutions and other data agencies. It is envisaged that the Data System Plan will require development over a

two year period, through the organisation of appropriate workshops where required, and through active collaboration and interaction with IGBP-DIS, IGBP-GAIM and the relevant international data storage and archive systems.

Output

- LOICZ Data System Plan

LOICZ Framework Activity 4 - Measurement Standards, Protocols and Methods

Introduction

Given the wide diversity of activities, tasks and sub-tasks envisaged in this Implementation Plan as being undertaken during the ten year life-span of this project and the need to ensure data comparability and compatibility if global syntheses and models are to result from these activities, agreed standards, protocols and methods for LOICZ Research will need to be developed. Whilst the standards and protocols needed to assure data quality control will be defined and developed within the context of the LOICZ Data System Plan a parallel and co-ordinated initiative will be required to address issues of measurement and quantification in the various research tasks envisaged. In some areas of research well defined, internationally agreed methods exist and where appropriate these will be adopted and recommended for use in the LOICZ Core Project. Such agreed methods cover a wide variety of physical and chemical parameters including *inter alia*, sea level, salinity, and determination of nutrient concentration in waters and sediments. In other cases no such standardised methods exist, and from time to time it may prove necessary for LOICZ to develop such methods to ensure that data are collected in a uniform manner throughout the LOICZ Research network. The absence of such standards causes major problems of synthesis as exemplified in the case of world-wide data for coral cover and rates of change in reefs. Since the techniques used to assess these variables are not standardised, even within countries in some instances, no global assessment of the state of coral reefs and their rates of change can be prepared from existing data.

In a number of instances, remotely sensed data exist, which can be used to provide information concerning variables in the coastal zone of interest to LOICZ research, but the algorithms to quantify this information may not yet have been developed. Where necessary LOICZ will encourage, in collaboration with appropriate organisations such as IGBP-DIS, the development of such algorithms and their adoption throughout the LOICZ networks. It is further recognised that in the case of much of the integrated natural and social sciences research and modelling envisaged under Focus 4, agreements will be needed concerning the spatial references used in the collection of both sets of data and mechanisms to ensure adequate linkage of such datasets will need to be developed.

Overall objective

- Ensure that the information and data contributing to the regional and global syntheses envisaged as being produced through the national and regional research contributions to the LOICZ Core Project are collected in such a manner as to be both comparable and compatible on a global scale

The LOICZ approach

The LOICZ approach will be to adopt, wherever appropriate, existing internationally agreed standards protocols and methods for use in LOICZ Core, Regional and National Research, and to ensure the wide dissemination of this information to participating scientists who will be encouraged to adopt them, for use where practical and appropriate.

Where appropriate agreed international standards, protocols and methods do not exist, LOICZ will encourage their development and adoption for those areas of LOICZ science which require compatible and comparable primary datasets. It is envisaged that this Framework Activity will be initiated on an *ad hoc* basis by the research nodes identified for specific purposes within the framework of LOICZ and that such standards, protocols and methods would be developed initially through: an international workshop review of existing techniques in current use for variables of interest to LOICZ; the selection of one or more appropriate and applicable techniques for trailing and validation where needed; followed by adoption of the technique as a LOICZ Standard, Protocol or Methodology, which scientists contributing to the LOICZ Core Project would be encouraged to adopt and use. The LOICZ CPO will be responsible for publishing and disseminating agreed standards protocols and methods once they have been adopted by the LOICZ-SSC on the advice of the relevant research node.

It is recognised that the costs of obtaining measurements using particular techniques or technologies may be beyond the capacity of certain sections of the LOICZ research community at this time. Where practical and feasible LOICZ will facilitate the upgrading of technologies in institutions contributing to Core and Regional research. It is however recognised that the operation of less expensive techniques may be required which could contribute vital data. Where such duplicate techniques or technologies are adopted their value is enhanced if both techniques or technologies are operated simultaneously at some reference points to provide standardised inter-comparisons and statistically valid relationships between the two data sets.

Since LOICZ activities and foci will involve considerable efforts directed towards regional and global modelling it is further envisaged that workshops will be needed to develop the modelling approaches for each focus, within the framework of the overall modelling approaches adopted by the project as a whole and outlined in the following Framework Activity (F.5).

Task F.4.1 Development and publication of the LOICZ measurement standards, protocols and methods

Rationale

To develop global syntheses will require the collection of data on environmental variables and processes using agreed measurement standards, protocols and methods which permit the comparison and aggregation of data and information derived from separate national and regional research programmes.

Specific objectives

- Identify and adopt as appropriate existing internationally agreed standards, methods and protocols for measurements and analyses which will be undertaken as part of LOICZ Core, Regional and National Research
- Formulate when necessary, appropriate standards, protocols and methods for measurements required as part of LOICZ Research and for which appropriate, agreed, international guidelines do not currently exist

Implementation

It is anticipated that following the adoption of the *Implementation Plan* and the identification of research nodes a series of workshops will be required to consider in broad terms issues of: measurement standards, protocols and methods; data acquisition and handling; and modelling within each of the foci separately. It is anticipated that these workshops will identify appropriate, existing international, agreed standards and methods and identify those areas which will require the development and/or adoption of agreed LOICZ standards, protocols and methods.

Outputs

- Workshop reports covering each of the four foci of LOICZ
- *Ad hoc* series of publications detailing agreed and approved LOICZ standards, protocols and methods
- Regular information to the LOICZ research network concerning standards, protocols and methods

LOICZ Framework Activity 5 - Modelling in LOICZ

Introduction

Understanding the interactions between the coastal zone and global change cannot be achieved by observational studies alone. Numerical modelling of key environmental processes is a vital tool which must be used in all components of LOICZ for it to attain its objectives. The process of developing models helps to improve scientific understanding of how coastal ecosystems function and respond to changing forcing functions while the models themselves, if properly constructed and validated, can be used to predict the effects of future change. Modelling must be initiated at the very beginning of LOICZ and carefully integrated with observational studies, both intensive and extensive.

There are three general categories of numerical models that should be developed as part of LOICZ.

- *Budget models*
  Mass balance calculations of specific variables (e.g. carbon, nitrogen, phosphorus, sediment, etc.) within defined spatial and temporal scales. Include all major sources, sinks, and transformation processes. Descriptive, with no internal dynamics.

- *Process models*
  Describe specific environmental processes (e.g. flushing, sedimentation, photosynthesis, respiration, etc.) and how they are influenced by major forcing functions. They are usually constructed from empirical studies.

- *System models*
  Based upon process models. Integrate what are considered to be the most important variables and processes for the system in question within defined spatial and temporal scales. Particular attention is usually given to the interaction among state variables. Can be either descriptive (e.g. network analysis) or dynamic (e.g. simulation models).

All three categories offer the potential for making predictions, but system models are expected to be of great value to LOICZ in this regard. In most cases it will be advisable to construct budget models before system models are developed, and simple extrapolations from budgetary models are likely to prove more robust predictors than system models for the foreseeable future.

Numerical modelling can be done on different spatial and temporal scales. Three general spatial scales are identified:

- *Local:* Scale on the order of 1-100 km. These would address specific habitats such as saltmarshes, mangrove forests, deltas, coral reefs, estuaries, bays and fishing banks.

- *Regional:* Scale on the order of 100-10,000 km. Incorporate a variety of near-shore and off-shore habitats out to the 200 m isobath. This scale will coincide with the units defined in the coastal typology exercise (Task F.2.1).

- *Global:* Incorporate several regional models representing the entire coastal zone of the Earth.

Models can have different temporal scales depending on their particular purpose, but prognostic, global scale models ultimately required by LOICZ must have a temporal scale on the order of 10-100 years so that they can incorporate episodic events.

It should be noted that because of the linear nature of the coastal zone, some of the LOICZ models will have a spatial configuration resembling a ribbon, that is the along-shore dimension will be much greater than the off-shore dimension. This is in contrast to Open Ocean models which usually have relative spatial dimensions of similar magnitude.

This activity describes the framework that is necessary to direct and co-ordinate numerical modelling in LOICZ. Specific modelling activities are described in more detail in the relevant sections of each Focus.

Overall objectives

The overall objective of numerical modelling in LOICZ is to develop predictive models capable of describing the interactions between the world's coastal zone and global change.

This requires conducting a wide variety of modelling activities, which must be developed through international scientific collaboration. These longer term objectives can be met through the following specific objectives:

- Develop a strong conceptual and organisational framework for numerical modelling activities
- Develop improved methods for assimilating fine scale models into large scale models
- Develop budget and system models at the local and regional levels
- Evaluate and validate local and regional models
- Scale up local/regional models in global coastal zone models
- Integrate global coastal zone models into Earth system models

The first two of these objectives will be met through Framework Activities and are outlined in further detail below. The remaining objectives will be met through research undertaken under the relevant Foci and Integrative Activities (Core Research), which are described in detail elsewhere in this document.

The LOICZ approach

LOICZ will give particular attention to budget and system models because of their highly integrative nature. It is recognised that the best modelling approach to follow for a particular situation will depend upon the questions being asked, the resources at hand and the availability of data. A sound rule that should be followed in modelling is to start with the simplest route possible and add complexity only when clearly justified. It is also recognised that the field of environmental numerical modelling is evolving rapidly and that techniques recommended today may be obsolete in just a few years.

It is essential that the large scale models ultimately required by LOICZ are developed in a closely co-ordinated manner. This requires the establishment of a LOICZ modelling framework under Task F.5.1 to provide the necessary degree of standardisation, communication and information exchange. In particular, it is important to develop recommended techniques based upon the best available methods for building budget and system models at the local and regional levels.

Under Task F.5.2, LOICZ will develop improved techniques for assimilating the output of fine scale models into large scale models which will be necessary to construct the global scale predictive models ultimately desired. These must address scaling up both temporal and spatial scales, interfacing with data bases and incorporating remote sensing data. It is important to develop techniques whereby the essential features of detailed models can be extracted and fed into more general models. In particular, it is essential to improve the methodology of coupling biogeochemical sub-models to hydrodynamic models. Coastal system models are highly dependent on hydrodynamic models, which are themselves usually constructed at grid dimensions of 5 km or less. Scaling these distances up may not lead to realistic models for highly heterogeneous systems because of the detail lost. On the other hand, it is usually impractical to run biogeochemical sub-models interactively for every grid of a hydrodynamic model because of limits on available computer capacity. This is a dilemma, which may be resolved in the near future by development of new hardware.

Under Focus 1, LOICZ will develop both local and regional scale carbon flow models following the recommended techniques. Through the modelling framework organisation that will be developed, software, algorithms, sub-models, and data, can be exchanged as appropriate.

Under Focus 2, LOICZ will develop models describing how changing sea level will affect biogeomorphological processes in the near-shore zone.

Under Focus 3, the results of different models developed for the same type of coastal unit will be compared and the possibility of developing generic models explored. In addition, models developed for different types of coastal units will also be compared.

Under Focus 4, LOICZ will develop integrated, inter-disciplinary, natural and social sciences models to explore impacts of global change on human use of the coastal zone. These will be primarily of local and regional scale and incorporate information on living and non-living resources.

Under its Integrative Activities (Core Research) LOICZ will also scale up the local and regional models into models of the entire global coastal zone. These global coastal zone models in turn will be fed into Earth system models, including atmospheric, terrestrial and deep-ocean components in co-operation with GAIM. It is recognised that it is almost impossible to development reliable predictive models of the global coastal zone within the ten year life time of LOICZ but the goal is worthy and a start must be made. It is hoped that as a minimum, LOICZ will develop some sound approaches and some preliminary products.

Task F.5.1 Development of a strong, centralised framework for LOICZ modelling activities

Rationale

The development of numerical models of coastal ecosystems encompassing all major forcing functions is a key activity of LOICZ and will require careful integration with data collection activities. Previous modelling work in the coastal zone has tended to focus on particular processes such as runoff, hydrodynamics, nutrient cycling or primary production, but sufficient progress has now been made, both in scientific understanding and in computer technology, to begin the development of realistic models for complete coastal systems at different spatial and temporal scales. In order to meet the goals of LOICZ, these models must be developed in a closely co-ordinated manner.

Specific objectives

Short-term

- Review the current state of coastal zone modelling activities around the world which contribute to the objectives of LOICZ
- Develop a guidebook of recommended techniques for constructing budget and developing system models
- Use the results of the coastal typology exercise (Task F.2.1) to identify specific coastal units for which new integrative models are needed

- Encourage the development of new local and regional coastal zone modelling studies using the recommended techniques
- Develop an international network of scientists who are interested in collaborating in model development under LOICZ
- Co-ordinate all numerical modelling activities to be conducted under LOICZ

Implementation

This task will require considerable co-ordination and the active participation of scientists from around the world who are involved in coastal zone modelling at all temporal and spatial scales. An initial activity will involve reviewing the results of the coastal typology exercise (Task F.2.1) and identifying the major coastal units world-wide for which new models should be developed. At the same time, existing numerical models of coastal habitats which can contribute to LOICZ objectives, should be identified and both the techniques and results reviewed. The existing results should then be collated and interpreted in relation to the LOICZ coastal classification units to ascertain the requirements for new modelling studies.

Given the importance of data collection to a wide variety of LOICZ Activities and Tasks and the need for consistent approaches to modelling if results are to be compared and compiled to produce regional and global syntheses, a small workshop of modelling experts will be convened in 1995 to develop a guidebook of recommended modelling techniques to serve as templates for the development of new local and regional models. The temporal relationship between this activity and others concerned with modelling is shown in Figure 7. An international network of scientists conducting and co-ordinating the required field work and modelling studies will be established and regular communications maintained by electronic mail (e.g. Internet) and through regional scientific workshops which will be convened at regular intervals as regional level activities develop. It is anticipated that reviewing the results of modelling activities will form a regular component of the annual LOICZ Open Science Meetings to be convened by the CPO and LOICZ-SSC.

Outputs

- An international network of coastal ecosystem modellers (1995 but updated continually)
- A guidebook of recommended LOICZ coastal modelling techniques
- A list of representative coastal units for which new local and regional models are needed to fulfil the long-term objectives of LOICZ
- A well co-ordinated series of inter-connected LOICZ modelling activities

Task F.5.2 Develop improved methods for assimilating fine scale models into large scale models

Rationale

It will be necessary to scale up fine resolution models of small spatial and temporal domain into larger scale ones to meet the regional and global objectives of LOICZ. Current methodology for achieving this is limited and there is a need to develop new and better techniques.

Specific objectives

- Review and develop as necessary suitable methods for assimilating fine scale models into large scale models
- Document these methods and distribute them to the LOICZ research community

Implementation

This task will be accomplished by holding a series of LOICZ sponsored international workshops. These workshops will review the current methodology for scaling up modelling results and draft recommendations for further research. The first such workshop should deal with the coupling of biogeochemical sub-models to hydrodynamic models. The recommended research will be co-ordinated as a LOICZ Framework Activity but will involve close integration with national programmes. Results will be documented and recommended methods will be communicated to the LOICZ research community.

The development of fully coupled large scale system models is seen therefore as a longer term goal of LOICZ, which will require funding to conduct and co-ordinate the research necessary for LOICZ to take advantage of advances in modelling capability as they occur.

Outputs

- Continuously up-dated reviews of state-of-the-art methods for scaling up fine scale models into large scale system models

LOICZ Framework Activity 6 - Determination of the Rates, Causes and Impacts of Sea Level Change

Introduction

Sea level variations are a component of environmental change that has both global causes (at least in part) and global implications. Present global estimates for future rates of sea level change (e.g. IPCC reports) are essentially empirical in that they are semi-quantitative "best guesses" incorporating information about a number of complex processes (steric, non-steric, tectonic and isostatic effects, ice-water mass interchange). Furthermore, for any particular locality or region they are likely to be of only limited use on account of local variability in these processes which results in rates of change up to two orders of magnitude greater than, or opposite in sign to, the present global average of a rate of rise of about 2 mm per year. Improved forecasts of rates of sea level change are needed for each of the four research foci of the LOICZ project, particularly in relation to the development of realistic scenarios of change within coastal environments over the next 10 to 100 years. This Framework Activity will complement existing international projects concerned with sea level by promoting further studies of the rates, causes and prediction of sea level change in the context of the aims and activities of the LOICZ project. It aims to stimulate greater collaboration between geophysical scientists who measure sea level and study causes of change, and environmental scientists who are investigating the various impacts (including socio-economic ones) of variations and trends in sea level.

Overall objectives

The overall objectives of this Framework Activity are to promote the development of a capability for estimating and predicting more reliably present rates and future variations of sea level change over local to global scales, and to assemble and make available the results from such studies to regional and national research projects conducted as contributions to the LOICZ Core project.

The LOICZ approach

Current knowledge of the rates and causes of sea level change will be reviewed in the context of the LOICZ project, and the conclusions disseminated in a form useful for planning new research projects and for evaluating environmental impacts. Regions where coastal erosion is likely to be severe will be identified. Close contact will be maintained with the Scientific Committee on Oceanic Research (SCOR) reporting on sea level change.

LOICZ will work with the International Association for Physical Sciences of the Ocean (IAPSO), the International Association of Geodesy (IAG) and other international and national organisations to encourage the collection of observations on sea level in order to identify causes of change and to validate the output of global and regional predictive models. Such observations include state-of-art determinations of sea level and ice volume changes taking into account the effects of visco-elastic processes in geodynamically unstable shorelines, transfer of groundwater to the oceans, glacial rebound and tectonic processes. Optimal use will be made of classical measurements, as provided for example by the GLOSS tide gauge network of IOC and by absolute gravity determinations, and of new space techniques including altimetry, Very Long Baseline Interferometry (VLBI), satellite laser ranging and the Global Positioning System (GPS). The potential applications of new types of measurements, such as temporal variation of the geopotential, will be evaluated, and the development of a better understanding of interactions between the different processes contributing to sea level change will be given priority. LOICZ will encourage the sharing of instrumentation and software for collecting sea level observations (particularly within developing countries), and for archiving and disseminating the results in a standard format. The objective use of model results and predictions in planning and policy decisions will be fostered and, through the requirements of LOICZ research initiatives, the development of large scale models that incorporate regional and local scale models for global predictions of sea level change will be stimulated.

Task F.6.1 Assessment and measurement of sea level change in the context of LOICZ research

Rationale

Variations in sea level have local, regional and global causes and impacts. There is an immediate need to ensure that the most reliable data on rates and causes of sea level change are readily available to support LOICZ research activities concerned with the effects of current and predicted variations of sea level on coastal environments and resources.

Specific objectives

- Review knowledge of the rates and causes of sea level change in the context of the scientific research objectives of the LOICZ project
- Assess the impacts of future sea level changes in relation to the use and management of coastal resources, and help define the needs for better understanding of the causes of sea level change and for improved predictive capability of future sea level
- Identify the regions where sea level change poses the greatest environmental and socio-economic threats, and help collect information required to model, disseminate and interpret the results in support of planning and policy decision making

Implementation

This task will require close collaboration among marine scientists, ocean modellers, geodesists and geophysicists to determine the observational data required to resolve quantitatively the various factors contributing to observed sea level changes, and then to assimilate this information into a comprehensive simulation model in order to improve predictions of global, regional and local sea level change for the next 10 to 100 years. The model must include the effects of ocean circulation, ice-water mass interchange, geodynamic processes (plate motion, glacial rebound), coastal morphodynamics (see LOICZ Focus 2), and human activities such as fresh water management and extraction and shoreline engineering. An international network of scientists undertaking the field observations and modelling studies will be established. High priority will be given to forming or strengthening research teams and to convening workshops within regions that have the highest risk of adverse impacts due to sea level change on the coastal environment and on socio-economic activities.

Outputs

- Publication of periodic reviews on current knowledge of rates and causes of sea level rise
- Publication of global and regional coastal zone maps showing where sea level change poses the greatest environmental and socio-economic threats, with supporting information on probable causes of sea level change and on research needed to quantify and understand better the causes of sea level change in aid of policy decision making
- Improved access for research scientists and environmental assessment groups to databases on sea level change
- Improved procedures for determining current rates of sea level change, identifying the causes, predicting future trends, and initiating actions to minimise the environmental and socio-economic impacts

Focus 1: The Effects of Changes in External Forcing or Boundary Conditions on Coastal Fluxes

Background

Organic production and the transformation of nutrients, carbon, pollutants and sediments in, and their transport through, coastal systems are strongly influenced by physical and chemical forcing at the land, ocean, and atmosphere boundaries. Surprisingly little is known on a global scale, however, about the qualitative responses of coastal systems to changes in external environmental conditions. Such changes may arise from direct human activities such as dam building and sewage discharge, from short- or long-term changes in climate and ocean dynamics, or from ecological processes such as succession in watershed plant communities. Both observational and modelling studies are needed to identify and quantify existing relationships between the fluxes of energy and material at system boundaries, and to describe system behaviour. To test specific hypotheses, comparative investigations of different coastal systems are required.

Activity 1.1 - Catchment Basin Dynamics and Delivery

Introduction

Climatic factors determine the distribution of natural vegetation on a global scale, whilst human activities and changes in land use are presently altering vegetation cover on continental scales. Some evidence for feedback between these processes exists, in that longer term variations in climate may be altering patterns of human land-use in some areas. Changes in land-use and vegetation cover result in major modifications to freshwater runoff, sediment transport, and the fluxes of carbon, nutrients, and some pollutants to coastal systems. The magnitude of these fluxes is such that the transfer of organic matter from land to oceans via rivers is a key link in the global carbon cycle. The impact of global changes on river systems occurs through changes in erosion of the land surface, changes in the nature of the sediment and its associated organic matter and nutrient content, and changes in precipitation resulting from longer term changes in regional weather patterns and climate. Direct anthropogenic influences at basin scales include changes in hydrology as a consequence of dam construction and large scale water diversion for irrigation and agriculture. As these fluxes change, they may significantly alter the metabolism, biogeochemical cycling, and the biogeomorphology of coastal systems. Changes in freshwater input to estuarine and coastal waters can have large effects on salinity distribution, flushing rates, mixing of the water column and other physico-chemical properties of inshore waters.

A critical problem in developing the capability to understand and ultimately predict how changes in drainage basins will impact coastal seas is to be able to develop an understanding of the linkages between regional-scale land surface processes and the capacity of the river systems to transport and process land derived materials. Changes in water quality and quantity in river systems is a fundamental property and integrator of basin-scale hydrology and its response to global change. At these scales, river basins are

natural integrators of processes occurring on the land surface, since carbon and nutrient fluxes in large rivers reflect the nature of their watersheds, floodplains, and tributaries. Organic and inorganic materials measured inland from a river mouth represent a mixture of materials derived from sources that may be thousands of kilometres away in upland regions, as well as material introduced continuously from the adjacent floodplain. Organic matter from both sources is subjected to within-channel transport and reactive processes before it is finally discharged into coastal waters.

To construct mass balances for coastal systems at regional and global scales, data concerning the quantity, and timing of delivery of river borne materials are essential. Data are required, not only on the bulk concentration of materials, but also on their specific chemical attributes, which relate to the sources and condition of the organic matter in transport. In order to understand the physical and chemical controls operating at regional and global scales, it is necessary to determine the terrestrial origin of the river borne material and the dynamics of downstream routing. The degree to which the fine and coarse particulate organic matter have been diagenically altered must be determined in order to understand the processes of carbon cycling, and to identify the biological and geographic sources, and marine sinks, of these materials.

Overall objectives

The overall objectives for the river input to the coastal zone activity of LOICZ are to determine at regional and global scales:

- The quantities and chemical attributes of the river water delivered to the ocean
- The quantities and chemical attributes of the bulk sediments, and particulate and dissolved chemical species (C, N and P) delivered to the ocean
- The temporal variation in quantities and chemical attributes of riverine inputs to the ocean
- The relationship between these fluxes and changes in the upstream environment
- The physical and chemical controls operating at continental-scales on these fluxes

The LOICZ approach

The classic approach to addressing the objectives detailed above has been based on a river-by-river inventory to produce a global estimate of flux. The assumption is made that since the Amazon accounts for more than 15% of the flux of freshwater from land to ocean and the 10 largest rivers account for about 30%, extrapolations to the global scale can be based on summations of measurements and estimation of missing values. The systematic data required to make such global estimates are, however limited, and there are large uncertainties concerning the magnitude of the material transport. These uncertainties result from: a lack of information on the particulate forms; the difficulty of sampling river particulate distributions that are neither uniform laterally, nor with depth; a lack of detailed chemical determination of how refractory or labile river borne organic material may be; differences in analytical methodologies (especially for particulate P); a lack of adequate seasonal records for many rivers; and, few data for rivers in developing countries or for rivers draining smaller basins. A recent review (Milliman & Syvitski, 1992) suggests that rivers draining smaller basins may have a disproportionately large discharge of solids to the sea.

Since the primary objectives of Activity 1.1 are to quantify, and to predict, natural and modified river discharge of water and material to the coastal ocean, the LOICZ approach will be to identify the central properties of rivers as a function of human use, climate, and geography. Rather than depend solely on a river-by-river characterisation, the strategy will be to develop and adopt general river models for known river types and to apply these to digital river networks of the world. The time frame for this Activity is shown in Figure 5 and the end product will provide an improved estimate of the flux of river borne-materials to the oceans on regional and global scales, and a greater understanding of the factors influencing those fluxes.

In addition to riverine inputs to inshore waters, groundwater flux and coastal erosion may, on a local scale, contribute significantly to the discharge of freshwater and particulate and dissolved solids and to sediments in coastal and shelf seas. Whilst these inputs are considered to be less significant at regional and global scales than riverine inputs their assessment and quantification are important in defining the present boundary conditions and extent of total fluxes across the land ocean boundary. These inputs will need to be included in mass balance budgets and must be quantified for localities where they are important sources of material in nearshore environments.

Task 1.1.1 Development of regional scale river delivery models in theory and practice

Rationale

The systematic data required to make global estimates of land to ocean flux via rivers are limited, and there are large uncertainties concerning the magnitude of the material transport. The classic approach based on a river-by-river inventory to produce a global estimate of flux is inadequate, and an approach based on the identification of the central properties of rivers, as a function of human use, climate, and geography, is required.

Specific objectives

Short-term

- Develop the theoretical basis for regional-scale river delivery models to the coastal ocean
- Develop a global typology of river systems based on the central properties of rivers, as a function of human use, climate, and geography
- Develop quantitative models for specific river catchment types
- Assemble an electronic, global database of existing river discharge data

Long-term

- Assemble a GIS global digital database of river networks delivering to the sea
- Apply the quantitative models to the digital database to determine present riverine delivery to the sea
- Develop scenarios of future delivery under conditions of changed climate and human land-use and freshwater use

Implementation

A number of activities are on-going world-wide that are designed to develop catchment basin scale models of discharge of water and materials from individual rivers to the coastal zone. Sufficient investment in research and data acquisition over the last few decades has been made to provide a strong theoretical basis on which to build more general models based on recognisable river catchment types. Development of a global river typology based on climate, geology, relief, biota, and degree of development is required if the results of single system models are to be extrapolated to the global scale. Groupings might include for example tropical forest (mountain or lowland origin), tropical savannah, Himalayan, temperate-industrialised, and Arctic. Clearly, further subdivision is required to account for the full range of river types, especially in regions that are not well documented. A particular emphasis needs to be given to the less well known, high sediment rivers of the western Pacific rim. LOICZ could provide a useful mechanism for facilitating the development of models through support to workshops and by field testing them through national and regional research networks established within the framework of the START initiatives. Initial workshops should be convened to:

- Review current global initiatives and research programmes concerned with measuring and modelling river discharge to coastal areas, and to develop a global typology of river systems based on the central properties of rivers, as a function of human use, climate, and geography
- Further develop the theory for describing river sediment and chemical concentrations at downstream points in river networks as a function of the basic physical attributes of the river basin (e.g. topography, vegetation cover, drainage density, physical and chemical soil properties) and in-channel processes
- Develop algorithms for describing river discharge at any point in the drainage network, given antecedent precipitation and multiple storage reservoirs (including dams)

At a later stage regional workshops should be convened to:

- Review, revise and update the appropriate regional section of the global database on riverine inputs
- Validate the quantitative models by applying them to data for specific rivers not used in the development of the models

Several individual and international initiatives have led to the development of hard copy and electronic databases concerning the discharge of water and materials from the world's rivers. LOICZ has initiated a process of consolidation of these data into a synoptic global database of existing information that should be available for wide use and distribution in 1995. The present initiative encompasses the Global Environment Monitoring System (GEMS), United States Geological Survey (USGS), and Max Planck Institute (MPI) databases and results obtained during the SCOPE/UNEP project "Transport of carbon and minerals in Major World Rivers" together with databases held by individual scientists. Of particular concern will be developing procedures for assuring data quality before their incorporation in databases and models. Once compiled this will be distributed throughout the LOICZ networks for critical review and additional inputs by individual scientists. Expansion and updating of this initial database will become the

responsibility of the LOICZ Core Project Office within the context of the Framework data activity of the LOICZ CPO.

Outputs

- A global database of existing river discharge data
- A global typology of river systems based on the central properties of rivers, as a function of human use, climate, and geography
- Algorithms for describing river discharge at specific points in the drainage system
- Quantitative coupled models of river chemistry, river networks, and river discharge
- A global estimate of the present export of water and river borne materials to the coastal zone encompassing those regions which are poorly described by actual monitoring networks

Task 1.1.2 Determination of temporal variations in discharge characteristics for selected and representative rivers

Rationale

One of the major weaknesses of present global syntheses of river flux to the oceans is a lack of adequate seasonal and inter-annual records for many rivers and an inadequate data and information base on which to develop estimates of temporal variations in rivers of different type.

Specific objectives

Short-term

- Provide input data on temporal variations in river fluxes to the development of a global typology of river systems (Task 1.1.1)
- Define the seasonal and inter-annual variation in the input of rivers representative of the major drainage basin types

Long-term

- Provide regional and global estimates of seasonal and inter-annual variation in river discharge to the oceans
- Encourage the development of appropriate river observation and measurement systems for those classes of rivers where present data on variables such as Q, POC, DOC, pCO_2 & TSS are inadequate

Implementation

A review of existing information concerning seasonal and inter-annual variations in basic variables such as the temporal distributions of discharge (Q), particulate organic (POC) and dissolved organic (DOC) carbon, free dissolved CO_2 (pCO_2), and total suspended sediments (TSS) should be undertaken to identify those river types that are inadequately represented in existing global river discharge databases. Present internationally agreed sampling and analytical methods should be reviewed and an agreed set of protocols compiled to provide a methodological framework for future programmes of discharge measurement.

It is important for model development to represent the widest possible range of river types, in terms of size, temporal variability and variability in terms of catchment characteristics and land-use patterns. It is anticipated that new measurement programmes will be required in certain classes of rivers where the present data are inadequate to describe inter-annual and seasonal variations in discharge. One such class of rivers, is small rivers with high intra- and inter-annual variability, for which inadequate data may lead to serious errors in the calculations of local, regional and global fluxes.

Outputs

- Data sets describing intra- and inter-annual variation in river discharge for identified classes of river system
- Input data on Q, POC, DOC, pCO_2 & TSS for the definition of the global river typology
- Protocols for future programmes of measurement, including sampling and analytical methods
- Regional and global estimates of temporal variation in river discharge to the coastal ocean
- Input data for developing scenarios of future regional and global river fluxes to the coastal ocean

Task 1.1.3 Chemical Composition: Gradients from Terrestrial Sources to Marine Burial

Rationale

Organic matter is subjected to within-channel transport and reactive processes before it is finally discharged into coastal waters. To construct mass balances for coastal systems at regional and global scales, not only are data concerning the quantity, and timing of delivery of river borne materials essential, but data are required, concerning specific chemical attributes of the organic matter in transport, in order to understand the physical and chemical controls operating at regional and global scales, and to determine the origin of the river-borne material, and the dynamics of downstream routing.

Specific objectives

Short-term

- Define the specific chemical attributes relating to the sources and condition of organic matter in transport and buried in temporary marine depocenters
- Define the required chemical information relative to sources, partitioning, and diagenesis, and on how refractory or labile different fractions will be in particular environments

Long-term

- Determine how catchment type influences the regional mass balance budgets for POC, TSS, C, N, and Si in the contiguous coastal zone
- Define the chemical composition of riverine inputs to coastal waters on regional and global scales

Implementation

Two approaches need to be developed initially: the first is to identify specific biomarkers and develop the technology (where necessary) for their measurement in order to identify the source of biological materials in transport and those buried in transitory marine depocenters. The second approach includes the development and application of appropriate compositional indices such as, percent organic matter (POC/TSS), C/N ratios, biomarkers (lignin oxidation products, carbohydrates, amino acids, sugars) and stable isotopes (^{13}C, ^{15}N, ^{34}S). GCTE's activity concerned with modelling discharge of C- and N- compounds for soil plant systems could serve as the basis for future LOICZ-GCTE collaboration.

A sampling protocol needs to be developed, based on size fractionation using, for example, ultrafiltration techniques of representative samples. Ideally this sampling should be undertaken not only where the long-term observation networks are in place (Task 1.1.2), but on an *ad hoc* basis to a wider range of rivers. Sampling should encompass not only the measurement of export from the river system, but also fluxes across key transition zones within the river system and transect measurements across the respective coastal zone.

Outputs

- Definition of chemical indicators of source and history of river borne organic matter
- Representative datasets for development of regional and global mass balance budgets
- Regional and global datasets on the chemical composition of riverine inputs to coastal waters

Task 1.1.4 Groundwater discharge and coastal erosion

Rationale

Global estimates of land-ocean exchange remain incomplete without a consideration of sub-surface water exchange, and coastal erosion. Groundwater discharge directly into the seas may be important in the hydrochemical, thermal and biogenic regime of the coastal zone. Neither of these sources of input to the coastal ocean are adequately understood at present.

Specific objectives

Short-term

- Develop databases of sub-surface exchange and coastal erosion
- Assess the regional and global significance of ionic groundwater discharge in the coastal zone
- Assess the likely changes in groundwater discharge under the impact of climate and anthropogenic factors causing change
- Regional and global estimates of the impact of sea water intrusion on the groundwater regime in the coastal zone

Long-term

- Develop and apply coastal erosion models based on climatic zonation, geology, geomorphology, palaeography and hydrodynamics for key regions and various climatic zones
- Define (quantitatively and qualitatively) the contribution of coastal erosion to the total terrigenous inputs
- Develop models of coastal vulnerability to erosion under differing scenarios of human land-use, climate change and sea level rise

Implementation

In comparison to the complex but relatively straight-forward problem of river input, exchanges of sub-surface water and sediment erosion are potentially significant but less tractable problems. Groundwater discharge is the least studied component of the global hydrogeological cycle. Estimates of global water and salt balances remain incomplete without data on groundwater discharges, which makes it impossible to predict changes under the influence of geocentric and anthropogenic changes.

The emphasis of Activity 1 is on the role of river inputs to the coastal zone. But it is also recognised that the catchment may export groundwater to the local coastal zone (or may receive intrusion) rich in chemical species. While it has a lower priority, a preliminary assessment of the issues needs to be made. To assess the scope of sea and land sub-surface exchange, workshops will be held to collate existing information on groundwater discharge and its effects on hydrochemical and temperature regimes of some coastal zones, and to develop the methods of studying, estimating and predicting the changes of sub-surface component of salt and water balance under different natural conditions and climate changes. On the basis of the results of these workshops, the possibility of making field measurements will be explored.

Erosion of the coastline may be important in certain localities in providing sediments to shelf seas, in areas where river discharge of suspended sediments is low. The Baltic coast and Chesapeake Bay are two examples, and given that various estimates suggest that between 50 and 70% of the world's coastlines are currently eroding, a global assessment needs to be made of this source of sediment input to the coastal zone and shelf seas. The study of coastal erosion will be based on the synthesis of existing information and the development of models for present climate zones and will include the definition of geological and geomorphological processes, palaeogeography, and hydrodynamics.

Outputs

- Regional and global estimate and models of groundwater discharge, dissolved solids, eroded sediments transported with the ground water and from cliffs into the sea
- A global database and synthesis of erosion and groundwater inputs and exchange between land and ocean

Activity 1.2 - Atmospheric Inputs to the Coastal Zone

Introduction

The composition of the atmosphere has been and continues to be altered by human activities. Elements and/or substances that may be transferred from land to the coastal zone via atmospheric processes include major and micro-nutrients (N, P and essential trace metals), potentially toxic heavy metals, and synthetic organic compounds. Such elements and substances can be present either in the gas phase or attached to aerosol particles, and may be deposited on the sea-surface by both dry and wet deposition processes. More information is needed, however, to quantify the atmospheric inputs to coastal areas on a global scale. It is also critical to assess the impacts on coastal systems of changing atmospheric deposition on watersheds that drain to coastal seas. It is not at all certain at present how the fluxes of carbon, nutrients or sediments from various terrestrial systems, will, in the long term, be affected by increased nitrogen deposition, by acid deposition, or by changes in rainfall and temperature over entire watersheds.

Data and conceptual models to resolve these questions are few. Over the last two decades, national and international efforts have been undertaken primarily in coastal areas of North America, Europe and Northeast Asia. There are very few data for coastal areas of developing countries or for Eastern Europe. Since two thirds of the world's cities with populations in excess of 1.6 million inhabitants are located on the coast, and since such cities are important centres of industry and power generation, there is an urgent need to document the scale and magnitude of the anthropogenic flux of materials to coastal waters via atmospheric deposition. Present estimates of atmospheric concentrations and fluxes over coastal areas are still very uncertain because of inadequate temporal and geographical coverage in the sample data. There is therefore a need to improve the data coverage in order to quantify the atmospheric transfer of materials and their deposition in the sea-surface.

Overall objectives

The overall objective of this activity is to quantify at regional and global scales, atmospheric deposition in the coastal zone of naturally and anthropogenically derived materials and to evaluate the impact of such deposition on the chemical and biological fluxes and processes in coastal systems. More specifically, this activity aims to determine:

- The proportion of atmospheric deposition that represents a net input to the coastal zone and that which represents a recycling of materials between coastal seas and land due to the emission, transport, and deposition of sea-spray aerosols
- The bioactive fraction of atmospheric deposition
- The contribution of atmospheric deposition on watersheds to the chemical composition of waters draining into coastal waters
- The role of local, regional, or global transport processes in controlling atmospheric deposition in coastal areas
- The spatial and temporal variation in atmospheric deposition to coastal areas
- The regional and global importance of atmospheric deposition as a natural and/or anthropogenic forcing function in the coastal zone

The LOICZ approach

Ideally, the use of atmospheric transport and deposition models, combined with inventory data concerning the land-based sources, should allow the prediction of atmospheric concentrations and flux fields. Such an approach has not been successfully applied to date, primarily owing to a lack of accurate source emission data for most elements and/or substances of interest. Existing information suggests that river inputs are generally more important than those from the atmosphere, although in certain areas and for some substances (e.g. lead and PCB in the North Sea and Nitrogen in the Mediterranean) atmospheric inputs are similar or even greater than those from rivers (GESAMP, 1990). Existing data are generally patchy in coverage with considerably more information being available for the northern hemisphere than for the southern and for enclosed and semi-enclosed seas than for open coastal areas. Sampling programmes must be conducted therefore, to document temporal and spatial variability in atmospheric inputs. These programmes must encompass short-term, pollution episodes, and sporadic but intense transport and deposition events of mineral dust from soil erosion determined by local meteorology including air movements and precipitation events; and, longer term, seasonal and inter-annual variability which depend on the temporal patterns of local climatology. A coherent sampling programme should include:

- Measurements of the total and bioactive concentration and flux of major and micro-nutrients (N, P and essential trace metals Fe, Mn, Al)
- Identification of suitable tracers of natural and anthropogenic sources
- Monitoring of relevant meteorological parameters, including wind fields and precipitation

Initially a synthesis of the available data from national and regional studies should be prepared by means of a series of regional workshops. "Hot spots" need to be identified on the basis of existing sampling and analytical protocols which have already been defined by international working groups, before any sampling programmes are initiated. Priority during the second phase must be given to: the development of automatic sampling systems, for example rain collectors; the development of accurate techniques for measuring directly, the particle and gas exchange between atmosphere and water surface; and to the development of methods for applying remotely sensed data on precipitation fields, aerosol loads and ocean colour, to the assessment of the impact of atmospheric deposition on the marine biota in coastal waters.

Activity 1.3 - Exchanges of Energy and Matter at the Shelf Edge

Introduction

Exchanges of energy and matter at the shelf edge are an important component in the global cycling of matter and energy, and their quantification is vital in understanding the mass balance of materials in the coastal seas. The fundamental processes regulating exchange across the shelf edge are not well understood at present. Consequently the quantification of these exchanges at regional and global scales cannot be determined with any degree of certainty. Exchanges between the coastal and open ocean are affected by large scale changes in the hydrodynamics of the open ocean, such as the El Niño Southern Oscillation (ENSO), as well as by changes in freshwater and sediment flux from land to

coastal ocean that result from such changes as deforestation, large scale irrigation and dam construction.

This activity is intended to foster research in that component of global material cycling involving exchanges between coastal and open ocean across the shelf-edge, and may be viewed as a stepping stone in the development of a predictive capability concerning future changes in both the coastal seas and open oceans.

Overall objectives

The overall objective of this activity is to quantify at regional and global scales: the exchange of energy and matter across the continental shelf edges; to estimate the seasonal and inter-annual variations in these fluxes; and to provide the basis for predicting future fluxes due to long-term changes in external forcing functions such as climate or land-use. This longer-term objective can only be met through incremental advances in scientific understanding. More specifically this activity aims to:

- Clarify scientific understanding of the basic processes that regulate energy and matter exchanges at the continental shelf edge
- Elucidate the seasonal and inter-annual variability in the fluxes of energy and matter across the continental shelf edge
- Quantify energy and matter fluxes across the shelf edge in representative shelf seas

The LOICZ approach

It is recognised that the scale of investments needed to implement the studies required to meet LOICZ objectives under this activity will be beyond the capacity of LOICZ to supply individually, and that significant advance in achieving the objectives of this activity will only be possible through close co-operation with on-going and planned national and regional research programmes. Further development of this activity will be undertaken in close collaboration with JGOFS through the Joint JGOFS/LOICZ Task Team on Continental Margin Studies.

Given the present lack of scientific knowledge concerning the fundamental processes that control and regulate exchanges at the continental shelf edge, emphasis must be directed initially to develop further the body of scientific knowledge and information relating to processes that determine the magnitude of the fluxes involved. Such processes include: mixing due to tidal forcing; frontal eddies; upwelling; and density or wind-driven currents. In parallel with such basic studies, representative case studies need to be undertaken in a number of continental shelf areas that represent different shelf edge conditions, but which nevertheless are characteristic of major classes of continental shelf margin. These might include studies on:

- Wide shelf seas with a strong western boundary current such as the East China Sea
- Wide shelf seas without a strong boundary current such as the North Sea or Indonesian Seas
- Narrow shelf seas with a strong western boundary current such as the South Atlantic Bight

- Narrow shelf seas without a strong boundary current such as the western coast of Canada
- Strong coastal upwelling regions such as the Peruvian Coast
- Coastal boundary current regions such as the western coast of Norway
- Shelves with strong seasonal surface currents such as the Grand Banks off eastern Canada

Selection of case study sites will be guided by the results of the coastal typology Framework Activity (Task F.4.2.1). Predicting the magnitude of future shelf edge exchanges at a global scale, under scenarios of change to the various forcing functions, will only be possible when a comprehensive range of large scale studies have been completed and regional assessments of present shelf edge exchange processes and their magnitude are available. Given the cost in both financial and manpower terms of the studies envisaged under LOICZ such a development is likely to be beyond the 10 year life-span of the LOICZ project. Nevertheless through successful completion of this activity (Figure 6) LOICZ could provide the knowledge and intellectual framework for future global assessments and modelling of shelf edge exchanges at regional and global scales.

Task 1.3.1 Synthesis of results of existing or on-going regional or national research projects on energy and matter exchanges at the shelf edge

Rationale

No regional or global review of the processes regulating and controlling exchanges at the shelf edge has been produced to date, hence the relative importance of different processes, their frequency of occurrence, temporal and spatial variability cannot be evaluated.

Specific objectives

- Update present knowledge on the processes regulating and controlling energy and matter exchanges at the shelf edge
- Prepare and publish a review of processes and extent of shelf edge exchanges based on the results of existing or on-going regional or national research projects related to Activity 1.3

Implementation

It is recognised that the resources will not be available for LOICZ to initiate and conduct independent shelf-edge studies and that successful achievement of LOICZ objectives in this field will only be possible through the agreement and close co-operation with JGOFS and with large scale national and regional projects, including *inter alia* KEEP, SEEP, MASFLEX, MFECS, ECOMARGE, EROS-2000, OMEX, CoOP, LMER, NOGAP86. Initially LOICZ will gather documents and papers on existing or on-going research projects related to Activity 1.3, and contact interested scientists with a view to sponsoring an international symposium on shelf edge exchange processes in 1996. The purpose of this symposium, which would be undertaken in collaboration with JGOFS, would be to review the state of knowledge of physical oceanographic processes, through presentation of state of the art results from on-going national and regional studies and to identify through workshops

the extent to which shelf edge exchanges can be adequately quantified at regional and global scales. LOICZ and JGOFS have established a joint Task Team to plan future joint research in this area.

Output

- Published review volume on global state of knowledge concerning shelf edge exchange processes

Task 1.3.2 Dissolved and suspended matter exchanges at the shelf edge

Rationale

The present data concerning shelf edge exchanges of energy and matter are inadequate for the purposes of preparing regional and global estimates of fluxes between the coastal seas and open oceans and a concerted and co-ordinated programme of measurements is required to develop such a database.

Specific objectives

- Clarify our understanding of the processes that regulate the exchanges of dissolved and suspended matter at the shelf edge
- Estimate the fluxes of dissolved and suspended matter across the shelf edge

Implementation

LOICZ should encourage the inclusion of specific programmes of measurements at the shelf edge in on-going national and regional research programmes designed to elucidate the role of stationary processes such as tidal currents and barotropic or baroclinic instabilities and event-like processes such as wind driven or density driven currents in the exchange of dissolved and suspended organic matter across the shelf edge; and to improve the regional and global databases needed for quantifying at regional and global scales the exchange of energy and matter across the shelf edge. Such programmes should be undertaken at selected sites encompassing at least the categories of shelf seas identified in Task 1.3.1 above and should include:

- *In situ* observations of water temperature, salinity, turbidity, concentration of dissolved matter (macro and trace nutrients, DOC), suspended matter (plant pigments, POC, PON and POP etc.) at least four, and preferably six times a year in the shelf sea and the adjacent open ocean
- Obtaining synchronous satellite images (NOAA, SeaWIFS, OCTS, etc.) for the time of the field observations
- Deployment of moorings with time-series sediment traps, current meters and nephelometers at some stations around the shelf edge for the period of at least one year
- To establish a box model which can estimate material budgets in the shelf sea and fluxes across the shelf edge

Outputs

- Quantitative assessment of the role of stationary processes such as tidal current and barotropic or baroclinic instabilities and event-like processes such as wind or density-driven currents in the exchange of dissolved and suspended matter exchanges at the shelf edge
- Quantitative estimate of the dissolved and suspended matter fluxes across the shelf edge and their seasonal variability
- Input data concerning the exchanges across the shelf edge for developing the coastal ecosystem models envisaged under Task 1.4

Task 1.3.3 Inter-annual variability in energy and matter exchanges at the shelf edge

Rationale

At present virtually no data exist concerning inter-annual variations in shelf edge exchanges of energy and matter. Such data are vital to developing global estimates of the role of coastal and shelf seas in the global carbon cycle and are a pre-requisite for developing future scenarios of shelf edge exchange under changed climatic conditions and anthropogenic, land based changes to the land-ocean flux of energy and matter.

Specific objective

- Investigate and quantify for representative shelf edge types, the inter-annual variation in fluxes of energy and matter at the shelf edge

Implementation

Following an initial review to determine the extent to which LOICZ objectives are met within the existing national and regional projects, LOICZ should encourage the inclusion of specific measurements at the shelf edge, where these are not presently taken, in order to ensure adequate coverage of the different shelf-edge types. These programmes should be designed as temporal extensions of the studies recommended under Task 1.3.2 above. Such programmes should include:

- *In situ* observations of water temperature, salinity, turbidity, concentration of dissolved matter (macro and micro nutrients, DOC) suspended matter (plant pigments, POC, PON and POP etc.) at least four, and preferably six times a year in the shelf sea and the adjacent open ocean
- Obtaining synchronous satellite images (NOAA, SeaWIFS, OCTS, etc.) for the time of the field observation
- Deployment of moorings with time-series sediment traps, current meters and nephelometers at some stations around the shelf edge for the period of at least four years

Output

- Quantitative estimate of inter-annual variations in energy and matter exchanges at the shelf edge

Task 1.3.4 The role of long-term fluctuations in shelf-edge exchange rates, in global cycles

Rationale

Exchanges at the shelf edge between coastal and open ocean are subject to open ocean forcing of long periodicity such as ENSO events or land use changes such as dam construction. The impact of such events on energy and material flux across the continental shelf edge is at present unknown.

Specific objectives

- Quantify the role of long-term basin scale phenomena such as El Niño on variations in the exchange of energy and matter at the shelf edge
- Quantify the role of anthropogenic forcing through large scale changes in land use in changes to the exchanges of energy and matter at the shelf edge
- Quantify the role of such phenomena in the global cycling of matter and their impact on the coastal environment

Implementation

Mass balance budgets for materials in the shelf seas could be constructed for years with and without significant aperiodic forcing; or for years before and after significant changes in land and/or water use which alters the flux of materials to the landward edge of the coastal seas.

Outputs

- Improved understanding of the role of changes in basin scale dynamics on the flux of materials across the shelf edge
- Improved understanding of the role of changes in land and water use on the flux of materials across the shelf edge
- Input data for developing scenarios of future global cycling of matter in relation to changes in exchanges of energy and matter at the shelf edge under conditions of global change

Activity 1.4 - Development of Coupled Models for Coastal Systems

Introduction

The development of coupled land-estuarine-atmospheric-ocean numerical models of coastal ecosystems is a key activity of LOICZ which should be carefully integrated into all data collection activities of all Foci. Previous modelling work in the coastal zone tended to focus on particular processes (e.g. runoff, hydrodynamics, nutrient cycling, primary production, etc.) but sufficient progress has now been made in both scientific understanding and computer technology to develop realistic models for complete coastal systems. Such ecosystem models can synthesise within a rigorous quantitative and interactive structure existing scientific information on key physical, sedimentological,

chemical and biological processes that shape and drive the carbon cycling in coastal ecosystems. These processes should include both internal dynamics and important exchanges with the land, atmosphere and deep ocean.

The clearest examples of global change today are increases in greenhouse gases such as carbon dioxide and methane in the Earth's atmosphere. It is important that the role of the Earth's coastal zone in controlling the concentrations of these greenhouse gases be quantified. Therefore, LOICZ is particularly concerned with developing better carbon flow models of the coastal zone which incorporate internal dynamics (e.g. production, respiration, transformations, storage, etc.), interactions with freshwater delivery, sediments and major nutrients (e.g. N, P and Si) and exchanges with boundaries (e.g. land, atmosphere and deep ocean). LOICZ models will be primarily biogeochemical in nature and biological components, when incorporated will be highly aggregated into major ecological categories (e.g. producers, consumers, etc.) Emphasis will be placed on lower trophic levels where carbon, nitrogen, phosphorous and silicate fluxes are greatest.

Overall objectives

The overall objective of this activity is to develop local and regional carbon flow models for particular coastal units as specified by the results of the coastal typology exercise (Task F.2.1). The output of these models will be used to determine whether these units are a net source (i.e. autotrophic) or sink (i.e. heterotrophic) of organic carbon. These models must include important associated variables such as nitrogen, phosphorus and silicate as well as major forcing functions. The overall objectives are to:

- Develop budget models for carbon, nitrogen, phosphorus and silicate in selected coastal units using the procedures recommended under Task F.5.1
- Develop carbon flow system models for a more limited number of coastal units, where the necessary resources are available, using the modelling procedures recommended under Task F.5.1

The LOICZ approach

Models developed under this activity will be of local and regional scale. The geographic locations selected will depend upon the results of the coastal typology exercise described under Activity F.2.1.

The variable of prime interest is organic carbon but important associated variables such as nitrogen, phosphorus and silicate must also be considered. The models will incorporate all available information on the sources and sinks of organic carbon within the defined geographic units. The sources should include import from land, import from the open ocean and *in situ* primary production by coastal vegetation, submerged and intertidal macrophytes, and phytoplankton. Sinks should include burial in coastal sediments, export to the open ocean and losses to the atmosphere through respiration. Model development will also require information on important driving variables which include inorganic carbon dynamics, freshwater runoff, shelf-edge exchanges, along shelf transport, atmospheric exchanges, sediment fluxes and nutrient cycling.

The models to be developed under this activity will be biogeochemical in nature and involve a large number of variables and processes. It is possible that some models can be developed using existing information, while others will require new data which will be generated by other LOICZ Activities and Tasks. The local scale models will focus on specific nearshore habitat types such as mangroves, seagrass beds, estuaries, bays and fishing banks. The regional scale models will have a much larger spatial domain on the order of thousands of kilometres along the coast and will extend seaward to cover the entire width of the continental shelf (at least to the 200 m isobath). Because of their integrative nature, the models will represent the biological components in highly aggregated variables such as detritus, bacteria, phytoplankton, zooplankton, benthos and fish. The models will focus on lower trophic levels and will not provide information at the species level. Wherever possible, the models should have a time frame on the order of 10-100 years so that the importance of episodic events can be evaluated.

In most instances the models will be developed using the techniques to be identified under Task F.5.1 that have been well tested by the scientific community and widely applied to coastal ecosystems. Consistency in modelling approaches within LOICZ is necessary to facilitate the comparison of results and synthesis at a later stage.

It is anticipated that the first step in the modelling process would be the construction of a carbon budget for the geographic unit in question. This would be followed by the preparation of similar budgets for important macronutrients such as nitrogen, phosphorus and silicate. If warranted and if the necessary resources are available, the next step would be to begin the development of a system model based upon the results of the budget models, the temporal sequence of actions is shown in Figure 7.

Because of their nature system models have many component sub-models. For example they must include hydrodynamic sub-models to provide a dynamic description of the necessary water exchange processes between spatial compartments. Sedimentation sub-models are needed to encompass the transportation processes for particulate matter. Biological and chemical models are necessary to describe important processes such as photosynthesis, respiration and nutrient cycling. Some of the required sub-models are well developed (for example phytoplankton photosynthesis) whilst others are in an early stage of development (for example sediment transport processes). Problems of coupling the necessary sub-models must be addressed during the development of system models under LOICZ.

While these local and regional carbon flow models are being developed for different coastal units around the world, it is important that research teams keep in contact through LOICZ networking (Framework Task F.1.1) and exchange software, algorithms, sub-models and data.

Task 1.4.1 The development of new local and regional ecosystems models

Rationale

Given the high spatial and temporal variability of the world's coastal zone, new models will have to be developed in order to adequately describe the functioning of the full range of coastal ecosystems. Some models can be built using existing information while others will require the collection of new data which will be done under various Activities in Foci 1-3.

Specific objectives

- Develop budget models for carbon, nitrogen, phosphorus and silicate in selected coastal units using the recommended techniques
- Develop carbon flow system models for a more limited number of coastal units using the recommended techniques

Implementation

This task should be undertaken within the context of national LOICZ programmes and regional programmes initiated under START (and other agencies) and will build upon the techniques recommended in Task F.5.1. Initial actions will be designed to encourage the development of mass balance budgets for as many geographic areas and variables as possible as part of national programmes. In many instances these can be constructed early during LOICZ using existing information but in other cases new data collection programmes will first be necessary. Once budget models have been collected, more complex system models will be developed for a more limited number of specific coastal units where the necessary resources and data are available. As groups of modellers become established at the national and regional level, links will be established on a wider geographic basis to encourage the exchange of modelling technology, especially between developed and developing countries.

It is difficult to estimate the number of local/regional models that have to be developed to meet the objectives of LOICZ. This will depend in part upon the number of similar coastal units identified on the basis of the coastal typology framework activity. It is expected however, that a reasonably large number of regional budget models (carbon, nitrogen, phosphorus and silicate combined) can be developed using existing as well as new data. It is likely that between 50 and 100 budget models will be needed to adequately describe the spatial heterogeneity of the world's coastal areas, while the number of regional system models would be much smaller due to their greater complexity (of the order of 25).

Outputs

- Budget models for carbon, nitrogen, phosphorus and silicate for a large number of representative coastal regions around the world (1996 onward)
- System models of carbon flow for representative coastal regions around the world (1998 onward)

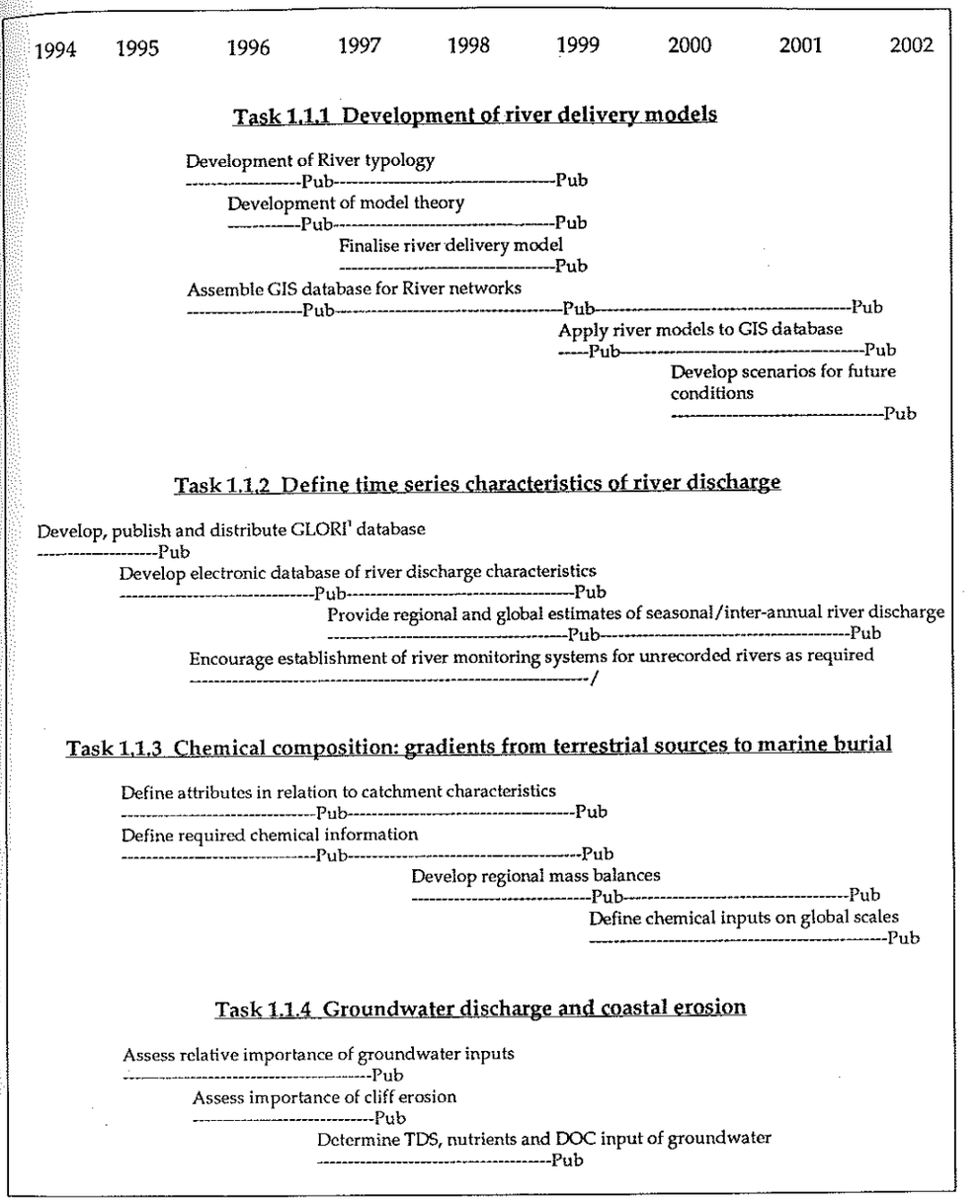

Figure 5. Time line for the implementation of LOICZ Focus 1 Activity 1.1 Tasks and Objectives.

[1] Global Land-Ocean River Inputs

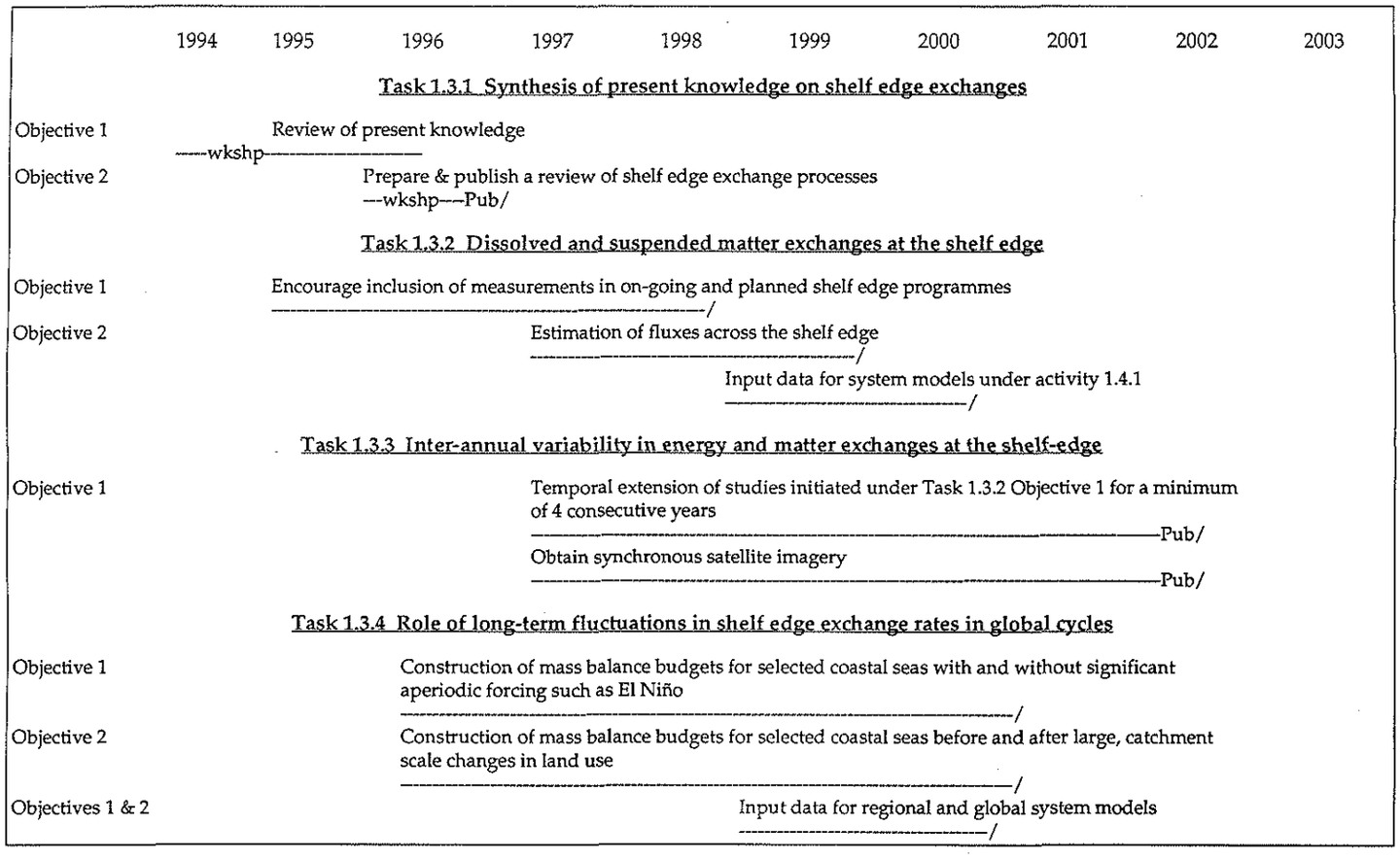

Figure 6. Time line for the implementation of LOICZ Focus 1 Activity 1.3 Tasks and Objectives.

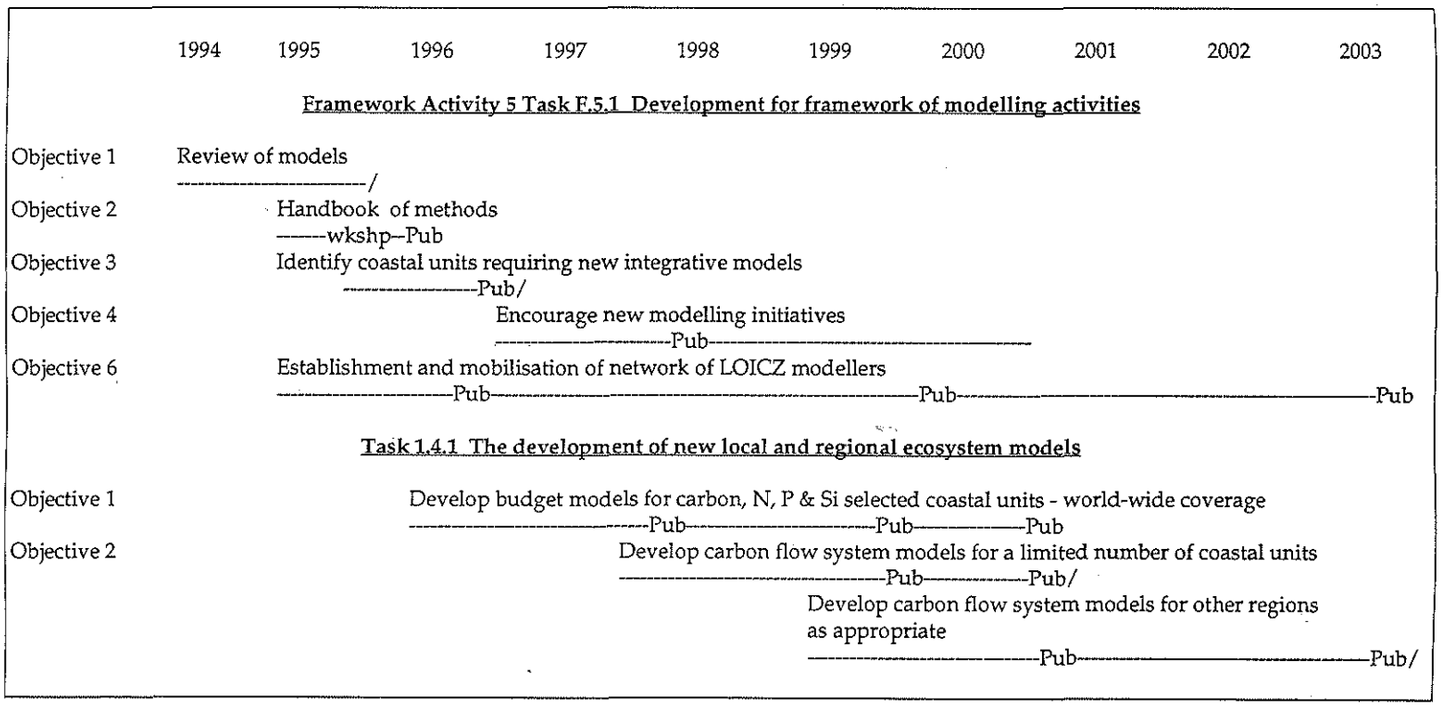

Figure 7. Time line for the implementation of LOICZ coupled coastal modelling activities.

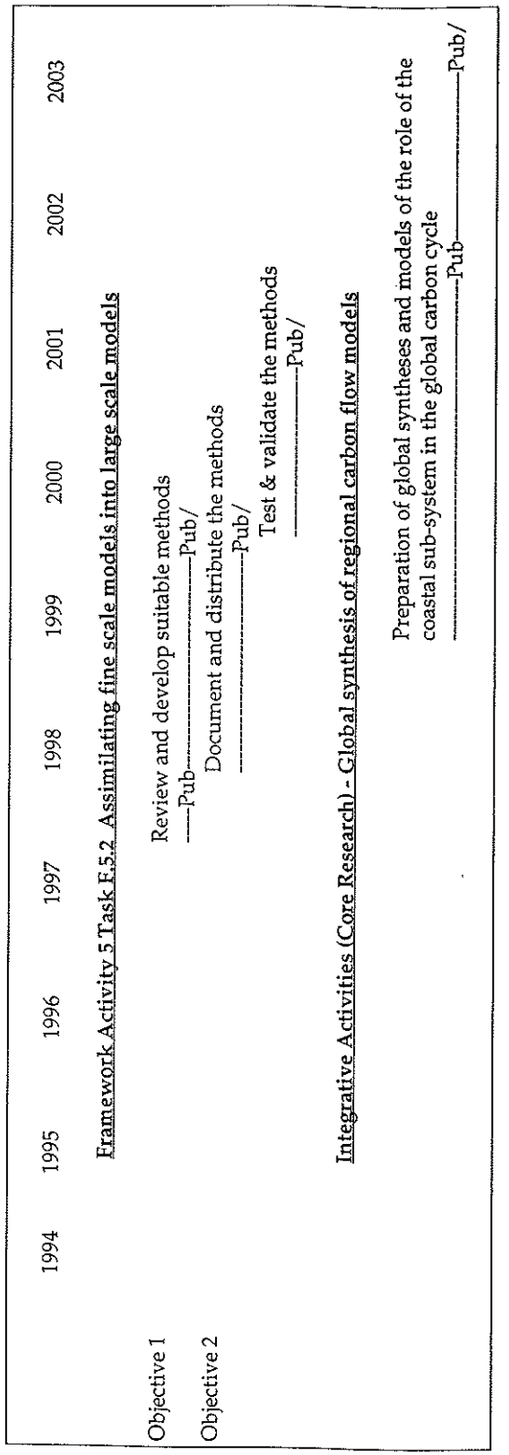

Figure 7. Time line for the implementation of LOICZ coupled coastal modelling activities (continued).

Focus 2: Coastal Biogeomorphology and Global Change

Background

The interface between the land and oceans is extremely dynamic as a consequence of the combined properties and interactions of the continents, the oceans, and the atmosphere. The interactions between these components of the Earth system vary on both short (diurnal, seasonal and inter annual) and long (decadal, century and millennial) time scales. As a consequence the form, dynamic properties and functional attributes of the coastal zone vary over a wide range of time and space scales. Changes to the dynamics of coastal systems are of cumulative global significance in terms of their effects on the land, ocean and atmosphere compartments of the Earth system. The large rise in sea level since the last glacial maximum, which resulted in the transformation of extensive areas of low lying coastal forest and wetlands with a high capacity for organic carbon storage and methane production, to a variety of coastal marine ecosystems which tend to produce and export or accumulate calcium carbonate, has probably been a significant factor contributing to the post-glacial changes in trace gas composition of the atmosphere (see Focus 3). Models of changes of carbonate production and dissolution in coral reef and related shallow water environments as a function of sea level can account for the glacial - interglacial atmospheric CO_2 changes (Opdyke and Walker, 1992), although the effects in marine sediments of organic matter oxidation on carbonate dissolution also need to be considered (Archer and Maier-Peiret, 1994). These biogeomorphic systems must be considered therefore as contributing as well as responding to global change.

Studies of coastline changes have tended to ignore or simplify the role of ecosystems in determining the properties of the land-ocean interface, leading to a rather static approach in considering the causes, consequences and rates of morphological change. The biota of the coastal zone play a fundamental role in the supply (principally of carbonates), retention, stabilisation and, to a lesser degree, erosion of sedimentary material in the near-shore region (Spencer, 1988). It is the interaction between such biologically driven processes and physical processes (hydrological factors, tide and wind mixing, storm erosion etc.) that produces what we define here as biogeomorphology. A principal concern within the context of global change is to achieve a better understanding of the effects of variations and trends in climatic factors and associated sea level conditions on coastal biogeomorphological processes, which are being strongly modified by direct and indirect human interference. In general, modification of coastal ecosystems by human activities almost certainly decreases the capacity of the coastline to produce, accumulate or retain sedimentary material, presumably with corresponding net losses of material by transport to the deep ocean, dissolution, or reduced local production. At present neither the role of ecosystems nor the ecological impacts of humans are properly taken into account in analysis of the effects of global mean sea level rise or other relevant global change factors such as changes in runoff, temperature, sediment supply from land or water chemistry.

Coastal ecosystems and organisms that have important biogeomorphological functions include coral reefs, calcareous algae, and a range of shell-producing animals that

contribute to the formation of calcareous sediments; coastal wetland forest, dune, mangrove, seagrass, saltmarsh and macroalgal communities that tend to trap land- or ocean-derived particulate material; benthic invertebrates that can stabilise or destabilise nearshore sediments; and various organisms (microalgae, bacteria) that promote sediment cohesiveness through the production of extracellular metabolites (Spencer, 1988).

Human activities are now both directly and indirectly affecting coastal geomorphology on a global scale such that a large proportion of the world's coastline is actively receding. This process can be attributed in part to changes in global mean sea level which is now considered by some to be rising at a faster rate (1-2 mm a^{-1}) than at any time for the last 4000 years in response to a combination of climatic warming and to freshwater mining on land. However, various anthropogenic factors are probably equally or more important on local and regional scales. Such factors include the reduction of sediment and freshwater delivery from the many rivers that have been dammed; the widespread destruction and degradation of coastal ecosystems resulting in remobilisation of coastal sediments and shoreline recession; and locally, coastal subsidence due to water, oil and gas extraction. The scales over which these processes act and interact are extremely variable, and the rates of change are influenced by other properties of the coastline such as tectonic activity, hardness of the underlying rocks, and climatic conditions. In some areas human influences may reverse the global trend; for example, along high relief coastlines sediment delivery from land is likely to be enhanced by agriculture and deforestation, leading to vertical accretion of the coast and hence a "fall" in relative sea level.

Prediction of the position and properties of the land-ocean interface over decadal to century timescales has fundamental implications for biogeochemical processes (Focus 3) and in particular for the management of human activities in the coastal zone (Focus 4). A combination of observational and modelling approaches is required to gain a better understanding of the complex relationships between the relevant physical, chemical and ecological processes, and human activities in the coastal zone. Comparative studies of particular types of ecosystems are needed to elucidate responses to variable conditions of sediment supply, sea level change and human impact. Research on episodic events and on changes during the Holocene period will help elucidate the nature of large scale processes in determining coastline evolution. Scenarios at regional and global scales of the future form and function of the land-ocean interface are needed in order to distinguish properties and regions that are most sensitive to change, and to determine priorities and directions for future coastal zone management.

In order to meet these broad aims, Focus 2 includes three activities which are designed to: examine how ecosystems affect the form and functional properties of the land-ocean interface; determine how human activities affect coastal biogeomorphology; and, to develop and validate scenarios of past and future coastline change. Future Integrative Activities (Core research) for Focus 2 will be developed to provide a new basis for formulating improved procedures for assessing coastal vulnerability to global change, by synthesising existing and new information on sea level change, coastal biogeomorphological processes, and human impacts on coastal systems.

The conceptual relationship between the various activities proposed in the following pages is outlined in Figure 8, whilst Figure 9 provides a more management oriented perspective of the sequence in which tasks and activities need to be undertaken in order to provide scenarios and predictions of coastal change on a century time scale.

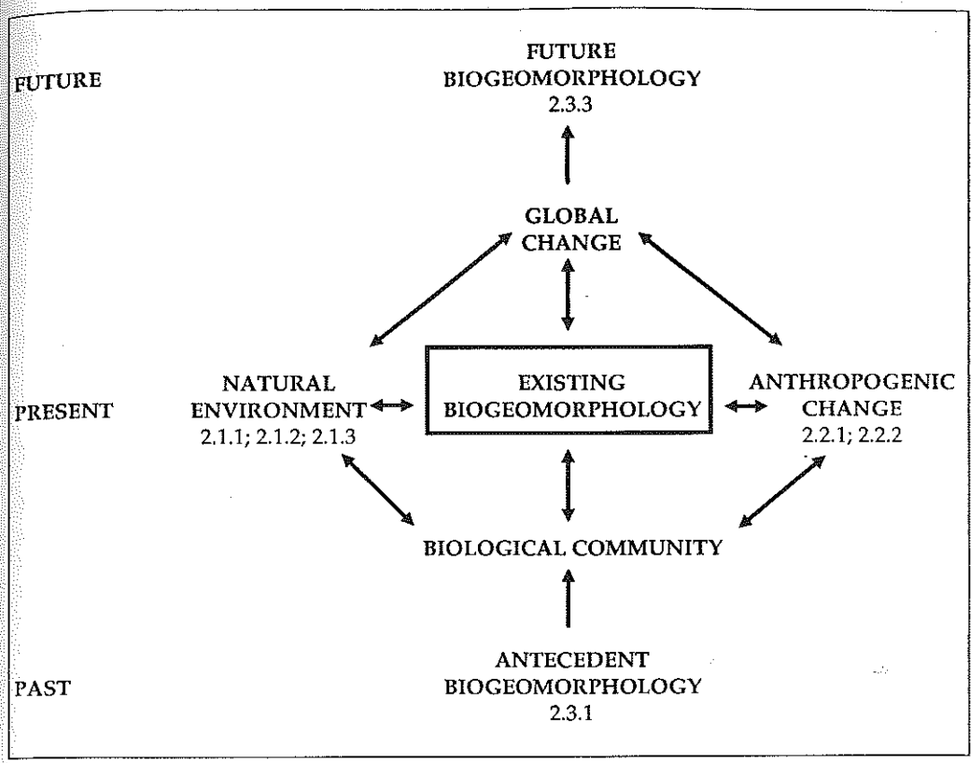

Figure 8. Conceptual Framework for Activities and Tasks envisaged under Focus 2.

Activity 2.1 - The Role of Ecosystems in Determining Coastal Morphodynamics under Varying Environmental Conditions

Introduction

The interactions between sea, land and atmosphere are highly dynamic, over both short and long time scales, and under the influence of variability and trends in climate and sea level, affect the biological and physical stability and forms of coastal systems. The external driving forces that determine rates of change in coastal systems are themselves subject to direct and indirect modification by human action at local, regional and global scales. A better understanding is required of community and ecosystem processes and function in response to varying environmental conditions, of the contribution of biotic and abiotic systems to the coastal sediment budget, and of the relationship between hydrodynamic forcing and ecosystems in controlling the coastal sediment flux. The importance of episodic events, such as floods and storms in determining coastal stability and form is, in particular inadequately understood.

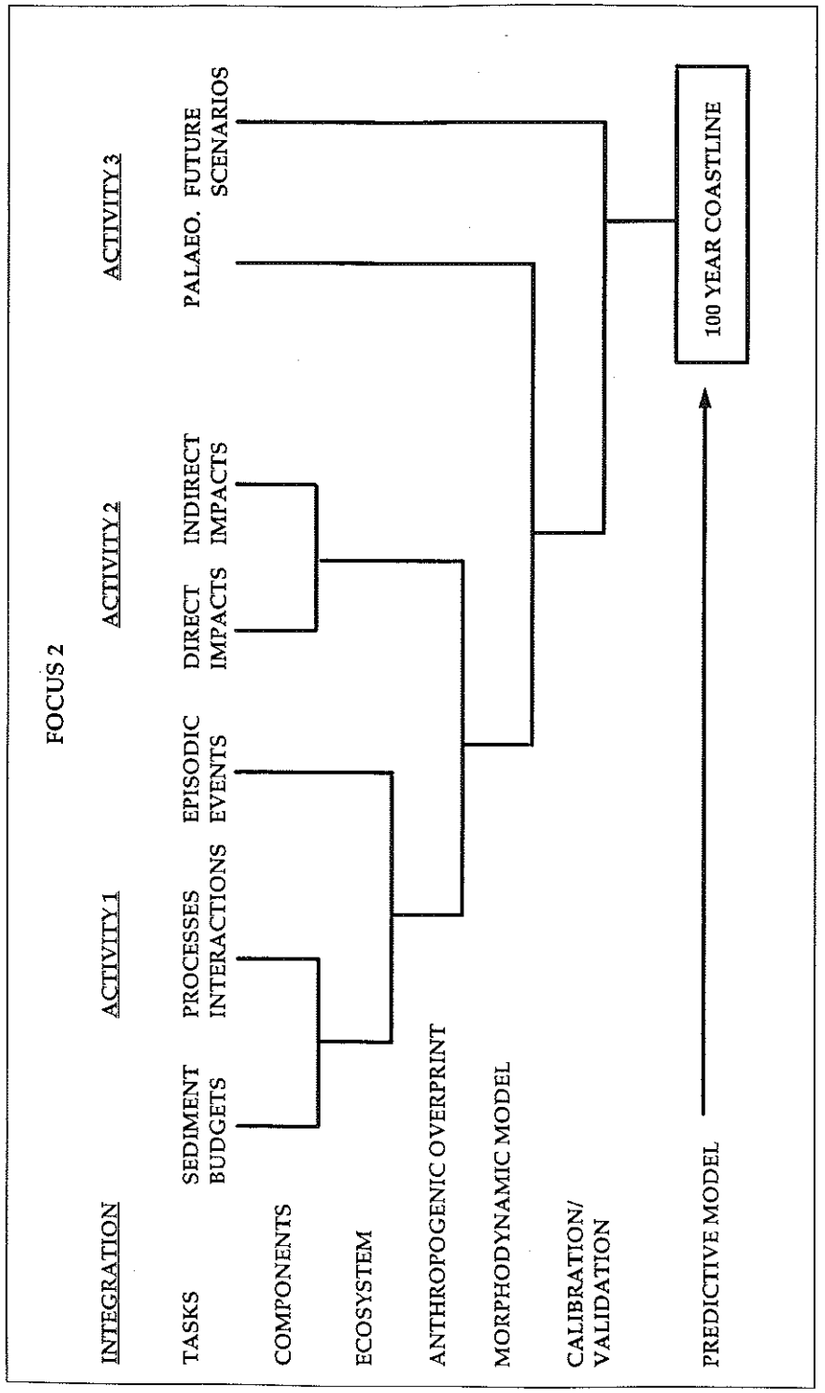

Figure 9. Implementation sequence for Tasks and Activities envisaged under Focus 2 designed to provide scenarios and models of future coastlines on century time scales.

Overall objectives

The overall objective of this activity is to assess, at regional and global scales, the role of ecosystems in coastal morphodynamics. More specifically this activity will:

- Elucidate and quantify the geomorphological role of representative ecosystems including interactions across coastal landscapes
- Evaluate the feedback between the biota and coastal geomorphology in relation to different types of physical environment and boundary conditions
- Develop models of the effects of large scale changes to the biota, on the form and stability of the coastline
- Determine for specific sedimentary and ecological settings, the rate and direction of biogeomorphological responses to trends in climate and sea level

The LOICZ approach

Perhaps the most obvious biotic communities that influence coastal morphodynamics by accretion of sedimentary material on a wide geographic scale are mangrove forests, coral reefs, seagrasses, sand dune vegetation and salt marshes. Each includes a wide range of species, ecotones and associations (macroalgae, various types of benthic animals, cyanobacteria, and many others) that affect the supply, retention and cohesion of sediments as well as the physical conditions for sediment mobilisation and transport. The research priority for LOICZ is to determine the sum of these biotic properties over a range of time and space scales within the context of global change in the coastal zone. Despite the fact that each coastal ecosystem exhibits unique attributes, the research questions and related tasks designed to address the overall objective of this activity are broadly similar for different types of coastline. In many tropical areas mangroves, coral reefs and seagrass meadows function as ecotones in a "mega-ecosystem", although exchanges of matter and energy between these components of the larger system are generally lower than the fluxes within them. In many temperate deltaic environments saltmarshes, freshwater swamps and agricultural systems function in a similar inter-related manner.

Broad tasks to be accomplished in each system will involve:

- Quantitative assessment of the environmental factors that influence the growth, productivity, species interactions, zonation and community replacement patterns of the major types of biotic communities that occur within specific coastal environments
- Identification of feedback processes through which ecosystems significantly affect coastal morphodynamics
- Development and refinement of mass balance models for sediments in different coastal ecosystems
- Development of models of the biogeomorphological functioning of components of coastal systems for incorporation into scenarios of climate and sea level change
- Quantitative assessment of system responses to trends in climate and sea level

A quantitative understanding of the nature and scales of biotic influences on coastal morphodynamics will ultimately lead to significant improvements in our capacity to predict the future evolution of the land-ocean interface under different scenarios of global change, including sea level rise.

Task 2.1.1 Sediment budgets in coastal ecosystems

Rationale

Coastal morphodynamics are determined to a great extent by ecosystem functioning, yet our knowledge of the role of coastal ecosystems in coastal sedimentary processes and their responses to trends in climatic conditions and sea level, and to changes in terrestrial and biogenic sediment inputs and transport, is inadequate, especially over large time and space scales.

Specific objectives

- Quantify the capacity of individual coastal ecosystems to supply and retain sediments under a range of physical settings including varying rates of externally derived sediment input
- Quantify the relationship between hydrodynamics and the sediment flux within and between coastal systems
- Develop sedimentary mass balance models for different coastal systems at the local and regional scale

Implementation

Case study sites will be selected on the basis of the results of the coastal typology Framework Activity. Case studies will require identification of the sources of clastic and bioclastic material, and identification of ecosystem components and functions responsible for production, trapping, consolidating and remobilising sedimentary materials in each system (see Task 2.1.2). In order to develop a framework for examining the role of different components of the community within particular ecosystem types such as mangroves, a matrix of studies will be required which encompass the present range of physical environmental conditions under which such communities are found. The response of biotic communities to variations in obvious physical parameters, such as the rate of terrigenous sediment supply, will require quantification and comparisons between communities under different conditions of climate and sea level change. Multiple sites should be chosen for such comparisons, representing a range of sediment inputs and trends in sea level change (non-eustatic), and time-series studies initiated to elucidate regional patterns of seasonal and inter-annual variation. To achieve the objectives of constructing regional models and scenarios of ecosystem contributions to mass balance and sediment flux, it will be necessary to develop common methodologies for the assessment of *inter alia* vertical and horizontal accretion rates, and to ensure close collaboration and data exchange in the design and execution of Tasks 2.1.1 and 2.1.2. The production of regional and global syntheses of information and scenarios of change will only be possible where such collaboration and exchange of data between individual case studies and tasks take place.

Outputs

- Determinations of ecosystem responses to variations in sediment input and transport for major types of coastal ecosystems over annual or longer timescales, co-ordinated with the outputs of Task 2.1.2
- Local-scale models of the role of coastal ecosystems in the morphodynamic evolution of the coastal zone

- Mass balance models for sediment transport and retention within and between ecosystems under varying climatic and sea level conditions
- Input data for the development of local, subregional and regional morphodynamic models in Task 2.3.2

Subtask 2.1.1.1 Coral reef system sediment budgets

Methodology

Net calcium carbonate production rates based on community calcification and dissolution, and net accumulation rates based on retention, lithification, and net sediment import or export are functional characteristics of coral reef communities that depend on community structure and on environmental conditions, including the input of exogenous sediments. A thorough review of existing knowledge will be used to identify representative classes of communities or environments for characterisation and quantification of biogeomorphological processes through selected case studies. Once the range and ecological and environmental correlates of sediment accumulation and export are determined for representative coral reef environments, basic production and retention models will be developed to provide input for hydrodynamic and morphodynamic coastal process models. These models will be designed to accommodate input data based on findings concerning the effects of anthropogenic and geocentric change on the structure and function of coral reef communities.

Outputs

- Quantitative descriptions of changes in coral reef community structure and function in relation to the supply, retention, and transport of both endogenous and exogenous sediments
- Mass-balance models and sediment budgets of coral reef community production, export, and accumulation of carbonate sediments based on community characteristics and process models derived from Subtask 2.1.2.1

Subtask 2.1.1.2 Determination of sediment budgets on mangrove shorelines

Methodology

Mass balances in mangrove systems are influenced by a series of boundary conditions including riverine sediment input, tidal hydrodynamics and climate, and are mediated by the biotic community. Budgets need to be established for sediments and organic carbon in representative mangrove systems both through measuring sedimentation and flux directly and by determining accretion rates from cores.

Outputs

- Quantification of primary production and partitioning of carbon above and below ground, especially root production, root turnover and peat accumulation, in response to changing environmental factors
- Quantification of accretion rates within different mangrove associations, and comparison between settings with different boundary conditions
- Models of sediment and organic carbon flux through mangrove systems

Task 2.1.2 Coastal ecosystem characteristics, processes, and interactions

Rationale

Coastal systems exhibit close and complex relationships between their biotic components and the physical characteristics of the environment, and are often interlinked across coastal land- and sea-scapes such that processes of sediment supply, deposition and binding are performed by different communities of organisms at different locations and time scales. An understanding of the structure and function of the individual ecosystems and their components is basic to identification and quantification of the scales and directions of feedback between coastal ecosystem changes and coastal biogeomorphology.

Specific objectives

- Identify and discriminate the role of different biotic components of particular ecosystems in the processes of sediment supply, trapping, stabilisation, remobilisation, erosion and dissolution
- Characterise and clarify in terms of the biological components the functional guilds of coastal ecosystems, as determined on the basis of their actual contributions to constructional or erosional processes
- Determine the responses to environmental forcing, including changes in climate and sea level of biota and their interactions, over a range of spatial and temporal scales and at various levels of the ecological hierarchy (i.e., population, community, ecosystem)

Implementation

There is a need to increase understanding of the way in which individual coastal ecosystems function and interact in terms of their biogeomorphic roles. Processes determining these roles will differ according to the nature of the ecosystems concerned and their specific climatic, sea level and geomorphological settings. Understanding of interactions within and between ecosystems requires fundamental understanding of the key components and controlling processes within the individual ecosystems. Standard survey methods can be applied to determine the biotic composition of an ecosystem in terms of functional (as opposed to taxonomic) groupings. Available information can be used to categorise the various biological components according to their different roles as calcifiers, eroders, organic carbon producers or consumers. Organism and ecosystem responses to environmental forcing and to intrinsic biological variations can be assessed from existing data, experimentation, or systematic observation.

Both conceptual and quantitative models are needed to integrate results and understand how the various biological processes contribute to the creation, maintenance, or destruction of biogeomorphological structures. *In situ*, long-term studies are also needed to address issues of the inter-dependence of such systems. Sites should be chosen where large scale landscape (seascape) studies across two or more habitats can be undertaken to elucidate the interactions of different ecosystems. Feedback mechanisms between ecosystems and physical forcing functions need to be studied over long time frames and co-ordinated with Task 2.1.1 in order to understand the role of the biota in coastal morphodynamics. Remote sensing, including aerial photography, will be a vital tool in observing change over decadal time scales and in validating the results of models.

Outputs

- Classification of typical coastal ecosystems and communities in terms of biogeomorphic guilds
- Quantification of the nature and effects of biotic variability and extreme events in coastal ecosystems (e.g., disease outbreaks, population die-off and explosions)
- Biological process models and inventories as input to the mass balance models identified as outputs of Task 2.1.1
- Conceptual and process models of interactions between neighbouring coastal ecosystems, including the feedback and the effects of changes in environmental forcing
- Input to the development of models of coastal change in Task 2.3.2
- Improved understanding and predictive capability of the biogeomorphological responses to variability and trends in climatic factors and sea level

Subtask 2.1.2.1 Coral reef ecosystem processes and external interactions

Methodology

In the case of coral reefs, the actual biogeomorphic structure which supports the biological communities is formed by the communities themselves, specifically, the calcifiers such as scleractinian corals and the coralline algae. Calcium carbonate is deposited and is either lithified to form the solid reef structure, or is eroded to contribute to loose sedimentary deposits on the various reef zones (e.g., reef flat, lagoon, supratidal or beach area) or in adjacent coastal areas. In this particular ecosystem, biological characterisation (this Subtask) and sediment budget considerations (Subtask 2.1.1.) are particularly closely linked. Standard methods and available information can be used to characterise reef communities in terms of their diversity and major functional components. The process-related responses of these components (e.g., net calcification, photosynthesis, and respiration) to environmental forcing will be identified and used for input to sediment budget models (Subtask 2.1.1.1). Process models of interactions among mangroves, seagrasses and coral reefs, which often occur in close proximity to one another in humid tropical environments, will help elucidate the roles of coastal ecosystem interactions in larger coastal biogeomorphic processes and in regional and global carbon and nutrient budgets.

Outputs

- Biogeomorphic characterisation and process sub-models of typical reef environments and guilds in terms of their production, export and accumulation of carbonate sediments
- Process models of the responses of coral reef community structure and function to environmental forcing, including episodic events (Subtask 2.1.3.1) and biotic extreme events
- Process models of reef-seagrass-mangrove community interactions and exchanges

Subtask 2.1.2.2 Mangrove ecosystem interactions and feedbacks

Methodology

Zonation, succession, and regeneration in mangrove systems need to be examined through field measurements and determination of tolerance limits from experimental trials. Sensitivity and resilience of mangroves in terms of reproductive and vegetative phenologies, and growth rates in relation to environmental factors across intertidal landform gradients need to be determined in representative biogeomorphological settings.

Outputs

- Classification of mangrove habitats in relation to community structure and function
- Quantification of community response to variation in environmental forcing and its relationship to coastal morphodynamics
- Dynamic models of the direction and rates of change of mangrove habitats, and associated sedimentary environments

Task 2.1.3 Episodic events

Rationale

In the context of coastal morphology and of the global change issues which are to be addressed by LOICZ, episodic extreme events with return frequencies of years to centuries are extremely important in causing large-scale change in coastal morphology. An understanding of their effects and relationships to climate change and variability is critical to the development of biogeomorphic models.

Specific objectives

Short-term

- Quantitative assessment of the role of episodic, high magnitude environmental events in determining long-term geomorphological changes in coastal ecosystems

Long-term

- Construction of future scenarios for morphodynamic change in coastal systems in response to changing frequencies and/or magnitudes of episodic events

Implementation

Various types of evidence demonstrate that episodic environmental events over different time scales can strongly influence the nature of the land-ocean interface. However, quantitative analysis or numerical simulation of the impacts of such events remains difficult, due to limited direct observations and a lack of suitable procedures for analysing the linkages between physical and biological processes at different scales. Methods for the analysis of episodic events should include: direct observation on an opportunistic basis, by remote sensing and by the deployment of *in situ* instruments that can withstand extreme environmental conditions; and analysis of past events through stratigraphic and other studies of coastal geomorphological structures. The application of high resolution dating of sedimentary structures will be important in these studies (see Task 2.3.1).

The comparative analysis of the structure and functioning of similar ecosystems under regimes of differing frequency of extreme events, such as hurricanes, may provide insights into the functioning of such systems under differing levels of stress, and hence provide information on the biogeomorphological consequences of such events for coastal form and evolution under various global change scenarios. Comparative investigations of coastal ecosystems following episodic events that have occurred at different times in the past, could provide information on the response of such systems and the resulting coastal form. The role of anthropogenic effects (assessed under Activity 2.2) in modifying or controlling ecosystem sensitivity to recovery from episodic acute stress will need to be considered and incorporated into predictive models

Outputs

- Quantitative descriptions of the impact of episodic events that significantly affect the biogeomorphological properties of coastal systems over decade to century timescales
- Regional scenarios of changes to biogeomorphological processes in particular ecosystems as a consequence of changes in frequency or magnitude of episodic events, under conditions of global change

Subtask 2.1.3.1 Episodic disturbances in coral reef communities

Methodology

Coral reefs are widely regarded as disturbance-adapted systems, but it is clear that physical and biological characteristics are strongly influenced by the frequency, magnitude, and nature of both abiotic (Task 2.1.3) and biotic (Task 2.1.2) extreme events. Representative reef communities in both high-impact and low-impact environments will be systematically compared to assess the effects of episodic events on the aspects of community structure and function relating to biogeomorphology. Palaeoecological investigations (Subtask 2.3.1.1) and retrospective environmental analysis (also used in Subtasks 2.2.1.1 and 2.2.2.1 for

other purposes) will be used to identify the role(s) played by past episodic disturbance in shaping presently existing structures and sediment distributions. A particularly important area of investigation will be the synergism of episodic events with chronic stresses or environmental modification (e.g., sediment or nutrient loading, over-exploitation; see Subtasks 2.2.1.1 and 2.2.2.1) that may modify or prevent recovery of the reef community from the effects of episodic damage.

Outputs

- Classifications of physical episodic events such as storms, temperature or salinity anomalies that impact coral reef communities
- Quantification of the nature and magnitudes of the impacts of such events on community structure and function
- Models of community structure, diversity, function, and sediment budget (integrated with Subtask 2.1.1.1) as a function of long-term variability including episodic events
- Descriptive/semiquantitative models of reef community response to episodic events in relation to varying levels of chronic stress

Subtask 2.1.3.2 Extreme events and their impact on mangrove shorelines

Methodology

The role of mangroves as a buffer, and their biogeomorphological response to extreme physical events requires quantification through assessment of the impacts of extreme events and mangrove system recovery.

Outputs

- Quantification of impacts of different magnitudes and frequencies of extreme events on mangrove shorelines in different settings
- Characterisation of the modes, and quantification of the rates of mangrove system recovery following extreme events, and of the consequences for community structure and function
- Conceptual and semi-quantitative models of the biogeomorphological response of mangrove systems to extreme physical events

Activity 2.2 - Coastal Biogeomorphological Responses to Anthropogenic Activities

Introduction

Human land and sea use are already causing changes in coastal environments at local, regional and continental scales, and altering the fluxes of freshwater, sediment and nutrients from land to ocean. The effects are both direct, due to dense human populations along the coastline, and indirect as a result of human activities within catchment systems. The extent to which changes are already altering the function of coastal ecosystems and

hence changing the role of these systems in global biogeochemical cycles is uncertain. To evaluate this issue in relation to sediment dynamics, the fluxes and fates of: terrestrial material derived from riverine inputs and erosion of coastal land; marine materials reworked from estuaries, bays and the continental shelf; and new biogenic sediments in coastal environments, must be better documented.

Coastal ecosystems are being strongly modified, partly through direct human exploitation of living resources and partly through ecological responses to alterations in the physical and chemical environment. Predicting the geomorphological responses of the coastal zone to climate change and rising sea level is therefore complex and difficult, given the strong background signal of human impacts and of variable hydrological and hydrodynamic forcing. Variations in sediment input to the coast from land for example, affect water column turbidity as well as sediment deposition, with major consequences for primary production, and the chemistry of the water and sediments. Reductions in freshwater flow in rivers cause abnormal displacements of the saltwater-freshwater interface, and changes in coastal mixing processes, especially in systems with a strong seasonal flood cycle; alterations in salinity distributions affect ecological and sedimentary processes especially in relation to the formation of estuarine turbidity maxima. These examples illustrate the complexity of the scientific issues involved and the consequent uncertainties in distinguishing between coastal biogeomorphological responses to local human activities and to global sea level rise.

Overall objectives

The overall objective of this activity is to identify and assess, at regional and global scales, the biogeomorphological responses of coastal systems to anthropogenic and environmental driving forces of change, more specifically this activity aims to:

- Identify the anthropogenic forcing functions of biogeomorphological change whether directly applied or through catchment systems
- Evaluate the actual and potential responses of selected coastal ecosystems to past and current human influences
- Determine the relative sensitivity of particular coastal ecosystems to variations in sediment supply, rising global mean sea level, and climatic trends

The LOICZ approach

This activity must be a longer term one, since its implementation will depend in part on the outcome of the ecosystem studies undertaken under Activity 2.1. Nevertheless syntheses of existing information and data can be undertaken to provide an initial framework which will permit a qualitative assessment of the relative importance of individual forcing functions and the potential geomorphological responses of coastal ecosystems to scenarios of future change. Historical reconstructions of coastal habitat alterations and land-use change in watersheds will be undertaken to provide a background against which the state of present coastal systems can be evaluated. On a global scale the last two hundred years represents the period of most rapid population growth and urbanisation although it is recognised that the temporal extent of such studies will vary from region to region and may extend back for several thousand years,

depending on local and regional patterns of population growth, urbanisation and land-use. The acquisition of compatible observational data on relevant ecosystem properties (Activity 2.1) and on rates of change in the coastal zone during historical times will provide the basis for developing biogeomorphological models for specific ecosystem types (e.g. saltmarshes, mangroves) and for defined geomorphological units such as deltas, and coastal lagoons.

Analysis of the response of coastal systems to large scale human interventions in catchment basins and in coastal ecosystems, such as clear felling of mangroves, river canalisation, dam construction and freshwater diversion projects, will provide information on the role of ecosystems and coastal biota in determining coastal form and dynamics. Such analyses will need to be undertaken for similar systems which are under the influence of differing driving forces of change if the biogeomorphological response of systems to the different sources of change is to be distinguished.

Task 2.2.1 Direct impacts of human activities on the coastal zone

Rationale

Increasing population densities on the coast result in physical, chemical, and biological alterations to coastal environments that adversely affect the functioning of coastal ecosystems. The impacts of these changes in terms of alterations to the dynamic properties of the land-ocean interface are inadequately documented and quantified at the present time.

Specific objectives

- Quantify the mechanisms, rates and scales of direct anthropogenic driving forces of change on the biogeomorphological processes in the coastal zone
- Elucidate the biogeomorphological consequences of changes to biological processes such as productivity, and to reduction in species diversity caused by human activities in the coastal zone
- Determine the biogeomorphological responses of coastal systems to anthropogenic modification of coastlines

Implementation

Human activities in coastal areas are resulting in impacts on the natural environment at an unprecedented scale. The rates of change are accelerating due to the rapid growth of human populations along the world's coasts, which in most areas, exceeds the average rate of population growth inland. This task should include case studies of stratigraphic, archaeological and palaeoecological records to provide information on the changing rates and scales of anthropogenically driven changes in coastal environments during historical times, primarily over the last 200 years. The temporal extent of such studies will vary from region to region, reflecting differences in rates of population growth, coastal urbanisation and land-use. Interpretation of geological and recent geomorphological records will depend on reliable discrimination of natural *versus* human forcing factors of biogeomorphological change at the land-ocean interface. A multidisciplinary approach is necessary with links to the research envisaged under Focus 4 and to other regional and global research projects and programmes dealing with the exploitation of the coastal zone by humans.

Outputs

- Quantitative assessment of the nature of biogeomorphological change resulting from human activities in the coastal zone
- Quantitative assessment of the relative importance of different anthropogenic forces driving change in coastal systems
- Inputs to regional models of the biogeomorphological consequences of direct anthropogenic forces driving change in coastal areas

Subtask 2.2.1.1 Direct impacts of human activities on coral reefs

Methodology

Human activities can undermine the processes that build and maintain a reef's physical structure, and change the biotic composition to shift the balance from net physical accretion to net erosion or dissolution. This Subtask should focus on human activities that, singly or together, constitute a chronic or cumulative source of stress on coral reef ecosystems over the long term. Emphasis should be made on human activities that are common in different parts of the world where coral reef ecosystems exist, or that have the potential to result in significant alteration of the role of coral reef and related shallow carbonate communities in the marine carbonate budget and the global carbon cycle. Examples would be chronic environmental alteration associated with human settlements, such as domestic sewage, agricultural runoff, and other wastes. In such cases that affect the nutrient balance and primary production, changes in community composition can result, such as a shift from scleractinian corals to fleshy algae. Methods should therefore be adopted that relate water quality, to the composition of reef communities in terms of functional groups. Quantitative data on reef community functional processes such as primary production, energy consumption and calcification need to be correlated with the effects of various types and levels of human impacts.

Outputs

- Analysis of reef sediments and dated coral cores to provide information on coral reef response to anthropogenic change
- A systematic catalogue of known anthropogenic stress factors and quantification of their effects on reef communities, individually, in combination, and as a function of the natural environment
- Estimations and projections of the magnitudes and locations of future changes in direct anthropogenic reef community stress, based on data from Focus 4 activities
- Process models of the effects of chronic or cumulative human impacts on coral reef community structure and functions, including primary production and calcification

Subtask 2.2.1.2 Direct impacts of human activities on mangrove shorelines

Methodology

The biogeomorphological effects of resource use, degradation and partial or total removal, require quantification at local and regional levels. It will be necessary to study both immediate consequences such as reduction in community resilience, and longer-term consequences, such as gradual oxidation of potential acid sulphate soils following drainage, and increased vulnerability in adjacent systems following mangrove removal (see Subtask 2.1.3.2).

Outputs

- Quantification of the short and long term effects of human impact on mangrove community structure and function
- Dynamic models of biogeomorphological response of mangrove shorelines to anthropogenic stress

Task 2.2.2 Indirect impacts of human activities on the coastal zone through changes in land and freshwater use

Rationale

Change in the world's coastal zones on continental and regional scales can result from human activities occurring within the catchment basins, often at some distance from the coast. There is a need to quantify the impacts of land and freshwater use on biogeomorphological processes at the land-ocean interface.

Specific objectives

- Identify and quantify present practices of land and freshwater use inland that exert significant influences on the biogeomorphological processes occurring in the coastal zone
- Quantify the nature of coastal changes resulting from different land and freshwater use practices on regional scale
- Determine the biogeomorphological responses of coastal systems to these changes in land and freshwater use
- Develop regional models and scenarios of the impact of future land and freshwater use on the rates and directions of change in coastal systems

Implementation

Present land use practices differ from region to region, and therefore initial synthesis of the nature of these driving forces of coastal change is best done on a regional basis. Certain human activities, however, are world-wide in occurrence such as deforestation and dam construction, but have cumulative global effects on sediment budgets and material transport across the coastal plains and continental shelves. The scale of such activities is considerable, and it has been suggested that the anthropogenic influence on

sediment flux to coastal waters may exceed the natural rate of flux (Milliman & Syvitski, 1992). This global trend may be reversing as a consequence of dam construction and large scale water diversion and irrigation projects. The impact of such human interventions on the functioning of coastal systems and shoreline form and stability, are inadequately understood or documented at the present time.

An attempt must be made to compare and synthesise within regional and smaller scale models the local impacts of these activities in terms of their significance for coastal biogeomorphological processes. The outputs of catchment basin studies within Activity 1 will be important in providing mechanisms for synthesis and extrapolation from local or single catchment basin studies to regional and global scales. Access to the appropriate remotely sensed data will be required for implementation of this task. Links with those elements of the GCTE, LUCC and BAHC projects that help define variability and change in the large scale transport of sediment, nutrients and organic matter from land to sea will be vital in defining appropriate methodologies and in providing new data for completing regional and global syntheses.

Outputs

- Quantitative assessment of the impacts of present inland freshwater and land use practices on the biogeomorphological processes occurring in the coastal zone
- Quantitative analysis on regional scales, of the nature of coastal changes resulting from different land and freshwater use practices on regional scales
- Conceptual models of the biogeomorphological responses of coastal systems to changes in land and freshwater use
- Regional models and scenarios of the impact of future land and freshwater use on the rates and directions of change in coastal systems

Subtask 2.2.2.1 Indirect effects of land use and hydrologic changes on coral reef communities

Methodology

Since many coral reef communities exist in shallow and/or enclosed water bodies or in close proximity to major land masses, river flow may transmit the effects of land and water use practices occurring hundreds to thousands of kilometres from the reef itself (see Focus 1 activities). The major goals of this Subtask will be to assess past and potential sediment, nutrient and toxic chemical loads of major rivers discharging into coral reef areas, to identify past, present and potential freshwater inputs, and to assess known coastal biogeomorphic effects and/or the potential effects of these factors in the absence of other environmental change. A significant factor in achieving these goals will be regional assessments of land and water use practices and their change over time. Coastal environmental inputs from these sources will have to be integrated with local anthropogenic alterations (Subtask 2.2.1.1) and with climate change or variability to determine the overall effects of the combined environmental change. This Subtask will share with Subtask 2.2.1.1 the use of sediment and core analysis for reconstruction of recent environmental changes.

Outputs

- Classification of reef communities according to the degree to which they are or may be affected by distant land and water use practices, the nature of the effects, and their proximate and original causes
- Identification and, where possible, quantification of situations where reef communities have been demonstrably impacted by land and water use practices at a substantial distance from the coast
- Assessment of the history and probable future trajectory of water quality and quantity changes due to known and predicted changes in land or water use in rivers discharging directly or indirectly into coral reef areas

Subtask 2.2.2.2 Indirect impacts of human activities on mangrove shorelines

Methodology
The extent and morphodynamic or ecological function of mangrove shorelines may alter as a consequence of indirect human actions such as land use change or damming in adjacent catchment areas that may result in altered sediment supply to estuarine or deltaic systems. Detailed studies will be necessary to discriminate these changes from natural coastal changes.

Output

- Quantification of the effect of *ex situ* land and water use upon mangrove shorelines

Activity 2.3 - Reconstruction and Prediction of Coastal Zone Evolution as a Consequence of Global Change

Introduction

New observational, experimental and modelling studies will only provide insight into the state of coastal systems under a limited range of environmental conditions, while studies of externally driven change can only encompass a restricted subset of system components within a limited spatial and temporal domain. In order to examine the responses of particular coastal systems to the relatively large changes in external forcing that might occur in the future, it will be necessary to develop palaeo-reconstructions of boundary conditions for the late Quaternary and to relate these to indicators of past conditions within the system. Through the reconstruction of past climatic, sea level and sediment supply conditions, the past responses of coastal systems to large scale global and regional changes can be determined.

The understanding of shoreline biogeomorphological response to medium to longer term global forcing will be facilitated by palaeogeographical reconstructions of a selected range of coastal settings, for selected windows in time. These will show the changes in shoreline position, and indicate past spatial relationships between biogeomorphological units.

An understanding of past and present processes that determine the nature of modern coastlines provides the basis for predicting future changes in coastal morphology related to a global rise in mean sea level. Objective scenarios of future local or regional conditions must take account of the best estimates of the rate of relative sea level rise, the dynamic properties of coastal ecosystems, and the broad environmental impacts of changes in land use and of the continuing exploitation of coastal environments by humans. Such scenarios will represent the scientific input to management decisions on socio-economic responses to the environmental impacts of future sea level rise. Just as the present is the key to the past, understanding the past can also be the key to predicting the future for the world's coastal area.

Overall objectives

The overall objectives of this activity are to assess, at regional and global spatial scales and decadal to millennial time scales, the responses of coastal systems to past climatic sea level and sedimentation conditions during the late Quaternary and to develop scenarios of the future evolution of the coastal environment under conditions of global change during the next century. More specifically this activity will:

- Reconstruct site-specific coastal zone palaeogeography at selected times during the late Quaternary
- Extrapolate locally and regionally to assess the relative extent of major coastal systems at selected times during the late Quaternary
- Reconstruct the processes responsible for the observed changes
- Develop predictive morphodynamic models of the relationships between processes and biogeomorphic response

The LOICZ approach

Stratigraphical, palaeoecological, geophysical, sedimentological and geochronological studies will be undertaken at representative indicator sites selected on the basis of the coastal typology Framework Activity (Task F.2.1) in order to reconstruct past coastal environments at selected times during the late Quaternary. These studies will be conducted over a selected range of biogeomorphological settings to determine temporal changes through the analysis of continuous records from cores, including coral reefs, peats and inorganic sediments. The results of such studies will: provide necessary inputs to the development of the geomorphological models of coastal evolution envisaged as being developed under Activity 2.2; contribute to the preparation of global syntheses of past coastal change; and provide the basis for the development of scenarios of coastal responses to relative sea level rise. LOICZ will interface extensively with working groups and results of present and past sea level projects, including the UNESCO Programmes (IGCP, CLIP).

This activity represents the end point of Focus 2, which will build on the outputs from the other activities and tasks undertaken within this Focus and will provide the necessary inputs to an evaluation of the socio-economic impacts of global changes on coastal systems undertaken under Focus 4. The other activities undertaken as part of this focus will generate qualitative and quantitative data concerning the range of responses of modern coastal systems to changing patterns of sea-level, climate and sedimentation, which,

together with the analysis of past responses, will provide the necessary basis for developing conceptual and semi-quantitative models of future, long-term system responses to further rises in sea level.

Task 2.3.1 Palaeogeographical, palaeoenvironmental and historical reconstructions of the coastal zone

Rationale

The extent and location of major coastal systems has varied substantially over the late Quaternary as a function of global change including sea-level movement. Local and regional palaeogeographical reconstructions over historical and prehistoric time indicate past interrelationships between biogeomorphological units and major forcing processes. Our understanding of past process-response relationships provides an empirical basis for model development for potential future coastal changes.

Specific objectives

- Reconstruct the palaeogeography and processes of the coastal zone at selected times
- Formulate scenarios of the responses of different coastal systems which have resulted from past global change

Implementation

The late Quaternary has been characterised by major variations in rainfall temperature, sea level and shoreline position and sediment supply. For example, with regard to the coastal zone, shorelines have migrated across the continental shelf which has been repeatedly exposed and submerged by fluctuations of sea level; the foci of organic and inorganic sedimentation have therefore also moved, and the latitudinal distribution of coral reefs has expanded and contracted.

Reconstructions of historical and pre-historical biogeomorphology provide large-scale physical models from which we can learn how the Earth's coastal systems have responded to variation in natural forcing processes. For more recent times, especially the historical, even more detailed interpretations of coastal morphodynamics are possible. By combining data from this range of temporal scales, we integrate records of short- to long-term environmental forcing and biogeomorphological response. Moreover, by interpreting past changes in the natural coastal environment, we are in a better position to understand how anthropogenic overprint in coastal settings has contributed to the larger picture of global coastal change.

Outputs

- Site-specific and regional palaeogeographic reconstructions of the coastal zone
- Data on the nature, magnitude, and rate of change of key medium to long term forcing functions including climate, sea level and sediment supply
- Detailed morphodynamic models for representative coastal types
- Input data for the development and validation of improved models of coastline evolution under varying scenarios of future global change, including sea level rise

Subtask 2.3.1.1 Reef palaeogeography and palaeoenvironments

Methodology

Changes in reef biogeography and geomorphology, including the biotic composition of coral reefs, will be determined for particular intervals in time; including the last interglacial, interstadial high stands, and for time periods during the Holocene.

Outputs

- A compilation of existing data on reef palaeogeography
- Local and regional palaeogeographic reconstructions
- Data on reef growth and sediment accumulation rate
- Data on local and regional sea-level history
- Models of reef response to changes in forcing functions over short to long time scales
- Input data for the development and validation of improved models of coastal evolution under varying scenarios of global change, including sea level rise

Subtask 2.3.1.2 Palaeogeographic and palaeoenvironmental reconstructions of mangrove shorelines

Methodology

Mangroves are extremely sensitive to changes in external forcing, including changes in freshwater availability and sea level. A record of mangrove system response to global change is preserved in Holocene coastal sequences. Palaeo-ecological reconstructions using indicators such as pollen, spores and diatoms will enable assessments of mangrove ecosystems response to past global change.

Outputs

- Local and sub-regional palaeogeographical and palaeoenvironmental reconstructions for mangrove shorelines
- Quantification of past sedimentation rates, and accretionary potential, in relation to patterns and rates of past global change including sea-level variation
- Models of mangrove ecosystem response to global change factors, particularly sea level
- Input to modelling scenarios for coastal change

Task 2.3.2 Systems modelling and future scenarios

Rationale

There is a need to consolidate our understanding of the functioning of the coastal zone at various time and space scales into the production of systems models by integrating inputs from previous Activity 2 tasks. This step will provide essential input for the preparation and calibration of predictive models for future coastal change under various global change scenarios.

Specific objectives

- Develop models of ecosystem functioning and interaction at local, subregional and regional levels
- Develop a conceptual modelling framework for determining the responses of coastal systems to future global change including sea level rise
- Formulate quantitative models for determining the response of different coastal systems to different rates of global change
- Develop regional scenarios of the biogeomorphological response of coastal ecosystems to global change
- Undertake case studies to validate the models

Implementation

Implementation of this task will necessarily rely heavily on the results of other activities and tasks within Focus 2, as well as from other Foci, and on input of appropriate climate, sea level, and sedimentation scenarios developed by other agencies and programmes. A knowledge of past and present conditions and driving forces of change in the coastal zone developed under these various tasks will provide the basis for developing scenarios of future coastline change under different scenarios for global change, including sea level rise.

Case studies of coastal change will be undertaken for specific coastline types or systems in order to construct local and regional models used to develop future scenarios. The conceptual framework for undertaking this task must include measurements of the physical and biological properties that determine coastal morphodynamics, as well as the changes to both, that result from continuing human activities and global change. In addition the possible effects of human intervention, such as ecosystem conservation and restoration (e.g. mangroves) must be taken into account, and linkage with the activities envisaged under Focus 4 will provide a framework for incorporating the results of studies undertaken under this task with assessment of the socio-economic impacts of global change in coastal systems. The results of studies of late Quaternary changes will provide a basis for model initialisation and validation. On-going, large scale "experimental" manipulations resulting from development activities in which hydrological, sediment input and ecological conditions are altered, provide an alternative approach to evaluating and validating model results. In addition, data from long-term observation systems including satellites and the coastal module of GOOS, will provide the data required for model initialisation and validation.

Outputs

- Quantitative system models based on integration of outputs of previous Activity 2 tasks
- A conceptual modelling framework for determining the responses of coastal systems to future global change
- Quantitative models for determining the response of different coastal systems to differing rates of future global change
- Case studies of system response to different forcing functions
- Scenarios of natural environmental change that can be used as input data for the investigation of socio-economic impacts (Focus 4)

Focus 3: Carbon Fluxes and Trace Gas Emissions

Background

Present and possible future changes in the structure and function of the coastal zone may alter biogeochemical processes in ways that ultimately have global consequences. The most evident of these changes concern processes involved in the global carbon cycle, and in the production and consumption of biogenic trace gases in coastal systems.

The natural carbon cycle between air, oceans, biosphere and soils has been significantly disturbed by human activity. Emission of fossil carbon, excessive burning/harvesting of tropical rainforests and agricultural degradation of soils have probably created a total imbalance in excess of 7 Gt C a^{-1}. Of this total, 3 Gt C a^{-1} contribute to the observed increase in pCO_2 in the atmosphere, and 0.5-1.5 Gt C a^{-1} are taken up by the buffer capacity of the ocean. The remainder is apparently distributed to a series of sinks, of unknown relative importance. One of the largest of these sinks is assumed to be northern temperate forests which some biologists have even suggested is more important than either the atmospheric or oceanic sinks. A suite of smaller sinks may be associated with medium-term depocenters in the freshwater system and/or with the coastal seas, since at least 75 % of marine carbon burial during the Holocene has occurred and continues to occur in deltas or along continental margins.

Activity 3.1 - Cycling of Organic Matter within Coastal Systems

Introduction

One of the currently unanswered questions of considerable importance to an understanding of global change is the role of the coastal seas in both the natural and the disturbed carbon cycle. Coastal seas serve as final receivers of natural and anthropogenic organic matter and nutrients derived from land and brought in by river and groundwater discharge, and through direct inputs of sewage and other wastes. It is estimated that roughly 0.4 Gt organic carbon are delivered annually by rivers to the coastal sea, an unknown part of which could be respired, constituting a natural source of CO_2 to the atmosphere. At the same time anthropogenically mobilised nutrients are delivered to the coastal seas. Consequently coastal seas may simultaneously sequester some carbon from the atmosphere at rates in excess of those occurring under natural conditions. The size of this sink, the potentially sequestered carbon (PSC), can be estimated by scaling the anthropogenic inorganic nutrient inputs according to the Redfield ratio (i.e. the atomic ratio in which C, N, and P are consumed by phytoplankton; 106:16:1). Estimates of total anthropogenic inorganic nitrate and phosphate inputs to the coastal zone are in the range of 1.5 and 0.05 10^{12} mol a^{-1}. The presumed coastal sink is therefore in the order of 6-10 10^{12} mol C a^{-1} or 0.07-0.12 Gt C a^{-1}. Organically bound nutrients, which also enter the coastal sea with sewage for example, may - upon remineralisation - also increase coastal primary productivity. However, organically bound nutrients probably result in as much fixation as release of CO_2 when they are first remineralised, and therefore enhanced nutrient inputs may not result in an increase in the coastal sink of atmospheric CO_2.

This approach to the problem, however, does not provide information on when, and how this PSC is fixed and where it eventually ends up. Nor does it provide information on whether coastal seas are natural sources or sinks of CO_2. If coastal seas functioned naturally as sources of CO_2, then the formation of PSC could either have switched them from source to overall sink, or simply diminished the natural source function, which would also constitute an anthropogenically created sink.

The PSC could either be deposited in tidal flats, in estuaries, in depocenters on the shelf or be exported over the shelf edge to the deep ocean basins. In the event that all of the PSC is respired, then the anthropogenic nutrients would simply be exported to the open sea and would add to the large pool of dissolved nutrients in the deeper ocean layers. Even under this extreme scenario, some of the carbon may escape recharge to the water column as CO_2 if the respiration proceeds under anaerobic conditions, by sulphate reduction in shallow sediments, or in stagnant basins. In this case additional alkalinity forms, in proportion to the buried sulphide phase and in proportion to any H_2S fluxes to the atmosphere such as that from tidal flats. This excess alkalinity can then be exported to the open sea. Similarly, calcite dissolution that occurs in sediments of high internal pCO_2, or at the mixing front of river water (high in pCO_2 and low in suspended calcite) with seawater (low in pCO_2, and high in suspended calcite or aragonite) could produce additional alkalinity to be exported to the open sea.

In addition to the uptake of carbon by phytoplankton, other coastal ecosystems may be undergoing anthropogenic fertilisation either from river runoff and direct discharge, or by atmospheric deposition. These systems include coral reefs, seagrass meadows, tidal flats, mangrove forests, salt marshes and coastal swamp forests. The role of these systems in the natural and disturbed carbon cycle is probably small, but not much quantitative data are available to evaluate their relative importance.

It should also be noted that coral reefs serve as regulators of the TCO_2 and alkalinity in warm surface waters. Supersaturation of $CaCO_3$ is prevented from becoming "supercritical", that is, supersaturated to the point where spontaneous inorganic precipitation occurs, by biocalcification occurring to a large extent in coral reefs and the associated biota. Inorganic precipitation of $CaCO_3$ does not occur anywhere in the ocean at present, in spite of a general supersaturation in ocean surface waters. Empirical observation suggests that the diversity of coral species may be correlated with supersaturation since both are highest around the Islands of the Western Pacific. Alteration of supersaturation by ocean warming, increase of alkalinity or other processes could have an impact on reefs of, as yet, unknown consequence. Production of $CaCO_3$ by biomineralisation also produces measurable amounts of CO_2, again regulating the natural air-sea exchange of CO_2.

Intrinsic to these problems is the fact that measurements in any one place cannot provide information on the global importance of these processes. Nevertheless case studies do provide an insight into the internal processes involved in sequestering dissolved inorganic carbon in the form of permanently or temporally deposited organic carbon.

With the advance of our understanding of palaeoclimatology, particularly of the Glacial-Interglacial cycles, the role of the coastal ocean under Glacial conditions becomes an interesting and important subject for study. As a result of the low sea level during Glacial times, much of the continental shelf was dry land until around 14,000 B.P., at the

beginning of the Bölling/Alleröd. Coastal marine primary productivity may therefore not have accounted for such a large percentage of total marine productivity, and much of the coastally produced organic carbon may have been exported to adjacent shelf slopes. The recycling of freshwater-derived nutrients that occurs in modern coastal environments, may have been less important on a global scale during periods of low sea level. Such differences may have played a significant role in determining the low atmospheric pCO_2 in Glacial times, as documented in Greenland and Antarctic ice cores. Enhanced understanding of present day coastal processes and development of improved modelling capacity may therefore cast light on the functioning of the global carbon cycle in Glacial times.

Overall objectives

The overall objective of this activity is to study, at regional and global scales, the disturbed and undisturbed carbon cycle of the coastal seas through:

- Data collection designed to provide spatially referenced information on the synoptic distribution of key carbon variables
- Conduct of in-depth studies of the carbon dynamics of selected coastal systems
- Sensitivity studies designed to assess the reliability of transferring case study results from one area to another or from year to year
- The use of spatially referenced data and model standardised reaction groups, to integrate the carbon budget for similar coastlines
- Develop global estimates on the basis of the regional budget values

The LOICZ approach

Individual studies can be conducted by many scientists in many areas simultaneously and the data assembled in a GIS database. Necessary data would include: the geographic extent and concentrations of inorganic and organic carbon in shelf and inshore water and in sediments; sedimentation rates and recent changes; concentrations of suspended matter; particulate organic and inorganic carbon and chlorophyll in the water column; temporal and spatial variations in the distribution of dissolved organic carbon; alkalinity; inorganic dissolved carbon; pH and pCO_2; and data on rates of remineralisation; photosynthesis and respiration.

In-depth case studies need to be undertaken in a number of areas representative of the range of different types of coastal seas identified through the coastal typology Framework Task (F.2.1) and will involve the use of high precision potentiometry, coulometry and infra-red pCO_2 methods to acquire precise enough data fields to detect seasonal differences and possibly net fluxes. Improved interpretation of remotely sensed data is needed through simultaneous ground truthing whilst the use of acoustic Doppler current profilers and detailed analysis of the isotopic composition of organic matter are valuable techniques which can be used to determine the dynamics of carbon cycling in coastal seas.

Sensitivity studies and subsequent extrapolation from site specific studies to regional and global scales are a vital component of LOICZ modelling of carbon in the coastal ocean, which are required to provide an improved understanding of the global carbon cycle and in particular the carbon cycling in coastal seas.

Task 3.1.1 Synoptic distribution of key carbon variables (data collection)

Rationale

Present data concerning carbon in the coastal ocean is both dispersed and inadequate in coverage, precluding the adequate assessment of the role of the coastal ocean in the disturbed and undisturbed carbon cycle.

Specific objectives

To assemble appropriate databases in georeferenced format, covering the following datasets:

- *Sediments:* Data on geographical extent and inorganic and organic carbon concentrations of shelf and inshore water sediments, on recent sedimentation rates and changes of sedimentation rates of Holocene depocenters of coastal seas
- *Particulate suspended matter:* Data on the concentration of total suspended matter, particulate organic carbon and inorganic carbon and chlorophyll in the water column covering both large areas and seasonality
- *Dissolved carbon:* Data on the distribution and seasonality of dissolved organic carbon (DOC), the alkalinity, total inorganic dissolved carbon (TCO_2), pH and/or CO_2-pressure (pCO_2)
- *Dissolved nutrients:* Phosphate, nitrate, ammonia and silicate
- *Rates:* Data on remineralisation rates of organic carbon in surface sediments, respiration and photosynthesis in the water column, on air-sea CO_2 exchange and trace gas emissions and on the amount and the composition of the vertical particle flux

Implementation

New data collection can be conducted by many scientists in many areas simultaneously. Technically, the four elements of the data collection task listed under the objectives above, are of increasing complexity. Sampling and processing of sediments is rather simple and can be done with inexpensive equipment, such as a small boat with a small winch, a portable echograph, and a small grab or sediment corer and access to a C, CN or CNS element analyser. Co-operation between labs that have the analytical capacity and groups that sample sediments could advance rapidly the achievement of the objectives of this Task. Operations could be fostered by bilateral research agreements between groups in developing and developed countries, and small cruises could be conducted profiling the coastal zone from the beach to the 200 m line (if relatively near-shore) and sampling the sediments at an agreed frequency. Such profiles could be run in parallel up and down the coast and could be repeated in different seasons (standard transects). To initiate such activities the LOICZ CPO will convene a small workshop in 1995 to define the recommended methodologies and standards. The sequence of actions is shown in Figure 10.

The second group of parameters will necessitate sampling of the water column with an oceanographic water bottle (such as a 5 l Niskin sampler). The particulate matter from 1-5 l of seawater, collected by filtration, washed and dried on glass fibre filters, can then be weighed to determine total suspended matter and processed for POC and PN (particulate

nitrogen) with the same elemental analyser as for the sediments. Additionally, particulate silica, particulate phosphorous and chlorophyll content (on frozen filters) can be measured with a photometer yielding information on the nutrient status and on the mass of diatoms constituting the plankton. In more advanced investigations, a shipboard CTD or a less expensive solid state memory self-contained CTD can be employed to record the water column structure and give information as to the position of freshwater plumes on the shelf.

Samples for the determination of dissolved parameters can be obtained if the filtrate of the POC-samples is preserved for DOC analysis and shipped to a partner organisation equipped with a DOC analyser. Measurement of the pH is comparatively simple and provides, through a Green-function, a rough estimate of the pCO_2. Adequate and accurate measurements of TCO_2, alkalinity and pCO_2 on samples from the standard sections are more difficult to obtain, and equipment for such investigations will include computerised potentiometric titration, a coulometer and an infrared spectrometer or a precision conductometer (for different direct pCO_2 measurements). These techniques have been developed to perfection in the last three decades and standards have been set by SCOR WG 75. Extensive training is needed before these methods yield the required reliability and accuracy of the data. They can, however, be run on a small boat (if stable electricity from a good generator is available) just as well as on a large research vessel. Dissolved nutrients have to be measured on the same samples, in order to calculate precise alkalinities. Measurements of dissolved phosphate, nitrate, nitrite, ammonia and silica determined by photometric methods are run routinely on biogeochemical cruises and JGOFS has developed standard methods for determining these parameters.

Measuring rates requires even greater laboratory experience and staff resources and standard techniques such as those developed by SCOR/JGOFS should be employed. A relatively simple measurement is to determine the rate of dark respiration by titrating the oxygen concentrations of a sample before and after the beginning of a specified period in the dark. Measuring photosynthesis directly involves the application of radio-isotope labelling. Release of carbon and nutrients by remineralisation from sediments involves *in situ* measurements and should only be undertaken in well equipped laboratories and only after having established that the site is representative of a wider area. Measurements of rates of settling involve the deployment of sediment trap moorings, although free floating neutral buoyancy traps are now under development.

Outputs

- Distribution maps of various forms of carbon in the coastal environment, as input information for the calculation of simple mass balances (for example for air-sea exchange of CO_2)
- Identification on a global scale of geographic sinks and sources for CO_2 in the coastal ocean
- Identification on a global scale of depocenters of organic carbon in coastal sediments
- In combination with some estimate of sediment deposition rate (isotope measurements, industrial markers, storm surge deposits etc.) an estimate of how much organic carbon is deposited in relation to input of nearby rivers and/or average autotrophic fixation

Task 3.1.2 Carbon dynamics of coastal systems investigated by case studies

Rationale

Measuring concentrations is only a first step in unravelling the carbon cycle. Therefore studies are needed which describe the dynamics of the system. This necessitates a thorough understanding of the hydrodynamics of the region under study as well as of the seasonality and long-term trends in climate and input forcing functions.

Specific objectives

- Initiate in-depth studies of the carbon cycle in coastal seas in representative areas determined on the basis of the coastal typology developed under Task F.2.1 and using high precision potentiometry, coulometry and infrared pCO_2 methods to acquire precise enough data fields to detect seasonal differences and possibly net fluxes
- Improve the interpretation of remote sensing data by simultaneous ground truth measurements in a variety of river plumes differing in sediment, gelbstoff and chlorophyll contents
- Develop the capacity to model water exchange, biogeochemistry and sedimentation in coastal seas and validate it with measured concentration fields
- Resolve the dynamics of carbon export, carbon remineralisation, carbon sequestering, carbon degassing and carbon burial in estuaries of large pCO_2, DOC, POC, and/or nutrient gradients
- Unravel the fate of terrestrial organic carbon in the marine system by analysing the chemical and isotopic composition of the organic matter as it moves from the river source through the estuary and into the marine realm to its final site of deposition
- Conduct studies with respect to the rate of deposition of organic carbon in near-shore waters, its rate of burial, its residence time and its remineralisation rate

Implementation

These case studies, aimed at understanding the processes of the carbon cycle, need the co-operation of several disciplines with a sizeable number of scientists and technicians, typically employing larger research vessels. They should only be undertaken after careful planning and after the basic hydrodynamic, sedimentological, ecological and biogeochemical characteristics of a certain area have been documented. Modelling and data acquisition should be coupled in order to answer quantitative questions about the internal workings of the coastal carbon cycle and in reaching a general understanding why a certain partition of the coastal ocean is a sink or source for atmospheric CO_2. Modelling involves standard hydrodynamic, weather or climate driven circulation models with a resolution large enough to reproduce the time scales of the carbon cycle in shallow marine environments, i.e. hours. Settling models and models of flocculation can then be applied to simulate the sinking of material versus the resuspension of fine particles. Furthermore models of biogeochemical cycles and of photosynthesis and respiration are needed. So far no study has been satisfactorily completed combining all of these models in an attempt to describe the carbon cycle in shallow marine environments reliably.

Such models need to be tested under various geographic and climatic boundary conditions and must show that they yield results which are corroborated independently by high frequency (spatially and temporally) sampling. The advance of current methods to measure water current velocity and direction with a parameter representing suspended matter in the water column in several layers by ADCP could prove to be an important technological advance in this connection. It allows measuring transport fields much faster than previously and could be the testing stone for the output of combined hydrodynamic and sedimentological models.

Studies of the rates of the various processes detailed in the objectives can be undertaken for the entire Holocene sediment column, possibly focusing on the last 3000 years. Further insight could be gained by also including carbon deposition during the last Glacial. Such studies should include anaerobic basins since they contain - due to the lack of bioturbation - sedimentary records of higher time resolution than sediments deposited under oxygenating conditions. These records may allow to establish long-term changes in the amount of terrestrial carbon input as well as autotrophic carbon input. These changes could yield clues as to the regional effects of climate shifts as well as anthropogenic changes of land use. Studies involving sediment records of the past 100 years could unravel the impact of pollutants and could yield an understanding of the average direction and strength of coastal sediment transport since the beginning of industrialisation.

Outputs

- Improved scientific understanding of the cycling of matter in the coastal zones
- New analytical techniques to describe monitoring results by algorithms representing hydrodynamic, sedimentological, biogeochemical and biological processes

Task 3.1.3 Sensitivity studies

Rationale

The coastal zone and shelf seas display high levels of heterogeneity in terms of their functioning in the carbon cycle, at present the importance of this spatial and temporal heterogeneity in determining the role of the coastal oceans in the global carbon cycle is inadequately documented.

Specific objectives

- Compare areas of similar settings and compare several seasonal cycles at the same area in order to assess how well the results of case studies can be transposed from one year to the next and from one area to the other
- Use statistics to discriminate groups of coastal sites with similar carbon cycle behaviour and establish averages of regional reactions in terms of characteristics of the seasonal cycle, turbidity and nutrient loading
- Use statistics to discriminate assemblages of coastal settings according to similarity in the GIS data set, and establish groupings as to regional coastal characteristics

Implementation

This task involves computer analysis of results mainly derived from the framework activity, i.e. it relies on similarity studies. These studies can either be undertaken at the CPO or regionally at START centres. In a first step, for example, the amplitude and the shape of seasonal pCO_2 cycles (duration of seasons) can be compared for several coastal seas.

Outputs

- Monthly maps of the magnitude of the carbon sink/source function of certain oceanic areas
- Maps of the extent of certain ecosystem functions (for example magnitude of diatom versus flagellate blooms) may also be constructed leading to testable hypotheses about the size and seasonality of the carbon cycle in little studied sections of the coastal zone which then in turn can be tested in the field

Task 3.1.4 Evaluation and validation of budget and system models

Rationale

The new models developed under Task 1.4.1 must be evaluated and validated if confidence in the results of global syntheses of model outputs is to be established and scenarios of future coastal systems under conditions of global change are to be developed.

Specific objectives

Short-term

- Strengthen and implement the modelling networks established under Task F.5.1
- Evaluate and compare the results of budget and system models developed for similar coastal units
- Evaluate and compare the results of budget and system models developed for contrasting coastal units
- Explore the development of generic sub-models that can be transferred from one geographic area to another and used with confidence in building system models
- Commence validation of regional system models using field data collected under Focus 3 Activities
- Identify critical information gaps that should be addressed in extensive and intensive observational programmes

Implementation

This task requires strong co-ordination from the CPO but at the same time active participation at the national and regional levels. Efforts will be directed early in the work to encouraging the exchange of ideas, tools and information through electronic networks. A series of regional workshops will be organised at which the results of models are compared, evaluated and discussed and to which experts from outside the region will be invited in order to provide inter-regional co-ordination and stimulate wider networking. These workshops will provide feedback to participating scientists which can be used to

improve individual models. Final workshops should be organised regionally once a sufficient body of models and results have been accumulated at which regional compilations and assessments will be produced. In addition an international series of workshops will be held to develop more generic sub-models, which can be used to develop regional system models. These will first identify those biogeochemical processes that can be confidently handled by generic sub-models and then specify the recommended algorithms.

Outputs

- A strong network of LOICZ numerical modellers
- An improved empirical understanding of the functioning of coastal ecosystems
- Generic sub-models to be used in the construction of biogeochemical system models
- Validated numerical models of coastal systems for evaluating environmental change
- A clearer understanding of optimum way to develop fully predictive models of the coastal zone at regional scales
- Recommendations for new data collection programs including process studies, time series observations at key coastal sites and remote sensing requirements for implementing coastal monitoring and predictive modelling of coastal environments

Activity 3.2 - Estimation of Net Fluxes of N_2O and CH_4 in the Coastal Zone

This activity is accorded lower priority than Activity 3.1 and will be developed later, in close co-operation with IGAC.

Introduction

In addition to the importance of coastal seas as sinks and sources in the natural and anthropogenically disturbed carbon cycle and the relative importance of CO_2 for climate change, other trace gases, that are important in climate change may originate in significant quantities in the coastal zone. For example, N_2O and CH_4 have, molecule for molecule, a much higher impact on the radiation balance than does CO_2. These gases are emitted from reducing sediments, such as those exposed in shallow water, and occur in organic carbon-rich environments. The relatively low mixing ratio of these gases in the atmosphere, 310 and 1700 nmol mol^{-1}, for N_2O and CH_4 respectively, has resulted in less scientific interest in these gases than in CO_2. It is now clear however, that these gases are increasing at significant rates of between 0.2 and 1 % per year respectively, and much work is therefore needed to identify their sources and to determine their biogeochemical importance.

Overall objective

The overall objective is first to establish the relevance of the coastal zone for atmospheric sources and sinks of N_2O and CH_4. Secondly there is a need to identify those ecosystems which contribute most to these fluxes and study the biological and biogeochemical processes occurring in them which determine the magnitude of these fluxes.

The LOICZ approach

Individual studies of N_2O and CH_4 fluxes need to be started in terrestrial coastal wetlands, and in inter-tidal and sub-tidal ecosystems in order to gain a first estimate of the importance of such areas in the cycling of these trace gases.

Activity 3.3 - Estimation of Global Coastal Emissions of Dimethylsulphide

This activity is accorded lower priority than Activity 3.1 and will be developed later, in close co-operation with IGAC.

Introduction

Dimethylsulfide (DMS) is another gas, the climatic relevance of which has only recently been acknowledged. This gas is produced by phytoplankton and is involved in the processes of aerosol formation through its oxidation to sulphate. In view of the higher rates of coastal productivity per unit area compared to the open ocean, it is expected that the coastal ocean has a significant role in the global production of DMS.

Overall objective

The objective is to establish the overall relevance of the coastal zone for the production of airborne DMS. Coastal zones that have higher outputs of DMS need to be identified, and research has to be focused there. The changes observed in ecosystem structure in highly eutrophic coastal environments may also have an effect on DMS source strength.

The LOICZ approach

Individual field studies are required to get a first view on the importance of the coastal zone for DMS production. Budget modelling can then extrapolate to the possible global role of the coastal zones, using the results of the LOICZ coastal typology Framework Task (F.2.1). Attention should be given to areas with rapidly changing ecosystems in order to obtain an understanding how eutrophication influences the DMS balance.

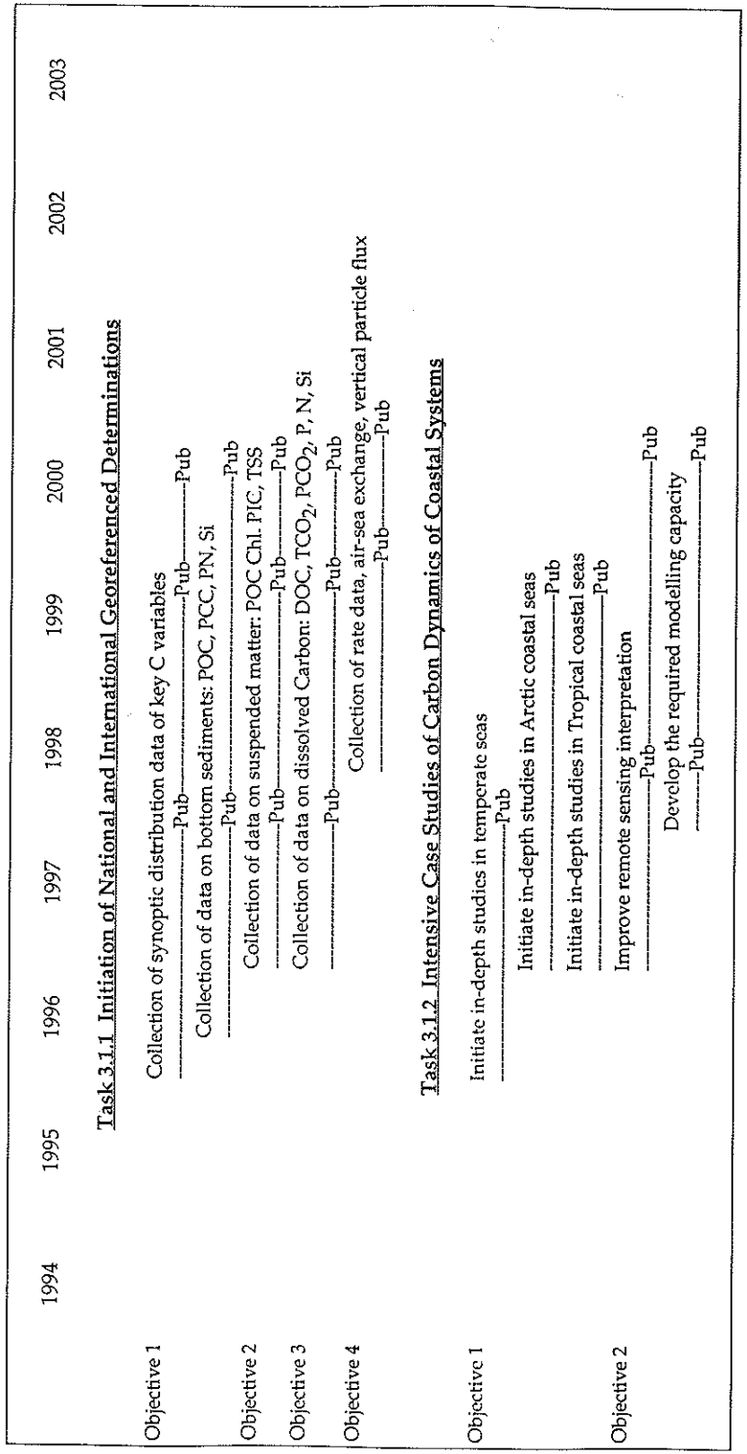

Figure 10. Time line for implementation of LOICZ Focus 3 Activities and Objectives.

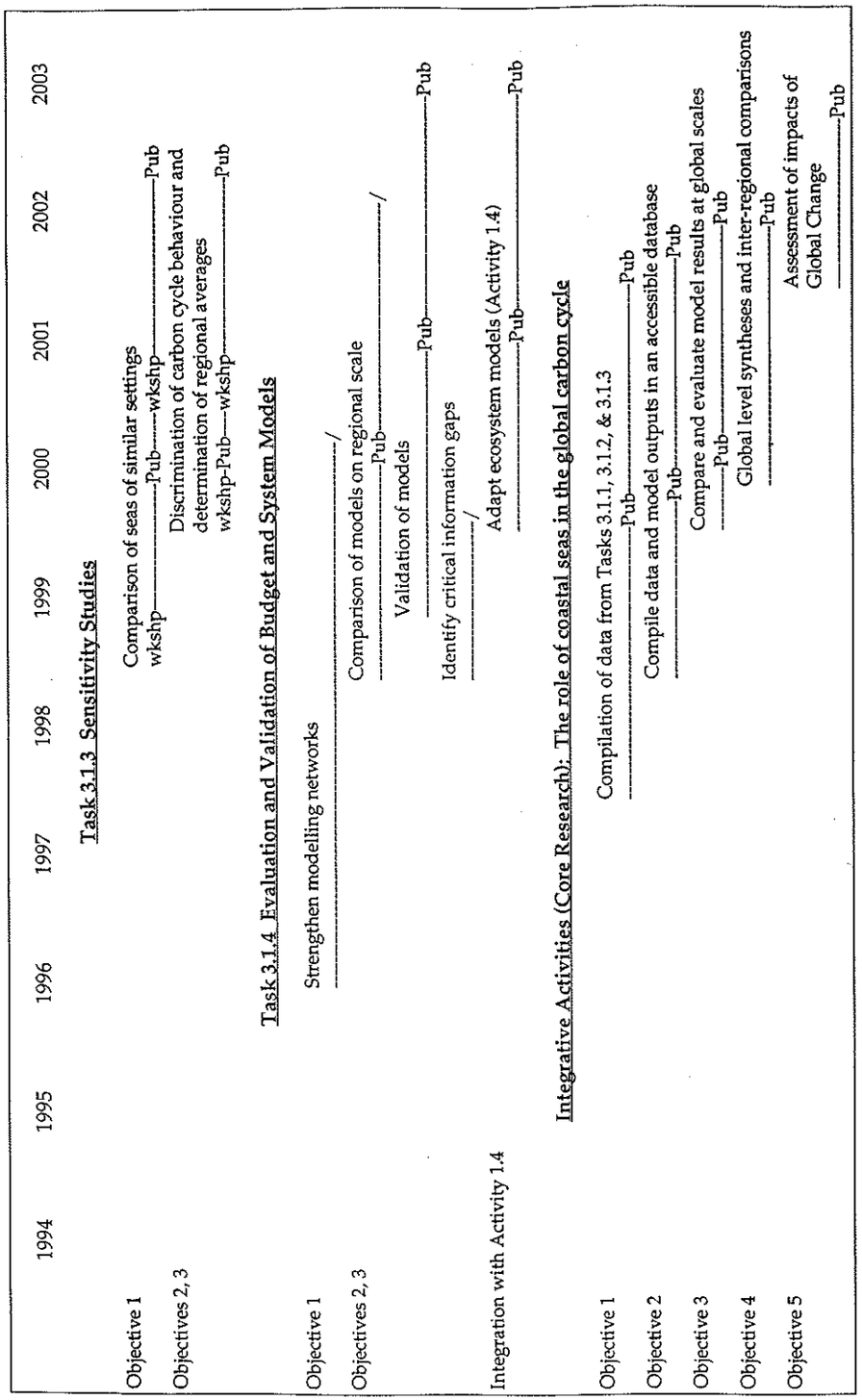

Figure 10. Time line for implementation of LOICZ Focus 3 Activities and Objectives (continued).

Focus 4: Economic and Social Impacts of Global Change in Coastal Systems

Background

The coastal zone occupies only about 8% of the planet's surface, but it accounts for approximately one fifth of total global primary production. Although only 5 to 10% of world food production is based on marine resources, as much as 85-90% of present world fisheries production comes from the waters of the Exclusive Economic Zones and approximately 60% of the population of developing countries derive between 40 and 90% of dietary protein from marine sources. Much of the world's productive agricultural land is found in low-lying coastal areas and in the flood plains of major rivers.

As a consequence, coastal areas have always been favoured locations for human habitation, and present estimates suggest that about 60% of the world's population lives within 60 kilometres of the shoreline. Over two thirds of the world's cities with populations greater that 2 million inhabitants are located in coastal areas, often in the vicinity of highly productive estuaries or coastal wetlands. Coastal human populations in many countries are growing at approximately twice their national growth rates due to migration and urban drift to coastal locations and cities. In addition, the bulk of world tourism centres on marine and coastal environments, resulting in extremely high transient population densities during peak seasons. The increase in coastal populations is of considerable global concern given the high productivity of coastal areas, which is lost when land is occupied by infrastructure and housing or the sea is polluted with sewage and industrial effluents. It is suggested that the anthropogenically induced transfer of nutrients from land to the coastal ocean now exceeds that of natural rates of transfer, a condition reached in the case of sediments much earlier in human history.

The consequence is that many coastal areas are already stressed or degraded, or both, and the driving forces for short- to medium-term change in these environments are anthropogenic. Focus 4 of the LOICZ Science Plan not only recognises that Global Climate Change will add new stress factors to all coastal ecosystems, influencing both their structure and behaviour, but also that direct, human-induced change to coastal systems could have major feedback to the global system as a whole. The suggestion that much of the world's in-shore waters are now being converted to more heterotrophic conditions than in the past has consequences not only for the global carbon cycle, but also for food production, whilst the estimate that 10-20% of the world's coral reefs are currently degraded beyond recovery by human action, has serious implications for global marine biodiversity.

The goal of Focus 4 is to assess how the responses of coastal systems to global change will affect the habitation and use by humans of coastal areas, and to develop further the socio-economic basis for the integrated management of the coastal environment (Figures 11, 12). In addition to recognising the importance of direct human-induced changes in the functioning of coastal systems, LOICZ Focus 4 recognises that forecasting the evolution of coastal systems under different scenarios of global change requires the active participation of social scientists in the development of realistic scenarios (Activity 4.1). Such scenarios

must encompass not merely the changes to the physical, chemical and biological components of the coastal sub-system of the biosphere-geosphere complex, but also realistic scenarios of land-use, human population growth and migration, consumption patterns and the use of coastal space and resources.

Developing realistic forecasts of change in coastal systems involves a further consideration, namely the feedback that exists between the coastal environment and coastal populations, hence the need to assess the socio-economic effects of alterations in the climatic, physico-chemical and ecological properties of the coastal zone (Activity 4.2).

Whilst the goal of LOICZ activities under this Focus is to contribute to the scientific basis for sound management of the coastal zone (Figure 11), the proposed activities are not aimed at producing management guidelines, methodologies or approaches. LOICZ activities in this field (Activity 4.3), which will be undertaken in close collaboration with the Human Dimensions Programme (HDP) and the coastal zone sub-group of the Intergovernmental Panel on Climate Change (IPCC), will be designed to assess the extent to which scientific understanding of coastal zone processes and the nature of changes in these areas could contribute to formulating integrated management strategies that ensure sustainable use of coastal environments and resources (Figure 12).

What follows is not intended as a proscriptive listing of LOICZ Research under this focus but as indicative research activities that should be undertaken. The sequence of actions envisaged in meeting these research goals is shown in Figure 13. Where specific coastal systems such as mangroves, or activities such as shrimp farming are detailed, equally relevant activities could be undertaken in coral reef or saltmarsh environments, or activities such as tourism, other forms of mariculture, forestry and coastal agriculture could be investigated. The precise nature of LOICZ research will therefore vary geographically according to the latitudinal distribution of coastal systems and the nature of human activities.

Activity 4.1 - Evolution of Coastal Systems under Different Scenarios of Global Change

Introduction

Coastal systems form a dynamic sub-system that are driven by physical and social agents of change. In the past few decades much attention has been given to the physical driving forces in global research programmes, while social forces of change have received less attention. The driving forces that have received the greatest attention to date, relate to aspects of climate change, principal amongst them being sea level change and riverine inputs to the coastal system. These phenomena are addressed under other foci within the LOICZ Project. This activity proposes a framework with some examples of how change in coastal systems might be studied from the combined perspective of social and natural sciences.

Many coastal systems are being impacted at present by anthropogenic driving forces of global change. These include estuaries, coral reefs, mangrove forests, seagrass beds, kelp beds, salt marshes and coastal plankton communities. To achieve the goal as outlined above, LOICZ Focus 4 activities will *require* active, collaborative research undertaken by teams of natural and social scientists working in concert. Integrated research

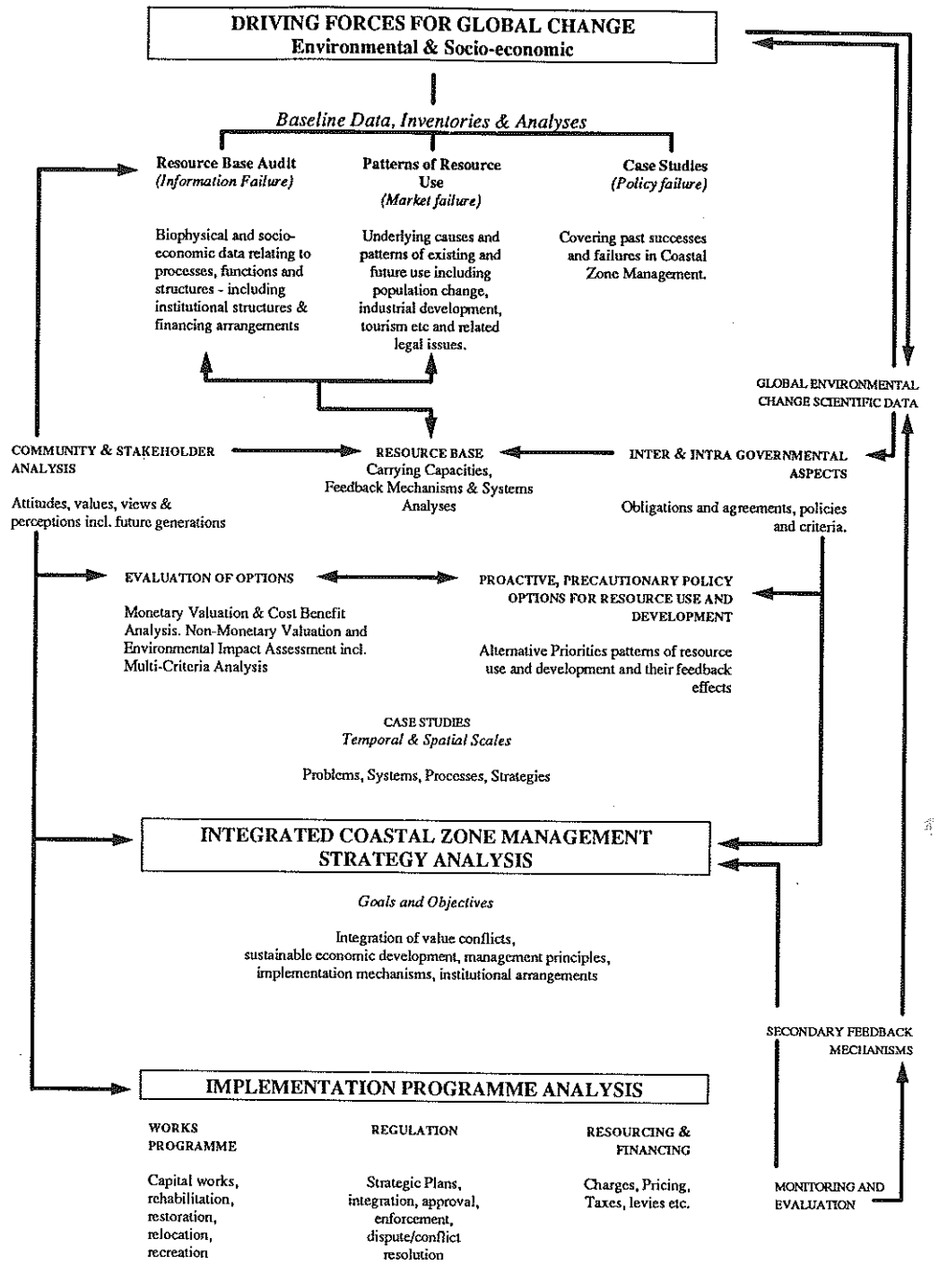

Figure 11. Conceptual framework for a research agenda concerned with the integrated management of coastal zone resource use and sustainable development. LOICZ scientific research will focus on the components of the upper half of this diagram.

encompassing both perspectives is required if appropriate scenarios and forecasts of change and coupled models are to be developed that adequately incorporate the feedback loops operating between societies and coastal environments.

Overall objectives

The overall objective is to develop integrated models for specific areas and systems, encompassing both natural and social driving forces of change. More specifically this activity seeks to:

- Establish collaborative research teams of natural and social scientists, to evaluate specific issues of coupled natural and social sciences data collection and management, and to conduct research on the dynamic interaction between people and resources (including space) in coastal areas
- Develop a sound scientific basis for producing forecasts of anthropogenically driven coastal change under different cultural and environmental conditions
- Develop conceptual and semi-quantitative models of change in coastal systems and their sub-components

The LOICZ approach

It is recognised that a considerable quantity of natural and social science research takes place, and will continue to take place, in coastal areas. Whilst much of this research contributes in part to the goals of LOICZ, it does not necessarily constitute an integral component of the LOICZ research agenda *per se*. Studies of coastal systems are often initiated at the local or national level for specific purposes, and while such studies are relevant to the IGBP, a broader framework is highly desirable if not essential. In order to contribute to this activity, studies focused on a particular ecosystem or coastal community should be based on past or on-going research undertaken from a global and/or regional perspective. Whereas past studies have been exclusively or principally undertaken from the viewpoint of the natural sciences, the socio-economic dimension must be added if the LOICZ objectives are to be achieved. Future studies that attempt to synthesise, initially at a regional level, and subsequently at the global level, rates of anthropogenically driven change in coastal systems should be initiated.

Research on rates of change in particular systems could be undertaken at the country level and the results integrated to provide a regional perspective of the forces driving coastal change. Depending on the system, latitudinal bands or trend, hot spots of change within certain longitudes may become apparent. The results of such research will identify the location of the greatest social and physical perturbations. While all coastal ecosystems from the equator to the poles will manifest some change, it is likely that the greatest rates of change currently occur in the tropical regions where the sheer pressure of human populations on coastal resources is heaviest. Hence some priority attention might be given to research related to rates of change in coral reef ecosystems and mangroves. The relatively under-researched area of the rates of change in the dynamics of coastal plankton communities presents considerable opportunities for research. With increasing turbidity and pollution of coastal waters, the contribution of plankton to coastal water productivity might be significantly altered and the consequences for the global carbon cycle and marine food production may be substantial.

Since much of the driving force for social change is economic, and much of the present coastal change is anthropogenically driven, it is logical that LOICZ Focus 4 should emphasise, at least initially, research programmes that link the natural sciences modelling of change in coastal systems with economic models of change. Such research will involve studies of the coastal resource base, its present capacity to provide goods and services, its governance and the social environment in which coastal space and resources are used. Developing from these activities is a need to evaluate options for resource use and alternative policies.

The development of integrated models will require an extensive suite of linked case studies that cover matrices of the driving forces for coastal change if the models are to be generally and widely applicable. The purpose of such models within the LOICZ project is to evaluate the effects of socially and demographically driven changes in the coastal sub-system of the Earth system, and conversely, to model the impacts of changes in the natural system on social systems.

Task 4.1.1 Linking natural and social science research on coastal issues

Rationale

A major problem in developing projections of change in coastal areas is the absence of coupled datasets covering both the natural and anthropogenic forces driving change. The boundaries of areas delimited for social and natural sciences data collection are rarely congruent, and the collection, management and storage of data are generally organised on a sectoral basis, making exchange and simultaneous analysis difficult.

Specific objectives

Short-term

- Establishment of collaborative research teams of natural and social scientists to evaluate specific issues of coupled natural and social sciences data collection and management
- Analysis of existing data sets for specific case study areas as a mechanism for identifying information failures, including non-congruence of spatial domain, missing and inappropriate data sets
- Development of protocols for future data collection in order to develop forecasts of change in coastal areas
- Development of databases, and conceptual and semi-quantitative, coupled natural and social sciences models for components of the coastal system

Long-term

- Development of integrated forecasts of change

Implementation

It is recognised that this is not a trivial task, but rather one that will require significant intellectual and manpower investment. Three Sub-tasks or major lines of research are considered essential: examination and analysis of existing datasets for selected coastal areas with a view to identifying data requirements for future scenario building; analysis

of historical datasets relating to recent changes in specific coastal areas; and initial scenario building for specific coastal areas where major changes to the coastal system are planned. Although necessarily restricted both spatially and temporally such studies will provide the necessary building blocks on which generalised regional and global scenarios and forecasts of change could be constructed at a later date.

Sub-task 4.1.1.1 Data requirements for scenario building

Methodology

If realistic coupled natural and social science forecasts of change are to be developed, problems of spatial domain, format compatibility and data management tools for coupled natural and social science data and information need to be addressed as a matter of priority. Consideration also needs to be given at the outset to issues of long-term data archiving beyond the lifespan of the LOICZ Project. Demographic data for example are normally collected according to political and administrative units which do not correspond to the boundaries of natural systems. Detailed analyses of the existing databases, both natural and social, for a series of defined coastal systems should be undertaken and the data collated and re-analysed in a collaborative programme to identify:

- Problems in compatibility of presently available data
- The data required for scenario building and forecasting but which have not been collected to date
- Methodological requirements for future data collection
- The phenomena and variables that require quantification in order to describe change in coastal areas from both the natural and social sciences perspectives

Outputs

- Defined natural and social sciences database required for scenario building
- Defined methodologies for data collection for scenario building

Sub-task 4.1.1.2 Post hoc evaluation of change in use of coastal areas

Methodology

Studies of past changes in use of the coastal resource base should be undertaken, in which past and present use of coastal resources are simultaneously evaluated from both the natural and social science perspectives. Coastal areas where major changes in the social component of the system have occurred over the last four decades, (such as areas where rapid growth in population due to migration and urbanisation, or development of large scale tourist complexes have occurred), and for which good baseline data collected prior to the change in use are available, should be identified for detailed analysis in which:

- Data collected prior to the change are compared with data for the current situation and quantitative estimates of the extent and rates of change are determined
- The two datasets are used to develop and test coupled models for sub-components of the system
- The original projections of changes to the natural and social sub-systems of the area (if available) are compared with actual changes that have occurred
- The causes of failure of projections and assessments are identified and evaluated

Outputs

- Databases for developing, validating, and tuning coupled models of change in system sub-components
- Input to the development of coupled social and natural science data collection and handling methodologies to be developed under Sub-task 4.1.1.1 above
- Conceptual and semi-quantitative models of social forces driving change in specified coastal areas

Sub-task 4.1.1.3 Projected changes in use of coastal areas

Methodology

Studies of future coastal change should be undertaken in which the present and future uses of coastal space are evaluated from both the natural and social science perspectives. These Sub-tasks are a necessary requirement for the testing of hypotheses and validation of the semi-quantitative models that will be developed under Sub-tasks 4.1.1.1 and 4.1.1.2 above. Coastal areas in which major developments are planned should be selected for detailed analysis and simultaneous assessment of:

- The present functioning of the natural system
- The potential response of the system to the proposed development
- The levels of sustainable use and economic value under present use regimes
- The levels of sustainable use and economic value under the proposed development
- The economic basis for past and present use
- The environmental and economic consequences of the proposed change in use

Outputs

- Integrated socio-economic and environmental impact assessments in which the outcomes of alternative patterns of use are evaluated from various perspectives
- Hypotheses of future change and datasets that can be used to validate the coupled natural and social science models developed under Sub-tasks 4.1.1.1 and 4.1.1.2

Task 4.1.2 Socio-economic pressures driving coastal change - changes in the use of coastal space

Rationale

The relationship between increasing densities of coastal populations and degradation of the coastal environment and its resources is obvious, yet this relationship has never been adequately quantified and the social forces resulting in transient and permanent migration to coastal areas are not well documented. These inadequacies in the present information and databases preclude the development of quantitative models of change in coastal systems that are applicable over wide spatial domains.

Specific objectives

Short-term

- Establishment of collaborative research teams of natural and social scientists that undertake research on the dynamics of the interaction between people and coastal space
- Development of appropriate methodologies for integrated social and natural sciences research
- Development of conceptual and qualitative models linking changes in socio-cultural settings and economic conditions with particular types of coastal resource use

Long-term

- Development of a sound scientific basis for producing forecasts of change under different social, cultural and environmental conditions
- Development of conceptual and semi-quantitative models that describe, the feedback loops operating between environmental changes and human use of coastal space

Implementation

To develop the information and databases required to provide regional and global perspectives on the human driving forces of change in coastal systems LOICZ will need to encourage proactively the establishment of joint research teams of social and natural scientists. Case studies, if they are to contribute to such regional and global syntheses, will require a comparable methodological approach to data collection, management, analysis and modelling, and consequently LOICZ will develop such methods as a matter of priority. The results from individual studies undertaken within the common research framework can subsequently be used as the basis for development of widely applicable generalised models. The following Sub-tasks are identified as priority areas for investigation under this task, however this listing is not intended to be exhaustive, but merely indicative, and many other issues not detailed below could be investigated that would contribute significantly to the specific objectives of this task.

Sub-task 4.1.2.1 Congestion in coastal areas

Methodology

The increase in resident population density, human activities and use of resources in coastal and maritime areas is a world-wide phenomenon with a long historical background. The rates of change of this phenomenon are gradually increasing and densities have reached critical levels already in some areas, resulting in dramatic alterations to the functioning of coastal systems. Congestion in coastal areas must be considered one of the major driving forces of environmental change in coastal areas but scientific knowledge and understanding of this process is limited. A number of coastal areas will be selected for detailed analysis of the recent historical trends in population change, and socio-economic analyses of the factors causing the migration of people to coastal areas. Within the limitations of the data, quantitative relationships between the densities of people and the rates and extent of change in environmental conditions will be determined.

Outputs

- Semi-quantitative models of the relationships between human population density and environmental degradation of coastal environments in selected areas
- Input data for global scenario building and to activities under 4.1.1
- Identification and quantification of the major forces driving historical migration to coastal areas
- Identification and quantification of the relationships between population density at the coast and historical rates of environmental change

Sub-task 4.1.2.2 Carrying capacity of coastal areas

Methodology

Research in this field will be directed towards identifying, for a range of locations under differing social and cultural conditions, the causes of coastal ecosystem collapse or dysfunction, and to developing semi-quantitative and if possible quantitative assessments of the relationship between population densities and non-linear environmental change.

Outputs

- Identification of non-linearities in the natural system in response to increases in human population density
- Semi-quantitative models of the relationship between abrupt environmental changes and human population density for specific coastal systems

Sub-task 4.1.2.3 Present and future capacity of small islands for tourist development[2]

Methodology

Enclave tourism, in which whole islands are devoted to single tourist resorts, has been developed in many small island states and in coastal countries such as Greece and Croatia with extensive archipelagos of off-shore islands. In some areas and countries an arbitrary capacity has been set prior to development and in others no such restriction applies. Research will be undertaken to establish the relationship between environmental degradation and tourist density and to determine the relationship between economic costs and benefits and environmental costs and benefits. Forecasts of the long-term sustainability of tourist developments on small islands will be developed, taking into account scenarios of future global change.

Outputs

- Quantitative models of the relationships between tourist density, activity and environmental change
- Models of tourist carrying capacity of small islands
- Models of sustainable tourist development for small islands
- Assessment of the long-term environmental and economic costs and benefits of island tourism

Task 4.1.3 Relationships between people and specific coastal ecosystems - changes in the use of coastal resources

Rationale

The spatial and temporal heterogeneity of coastal systems and the enormous diversity of social, cultural and economic conditions under which such systems are used present formidable problems of analysis. Co-ordinating and concentrating research under this task, on particular coastal ecosystems will reduce the inherent complexities of analysis resulting from the biological and physical variability of coastal areas; and may enhance our understanding the human sources of variability in the feedback loop.

Specific objectives

Short-term

- Comprehensive analyses of the social and economic forces driving change in use of specific coastal ecosystems
- Development of models of change in specific coastal ecosystems
- Local, and national assessments of rates of anthropogenically driven change in specific coastal ecosystems

[2] This example is included since it provides a clear case where a single driving force, tourism, results in major regional change in a single ecosystem type, coral reefs, which are the most diverse extant marine ecosystems. Potentially, therefore, coral reef tourism represents a threat to global marine biodiversity. Similar sub-tasks could be designed around tourism in the Mediterranean coastal region, for example where the vast numbers of tourists contribute significantly to the flux of nutrients and hence to increasing eutrophication of coastal waters.

Long-term

- Regional and global assessments of rates of change in specific coastal ecosystems
- Identification of regional trends in the forces driving coastal change

Implementation

A two pronged approach to addressing this issue should be adopted, the first line of research should involve studies of ecosystem use covering a wide matrix of physical, social, cultural and economic conditions, and the second more focused research on specific activities which are demonstrably major driving forces of change at national and regional scales.

Studies of human habitation and traditional uses of specific coastal ecosystems should be undertaken in order to evaluate actual and potential use of the resources from both the natural and social sciences perspective. Such studies should be linked to the Sub-tasks detailed under Task 4.1.1 specifically Sub-task 4.1.1.2. Sites should be selected that provide a range of conditions and intensity of uses over a diversity of biogeomorphological settings. Detailed analysis should be undertaken on the environmental and economic costs and benefits of alternative uses of specific coastal ecosystems such as mangroves, coral reefs, and saltmarshes, and their resources. Realistic forecasts of future conditions should be developed incorporating projections of future social, economic and environmental conditions under differing scenarios of climate change. Human feedback to rates of change in coastal environments should be quantified and incorporated into this scenario building. Sub-tasks that focus on particular human activities can be integrated into particular ecosystem research where appropriate.

Research on rates of change in particular systems could be undertaken at the country level and the results integrated to provide a regional perspective of the forces driving coastal change. Depending on the system concerned there may be latitudinal bands or trends, and hot spots of change within certain longitudes. The results of such research could identify the location of the greatest social and physical driving forces of coastal change.

Sub-task 4.1.3.1 Relationships between people and mangroves[3]

Methodology

In 1987 some 13.9 million hectares of mangroves were estimated to remain in the 22 countries containing the world's major mangrove stands. Of this total only 10% occur in developed countries, the remainder being found in tropical developing countries where development pressures have resulted in an accelerating rate of habitat loss. In general, change in use of mangrove systems has been undertaken with inadequate consideration of the goods and services, - such as shore-line protection provided by the natural ecosystem. Research therefore should be focused on: the social and economic driving forces for change; quantifying the loss

[3] This example is included since mangroves constitute a dominant ecosystem of tropical coastlines that is currently subjected to considerable human-induced change including: clear-cutting for timber; changes of use to mariculture, rice production; and use for human habitation. These changes in areas such as Southeast Asia and Central America are affecting - to an unknown degree - the flux of nutrients and organic carbon to coastal and near-shore waters. Similar sub-tasks should be developed encompassing systems such as coral reefs, seagrasses, temperate saltmarshes, coastal lagoons and deltas.

of natural environmental goods and services; and the relationships between social and environmental change. The development of integrated models will require an extensive suite of linked case studies covering matrices of the driving forces for change in mangrove systems based on comparable methodologies. Without such a matrix of studies, generally and widely applicable models cannot be developed.

Outputs

- More realistic economic valuations of space and resources within mangrove ecosystems
- Integrated assessments of the environmental and socio-economic costs and benefits of alternative uses of such systems, as input to Tasks under activity 4.3
- Improved understanding of the environmental changes consequent upon human modification of mangrove ecosystems
- Scientific information and data leading to more environmentally sustainable and economically cost effective use of mangrove ecosystems
- Where appropriate, estimates of changes in flux rates through coastal ecosystems impacted by varying intensities of human use
- Integrated socio-economic and environmental models, scenarios and forecasts of change in mangrove systems

Sub-task 4.1.3.2 Shrimp culture in mangrove ecosystems[4]

Methodology

One of the main forcing functions driving change in Southeast Asian mangrove systems is their clearance for intensive and extensive pond mariculture. Present practices in shrimp mariculture in Southeast Asia are unlikely to prove sustainable in the long term due to changes in the chemistry of acid sulphate soils following mangrove clearance. The rates of pond construction are high in many countries resulting in a rapid loss of mangrove habitat. Sites should be selected to encompass a range of intensive and extensive culture conditions, and this research should be designed to contribute to Sub-task 4.1.3.1 Detailed analysis should be undertaken on the environmental and economic costs and benefits of the use of mangrove environments and resources for shrimp mariculture, which include total valuations of the natural mangrove goods and services.

Outputs

- More realistic economic valuations of mangrove space and resources and the environmental costs of intensive and extensive shrimp farming in mangrove areas as input to Sub-task 4.1.3.1
- Improved understanding of the changes to soils consequent on shrimp pond construction and operation

[4] This example is included since it provides a clear case where a single major driving force, shrimp mariculture, is resulting in national and regional level change in a single ecosystem type, with potentially major impacts on carbon fixation and flux in the coastal zone. Similar sub-tasks could be designed around dam construction and delta erosion; salmon farming in fjord environments; and rice production in deltas.

- Scientific information and data leading to more environmentally sustainable and economically cost effective shrimp mariculture based on both extensive and intensive methods
- Estimates of changes in flux rates through mangrove systems impacted by varying intensities of mariculture activities

Actvity 4.2 - Effects of Changes to Coastal Systems on Social and Economic Activities

Introduction

Research under this activity should be directed towards the feedback between global change in coastal environments and people. As such, it complements activity 4.1 which examines human activities as driving forces of change in coastal environments. Given the present uncertainties surrounding predictions of future global change and the even greater difficulties of predicting the responses of coastal systems to external physical forcing, predictive modelling of the feedback between coastal environments and their dependent human populations may not be achieved within the life-span of the LOICZ Project. Nevertheless, significant progress towards this longer term goal can be achieved through an improved understanding of the valuation of coastal space and resources under different social, cultural and environmental settings and through quantification of the degree of dependence and vulnerability of coastal populations. Research on a range of situations in which human use of coastal space and resources is changing as a consequence of environmental changes should provide the conceptual and modelling tools required to develop forecasts in which the feedback between natural and social systems are taken into account.

The proposed Tasks and Sub-tasks will contribute towards improving the scientific basis for coastal zone management, the overall goal of LOICZ Focus 4, and more specifically to Tasks undertaken under Activity 4.3. In reality coastal zone management is the management of human activities in coastal areas rather than the management of natural coastal systems *per se*, and environmental boundary conditions for management systems are changing as a consequence of global changes. It is important therefore that the relative costs and benefits of action and non-action in modifying people's use of coastal space and resources are adequately quantified if forecasts of future conditions are to reflect realistically, the societal investments needed to address the problems consequent upon global climatic change.

Overall objectives

The overall objective of this activity is to develop the tools for producing regional and global forecasts of the effects of coastal change on social and economic activities in the coastal zone and the feedback between social and environmental change. More specifically this activity will develop:

- Coupled natural science and economic sub-models for components of coastal systems
- Test the wider applicability of such sub-models

- Aggregate appropriate sub-models to develop the capability for predicting the impacts of change in coastal systems on coastal communities, under differing scenarios of change in environmental forcing functions

The LOICZ approach

Research projects will be undertaken at the interface between natural science, data and models and their socio-economic science equivalents. These will include natural sciences and economic research covering audits of the coastal resource base and its current use. Particular attention will be paid to the spatial and temporal domains in order to ensure, where possible, congruence between natural system and social system boundaries. Research is required to elucidate the contexts in which price and resource allocation decisions fail to reflect the real value of coastal zone resources, or, where markets are distorted by taxes or subsidies resulting in exacerbation of degradation trends. In this field of activity there is a requirement for economic valuation studies of resource use, damage cost and abatement cost, and change related adaptation costs in coastal zones. Hence future studies must take into account trends in population and other socio-economic pressures in the coastal zone.

Given the high density of coastal populations, the degree of dependence of many coastal communities on marine resources and low-lying agricultural land, and the considerable capital investment in the coastal zones of many countries there is an urgent need to develop models that describe quantitatively; the dependence; vulnerability; and risks to coastal populations resulting from potential changes to the physical environment and the coastal resource base.

Task 4.2.1 Economic valuation studies

Rationale

Present methods of valuing environmental goods and services in the coastal zone are inadequate since they often fail to take account of the dynamic nature of coastal systems; undervalue or ignore some natural goods and services; externalise some environmental costs; and generally do not consider long-term environmental trends. These failures often result in planning decisions that are unsustainable in the long-term, leading to undue dependence on single sector development, thus increasing the vulnerability of the community to long-term changes in environmental parameters, and hindering assessments of the impacts of global change on coastal populations.

Specific objectives

Short-term

- Development of more realistic valuation systems applicable in different natural and socio-cultural environments
- Incorporation of environmental trends and variability into economic valuation systems
- Development of conceptual and semi-quantitative economic models of societal response to environmental change

Long-term

- Development of a sound scientific basis for the economic valuation of coastal environments and resources, in support of sustainable coastal area development
- Development of realistic forecasts of future coastal change

Implementation

Developing appropriate forecasts of the response of coastal communities to long-term environmental changes requires a quantitative understanding of the relationship between coastal communities and their resource base. Whilst a number of the Sub-tasks envisaged under Activity 4.1 will contribute to this quantitative understanding specific areas of research need to be developed in the fields of: damage cost, abatement cost, and cost benefit analyses. These will provide a conceptual framework for assessing risks and vulnerability to change in coastal environments, driven by both local and global changes. Nutrient enrichment is considered in the following examples but such studies could be expanded to include soil erosion and freshwater resource availability and quality in coastal areas.

Sub-task 4.2.1.1 Damage cost valuation studies[5]

Methodology

Nutrient enrichment of coastal waters is a world-wide problem with impacts that include *inter alia*: local eutrophication; toxic algal blooms resulting in the closure of shellfish beds; adverse impacts on coastal tourism as a consequence of algal "scum"; and potential changes in the role of coastal oceans in the global carbon cycle. Studies should be undertaken to provide comprehensive valuation of the direct and indirect impacts of eutrophication of coastal waters. Such studies will require:

- Natural science assessment and quantification of environmental impacts in relation to varying scales of nutrient discharge
- Natural science assessment of the nature of system response to nutrient enrichment (linear and non-linear responses)
- Natural science assessment of the degree of uncertainty pertaining to the above
- Economic assessment of the costs of direct and indirect impacts resulting from nutrient enrichment

Outputs

- Scientifically and economically sound methodology for damage cost valuation
- Models of the relationship between natural system response to different levels of nutrient enrichment
- Input to cost benefit analyses of alternative waste treatment and disposal methods

[5] This example is included because nutrient enrichment is a global problem in terms of: the present geographic extent; the rate of increase of discharge; and the nature and extent of impacts which may be of global consequence in terms of altering the role of coastal systems in the global carbon cycle.

Sub-task 4.2.1.2 Abatement cost valuation studies

Methodology

Since nutrient enrichment of coastal waters is a world-wide problem, often with economic impacts, numerous management responses such as the installation of waste water and effluent treatment facilities have been implemented. Future studies should be undertaken to provide comprehensive valuation of the direct and indirect benefits of various treatment options, which in many instances may be based on existing data. Such studies will require:

- Natural science assessment and quantification of the improvement in environmental quality resulting from various levels of waste water treatment
- Natural science assessment of the nature of system response to reduction in waste water inputs (linear and non-linear responses)
- Natural science assessment of the degree of uncertainty pertaining to the above
- Economic assessment of the costs of improvements in environmental quality under differing levels of investment in waste water treatment

Outputs

- Scientifically and economically sound methodology for pollution abatement cost analyses
- Models of the response of natural systems to reduced nutrient inputs
- Data for use in cost benefit analyses of alternative waste treatment and disposal methods (Task 4.3.1)

Sub-task 4.2.1.3 Long-term environmental and economic costs and benefits of coastal tourism

Methodology

For many insular developing countries, coastal tourism represents the major if not sole source of hard currency earnings. Such tourism is frequently centred on coral reefs or takes the form of enclave developments occupying whole islands. High densities of visitors combined with infrastructural development frequently result in environmental damage and degradation with destruction or deterioration of the resource that forms the basis for the tourist industry. Studies are needed of the environmental and economic costs and benefits of different forms of tourist development. Such studies should be integrated with and build upon those conducted under Sub-task 4.1.2.3 and should include *inter alia:*

- Assessment and quantification of the environmental impacts of present resort development and operation
- Quantitative assessment of the relationships between present environmental change and tourist density
- Realistic economic valuation of the environmental change resulting from present tourist operations

- Identification of alternative strategies for tourism development
- Comparison of the costs and benefits of present and alternative modes of tourism development

Outputs

- Quantitative models of environmental and economic costs and benefits of different densities of tourist visitors
- Comparative cost benefit analyses of alternative modes of tourist development
- Guidelines for sustainable economic development of coastal tourism in different coastal environments
- Input to the global vulnerability assessment and national dependence studies

Sub-task 4.2.1.4 Cost benefit analyses of alternative future use of coastal area and resources

Methodology

Conflicts often arise from elevated levels of use of coastal environments. This is generally a consequence of the increased levels of human populations both permanent and seasonal, such that space itself becomes a limiting factor to the use and enjoyment of coastal areas. Extensive and intensive planning studies should be conducted in the actual and potential use of coastal areas and resources under increasing human population densities subject to varying scenarios of global change. Such studies should build on those envisaged under Activity 4.1 and should encompass:

- Assessment and analysis of the present resource base (including space)
- Analysis and modelling of the future resource base under varying scenarios of climatic change and sea level rise
- Identification and quantification of present resource use and rates of change in that use
- Development of forecasts of the future size, distribution, economic status and degree of marine resource use by the coastal population
- Evaluation of potential alternate uses of coastal space and resources
- Development of alternate forecasts of change in the coastal area concerned under various patterns of resource use and development

Outputs

- Environmental and economic cost benefit analyses of alternate scenarios of coastal resource use and development under present environmental conditions
- Environmental and economic cost benefit analyses of alternative scenarios of coastal resource use and development under future environmental conditions
- Integrated models for the development of forecasts of change in coastal systems

Task 4.2.2. Stakeholder analyses

Rationale

Marine and coastal resources are subject to complex and varied patterns of ownership, regulation and control; yet at present no systematic evaluation of the rates of change under these differing conditions exists. Similarly the degree of dependence of communities and nations on marine resources varies widely, but no evaluation has yet been undertaken of the relationship between dependence on coastal space and resources and rates of change in the coastal environment.

Specific objectives

Short-term

- Determine the quantitative relationship (if any) between differing patterns of ownership of coastal space and resources and the rates of change in coastal environments and resources
- Determine at local and national levels the quantitative relationship between degree of dependence on coastal resources and rates of change in coastal environments

Long-term

- Development of a sound scientific basis for future management strategies
- Input data for global coastal vulnerability assessment

Implementation

Evaluating the role of different degrees of dependence on marine resources at different scales will provide the empirical data needed for model construction and validation concerning the quantitative relationship between communities and nations, and rates of change in their coastal environments. A matrix of case studies over a range of social and economic conditions should be examined to encompass representative communities and countries encompassing the range from subsistence (internal production-consumption) to commercial (internal production, external consumption) use of marine and coastal resources. Similarly evaluating the rates of coastal change under different ownership patterns and institutional arrangements would provide the empirical data needed for determining the quantitative relationships between such conditions and rates of change in coastal environments. Whilst the two sets of case studies need not be linked, the data required for both types of analysis could be collected simultaneously, hence providing added value in terms of cross comparisons between the two Sub-tasks. The outputs envisaged from this task will provide important information useful in addressing the objectives of activity 4.3.

Sub-task 4.2.2.1 Marine resource dependence studies - local

Methodology

Studies should be undertaken on the relationships between people and coastal resources under differing conditions of economic development. These should include situations ranging from low density and hence low impact, to high density areas where destructive practices have been adopted (blast fishing on coral reefs for

example) and should encompass: communities in which production is consumed within the community; situations where production is both consumed internally and exported to neighbouring communities; situations where production is wholly for export and is consumed outside the community. Multi-variate statistical analysis of the relationships between community density, numbers of producers, rates of internal consumption, export and consequent income, and other internal variables can then be used to derive quantitative relationships between patterns of dependence and rates of change in coastal environments.

Outputs

- Local case study reports providing empirical data for model building and validation
- Quantitative relationships between community dependence on coastal resources and rates of change in coastal environments

Sub-task 4.2.2.2 Marine resource dependence studies - national

Methodology

Studies should be undertaken on the extent of economic dependence of different categories of nations such as small island states, coastal states and continental states on marine resources and the relationship, if any, between dependence and rates of change in coastal systems. A matrix of national studies should be undertaken to provide a comparable analysis to that of local communities but at a differing spatial scale.

Outputs

- National case study reports providing empirical data for model building and validation
- Quantitative relationships between national dependence on coastal resources and rates of change in coastal environments
- Input data for regional assessments of rates of coastal change
- Input data for regional and global coastal vulnerability analyses (Task 4.2.3)

Sub-task 4.2.2.3 Analyses of the impacts of different institutional arrangements on rates of change in coastal environments.

Methodology

Development and exploitation of coastal space and resources is subject to widely differing management systems, ranging from centrally to locally, planned and managed. In addition the number of agencies and institutions involved in the various economic sectors that depend on coastal space and resources varies widely from country to country and culture to culture. Integrated social and natural science research should be directed towards elucidating the relationship between the numbers and co-ordination of institutions involved in controlling coastal

developments and the extent of coastal zone management "success" and "failure". Such studies can provide a framework for modelling rates of change in coastal environments in relation to the institutional framework for management.

Outputs

- National case study reports providing empirical data for model building and validation
- Quantitative relationships between national dependence on coastal resources and rates of change in coastal environments
- Input data for improved coastal zone management

Sub-task 4.2.2.4 Analysis of the impacts of different patterns of ownership and usufruct rights on coastal resource use

Methodology

Patterns of ownership and use of coastal space and resources vary widely from culture to culture ranging from individual or community "ownership" to "free access". The concept of "limited entry" now widely agreed as the *sine qua non* for sustainable use of fisheries resources, has long been the practice in many coastal communities, particular in insular developing countries. No comparative analysis of rates of change in coastal environments under differing patterns of ownership and use has yet been undertaken and a matrix of comparable case studies should be undertaken to determine any quantitative relationship between such patterns and rates of change in coastal environments. Integrated social and natural sciences research is required to document different patterns of ownership and use of resources in relation to trends in coastal environmental change. Such studies should be undertaken in close collaboration with studies of local coastal resource dependence, and as noted above, added value would be obtained by such linkages.

Outputs

- Local case study reports providing empirical data for model building and validation
- Quantitative relationships between patterns of ownership and use of coastal resources and rates of change in coastal environments
- Input data for improved coastal zone management

Task 4.2.3 Vulnerability of coastal systems and human populations to global change

Rationale

The Intergovernmental Panel on Climate Change has developed a framework methodology for assessing vulnerability to sea level rise which was widely applied during the preparation of the 1995 IPCC Assessment report. The initial results of applying this framework methodology were reported to the World Coast Conference '93 in November 1993. The validity of the conclusion drawn from

these assessments has been questioned due to the static nature of the scenarios used and the problems of realistic comparative valuation of resources and artefacts between different cultural and economic situations.

Specific objectives

Short-term

- Development of improved valuation methods for coastal space and resources under scenarios of global change
- Development of dynamic forecasts of change in coastal environments in which environmental and socio-economic feedbacks are incorporated

Long-term

- Improved methodologies for vulnerability assessment at regional and global scales

Implementation

Vulnerability to global change can be viewed from the physical, biological or human perspective, thus a coastline is physically vulnerable to wave attack regardless of the presence or absence of human populations. Similarly biotic systems are vulnerable to changes in various physical forcing functions. From an anthropocentric viewpoint vulnerability is seen merely in terms of the vulnerability of human communities and their capital assets. Research is required that improves the methods of valuation of natural coastal resources (Sub-task 4.2.1.4 above) other than human and capital resources and that provides a more dynamic element to the process of scenario building. Selected activities will be initiated in which the dynamic element of change is introduced, and transient conditions between the present and future conditions are built into future projections. It is suggested that systems such as deltas, which are highly dynamic in the short and medium term, might provide micro-scale analogues for analysing, physical, biological and human vulnerability and the response of the human populations to environmental change.

It is recognised that this Task will need to build not only on other Tasks undertaken under activity 4.1, but also will require input from activities and Tasks initiated under other LOICZ Foci, particularly Focus 2.

Outputs

- Improved methodologies for valuation of coastal space and resources
- Forecasts of future change in coastal systems, incorporating consideration of the dynamic elements of system response
- Improved methodology for assessment of coastal vulnerability to global change

Activity 4.3 - Development of Improved Strategies for the Management of Coastal Resources

Introduction

Most current management practices are reactive rather than proactive and lack a sound scientific basis in terms of the required information and an understanding of the processes that characterise coastal systems. Whilst LOICZ Focus 4 research does not include implementing management regimes it is concerned with the scientific basis for management. This includes research on issues such as the recovery of degraded ecosystems following management intervention and informational failures of science in the process of management. Such an understanding is required not only to support improvements in integrated coastal zone management but to elucidate the nature, rates and causes of present coastal change. Furthermore, the results of such research are critical to the building of dynamic models that are successful in generating realistic future forecasts since coastal change is not uni-directional in space and over time.

Overall objectives

The overall objective of this activity is to improve the scientific basis for integrated management of human use of coastal space through the development of a common framework for analyses that can encompass both the natural science and socio-economic viewpoints. Specifically this activity will:

- Evaluate the effectiveness, costs and benefits of alternative forms of intervention in addressing coastal resource and environmental degradation
- Develop quantitative models for cost-benefit, policy feasibility and social acceptability analyses of alternative uses and management strategies for coastal space and resources

The LOICZ approach

A review of principles and concepts, and an evaluation of the value of paradigms such as: carrying capacity; feed-back mechanisms and system dynamics; precautionary principles and sustainable development to both natural and social sciences, will be undertaken as background to the intensive studies envisaged under this activity. Research on alternative valuation methods for coastal zone resource and development options, in different regional cultural settings undertaken under Activities 4.1 and 4.2, are required to evaluate the potential for development of objective techniques that are applicable in different socio-cultural environments. A critical examination of IPCC's common methodology and the "concepts and tools" as presented at the World Coast Conference '93 will be undertaken, to improve their wider applicability in developed and developing economies (Task 4.3.1). Successful achievement of the overall objective would permit global scale modelling of the economic forces driving coastal change although it is recognised that at present appropriate modelling tools do not exist and these will need to be developed during the course of LOICZ activities under this focus. Comprehensive global scale modelling may not be achievable in the time frame of the LOICZ Project.

Task 4.3.1 Management and recovery of degraded coastal environments

Rationale

There is a general belief that following cessation or reduction of the causes of environmental change, such as the construction of waste treatment and disposal facilities, affected ecosystems will recover quickly. There is little scientific knowledge or evidence to support this contention and present understanding of the recovery process of natural coastal systems is limited.

Specific objectives

Short-term

- Evaluation of the effectiveness, costs and benefits of alternative forms of intervention in addressing coastal resource and environmental degradation
- Development of quantitative models for assessing the costs and benefits of management actions in environmental restoration and recovery

Long-term

- Development of coupled natural and social science models of the effects of management actions on rates of change in specific coastal systems
- Development of a sound scientific basis for management action designed to restore degraded coastal environments

Implementation

Despite the absence of sound scientific information to justify management intervention a number of actions are being undertaken to reduce or eliminate the driving forces of change in coastal ecosystems. Numerous sites exist world-wide which display a range of intervention and non-intervention strategies addressing various sources of anthropogenic change in coastal environments, thus providing the opportunity for comparative studies of the recovery process. It is suggested that priority should be given to sites with and without sewage treatment and discharge into semi-enclosed bays[6] which might provide a suitable range of comparative and control sites for an in-depth analysis of the recovery process of similar in-shore ecosystems. Such studies should include full realistic economic and environmental cost-benefit analyses, and build on research undertaken under Sub-tasks 4.2.1.1 and 4.2.1.2.

Outputs

- Models of the response of in-shore ecosystems to mitigation strategies for in-shore urban waste disposal
- Cost benefit analyses of alternative urban waste disposal strategies

[6] The choice of sewage and semi-enclosed bays is based on the recognition that a sufficient number of similar sites exist world-wide to provide the necessary matrix of case studies that would provide internal controls for multi-variate statistical analysis. It is possible that other driving forces of change and other geomorphological settings could be investigated if sufficient examples were available world-wide to provide the necessary replicates and controls.

Task 4.3.2 Analysis of distance effects in sustainable use of coastal areas

Rationale

Numerous human activities on land have direct and indirect impacts on the rates of change in coastal systems. Management of land-based activities is rarely co-ordinated with that of maritime activities and coastal impacts of land based activities are externalised in cost benefit analyses of land-based developments, if they are considered at all.

Specific objectives

Short-term

- To complete representative cost-benefit analyses of past inland developments in which the spatial domain is expanded to include coastal costs and benefits

Long-term

- To develop the methodologies for total environmental and economic cost benefit analyses in which all environmental costs and benefits are internalised

Implementation

In a number of instances inland activities are sufficiently widespread and undertaken on such a scale as to alter, on a global basis, flux rates of material between land and ocean. Whilst poor land use and practices and poor water management enhance the rate of sediment mobilisation and transport to coastal areas, dam construction and large scale irrigation has the reverse effect, trapping sediment and water inland and altering the balance of nutrients in coastal waters. A number of sites should be selected covering the full range of potential conditions from sediment starvation to large volume increases and full analyses undertaken of the driving forces for changes inland. Such studies should include a complete analysis of the coastal changes consequent on such inland activities and encompass a full and realistic cost benefit analysis which transcends the traditional sectoral boundaries separating the management regimes for inland and coastal activities

Outputs

- Cross-sectoral analysis of the environmental and economic costs and benefits of inland activities in which the coastal costs and benefits are included in the analysis of inland activities, and *vice versa*
- More realistic assessment of the total costs and benefits, both environmental and economic of inland developments

Task 4.3.3 Evaluating past successes and failures in coastal zone management

Rationale

Integrated coastal zone management is seen as the solution to current unacceptable rates of change in coastal environments world-wide. The adoption at the Earth Summit in Rio of Agenda 21 implies an international acceptance of the need for all countries to develop integrated coastal zone management plans by the year 2000. The scientific basis for present management strategies is

inadequate since it does not encompass adequate understanding of the feedback between environmental and socio-economic changes.

Specific objectives

Short-term

- To identify the causes of failure in past coastal zone management strategies through a comparative analysis of past successes and failures
- To identify the scientific contributions to past successes and failures of coastal zone management

Long-term

- To provide a sound scientific basis for the development of future coastal zone management strategies

Implementation

Research will involve joint evaluations by natural and social scientists of specific coastal management regimes[7] to identify the information, market and policy failures which have resulted in varying degrees of successful coastal zone management. The process should also highlight the nature of the scientific information and understanding required for improved management action in coastal areas. In evaluating the scientific basis for past successes and failures of management interventions in the coastal zone, LOICZ evaluations of specific management regimes should identify:

The scientific basis for:

- Setting policies and goals
- Defining plans, activities and projects
- Establishment of monitoring activities

The socio-economic basis for:

- Establishment of institutional arrangements
- Legislation, training and public education

Outputs

- Criteria for identifying "success" and "failure" in coastal zone management
- Evaluation of individual successes and failures in coastal zone management under different social, economic and cultural settings
- Identified requirements in terms of scientific information and data required for implementing integrated coastal zone management
- Identification of the causes of failure of existing management regimes
- Improved methodological framework for initiating integrated coastal zone management
- Improved understanding of the capacity of different societies to adapt to change through management action and of the time lags involved in responding to change

[7] In a number of countries whose coastlines are dominated by one or more coastal systems, specific management strategies have been developed for such systems, outside the framework of a more general strategy of coastal zone management. The comparative impact of such strategies in terms of halting unacceptable rates of change is not known at the present time potentially therefore a Sub-task could be developed to examine coral reef, or mangrove management plans and their national level impact or otherwise on rates of change.

Resource Base Audit
(Information Failure)

Biophysical and socio-economic data relating to processes, functions and structures - including institutional structures & financing arrangements

Task 4.1.1 Linking natural & social science research
Sub-Task 4.1.1.1
Data requirements for scenario building & forecasts
Sub-Task 4.1.1.2
Post-hoc evaluation of change in use of coastal areas
Sub-Task 4.1.1.3
Projected change in use of coastal areas

Resource Use Patterns & Scenarios
(Market failure)

Underlying causes and patterns of existing and future use including population change, industrial development, tourism etc and related legal issues.

Task 4.1.2 Socio-economic pressures driving coastal change - changes in use of coastal space
Sub-Task 4.1.2.1
Congestion in coastal areas
Sub-Task 4.1.2.2
Carrying Capacity of coastal areas
Sub-Task 4.1.2.3
Present and future capacity of small islands for tourist development

Task 4.1.3 Relationships between people and specific coastal ecosystems - changes in use of coastal resources
Sub-Task 4.1.3.1
Relationships between people and mangroves
Sub-Task 4.1.3.2
Shrimp culture in mangrove ecosystems

COMMUNITY & STAKEHOLDER ANALYSIS

Attitudes, values, views & perceptions incl. future generations

RESOURCE BASE

Carrying Capacities, Feedback Mechanisms & Systems Analyses

Task 4.2.1 Economic valuation studies
Sub-Task 4.2.1.1
Damage cost valuation studies
Sub-Task 4.2.1.2
Abatement cost valuation studies
Sub-Task 4.2.1.3
Long-term environmental and economic costs and benefits of coastal tourism
Sub-Task 4.2.1.4
Cost benefit analyses of alternative uses of coastal space and resources

Task 4.2.2 Stakeholder analyses
Sub-Task 4.2.2.1
Marine resource dependence studies - local
Sub-Task 4.2.2.2
Marine resource dependence studies - national
Sub-Task 4.2.2.3
Analyses of the impacts of different institutional arrangements on rates of change in coastal environments
Sub-Task 4.2.2.4
Analyses of the impacts of different patterns of ownership and usufruct rights on coastal resource use

INTER & INTRA GOVERNMENTAL ASPECTS

Obligations and agreements, policies and criteria.

Case Studies
(Policy failure)

Covering past success and failures in Coastal Zone Management.

Task 4.2.3 Vulnerability of coastal systems and human populations to global change

Task 4.3.1 Management and recovery of degraded coastal environments

Task 4.3.2 Analysis of distance effects in sustainable use of coastal areas

Task 4.3.3 Evaluating past successes and failures in coastal zone management.

Figure 12. Relationship between the LOICZ defined research Tasks and Sub-tasks and the conceptual research framework outlined in Figure 10.

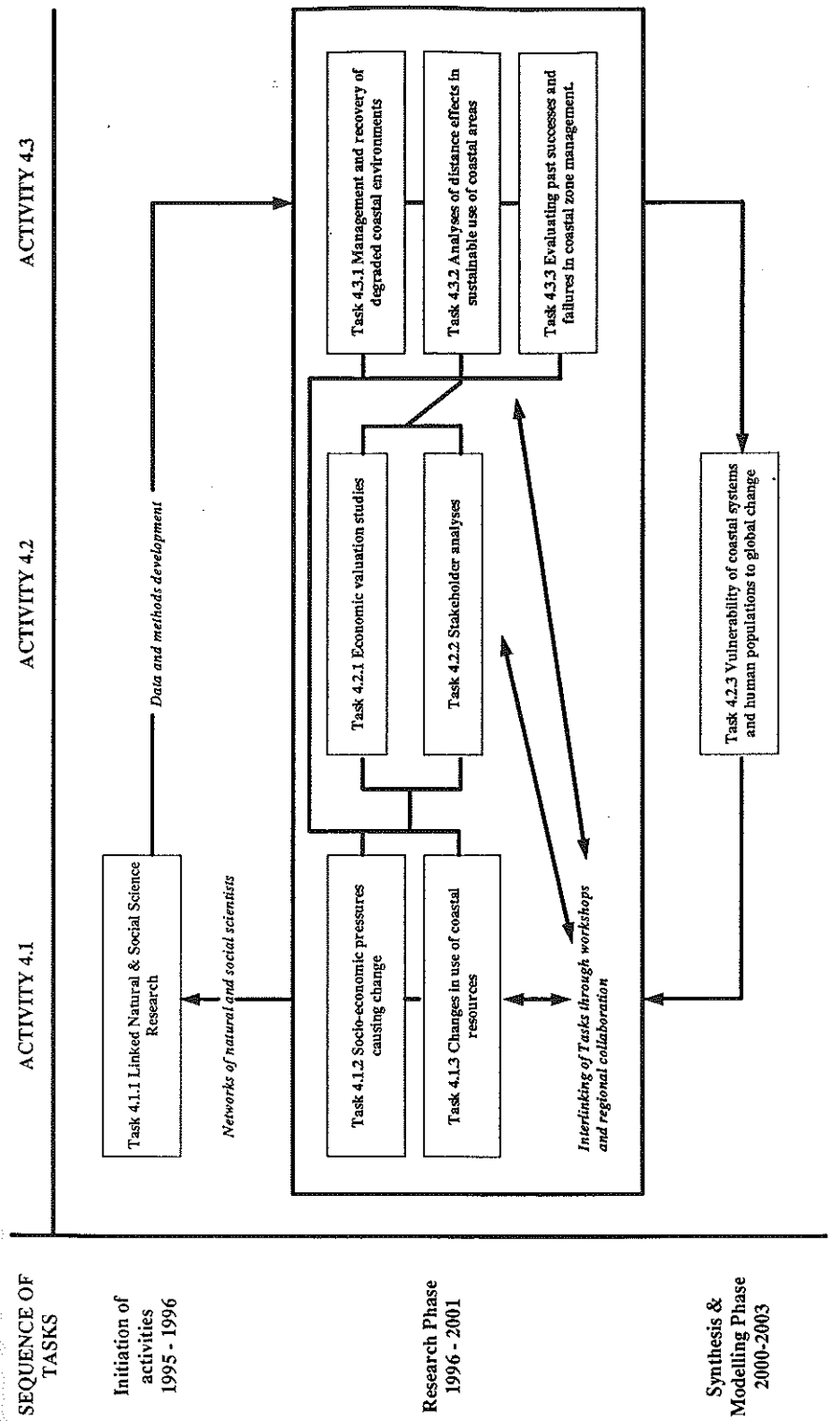

Figure 13. Temporal sequence and relationships between the Research Tasks of Focus 4.

Integrative Activities
(Core Research)

Introduction

The research agenda laid out for each focus in the preceding chapters, represents specific Activities, Tasks and Sub-Tasks which could be accomplished by individual scientists, institutions or national (and in some instances regional) research groups. To compile the outputs from such studies into regional and global models, scenarios and predictions, will require considerable investment from the Core Project Office and Scientific Steering Committee in terms of methods, database and model development, networking and liaison. These framework activities are detailed in an earlier section of this Implementation Plan and will require substantial input from the Core Project Office, which greatly exceeds its present manpower and financial capacities. Even with a comprehensive, additional investment in strategic and framework activities the possibility remains that the regional and global goals of LOICZ will not be met since the compilation and synthesis of results from small, isolated studies (small, in terms of either spatial domain or subject area) will not necessarily provide insight and answers to global scientific issues and uncertainties involving the inter-relations between wider sub-sets of the total coastal system.

It is clear therefore that a number of Integrative Activities will need to be developed which encompass most if not all of the specific research activities and tasks envisaged under a particular focus, or which address, in a cross-cutting manner, multiple activities from two or more foci. In the following pages two such Integrative Activities are outlined covering the carbon cycle in coastal oceans and the socio-economic impacts of global change in coastal systems. It is envisaged that further Activities will be developed in the near future addressing in particular the vulnerability of physical and biological processes in the nearshore zone to global change and the implications of such vulnerability for future human use of coastal areas.

The following Integrative (Core Research) Activities: "The Role of Coastal Seas in the Global Carbon Cycle"; and, "Integrated approaches to assessing the economic and social impacts of global change in coastal systems", have been developed as examples of the approaches which will be adopted by LOICZ to Core Research. Both of these activities encompass scientific issues considered to be of high priority at the present time and both are designed to provide a framework within which nationally funded and supported activities can be integrated to provide a wider regional and global perspective. Where possible, both will build on existing activities and integrate closely with related on-going initiatives implemented by other organisations and bodies. These Activities will also serve as the major interface between LOICZ and IGBP's Task Force Global Analysis, Interpretation and Modelling (GAIM) activity.

In other respects the two projects differ substantially. The project entitled "The Role of Coastal Seas in the Global Carbon Cycle" addresses issues relating to Focus 1 and Focus 3 of the LOICZ Science Plan. In this respect the Activity is cross-cutting and designed to provide a framework for overall integration of several different Tasks and Sub-tasks

related to carbon in the coastal ocean. This Activity can only be implemented on a global basis since the heterogeneity of the world's coastal zones does not permit extrapolation of the results from individual models of limited spatial domain to a global scale. The structure of the regional components of this Integrative Activity will be based in part upon the output of the Framework Activity concerned with developing a global coastal typology. The proposed mode of implementation recognises that substantial infrastructural support and capacity building will be required in regions which encompass primarily developing countries and countries with economies in transition, since such countries are unlikely to accord high priority and therefore allocate scarce research funds to ascertaining the role of their coastal oceans in the global carbon cycle. It is unlikely therefore that site-specific budget models and regional system models will be developed for these regions without substantial external inputs of equipment and finance designed to enhance the indigenous capacity for research related to the carbon cycle of coastal oceans. Without the involvement of such countries, global syntheses and models cannot be produced and the goals of LOICZ cannot be met.

In contrast the project entitled "Integrated approaches to assessing the economic and social impacts of global change in coastal systems" builds on existing regionally co-ordinated activities concerned with human use of and change in the coastal zone. This Integrative Activity addresses all components of Focus 4 simultaneously and through the production of three large scale regional syntheses and models aims to develop a global synthesis and provide a solid scientific basis for future global scenario development.

Neither of these activities can be initiated without significant input of new research funds and a failure to adequately fund LOICZ Integrative Activities (Core Research) will seriously compromise the achievement of the overall goal and objectives of this Core Project of the IGBP.

The Role of Coastal Seas in the Global Carbon Cycle

Background

The coastal areas[8] are among the Earth's most dynamic systems due to the processes at the interface between the land, the oceans, and the atmosphere and the intensive interaction of the natural environment and man's socio-economic activities. Coastal marine areas comprise around 8% of the surface area of the globe, contribute about 15% of global biological production, and account for: around 80% of the global organic burial; 90% of global sedimentary mineralisation; 75-90 % of the global sink of suspended river load and its associated carbon; and, in excess of 50% of present day global carbonate deposition. Coastal areas are also the regions of the global ocean where the wide range of present human activities is causing extensive alteration to the functioning of these systems in global biogeochemical cycling.

Despite the long-standing interest of scientists in the land-sea interface, and the intensity of the past, present and predictable human interventions in the coastal, terrestrial and marine environment, the role of the coastal seas in the natural and disturbed global

[8] In the context of this project "coastal areas" are broadly defined as shallow coastal seas and the adjacent coastal terrestrial environment, approximately covering the seas to a depth of 200 m and the coastal plain to 200 m above sea level.

carbon cycle is still uncertain. The proposed project intends to deal with a neglected section of the global carbon budget which is currently subject to rapid rates of direct anthropogenic change resulting from fertilisation effects and enhanced flux rates of carbon, nutrients and sediments from land to sea. This Integrative Activity plans to build, whenever possible, on the relevant existing efforts of the international scientific community, and to take advantage of other initiatives by setting-up co-operative (joint) programmes between LOICZ and the existing or evolving programmes fostered by other bodies in the fields of interest to the proposed programme.

Approximately 0.4 gigatons (Gt) of organic carbon in solid and dissolved form reach the coastal seas annually via river discharge, all or part of which may be respired forming a source of CO_2 for the atmosphere. The extent of this source of atmospheric CO_2 is unknown since apparently much of the riverine transported carbon is inert and mixed with sea water conservatively. In addition the anthropogenic input of nutrients to coastal seas, in particular nitrogen and phosphorus (now believed to be twice the natural flux) can result in enhanced primary production constituting an additional sink for atmospheric carbon of the order of 0.07-0.12 Gt C a^{-1}. The behaviour of coastal systems in both the natural and disturbed carbon cycle is of direct socio-economic importance in terms of future policies and decisions concerning global carbon emissions and in terms of the sustainable multiple use of coastal areas and systems.

This area of LOICZ research aims to produce a large number of regional budget and system models representative of the major typical environments. An idealised goal would be around 100 budget and 25 system models but the number attained will depend upon the extent of participation of IGBP countries. These models will summarise existing knowledge of carbon dynamics for key units of the world's global coastal zone and include the influence of major forcing functions (e.g., nutrients, sediment, etc.) as well as important exchanges with the land, atmosphere and open ocean. In order to meet the long-term objectives of LOICZ, the results of the individual regional models must be synthesised to produce a clearer understanding of the magnitude of the net carbon fluxes in the total world coastal zone. This exercise will require considerable extrapolation of data in order to fill the many holes that will still exist in the global data base but this can be done with considerable confidence on the basis of the coastal typology to be developed by LOICZ under Framework Activity 2. Once compiled, the summary information can be fed into Earth system carbon models which do not currently consider processes taking place in the coastal zone.

Developing a truly global synthesis of carbon dynamics in the coastal zone, and feeding the results into global carbon models for the entire Earth system, represents a significant scientific challenge. This challenge is best met by developing an Integrative Activity led centrally by the LOICZ-Scientific Steering Committee and Core Project Office. While planning should commence immediately, and some preliminary syntheses can be made using existing data and models, work on syntheses can not begin until a reasonable number of regional models have been developed and tested (during Operational Phase 2). Successful completion of this activity is of critical importance to achieving the overall objectives of the IGBP.

1. Outline of the Integrative Activity (Core Research)

1.1 Goal and objectives

The overall/ultimate goal of the proposed Activity is to develop global syntheses and models of the role of the coastal seas in the disturbed and undisturbed carbon cycle based on a series of regional models capable of describing the seasonal and inter-annual variations in carbon fixation, metabolism and exchange in coastal zones.

The objectives of this Integrative Activity are:

(a) To serve as LOICZ Core Research encompassing activities of Focus 1 and Focus 3, and as a scientific and management framework for integration of the output from a number of subject-specific activities undertaken as national and regional contributions to LOICZ

(b) To provide policy-makers, planners and managers with the output of dynamic models of the carbon cycle in coastal areas as a contribution to the scientific basis for development of long-term global and regional strategies relating to carbon emissions and the use of coastal systems

1.2 Activities

The programme is envisaged to consist of several phases. The first is a Preparatory Phase of one year during which the scope and activities of the three Operational Phases will be defined in detail. The Operational Phases will encompass an initial data gathering and preliminary model development phase (4 years); a regional model development and validation phase (3 years); and a final global synthesis and modelling phase (2 years).

Preparatory Phase

The operational phases of the programme will be implemented in close collaboration with existing UNEP sponsored programmes, IOC Regional bodies, the IGBP System for Analysis Research and Training (START), Regional Research Centres, and the National IGBP Committees of those countries participating in the LOICZ Project, and will be based on a preparatory phase of ten months during which:

(a) A detailed work plan and timetable for the operational phases of the project will be determined, including the modalities of co-operation with partners involved in the project (see section 2.3), and more detailed financial requirements (budget) for the implementation of the project's operational phases

(b) Institutions which could act as regional nodes will be selected, their need for additional equipment and operating finance[9] will be assessed, and their mode of operation detailed

(c) Scientists who will participate in the operational phase will be identified and appropriate training requirements will be assessed

[9] A preliminary estimate of the equipment and operating costs of a regional node are provided in Appendix 4

(d) Sites will be selected within each region for execution of project activities

(e) The work plan and the budget of the operational phases shall be cleared, endorsed and approved, as necessary, by the relevant structures, bodies and authorities

Data gathering and preliminary model development: Operational Phase 1

A preliminary activity of this phase will involve the compilation of existing data concerning the dynamics of carbon in coastal seas, and the development of networks for data compilation and exchange between regional nodes.

The central activity will involve extension of this data set through the provision of support to selected regional research centres in the collection, using standardised methods, of data concerning carbon flow in the coastal oceans. Suitable centres of research expertise identified during the preparatory phase, will be provided with the necessary equipment and training, and mechanisms for regional data management and storage will be established.

On-site field experiments will be run to collect carbon data from coastal marine sediments (POC, PIC, PN, PP), from suspended sediment (POC, PIC, PN, TSS, Chlorophyll) and from the water column (pCO_2, TCO_2, Alkalinity, pH, DOC, nutrients). For each of the field sites two seasons must be covered and from each regional node at least two stations must be sampled weekly for one year in order to evaluate the seasonal pattern for the region concerned. Data will be shared between the regional nodes, and centrally controlled and managed for consistency and quality.

The development of initial carbon budget models for a large number of representative areas of the World's coastal seas (up to 100); and, initial identification of the strategies for development of regional system models for up to 25 regions, is envisaged during this phase. The output of the budget models will be used to determine whether these areas are a net source (i.e. autotrophic) or sink (i.e. heterotrophic) of organic carbon.

Regional model development and validation: Operational Phase 2

The central activity of this phase of the project will be the development of up to 25 regional system models summarising existing knowledge of carbon dynamics for key regions of the world's coastal oceans and including the influence of major forcing functions such as nutrient and sediment inputs, as well as the major exchanges with land, atmosphere and open ocean.

The details of specific activities leading to the build up of the regional carbon flow system models will be determined for each of the identified regions during the preparatory and first operational phases, and the following are only examples of the possible activities which may be included in the regional modelling phase of the project:

(a) Development of budget models for carbon, nitrogen, phosphorus and silicate for component units of the region concerned

(b) Adopt, modify or develop sub-models for necessary hydrodynamic, sedimentation, carbon sequestration and transport processes

(c) Adopt modify or develop biological and chemical sub-models describing important processes such as photosynthesis, respiration and nutrient cycling

(d) Develop carbon flow system models through coupling of the sub-models outlined above using site specific forcing functions

(e) Test and validate the models for different coastal systems

Global Synthesis and modelling: Operational Phase 3

This will require considerable extrapolation of data and regional model outputs to produce summary information for input to Earth system carbon models which presently do not adequately consider processes taking place in the coastal zone. Whilst planning for this phase will commence early in the overall Activity, it cannot be implemented until the regional models have been developed and validated in Operational Phase 2. Successful completion of this phase is critical to the overall goals of the IGBP, resulting in dynamic system models of carbon cycling in the world's coastal zones, which will allow development of scenarios of future carbon fixation and metabolism under differing conditions of global change and changes in forcing functions resulting from direct and indirect anthropogenic influences on coastal systems. Together with the regional models developed under Phase 2 the global syntheses and models will allow:

(a) Formulation of proposals for development of improved strategies for the management of coastal environments including their use for waste disposal

(b) Identification of additional actions that may promote the effectiveness of coastal environments as sinks rather than sources of atmospheric carbon

2. Implementation

2.1 *Approaches*

The programme plans to build, whenever possible, on the relevant existing efforts of the international scientific community, and to take advantage of other initiatives by establishing co-operative (joint) efforts between LOICZ and the existing or evolving initiatives fostered by other bodies in the fields of interest to the proposed programme.

Four existing international research efforts have been identified as the main potential counterparts of the proposed LOICZ programme. These include: the World Climate Research Programme; the Joint Global Ocean Flux Study (JGOFS); the International Global Atmospheric Chemistry Project (IGAC); and the Biospheric Aspects of the Hydrological Cycle (BAHC). Each of these covers a highly specific domain, yet taken together they cover the major boundary conditions necessary for modelling carbon in the coastal seas.

In addition a number of national and regional programmes concerned with coastal zone management and pollution monitoring and abatement provide a solid basis of information and data contributing to the formulation of the regional and global models, and providing the scientific infrastructure within which additional data could be collected, and the modelling activities organised.

2.2 *Potential partners*

The execution of the proposed programme would be co-ordinated by LOICZ, with the secretariats of the appropriate Regional Seas Action Plans of UNEP, IOC Regional bodies, START Regional Research Centres and National IGBP Committees, as bodies closely co-operating with LOICZ in the execution of the programme. A broad participation of scientists and experts in the programme would be expected, with a prominent role being played by scientists and experts from the countries of the regions covered by the proposed programme.

The establishment of co-operative arrangements is envisaged between the proposed programme and some other projects and activities of IGBP (LOICZ, BAHC, IGAC, JGOFS, GAIM and START, in particular), IOC's global and regional programmes (e.g. GOOS[10]), ISSC's[11] Human Dimensions of Global Environmental Change Programme (HDP), and IUCN's marine programme.

2.3 *Timescale and budget*

Assuming that the proposed programme could be formally approved and initial funding secured before the end of 1994, the Preparatory Phase could start in early 1995 and the first of the three operational phases in early 1996. The preparatory phase is envisaged as lasting approximately one year, followed by the three operational phases of approximately four, three and two years duration respectively. The phases of the programme would be initiated sequentially, implemented in partially overlapping stages, and the completion of the last phase, global synthesis and modelling, is envisaged by the year 2003/2004 (see Figure 14).

The costs of the three operational phases are estimated at approximately: 11, 8 and 3 million US$. The preparatory phase of the programme is estimated to cost approximately 500,000 US$. A Framework budget for the entire Activity is provided in Table 1 and detailed preliminary cost estimates are given in Appendix 4.

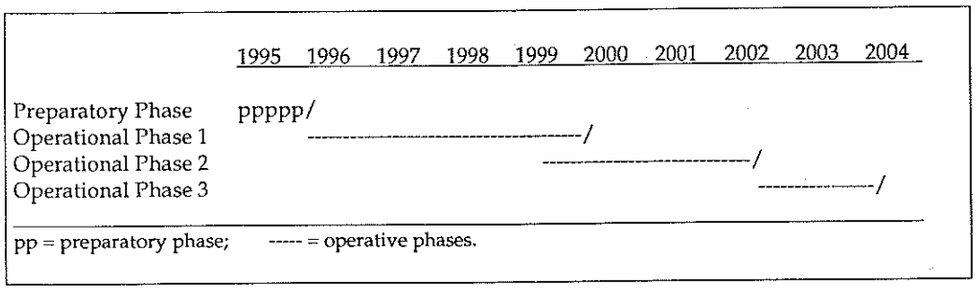

Figure 14. Time table for the implementation of LOICZ Integrative Activity (Core Research): "The role of coastal seas in the global carbon cycle".

[10] GOOS: Global Ocean Observing System, co-ordinated by the Intergovernmental Oceanographic Commission of UNESCO.
[11] ISSC: International Social Science Council.

Table 1. Indicative Framework Budget (1,000 US$) for The Integrative Activity: "The role of coastal seas in the global carbon cycle".

	Preparatory Phase	Operational Phases			TOTAL
		1	2	3	
Duration	12 Months	4 years	3 years	2 years	10 years
Project Personnel	140	840	790	580	2,350
Consultants	60	280	200	160	700
Administrative support	-	165	180	110	510
Travel	60	460	320	160	1,000
Fellowships	-	200	200	-	400
Sub-contracts	-	3,650	2,600	500	6,750
Meetings	50	700	650	450	1,850
Expendable Equipment	10	115	130	65	320
Non-Expendable Equipment	20	2,960	800	-	3,780
Premises & Operating Costs	100	600	530	400	1,630
Equipment maintenance	-	185	190	50	425
Reporting costs	15	125	110	100	350
Communication costs	15	105	95	50	265
Evaluation costs	-	80	80	100	260
Total	470	10,520	6,875	2,725	20,590
Contingency	24	526	344	131	1,030
GRAND TOTAL	494	11,046	7,219	2,856	21,620

Integrated Approaches to Assessing the Economic and Social Impacts of Global change in coastal systems

Background

The spatial and temporal variability of coastal systems is extremely high. Therefore, at the present stage of our understanding of the processes causing and shaping the variability and site-specificity of coastal systems, any attempt to produce a global study, or predictive model, of the economic and social impacts of global change in coastal systems on the basis of existing data, may turn out to be too general to be of any practical value or significance.

A number of small-scale, site-specific studies and models/scenarios have been developed in the past along the general lines suggested by the goals of the LOICZ Project, albeit rarely covering all elements of these goals. The number of similar medium-scale, regional studies and models is much smaller, but building LOICZ' studies and models on such regional studies and models is probably the most promising avenue which could be initially followed in integrating all three activities envisaged under Focus 4. Once the experience gained through a few well selected regional studies make it justifiable, an attempt could be made to "globalise" the approach, and to develop a global model of the processes at the interface between the land and the oceans.

The quality of projections, models and scenarios expected to result from the activities of Focus 4, will depend on the availability of reliable data describing the present situation

and characterising the past trends which have led to the present situation. LOICZ could, naturally, select a few regions deemed representative for certain types of coastal systems, and start to collect *ab ovo* data needed for making projections, models and scenarios. This would be a very time consuming process which would exceed the ten year life span of the project. Therefore, it would appear to be more appropriate to select from among the existing regional studies those which seem to have covered most of the ground intended to be covered by LOICZ activities, complete these studies in order to meet the full requirements of LOICZ, and to develop predictive models (projections, and scenarios) which could be used in formulating scientifically grounded management strategies for the studied areas, including "new policies on the use, conservation and restoration of living resources of the coastal Zone" and "more effective protective measures leading to greater efforts to attain sustainable use of living resources"[12]

Criteria for selection of regions

Criteria which could be used in the selection of regions for Core Research in the framework of the LOICZ Focus 4, and for the development of predictive models/scenarios include:

- Regions with reliable data characterising the present status and interaction between the physical, chemical, biological, and anthropogenic processes occurring in the coastal zone
- Regions with good historic records and scientific research about the past changes in its coastal zone, including *inter alia*: changes in shore dynamics; changes in estuarine and deltaic conditions and processes; sea-level changes; climate changes and associated ecological changes, including changes in biodiversity and food-chain dynamics; demographic changes, including changes in settlement patterns; socio-economic changes directly or indirectly attributable to environmental changes; changes in physical and ecological conditions due to human activities (e.g., sediment erosion/accretion, loss of wetlands and coastal lakes, changes in fishery yields)
- Regions for which specific climate change (temperature, precipitation) models or scenarios have been developed (e.g. Mediterranean, Caribbean)
- Regions for which predictive models or scenarios have been developed in respect of their possible future environmental and socio-economic conditions; regions where such models are using the predicted climate change (including sea-level rise) as the primary driving force, should be of special value
- Regions where it could be reasonably assumed that a good and effective working relationship could be established between the LOICZ programme and the bodies associated (co-ordinating, sponsoring or supporting) with the development of the regional studies of interest to LOICZ
- Regions which are representative both ecologically and functionally of various types of coastal zones

[12] Land Ocean Interactions in the Coastal Zone, Science Plan, IGBP Report No 25 p.15.

Proposed regions

On the basis of the above criteria, several examples could be given for regions and regional programmes which may be suitable for LOICZ research: North Sea, Mediterranean, eastern Atlantic seaboard of North America, insular Caribbean, west and east Africa, Oceania, Pacific Latin America and the SARCS region of Southeast Asia, to name but a few. Two possible regional programmes covering the Mediterranean and Southeast Asian Regions are outlined below. The Mediterranean is a region which meets all criteria, and where past and present activities cover to a large extent, all three activities of Focus 4.

The Mediterranean and its associated Action Plan (MAP) is, naturally, not the only mature regional programme dealing with the great complexity of natural and human interactions in the coastal zones, which may be considered in the framework of Focus 4. The South Pacific Regional Environment Programme (SPREP) (covering the Oceania region of START) and the East Asian Seas Action Plan should be considered as suitable complementary LOICZ projects. While the MAP deals with the coastal zone of a relatively small, but economically highly important and well researched semi-enclosed sea, SPREP covers the coastal zones of the South Pacific islands and thus encompasses an almost totally different set of land-sea interactions; whilst the East Asian Seas region (equivalent to the SARCS Region of START) represents a region dominated by high density developing countries in which marine and coastal resources play a major role in development. By analysing these three regions, and comparing the models (predictions) of their development and concomitant environmental impacts, LOICZ could make considerable progress towards the development of global models.

Overall Work Plan and Time table

MAP, SPREP, and the East Asian Seas Action Plan are complex, large scale programmes, cutting across all three activities of Focus 4. The logistics of their use as bases for LOICZ projects are formidable, but the outputs of such LOICZ projects may have relatively high visibility, scientific significance, practical value and impact on future management strategies. It is proposed that no more than two of these regional activities should be operated concurrently and that sequential, but over-lapping development is desirable. It is proposed to initiate the Mediterranean study in 1995; SARCS in 1997; and SPREP in 1988/1999 thus providing a two year period for consolidation of the results and development of global models before the completion of the LOICZ project in June 2003 (Figure 15). Each regional study is envisaged as requiring a minimum of three years during the operative phase and around 12 months in the Preparatory Phase. The latter would be underwritten, in part, by the Core project Office as part of its Framework Activities [13].

[13] See p 11 of the Implementation Plan relating to strategic elements and framework activities.

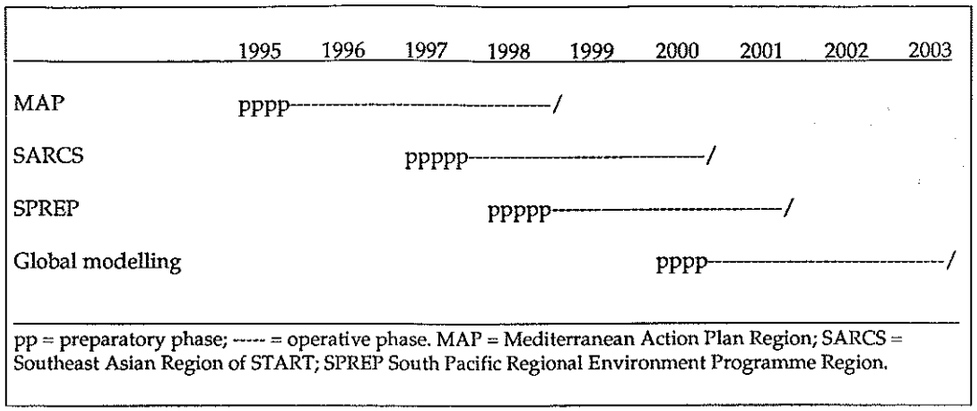

Figure 15. Time table for the implementation of LOICZ Integrative Activity (Core Research): "Integrated approaches to assessing the economic and social impacts of global change in coastal systems".

Framework budget

Each individual regional programme is estimated to cost between 4.5 and 6 million US dollars and a further 2 - 3 million would be required for the global modelling (Table 2) which would build, not only on the regional studies, but also on the framework activities and global databases established by the Core Project Office in the intervening period (1995 - 2000). Funding the regional projects individually would provide regional level models and products of importance in future management but would not provide the added value to be derived from completing several such studies and investing in the global scale modelling.

Table 2. Total cash flow (US$ 1,000,000) required for implementation of the Integrative Activity (Core Research): "Integrated approaches to assessing the economic and social impacts of global change in coastal systems".

Phase	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
MAP	0.7	1.5	1.3	1.4						4.9
SARCS			0.8	1.7	1.5	1.6				5.6
SPREP				0.9	2.0	1.7	1.9			6.5
Global modelling						0.4	0.9	0.8	0.9	3.0
Total	0.7	1.5	2.1	4.0	3.5	3.7	2.8	0.8	0.9	20.0

Regional Study No. 1
The Mediterranean: An Example of a Regionally Co-ordinated Research Agenda for the Development of an Integrated Approach to LOICZ Focus 4

The Mediterranean Action Plan (MAP) is a UNEP-sponsored and co-ordinated programme for the protection and development of the Mediterranean basin, with focus on the integrated management of the coastal zone and its resources. The MAP was adopted by a high-level intergovernmental meeting in 1975. It operates under the authority of the contracting parties to the Barcelona Convention (20 Mediterranean states + the European Union) which provides the legal framework for the MAP, and it enjoys the support of more than 100 national scientific and other type of institutions from all Mediterranean states, as well as of a large number of international organisations. It is co-ordinated by a secretariat located in Athens. Co-operative arrangements between the MAP and START are being established.

On-going activities relevant to LOICZ

From the manifold activities of the MAP the following are of particular relevance to LOICZ:

(a) A retrospective and prospective study of the socio-economic development of the Mediterranean coastal zone (the "Blue Plan") was completed in 1987[14]. The study, based on the analysis of a vast database, describes the distinctive characteristics of the Mediterranean basin with respect to both physical and human geography, and identifies the main features of the Mediterranean environment (climate, relief, ecosystems, etc.). The findings of the study relating to the economic activities and their impact on the environment are used for development of sectoral scenarios, with specific reference to the trends relevant to the coastal zone. The study includes five cross-sectoral scenarios analysing the possible trends of the Mediterranean environment for the time horizons of years 2000 and 2025, based on environmental, economic and demographic variables, and placed in the context of present economic and environmental policies.

(b) Since 1975, an intensive research and monitoring programme (the "MED POL"), involving several hundred scientists from all Mediterranean countries, has been carried out to identify the physical, chemical and biological characteristics and processes of the Mediterranean Sea, their interaction with similar processes in the coastal terrestrial zone, and the trends in factors and parameters characterising the environmental quality of the coastal waters. The programme has produced an overall assessment of the state of the Mediterranean marine environment[15], eighteen subject-specific evaluations of the major environmental problems of the Mediterranean marine environment, and thirteen concrete proposals for pollution control measures. Eleven of these measures have been adopted by the parties to the Barcelona Convention as the legal and technical basis for the Mediterranean-wide strategy for pollution control.

[14] M. Grenon and M. Batisse (eds.): Futures for the Mediterranean basin: The Blue Plan. Oxford University Press, 279 pp, 1989.
[15] The state of the Mediterranean marine environment. MAP Technical Report No. 28, UNEP/MAP, 221 pp, 1989.

(c) The potential impact of the direct and indirect consequences of predicted climate change was specifically studied in the framework of the MAP. A Mediterranean-wide assessment of the impact on the Mediterranean natural environment, and on the socio-economic structures and activities, was prepared in the late 1980s[16], and since then this has been complemented by 11 site-specific assessments using the years 2030 and 2100 as time horizons for assessing the effects. The assessments are based on a regional Mediterranean and several site-specific computer-generated climate change scenarios prepared by the Climate Research Unit of the University of East Anglia. Each assessment is accompanied by a set of recommendations on the possible measures for the mitigation of the negative impact of the changes.

(d) Since 1990, four site-specific coastal area management programmes (CAMPs) have been completed; and the preparation of an additional eight CAMPs is in progress. The goal of the CAMPs is: (a) to analyse the environmental characteristics and problems of a specific region in the light of the present and foreseeable impact of the socio-economic activities on the environment; and (b) to formulate plans for "environmentally friendly" management of the coastal areas, including their natural resources. The plans are largely based on "Blue Plan" types of scenarios prepared for each of the study areas and on the methodology of Integrated Coastal and Marine Area Management (ICAM) developed by MAP/PAP and UNEP. The geographic size of the CAMPs varies: from those covering the whole of the coasts of Syria and Albania, to those dealing with a particularly vulnerable location (e.g., Island of Rhodes, Bay of Izmir).

The advantages of using the MAP as the possible basis for a LOICZ Focus 4 project would be considerable. Specifically, it would provide LOICZ with:

- A rich database and analyses responding to most of the needs of the activities envisaged in Focus 4
- Facilitated access to a solid infrastructure (scientific institutions, scientists) which could be easily and effectively engaged in work on the LOICZ project
- Practical, region specific experience in coastal management

Thus considerably shortening the period which may be required for the achievement of the goals of Focus 4.

Overall objectives

Building on the material available through the MAP, LOICZ could specifically:

(a) Analyse the extent to which the best available science was used in the work of the MAP, and the effectiveness of its use
(b) Identify the gaps in, and the shortcomings of, the MAP, as seen from the perspective of the requirements specified by the activities of Focus 4
(c) Complement the research and studies accomplished under the MAP with additional research and studies, in order to meet the specific requirements of Focus 4

[16] L. Jeftic, J.D. Milliman and G. Sestini (eds.): Climate Change and the Mediterranean. 673 pp. E. Arnold, London, 1992.

(d) Assess the impact made by MAP activities on the national and regional strategies, policies and practices used in coastal zone management
(e) Identify the factors that may have hindered a more effective impact of the MAP activities on the national and regional strategies, policies and practices used in coastal zone management
(f) Evaluate (predict) the prospects of the evolution of coastal systems under the predictable influence of the MAP (Activity 1 of Focus 4)
(g) Identify additional actions which may promote the effectiveness of the environment protection measures and sustainable use of coastal resources (Activity 2 of Focus 4)
(h) Formulate proposals for the development of improved strategies for the management of coastal resources (Activity 3 of Focus 4)

Project initiation

In practical terms, the following steps could be envisaged to initiate a LOICZ project based on the MAP:

(a) Initiate formal contacts between the LOICZ Core Project Office and the Secretariat of the MAP in order to explore the desirability and feasibility of a joint LOICZ/MAP project
(b) Determine, in consultations between the Office and the Secretariat: the possible contents and work plan of the joint project; the modalities of co-operation between the Office and the Secretariat on its implementation; and the eventual political, logistic, and financial constraints on the execution of the project
(c) Clear (or submit for endorsement, if appropriate) the proposal for the joint project, including elements listed in the preceding sub-paragraph, with the relevant LOICZ and MAP structures
(d) Raise the necessary funds for the implementation of the joint project, and implement the project

Duration of the project

The duration of the operational phase of the project would be approximately 3 years.

Project management & implementation

The management (co-ordination) of the project would require a high-level full-time professional (Project Co-ordinator) at the LOICZ Core Project Office, assisted by a executive level secretary. The presence of a full-time professional programme officer out-posted from the Project Office as a liaison officer to the Secretariat of the MAP in Athens, would be a great advantage.

The implementation of the project activities and tasks could be envisaged through well selected consultants, working individually or in networks of small working groups under the overall guidance and co-ordination of the Project Co-ordinator and Core project Office.

Table 3. Indicative Framework Budget (1,000 US$) for the Mediterranean regional component of the Integrative Activity: "Integrated approaches to assessing the economic and social impacts of global change in coastal systems".

	Preparatory Phase	Implementation Phase			TOTAL
	10 Months	Year 1	Year 2	Year 3	46 Months
Project Personnel	175	210	210	210	805
Consultants 56 Months	120	300	300	300	1020
Administrative support	25	85	85	85	280
Travel	100	120	120	120	460
Sub-contracts	-	350	200	100	650
Meetings	50	100	100	100	370
Expendable Equipment	10	25	15	10	60
Non-Expendable Equipment	20	60	40	5	125
Premises & Overheads	110	150	150	150	560
Equipment Operation & maintenance	5	8	8	10	31
Reporting costs	25	15	30	200	270
Communication costs	15	20	25	30	90
Evaluation costs	-	-	-	30	30
Annual Total	655	1,443	1,283	1,370	4,751
Contingency	33	72	64	69	238
GRAND TOTAL	688	1,515	1,347	1,439	4,989

Financial requirements

The operational, financial requirements of the project could be roughly estimated as US$ 4-5 million, over a three year period Table 3 (for details see Appendix 4).

Regional Study No. 2
The East Asian Seas: An Example of a Regionally Co-ordinated Research Agenda for the Development of an Integrated Approach to LOICZ Focus 4

The EAS Action Plan (EASAP) was formulated for the protection and sustainable development of the marine and coastal areas of the EAS region, originally encompassing ASEAN, but with provision for expansion to include a wider region. The action plan was adopted in 1981 by the Co-ordinating Body of the Seas of East Asia (COBSEA), an intergovernmental entity presently with the same membership as ASEAN. A revision of the Action Plan is presently being prepared for submission by UNEP to COBSEA for adoption. The programme is co-ordinated by COBSEA through the Regional Coordinating Unit (RCU) of the EAS Action Plan, based at ESCAP, in Bangkok, Thailand and serves as the Secretariat to the Action Plan. This regional seas programme is being expanded to include, in addition to the original 5 ASEAN countries, countries in the broader EAS

region such as Australia, Brunei Darussalam, and Vietnam in the near term and hopefully Cambodia, Myanmar, China and others subsequently.

Past and ongoing EAS activities related to LOICZ

- Study on the effects of destructive factors on coral reefs
- Clean-up of the Singapore River
- Intercalibration exercise on the detection of heavy metals and organic pollutants in tissues of marine organisms
- Survey and assessment of non-oil pollutants
- Training programmes for marine park managers
- Workshop on the biological effects of pollutants

A number of other assessment projects were implemented by the programme with less success than the above. It should be noted that most of the activities under the EAS Action Plan to date have focused on pollution. The activity on marine park management is more recent and is ongoing.

In addition, under the EAS programme a Task Team on Implications of Climate Change in the EAS region was established to examine the potential impacts of anticipated climatic change on oceanography, natural ecosystems and socio-economic structures. The final report of this Task Team was recently published by the RCU/EAS of UNEP[17].

Non-EAS activities related to LOICZ and that may be built on by a joint EAS/SARCS-LOICZ activity

- ASEAN/US Coastal Resource Management Project (1985 to 1992):

  This project focused on Lingayen Gulf in the northern Philippines, and on the following sites in the remainder of the ASEAN region: Indonesia - Segara Anakan; Malaysia - Strait of Johore; Thailand - Southern Gulf; Brunei Darussalam - Bandar Seri Begawan; and the coastal waters of Singapore. This project was co-ordinated by the former Coastal Area Management Program of ICLARM and developed integrated coastal resources management plans for the above pilot sites.

- ASEAN/Australia Economic Co-operation Programme (AAECP) Living Coastal Resources (1983-1994)

  This project produced a database on the status, distribution and dynamics of coastal ecosystems (coral reefs, mangroves, seagrass beds and other soft bottom benthic communities) and their associated fisheries throughout ASEAN. It left a legacy of infrastructure, trained manpower and a network of collaborating scientists. A further phase of the project is being formulated to address management issues and the use of the scientific database for decision making.

[17] Chou, L.M. (ed.). Implications of expected climate changes in the East Asian Seas Region: an overview. RCU/EAS technical reports Series No. 2.

- AAECP: Regional Ocean Dynamics (1983-1994)

  The project involved the regional monitoring of tides and tidal phenomena over the long term.

- ASEAN-Canada Marine Science Program (1987 on-going)

  The first phase primarily involved training. However, the on-going second phase has 3 major areas:
  1. Development of water quality standards
  2. Establishment of environmental baseline data
  3. Red tide studies

Prospects for implementation

The planning, initiation and development of activities has largely been on an *ad hoc* basis (for EAS as well as non-EAS projects), depending on particular needs and opportunities for funding at a given moment. The overall impression, therefore, is that efforts to date have been fragmented and poorly integrated. The following benefits, however, have been gained from the past programmes, and provide a rich fabric for integration with LOICZ:

- Highly capable scientists, strategically situated all over the region
- Networks of communication and co-operation
- Some well-developed laboratories
- The beginning of a comprehensive database on living coastal resources
- The outlines of management plans based on specific situations, cultures, environments and socio-economic profiles

One shortcoming is the failure to date of the East Asian States to adopt a legal framework for regional co-operation.

Overall objectives

Building on the material available through the past activities of the EASAP and other initiatives such as the START regional initiative (SARCS), LOICZ could specifically:

(a) Analyse the extent to which the best available science was used in the work of the EASAP/SARCS, and the effectiveness of its use
(b) Identify the gaps in, and the shortcoming of, the EASAP/SARCS, as seen from the perspective of the requirements specified by the activities of Focus 4
(c) Complement the research and studies accomplished under the EASAP/SARCS with additional research and studies, in order to meet the specific requirements of Focus 4
(d) Assess the impact made by EASAP/SARCS activities on the national and regional strategies, policies and practices used in coastal zone management
(e) Identify the factors which may have hindered a more effective impact of the EASAP/SARCS activities on the national and regional strategies, policies and practices used in coastal zone management
(f) Evaluate (predict) the prospects of the evolution of coastal systems under the predictable influence of the EASAP/SARCS (Activity 1 of Focus 4)

(g) Identify additional actions which may promote the effectiveness of the environment protection measures and sustainable use of coastal resources (Activity 2 of Focus 4)
(h) Formulate proposals for the development of improved strategies for the management of coastal resources (Activity 3 of Focus 4)

Project initiation

In practical terms, the following steps could be envisaged to initiate a LOICZ project based on the EASAP and SARCS.

(a) Initiate formal contacts between the LOICZ Core Project and the Secretariats of the EASAP and SARCS in order to explore the desirability and feasibility of a joint LOICZ/EASAP/SARCS project
(b) Determine, in consultations between the Office and the Secretariats; the possible content and work plan for the joint project; the modalities of co-operation between the Office and the Secretariats on its implementation; and the eventual political, logistic, and financial constraints on the execution of the project
(c) Clear (or submit for endorsement, if appropriate) the proposal for the joint project, including elements listed in the preceding sub-paragraph, with the relevant LOICZ and EASAP/SARCS structures
(d) Raise the necessary funds for the implementation of the joint project, and implement the project

Duration of the project

The duration of the operational phase of the project would be approximately 3 years.

Project Management & Implementation

The management (co-ordination) of the project would require a high-level full-time professional (Project Co-ordinator) at the LOICZ Core Project Office, assisted by an executive level secretary. The presence of a full-time professional programme officer out-posted from the Project Office as a liaison officer to the Secretariats of the EASAP/SARCS in Bangkok, would be a great advantage.

The implementation of the project activities and tasks could be envisaged through well selected consultants, who would be regional scientists working individually or in networks of small working groups under the overall guidance and co-ordination of the Project Co-ordinator and Core Project Office.

Financial requirements

The operational, financial requirements of the project could be roughly estimated at US$ 5-6 million, over a three year period. The indicative Framework budget for the Mediterranean provided in Table 3 can be used as a basis for estimating costs of this activity bearing in mind that additional funds will be required under the sub-contract line to execute further research. Further details are provided in Appendix 4.

Existing International and Major Regional Programmes of Research Relevant to LOICZ

Background

The existence of numerous local, national, sub-regional, regional and international projects and programmes of coastal zone research, is both an advantage and a disadvantage in the implementation of LOICZ. It is an advantage in that LOICZ can, through various collaborative and co-operative arrangements build on existing research and studies, thus conserving scarce financial and manpower resources and providing value added both to LOICZ and to the collaborating/co-operating agency or programme. The disadvantages stem from the complex nature of ongoing coastal research, in terms both of the diversity of executing agencies and the enormous diversity of projects and activities, that makes identification of key linkages difficult.

The approach of LOICZ to date has been to establish formal and informal linkages with agencies involved in both funding and executing research, rather than attempting to build linkages at the project level. This approach is based on the assumption that the project linkages will flow from the initial higher level contacts, once LOICZ commences implementation. Nevertheless collaboration has been sought and achieved in implementing and planning various activities at national, regional and international levels.

What follows is not a definitive listing of all current coastal research related to LOICZ, rather an indication of the major agencies with programmes of coastal research and an indication of the linkages which have been or are being established in order to reduce overlap and maximise the benefits to be derived from collaboration. A number of major research programmes of relevance to LOICZ are also briefly mentioned.

Relationships of LOICZ to other IGBP Core Projects and Framework Activities

IGBP Core Projects

The three existing Core Projects of the IGBP with which LOICZ has clear scientific linkages are BAHC, IGAC and JGOFS (Figure 16). These three Core Projects are concerned with process studies that define the boundary conditions for the coastal studies of LOICZ. Of the three, links with IGAC are least well developed although initial contacts will be pursued in the development of studies and activities relating to trace gas emissions and fluxes in the coastal zone (Focus 1 & 3).

Links with PAGES in terms of Focus 2 Activity 3.1 are clearly required although at this time PAGES has designated studies of past shorelines as of low priority. LOICZ will therefore seek other collaborative linkages to achieve its objectives in this area of research.

Linkages have not yet been established with GCTE and given the present emphasis within GCTE it is difficult to identify areas in which joint activities might be undertaken, nevertheless the output of various GCTE activities will be important input to the Catchment Basin modelling and projections of future riverine transport of freshwater and materials to the coastal ocean.

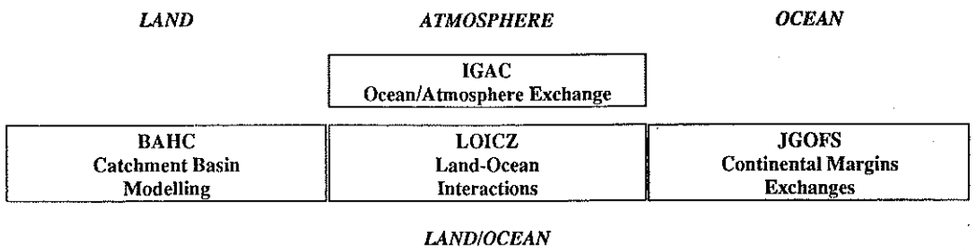

Figure 16. IGBP Core Projects concerned with processes at the boundaries of the LOICZ domain.

In 1992 JGOFS and LOICZ established a joint Task Team to plan continental margin studies and the report of that Task Team was jointly published in 1993[18]. JGOFS has now nominated four members to a joint Continental Margins Task Team and LOICZ will follow suit in the near future. This Task Team will work for three years and be responsible for defining in more detail the nature of collaborative research which is required to elucidate exchanges of energy and matter across the continental shelf margin and to plan carbon flux studies in continental shelf seas.

LOICZ is participating in an initial activity sponsored by BAHC and PAGES concerned with catchment basin modelling and it is hoped that this initial joint workshop to be held in Durham, New Hampshire, December 1994 will result in a draft science plan defining the nature of joint activities to be undertaken by both projects. The primary interest of LOICZ in this field is in the output of such models, rather than the modelling *per se*.

To date, a number of the inter-core project activities involving LOICZ have been driven by the needs and interests of the other core projects rather than being truly collaborative, reflecting the early stage of development of LOICZ. This situation will be rectified once the Implementation Plan for LOICZ is adopted and the nature of LOICZ research becomes better established.

Proposed IGBP Core Projects

It is clear that the new Core Project Land Use and Cover Change (LUCC) and the proposed projects, Global Euphotic Zone Study (GOEZS) and Global Ocean Ecosystem Dynamics (GLOBEC), have relevance to the research goals of LOICZ. Accordingly copies of this draft Implementation Plan have been despatched to the relevant Committees for

[18] Report of the JGOFS/LOICZ Task Team on Continental Margin Studies. JGOFS Report No. 15. April 1994

comment and review. It is anticipated that links between LOICZ and these studies will be further developed if and when they are accepted by the SC-IGBP as Core Projects or reach their implementation phase.

IGBP Framework Activities

Due to its early stage of development LOICZ has been unable to interact fruitfully with IGBP-DIS in terms of defining the future data requirements of LOICZ. It is anticipated that the appointment of the LOICZ Project Scientist will result in these linkages being strongly developed in 1995 and beyond and LOICZ anticipates developing a Data System Plan during 1995. This and other data related activities will be undertaken in close collaboration with the IGBP-DIS Office.

The LOICZ CPO has maintained close contact with START particularly relating to the development of activities in the Southeast Asian and African regions. Contacts with the SARCS Research Centre and SARCS-COM are well established and it is anticipated that this region of START will be directly involved in the regional project planned under the Integrative Activity encompassing Focus 4 of LOICZ. Southeast Asia has been designated by LOICZ as a priority area for research given the global significance of sediment and freshwater flux from land to oceans in this area, and given the intense use of coastal and marine resources for subsistence and development in this region.

During 1995 initial contacts with the SAFCOM region will be extended and a LOICZ research agenda for sub-Saharan Africa will be developed. In addition it is anticipated that MEDIAS will be involved in the execution of the Integrative Activity concerned with LOICZ Focus 4 research.

At present links with GAIM are not well developed, in part reflecting the early stage of development of LOICZ. Nevertheless LOICZ intends to seek guidance from GAIM concerning the implementation of the Integrative Activity concerned with the role of the coastal ocean in the global carbon cycle. Such guidance is of paramount importance not only to LOICZ but also to other Core Projects and to the IGBP as a whole, if the overall global modelling objectives of the IGBP are to be addressed. Issues of linking models between Core Projects need to be urgently addressed if sub-models developed within each Core Project are to be linked into Global System Models.

Relationships of LOICZ to International Programmes and Projects

A number of international agencies are currently involved in funding and executing coastal zone research and to date LOICZ has established formal contacts with three of these and informal contacts with a number of others.

The Intergovernmental Oceanographic Commission of UNESCO

LOICZ and the IOC have signed a joint memorandum of understanding, in which agreement is made to collaborate in areas of mutual interest. To date it has been agreed that LOICZ will provide scientific advice and support to the further development of the

Coastal Zone, Living Resources and Health of the Oceans Modules of the Global Ocean Observing System (GOOS) and a joint workshop was held (in collaboration with the IUCN) in Bermuda, in November 1994, at which a work plan for the global monitoring of coral reefs (to be implemented by GOOS) was drafted and a research agenda for LOICZ Focus 2 research was prepared. Members of the LOICZ-SSC and CPO have participated in various meetings of the IOC including the second meeting of the Intergovernmental body responsible for the development of GOOS (I-GOOS) and workshops of the Health of the Oceans *ad hoc* advisory panel.

It is anticipated that following the appointment of the LOICZ Project Scientist closer links will be established with the IODE of IOC to facilitate access to data and to IOC's regional and specialist networks. By using existing IOC structures LOICZ will be able to disseminate information to a wider scientific community and it is anticipated that various research activities will be implemented at a regional level in collaboration with the IOC regional bodies. IOC has agreed to co-sponsor the LOICZ Open Science Meeting in Manila in April 1995. The collaborative interactions will be further extended and strengthened as the LOICZ research agenda is implemented.

The United Nations Environment Programme

Initial contacts have been established with GRID, with the Regional Seas Programme, and with the GEF Unit, encompassing a variety of potential linkages in the execution of LOICZ Research activities. A major research proposal covering the Integrative Activity in Focus 4 has been prepared in consultation with the Co-ordinating Unit for the Mediterranean Action Plan, and this has been included in the current UNEP work plan for funding under the first operational phase of the Global Environment Facility. The Integrative Activity concerned with modelling carbon in the coastal ocean is being further developed in consultation with the relevant sections of UNEP headquarters, Nairobi.

UNESCO

Initial informal contacts have been established with the MAB programme in the area of Focus 4 and MAB has indicated a willingness both to fund and to be actively involved in LOICZ research in this area. Further discussions will be undertaken in the first quarter of 1995 to develop a joint work plan and formalise these arrangements. A joint workshop and symposium on the "Science and management of coastal lagoons: a global change perspective", is planned for early 1996.

Initial contact has been made with the UNESCO Division of Marine Sciences with a view to collaborating in joint research in tropical coastal areas. UNESCO-DMS has well established programmes in the field of mangrove research and various LOICZ research activities could be built on the results of past research conducted through the COMAR programme.

Contact has been established with the Climates of the Past programme (CLIP) which has expressed interest in collaborating in research addressing Focus 2, Activity 2.1. In addition the International Geological Correlation Programme 267 is highly relevant to LOICZ interests in past coast-lines.

Intergovernmental Panel on Climate Change

Through individual membership of various groups and drafting committees the LOICZ-SSC and CPO have provided inputs to the 1995 IPCC Assessment report. In addition the IPCC Coastal Zone Management sub-group, through its co-chair, has been involved in the further elaboration of Focus 4 research activities and has expressed interest in supporting and collaborating in this area of the LOICZ Research agenda.

IUCN-The World Conservation Union

Following initial discussions and approval of a joint memorandum of understanding by the IUCN Council and LOICZ-SSC, LOICZ and IUCN together with IOC jointly co-sponsored a workshop on coral reef research, monitoring and management in relation to Global Change. IUCN headquarters is however undergoing a major restructuring and the future of this collaboration is uncertain at this time. IUCN will however co-sponsor the LOICZ Open Science Meeting in 1995 and the established networks of the IUCN particularly in developing countries provide suitable opportunities for initiating collaborative research of interest to LOICZ.

The Food and Agriculture Organisation of the United Nations (FAO)

Initial contacts have been established with FAO in the field of GIS databases relating to agriculture and forestry in low-lying, tropical, coastal areas and FAO has agreed to make available its existing GIS databases for use in by LOICZ. It is anticipated that joint activities are likely to be developed particularly in relation to the further elaboration of the coastal typology (LOICZ Framework Activity F.2).

Scientific Committee on Ocean Research (SCOR)

Two members of the LOICZ SSC are also members of SCOR and have maintained contact with that body on behalf of LOICZ. SCOR has recently approved the establishment of two working groups which are of interest to LOICZ: one is concerned with the implications of climate change for coral reefs, the other with sea level rise and muddy shorelines. Consideration is being given by LOICZ to offering to co-sponsor the former working group. In 1995, LOICZ will co-sponsor a workshop with the US-SCOR Committee.

The Human Dimensions of Global Environmental Change Programme (HDP) of the International Council of Social Sciences (ISSC)

Members of the HDP Steering Committee have been involved in the initial design of the research agenda for Focus 4 and initial drafts of the relevant sections of this Implementation Plan were despatched through the Executive Director, for review by the entire Scientific Committee of HDP. It is anticipated that LOICZ will collaborate individually and collectively with the HDP in the execution of the research planned under Focus 4.

Major Regional and National Research Programmes of Relevance to LOICZ

Commission of the European Union

Official liaison, contact points have been designated for LOICZ within the MAST and Environment Programmes of the Commission and the LOICZ Core Project Manager and Chairman LOICZ-SSC actively participated in the preparation of the ELOISE Science Plan, which is seen by the Commission as designating the European contribution to LOICZ. This document has now been approved by the MAST, Environment and Aid programmes of the Commission and will be used as one criterion for evaluating research proposals under the next Framework Plan. Support is being provided to the LOICZ Open Science Meeting by the Commission.

The Commission is currently funding a number of large scale collaborative projects of considerable interest to LOICZ including the North-West European Shelf Programme (NOWESP) which aims to asses the fluxes of energy and matter as well as their variability on the basis of existing field and model data.

National and multi-lateral studies

The Land Margin Ecosystems Research programme (LMER) is a major US collaborative programme involving a number of Institutions and sites throughout the United States. The programme is mature, having run for a number of years and there are extensive opportunities for fruitful collaboration since a number of the activities of the LMER programme coincide with the goals and objectives of LOICZ particularly in regard to Foci 1 and 2. Initial contacts have been established and the LMER Principal Investigators have been invited to participate in the LOICZ Open Science Meeting in 1995 to explore further collaboration.

A number of large scale national and collaborative projects concerned with the exchange of energy and matter at the continental shelf edge or the fluxes of material in continental shelf seas, are nearing completion, ongoing or planned for implementation in the immediate future. These include *inter alia* MASFLEX, ECOMARGE, SEEP, TROPICS and OMEX. LOICZ has established contact with the co-ordinators of a number of these studies and will endeavour to ensure close collaboration in the implementation of the various activities concerned with elucidating the fluxes and exchange of material between shelf seas and the open ocean. Joint studies between LOICZ and various planned regional multi-national programmes are in the early stages of planning for the Southeast Asian region.

CONFLUENCE, a collaborative US, French and Argentinean Project is concerned with investigating upwelling and the mixing of the Rio de la Plata into the S-W Atlantic. This region is thought to be a significant sink of CO_2 and as the work is concentrating on pCO_2 it forms a valuable contribution to the objectives of Focus 3. PARAT funded by the International Scientific Co-operation of the European Communities programme (DG XII-B4) involves German, French and Argentinean partners studying the river and aeolian transport from Patagonia to the Atlantic.

KUSTOS is a large scale, primarily German initiative to examine the near-coast matter and energy fluxes in the southern North Sea. The intention is to measure high resolution parameter fields (hydrographic, biogeochemical, sedimentological and biological) and then to have the modellers attempt to reproduce the measured field by implementing a biogeochemical sub-model into the existing high resolution hydrographic model. This programme is of high relevance for activities under Foci 3, 2 and 1, as is LOIS, the large scale UK study considered as the UK contribution to LOICZ. A number of such studies however, suffer from the problems of limited spatial domain and the absence of efforts to link them into larger spatial scale syntheses, or to develop approaches that can be transferred to other regions of the world's coastal zone.

The "Forschungsverbund-Mecklenburg-Vorpommersche Kustenlandschaft" is an integration of three projects aimed at studying the ecology, biogeochemistry and transport of matter in the highly structured coast of the southern Baltic Sea. A number of other proposed programmes in the Baltic and North Sea are also highly relevant to LOICZ, and the Baltic Sea is seen as a potential model area for research on semi-enclosed seas given the well established research capacity in the surrounding countries.

The International Arctic Science Committee and the Scientific Committee on Antarctic Research are currently planning various large scale programmes of relevance to LOICZ. Various Canadian programmes, focused on the Arctic including CASP, MBIS and ACSYS are also of relevance to LOICZ.

Conclusions

The LOICZ CPO has requested information from National IGBP Committees concerning ongoing research of relevance to LOICZ. A considerable volume of information has already been received and attempts will be made in 1995 to synthesise this information and develop approaches to the integration of such research activities within the LOICZ framework.

It is clear that considerable research effort by various agencies, governments and research institutions, is concentrated on a number of issues and areas of interest to the LOICZ Core Project of the IGBP. An early effort in the implementation of LOICZ must be directed to developing an inventory of existing large-scale activities and projects and attempting to develop, where appropriate, linkages with LOICZ in terms of facilitating access and exchange of data and results. It is anticipated that a number of workshops will be convened in 1995/1996 to synthesise existing information and understanding of *inter alia:* carbon flux studies in coastal seas; continental shelf edge exchanges of energy and matter; the applicability of currently used economic methods for application in LOICZ Focus 4 studies; and approaches to budget and system modelling.

Project Management

Managing a project of the potential scope and complexity of LOICZ will require: careful planning and co-ordination; on-going networking of individual scientists and institutions; close collaboration with national IGBP committees and other Core Projects of the IGBP; liaison and integration of LOICZ activities with other international organisations, programmes and initiatives; good communication both vertically and horizontally with all organisations and individuals concerned with project implementation; and if the overall global objectives of the project are to be met, a high level of investment in data management and the preparation of global models and syntheses. The mechanisms by which it is proposed that these overall objectives should be met are detailed in the section entitled Framework Activities. The overall philosophy for the development of the co-ordination functions within the LOICZ Project will place strong emphasis on networking, disaggregated data storage, and the use of modern information technology, where appropriate.

As a Core Project of the IGBP, LOICZ implementation is guided by the Scientific Committee of the IGBP (SC-IGBP) and by its own international Scientific Steering Committee (LOICZ-SSC) and managed on a day-to-day basis by the staff of the Core Project Office (CPO).

The IGBP Secretariat and the Scientific Committee of the IGBP

The Scientific Committee for the IGBP (SC-IGBP) established by ICSU in 1990, consists of members appointed by ICSU, plus all Chairs of IGBP SSCs, Standing Committees and Task Forces, and as *ex officio* members, the Chairs of the Joint Scientific Committee of the World Climate Research Programme (WCRP) and the Scientific Committee of the Human Dimensions of Global Change Programme (HDP). The IGBP Secretariat, based in the Royal Swedish Academy of Sciences, serves the Scientific Committee of the IGBP which provides the overall scientific guidance concerning programme implementation. The SC-IGBP makes decisions concerning the inclusion of new projects and activities; appoints members to the Scientific Steering Committees of the Core Projects; and recommends on the financial and other support required to achieve the overall goal of the programme, which is to:

> *"Describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the unique environment which it provides for life, the changes that are occurring in this system, and the manner in which they are influenced by human actions."*

The responsibility of the IGBP Secretariat is to implement the decisions of the SC-IGBP and to serve as a focus for overall programme planning and implementation and to assist the Core Projects in their work through ensuring the adoption of the common approaches, necessary for programme-wide integration of results. LOICZ forms one of six currently approved Core Projects. To assist in achieving its overall goal of programme-wide

integration, the IGBP Secretariat, on the advice of the SC-IGBP, has established three Framework activities which form an over-arching chapeau and integrative forum for the individual Core Projects. These Framework activities are:

- The Task Force on Global Analysis, Interpretation and Modelling (GAIM)
- The Data and Information System (IGBP-DIS)
- The System for Analysis Research & Training (START)

Since the Chairmen of individual Core Project Scientific Steering Committees are members of the SC-IGBP, information concerning the scientific development and implementation of the IGBP as a whole is disseminated to the Core Project level through their attendance at regular meetings. In addition the Secretariat publishes a regular IGBP newsletter and the series of Global Change Reports. Regular meetings of Core Project Officers are convened by the Secretariat to discuss and decide on administrative and co-ordination matters relating to the day-to-day operation of the Core Projects and their integration. The overall structure of the IGBP is outlined in Figure 17.

The LOICZ-Scientific Steering Committee & Core Project Office

The members of the LOICZ Scientific Steering Committee (LOICZ-SSC) are appointed for three-year terms by the SC-IGBP and are eligible for re-election for one further period of three years. The present membership of the LOICZ-SSC is appended as Appendix 1 to this plan, and the terms of reference for the committee as approved by the IGBP Officers is attached as Appendix 5. In essence the LOICZ-SSC is responsible for guiding the scientific development and implementation of the LOICZ project within the framework of the IGBP and for the organisation of regular Open Science Meetings, at which the results of LOICZ research are disseminated to as wide an audience as possible, and future developments in the implementation of the project are discussed.

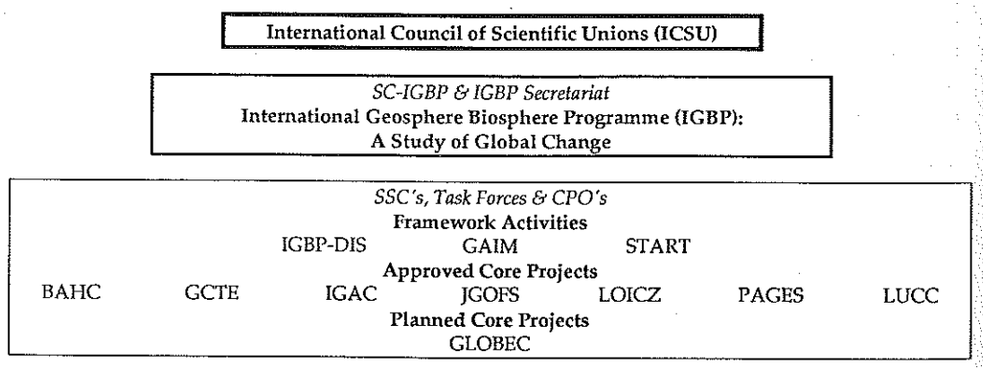

Figure 17. The administrative framework of the International Geosphere-Biosphere Programme.

The LOICZ Core Project Office (CPO) which opened in November 1993, is housed in the *Nederlands Instituut voor Onderzoek der Zee* (Netherlands Institute for Sea Research) and is funded through the generosity of the Netherlands Government under an agreement with the IGBP Secretariat. The Office is currently staffed by a Project Manager, Project Scientist and professional Secretary. The functions of the Core Project Office as approved by the SC-IGBP and LOICZ-SSC are detailed in Appendix 6 of this plan and the primary functions of the CPO are: to provide co-ordination of project activities; to liaise between participating scientists, national IGBP Committees, LOICZ Focal Points, and relevant international projects and programmes including the other Core Projects of the IGBP; to manage LOICZ databases; to produce global syntheses and overviews; and to facilitate data and information transfer between networks of participating LOICZ scientists. The research elements of LOICZ and their links with other projects and programmes are illustrated in Figure 18.

National IGBP Committees

IGBP National Committees provide the formal interface between researchers in participating countries and the international structure of the IGBP. They are expected to assist with national planning and co-ordination; to contribute to the conceptual and practical development of the IGBP as a whole; and to arrange for payment of the national contributions towards the central costs of the programme. At the end of 1994 there were 72 National Committees in all. The benefits and obligations of participation in the International LOICZ Project of the IGBP are detailed in Appendix 7 of this Implementation Plan.

The National Committees have responsibility for assembling descriptions of national projects, planned or underway, that they consider to be within the Core and Regional/National categories of research (IGBP, 1994). To assist in this information gathering exercise, National Committees are encouraged to set up working groups or sub-committees matching the Core Projects that are of greatest national interest. A listing of the LOICZ focal points appointed by National Committees as of September 1994 is appended as Appendix 3 to this plan.

Categorisation of Research

The majority of the work of the Core Projects to date has been undertaken through national research activities co-ordinated by the CPOs and SSCs. Research results are compiled, data exchanged and regional and global syntheses produced, which assist in clarifying the scientific uncertainties surrounding different aspects of Global Change and the functioning of the Earth system. As noted in the section of this Plan entitled, "Global Change & the Coastal Zone", LOICZ is a project which addresses the effects of cumulative changes to the world's coastal zones, the effect of these changes on the functioning of the Earth system as a whole, and on the human populations of coastal areas. The complexity of the project in terms of the scientific issues and uncertainties which need to be addressed in achieving the LOICZ goals will necessitate meticulous compilation and analysis of data from individual, national and regional studies.

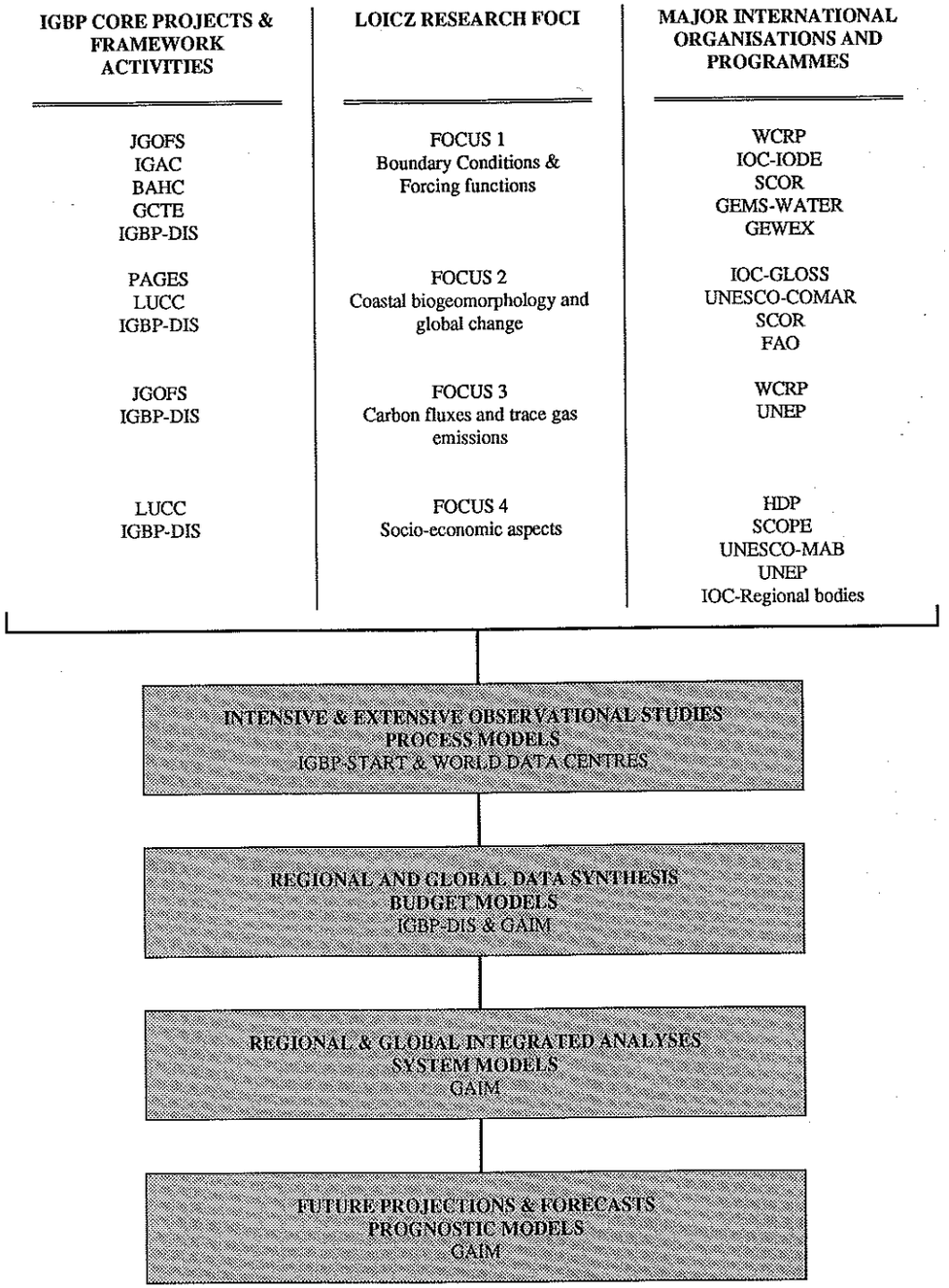

Figure 18. Research elements of the LOICZ project and their links with other projects and programmes.

IGBP has developed a three category system for defining IGBP research:

Core Research, which directly addresses the Science Plan goals of IGBP Projects, being part of their formal structure and co-ordinated by the relevant SSC.
***Regional/National Research**, which is closely linked to the Science Plan objectives (but may have other overall aims), and is co-ordinated at a national or regional level.*
***Relevant Research**, which makes an indirect contribution to the project, without formal affiliation.*
(IGBP, Report No 28)

The criteria for the categorisation of research are not based on scientific merit *per se*, but relate to research objectives, implementation procedures, and the practicalities of dividing co-ordination responsibilities between the different levels of Core Project structure. The interim specific criteria adopted by the LOICZ-SSC are appended as Appendix 2 to this report, these are additional to those above and do not replace them. It is anticipated that this set of LOICZ criteria will evolve as the project develops; as the nature of national contributions becomes clearer; and, as feedback is received from the National Committees.

The heterogeneity of coastal environments and the nature of the LOICZ Project in terms of the cumulative nature of the changes that are considered to be within the goals of LOICZ will necessitate the inclusion of a consideration of the spatial and temporal domain of particular research initiatives in deciding whether an individual research activity is classed within a particular category. For example, an isolated study of the changes in fluxes of material through an individual estuary, or of the changing role of a specific mangrove community in trapping sediment would be considered *Relevant Research*. If such studies are however, co-ordinated in a wider framework, for example through a national or regional programme of estuarine or mangrove research, in which comparable methodologies, data exchange and wider spatial synthesis of results are anticipated, then the studies might be considered as *National or Regional* contributions to the overall goals of LOICZ.

Since the scientific goals of IGBP and LOICZ are concerned with "change", the element of temporal comparison must be included, if any study is to be considered a contribution to the LOICZ Project. Whilst LOICZ is primarily concerned with temporal changes over decades and centuries, projects of more limited temporal domain which are concerned with understanding the nature of the forces driving change in coastal zones are also highly relevant.

To date much coastal research has been undertaken within limited spatial and temporal bounds, although notable exceptions are found, *inter alia* in some regionally co-ordinated programmes of pollution monitoring, and coastal zone management which have wide spatial domain and involve long-term programmes of work. As a consequence, considerable methodological difficulties arise in compiling and comparing data and conclusions from this work. For example, although considerable assessment of the state of individual coral reefs, and of the driving forces of change to particular reef systems has been undertaken throughout the world, assessment methods differ from one region to another, and even between studies conducted in the same country. Consequently the data are not comparable and no global assessment either of the present state of coral reef ecosystems, or of the rates of change in such systems can be made at present. Thus, the

changing role of such coastal systems in the total Earth system and in biogeochemical cycling cannot be evaluated or modelled on a global scale.

Core and Regional Research within LOICZ is expected therefore to contain substantial investment in the development of appropriate methodologies, data collection, handling and management procedures and modelling techniques. These activities will be closely co-ordinated with international agencies and where appropriate, existing internationally agreed standards and methodologies will be adopted. During the initial stages of LOICZ implementation such studies will be given priority and an area for much fertile research in this regard is found at the interface between the natural and social sciences in executing Focus 4, and modelling the influence of human populations as agents of environmental change, and environmental change as a driving force for socio-economic change. At least during the first five years of the project, individual and national level research which is concerned with developing data management and exchange techniques and models that are widely applicable to a range of coastal systems may therefore be considered *Core Research*, if it is undertaken in close collaboration with the SSC.

Future Considerations for Project Management

Bearing in mind that the overall perspective of LOICZ is global, then compiling the outputs from individual studies into regional and global assessments, models, scenarios and/or predictions, will require considerable investment from the Core Project Office and Scientific Steering Committee in terms of defining methodologies; database and model development; networking and liaison. Even, with a comprehensive investment in strategic and framework activities, the possibility remains that LOICZ will be unable to fulfil its regional and global goals since the compilation of results from small studies (small, in terms of either spatial domain or subject area) will not necessarily provide insight and answers to issues involving the inter-relations between wider sub-sets of the total system.

It is clear therefore that the SSC will need to develop a number of Core Research Activities, which encompass most, if not all of the activities envisaged under a particular focus, or which address, in a cross-cutting manner, multiple activities from two or more foci. It is unlikely that such studies will be funded through national level research, which is generally somewhat narrowly focused, of limited spatial domain, and target oriented. Consequently the investment of substantial new research funds is seen as a necessary pre-requisite to the achievement of LOICZ goals.

The small size of the Core Project Office, in comparison with the magnitude of the tasks outlined in this Operational Plan, will necessitate some decentralisation of co-ordination functions. In addition, achieving the long-term goals of LOICZ will depend on the contributions of national research which must be organised into networks dealing with individual LOICZ themes and scientific issues. It is envisaged therefore that as particular Activities become operational, centres or nodes will be identified by the LOICZ-SSC, which can function as the focus for large scale regional research activities, or for the further development of particular fields of specialist research. The responsibilities of such centres or nodes and the lines of communication must be laid down clearly at the outset to avoid duplication of effort and to ensure that scarce resources are not wasted.

Research Nodes

Research nodes will be centres of excellence in a particular field of LOICZ research interest such as carbon flow modelling, near-shore ecosystem modelling, river catchment modelling, or environmental economics for example, which would be responsible, under the overall guidance of the LOICZ-SSC and LOICZ-CPO and in close collaboration with the Core Project Office, for *inter alia*:

- The development of a specialist global network under the umbrella of LOICZ
- Taking the lead in providing guidance and assistance to the wider LOICZ network in developing appropriate standards, methodologies and data management protocols
- The development of specialist observation networks, such as coastal stations collecting carbon data
- Organising appropriate workshops to develop regional and global products
- Disseminating results to the wider scientific community
- Issues of scaling from local to regional and global

In identifying such operational research nodes, careful consideration will be given to the individual's, institution's or organisation's existing capacity: to support the envisaged programme of work; the nature of additional investment in manpower and financial terms required to meet the objectives of the node as laid down by the LOICZ-SSC; the proposed nodes' existing international research linkages; and its existing record of excellence in the research field concerned.

Regional Nodes

Regional nodes, as their name suggests, will serve as a regional focus within the global network for the co-ordination of LOICZ research within a defined geographic region. In most instances such nodes will be co-incident with the START Regional Centres, although in regions where START centres do not exist or where alternate considerations arise, specific LOICZ nodes may be identified, which would be required to maintain close liaison with the appropriate START Centre. In the case of Africa, for example, the particular research issues of interest to LOICZ differ considerably along the East and West African coasts, hence, if research activities are to be developed in these regions, then networking would be facilitated by the presence of both an East and a West African LOICZ node, both of which would then be expected to maintain close collaborative links with the START SAFCOM Centre when established.

A diagrammatic representation of the resultant management structure based on LOICZ networking through such nodes is provided in Figure 19.

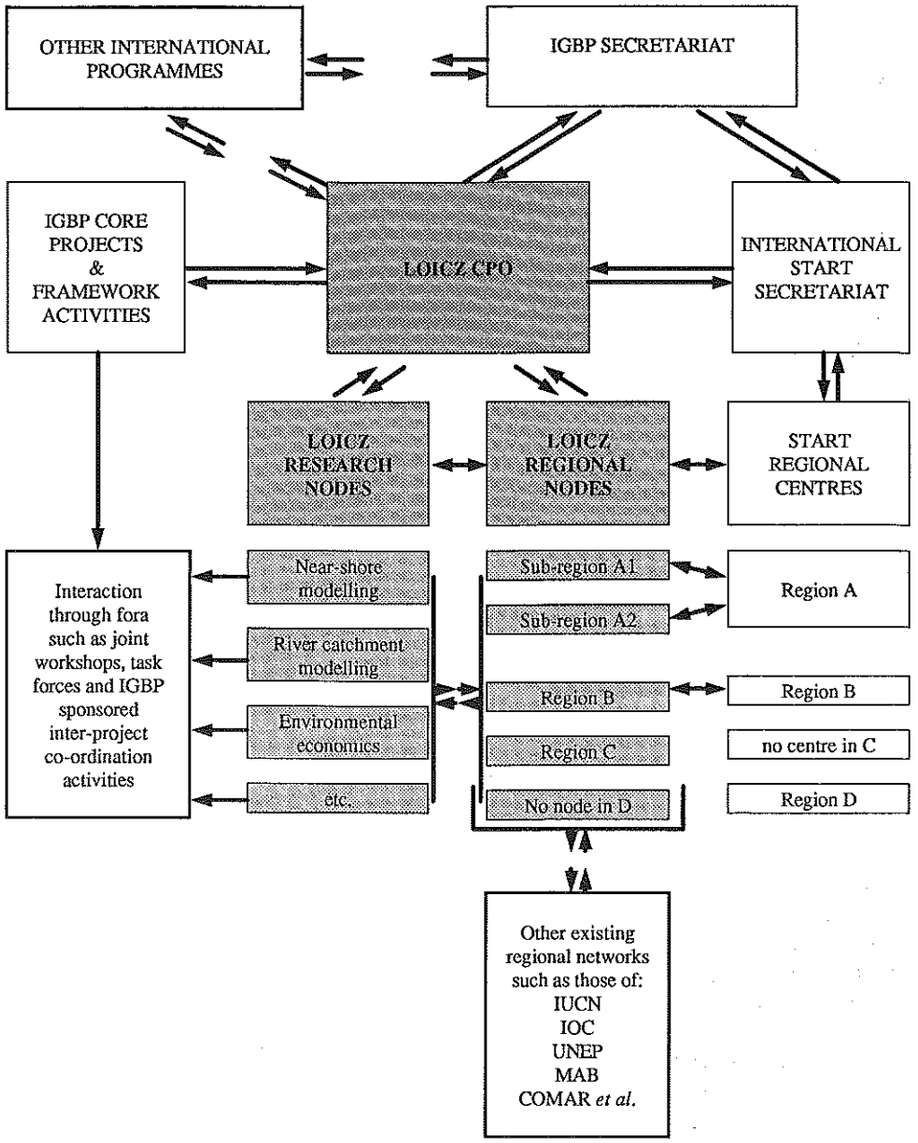

Figure 19. Management Framework for the LOICZ Project indicating relationship between proposed LOICZ nodes and existing management structures for Global Change Research.(⟷ management connections; ⟷ communication linkages; ⇄ ⇄ linkage development on case by case, or *ad hoc* basis)

Formal Linkages Between the LOICZ Research Nodes and the Core Project Office

From a management perspective it is envisaged that formal linkages will be established between the Core Project Office and the designated regional and research nodes. These may take the form of Memoranda of Understanding (MOU) or legal contracts where the transfer of funds to enable a Node to execute approved LOICZ activities is involved. These MOU or contracts will vary on a case-by-case basis reflecting the nature of the responsibilities undertaken by any one particular node at any one time but, in principle they should contain at the very minimum the following heads of agreement:

- A statement of purpose containing a work plan and timetable for the activities envisaged as being undertaken by a designated individual (Principal Investigator; PI) responsible for the overall operation of the node
- A statement of the expected outputs resulting from the workplan and timetable
- A statement of agreement from the funding agency and/or host Institution of the Principal Investigator to the participation of the PI in the agreed LOICZ activities
- A statement of the inputs in terms of financial, manpower, and other administrative support which will be provided by the Principal Investigator and their host institution

Such an MOU should be signed by the Head of the Institution hosting the LOICZ Node, the Individual Researcher responsible for the operation of the node and the LOICZ Core Project Manager.

Where such an agreement involves the transfer of funds from the LOICZ Trust Fund or other source administered by the Core Project Office, the Director of the Netherlands Institute for Sea Research (NIOZ) shall also be a co-signatory. Such an agreement should contain in addition to the above clear statements of:

- The anticipated schedule of payments to be made
- The mode and frequency of financial reporting required of the Principal Investigator, concerning the expenditure of LOICZ funds transferred to the node
- The nature and frequency of substantive and technical reports anticipated under the agreement

Designation of LOICZ Research

The nature of the approved categories of IGBP research and the interim criteria adopted by the LOICZ Scientific Steering Committee are detailed in Appendix 2. Once a particular project or programme of research has been approved by the National IGBP Committee and the LOICZ Scientific Steering Committee and the project has been designated as LOICZ approved Research there is an obligation on the Principal Investigator to ensure that:

- Data and information resulting from the project are made available to the Core Project Office on request, for incorporation into LOICZ databases
- All scientific publications resulting from the research include a statement that the project is an approved contribution to the LOICZ Core Project of the IGBP

- Copies of all scientific publications are lodged with the Core Project Office
- Copies of all substantive and technical reports of the project are copied to the Core Project Office

Until such time as the Principal Investigator co-ordinating or undertaking a project or programme, has received in writing from the Core Project Office a statement to the effect that the project or programme has been considered and approved by the LOICZ-SSC as designated LOICZ Research:

- The Principal Investigator may not refer to the project or programme as being a contribution to the LOICZ Core Project of the IGBP
- The principal investigator may not represent themselves as being a LOICZ Researcher

Following receipt of approval in writing from the Core Project Office of the project or programme, as either designated Core, Regional, or National Research the Principal Investigator, may if they so wish, refer to the project or programme as being "LOICZ Research" and to themselves as a "LOICZ Researcher". Such privileges do not accrue either to projects or to Principal Investigators of research designated by the LOICZ-SSC as Relevant, and may be withdrawn by the LOICZ-SSC should the Principal Investigators of Approved Core, Regional or National Research fail to comply with the obligations set out above and in Appendix 7 of this Implementation Plan.

Designated Core, and Regional, Research Projects, are encouraged to include the LOICZ Logo on substantive and technical reports and publications produced by the Project, but prior agreement of the LOICZ CPO must be sought and received in writing before any such use.

LOICZ Researchers & Corresponding Scientists

It is anticipated that there will be several categories of LOICZ Researchers, reflecting the degree and extent of the individual's involvement in the LOICZ Core Project as a whole. In general, however, Principal Investigators of designated Core, Regional and National LOICZ Research will form the backbone of the LOICZ network and as noted above may if they so wish designate themselves as LOICZ Researchers following receipt in writing from the CPO of confirmation of the categorisation of their Research Project or Programme. Principal Investigators of Projects designated as relevant research will be considered as LOICZ Corresponding Scientists and will receive, together with LOICZ Researchers, the LOICZ newsletter. Corresponding Scientists are expected to provide the CPO with periodic information concerning their research as appropriate.

From time to time, individual LOICZ Researchers may be asked to represent the LOICZ Project at national and international meetings or workshops. Neither LOICZ Researchers nor Corresponding Scientists may represent the LOICZ Project unless specifically designated to do so, in writing, by the Core Project Office in consultation with the LOICZ-SSC. In general the LOICZ Project will be represented in meetings, workshops and symposia, either by the full-time staff of the Core Project Office or by the Chairman or by a member of the LOICZ Scientific Steering Committee. Only the Core Project Manager may make official commitments of LOICZ financial and manpower resources.

Appendix 1
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Appendix 2
Procedures for Submission of Research and Criteria for Assignment

Defining IGBP Research

IGBP has developed a three category system for defining IGBP research:

Core Research, which directly addresses the Science Plan goals of IGBP Projects, being part of their formal structure and co-ordinated by the relevant SSC

Regional/National Research which is closely linked to the Science Plan objectives (but may have other overall aims), and is co-ordinated at a national or regional level

Relevant Research which makes an indirect contribution to the project, without formal affiliation
(IGBP, 1994)

These criteria for the categorisation of research are not based on scientific merit *per se*, but relate to research objectives, implementation procedures, and the practicalities of dividing co-ordination responsibilities between the different levels of Core Project structure. The interim specific criteria adopted by the LOICZ-SSC are given below. These are additional to those above and do not replace them. It is anticipated that this set of LOICZ criteria will evolve as the project develops; as the nature of national contributions becomes clearer; and, as feedback is received from the National Committees.

Additional Criteria for the Categorisation of LOICZ Research[19]

Core Research
Addresses global issues, either through the production and testing of widely applicable models of change in coastal zones or through providing wide geographic syntheses of information on flux rates, or coastal processes and their rates of change.

Regional Research
Addresses global issues, within a regional framework, either through the production and testing of widely applicable models of change in coastal zones or through providing regional syntheses of information on flux rates, or coastal processes and their rates of change.

[19] As approved at the third LOICZ Scientific Steering Committee Meeting, June 1994.

National Research
Addresses issues identified as of priority in the Implementation Plan of LOICZ, either through the production and testing of models of change in coastal zones or through providing syntheses of information on flux rates, or coastal processes and their rates of change for entire countries or extensive areas within countries.

Relevant Research
Addresses issues identified as of priority in the Implementation Plan of LOICZ, either through the production and testing of models of change in coastal zones or through providing information on flux rates, or coastal processes and their rates of change and thus contributing to national and/or regional level syntheses.

Procedures for category allocation

- The National Committees have responsibility for assembling descriptions of national projects, planned or underway, that they consider to be within the Core and Regional/National categories. The information needs to be more than just the project title; its relationship to Core Project objectives must be made clear. A format for project descriptions already exists for GCTE, and similar guidance will be made available by the other Core Projects. To assist in this information-gathering exercise, National Committees are encouraged to set up Working Groups or sub-Committees matching the Core Projects that are of greatest national interest.

- The National Committees submit descriptions of projects considered to be within the Core Research category to the SSCs, via the relevant CPO; preferably as a packaged national contribution to each project. Following the review of such material by the SSCs, formal recognition of its category status, or other feedback, will be provided. In cases where the National Committees are unable to carry out preliminary assessments, research groups may need to make heir submissions directly to the SSCs/CPOs.

- The SSCs will use the information on Core Research to guide the further development of their projects, encourage collaboration, and, where necessary, taking action to attract effort and resources to "neglected" areas.

Following the category-allocation exercise, information on the component studies of each Core Project will be published. National Committees are also encouraged to publish national compendia of information on projects that could combine a listing of studies within both Core and Regional/National categories. Information on Relevant Research may also be included, but its different status should be indicated. (IGBP, 1994)

Appendix 3
LOICZ National Focal Points

Status of National LOICZ Contact Points
As of January 13th, 1995

COUNTRY	LOICZ Committee[20]	Nature of the LOICZ Contact
Argentina	No	National IGBP Committee nominated Individual
Australia	No	Member of National IGBP Committee
Bangladesh	Yes	Convenor of National LOICZ Committee
Belgium	Yes	Chair of National LOICZ Committee
Benin	Yes	Chair of National LOICZ Sub-Committee
Botswana	No	National IGBP Committee (no national participation in LOICZ envisaged)
Brazil	Yes	Co-ordinator, National LOICZ Sub-Committee
Bulgaria	No	Member of National IGBP Committee
Canada	(Yes)[21]	Chair National LOICZ Committee
China (Beijing)	Yes	Chair National LOICZ Committee
China (Taipei)	Yes	Chair National LOICZ Committee
Colombia	No	Chair National IGBP Committee
Côte d'Ivoire	Yes	Co-ordinator National LOICZ Sub-Committee
Cuba	?	Member National IGBP Committee
Czech Republic	No	National IGBP Committee (no national participation in LOICZ envisaged)
Denmark	No	Member National IGBP Committee to be appointed
Egypt	No	Member National IGBP Committee
Estonia	No	Member National IGBP Committee
Finland	Yes	Chair National LOICZ Sub-Committee
France	No	Two contacts, Chairmen of nationally adopted LOICZ research programmes
Germany	No	Two Co-ordinators National LOICZ Committee
India	No	National IGBP Committee (Co-ordinator for LOICZ to be appointed)
Indonesia	No	National IGBP Committee nominated Individual
Ireland	No	Member of national IGBP Committee
Israel	No	National IGBP Committee nominated Individual
Italy	No	Member of National IGBP Committee
Jamaica	No	Chair National IGBP Committee
Japan	Yes	Chair National LOICZ Sub-Committee

[20] In some instances the "committee" has been constituted as a sub-committee of the National IGBP committee in others as a full committee apparently reporting to the National IGBP Committee.
[21] (Yes) indicates the intention to form a National LOICZ Committee or Sub-committee

COUNTRY	LOICZ Committee	Nature of the LOICZ Contact
Kenya	No	Member of National IGBP Committee
Mexico	Yes	Chair National LOICZ Sub-Committee
The Netherlands	Yes	Chair National LOICZ Committee
New Zealand	No	National IGBP Committee (LOICZ contact to be appointed)
Norway	No	Member of National IGBP Committee
Peru	No	National IGBP Committee nominated Individual
Philippines	No	Member of National IGBP Committee
Poland	No	Three contact points, members of National IGBP Committee
Romania	(Yes)	Member National IGBP Committee
Russia	Yes	Co-ordinator, LOICZ Working Group
Singapore	No	Chairman National IGBP Committee
Slovak Republic	No	National IGBP Committee (no national participation in LOICZ envisaged)
South Africa	Yes	Chair National LOICZ Committee
Spain	No	Member National IGBP Committee
Sweden	Yes	Member National IGBP Committee
Switzerland	No	National IGBP Committee (no national participation in LOICZ envisaged)
Thailand	No	Chair National IGBP Committee
Togo	Yes	Chair National LOICZ Sub-Committee
Tunisia	No	Chair National IGBP Committee
United Kingdom	No	National IGBP Committee nominated Individual
United States	No	Three contacts, Board of Global Change (IGBP contact)

Of the 69 countries with an IGBP National Committee contacted in 1994, 49 countries responded to the request of the LOICZ Core Project Office for information on the status of national LOICZ contact points. In 17 countries LOICZ (sub-)committees have been established, and 32 countries have identified LOICZ contact points.

The LOICZ Core Project Office has established an independent mailing list of LOICZ Corresponding Scientists which encompasses as of January 1995 1,100 individual scientists in 124 countries.

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Appendix 4
Indicative Framework Budget

Background

The financial requirements for implementing the LOICZ Project and this Implementation Plan can be considered under three major categories:

- Costs of implementing the individual Activities, Tasks and Sub-tasks detailed in the Implementation Plan
- Co-ordination and management costs of the project
- Costs associated with the implementation of Integrative Activities (Core Research), initiated by the LOICZ-SSC and operated through the Core Project Office

As discussed elsewhere in this document the IGBP is financed through national contributions to the central funding of the programme, together with funding of national research designed to contribute to the goals and objectives of the Core Projects. The Core Project Offices are funded under individual agreements between the host government (in the case of LOICZ the Netherlands Government) and the IGBP Secretariat.

In comparison with the relatively uniform environment of the Open Ocean, or the rapidly mixed environment of the atmosphere, the spatial and temporal heterogeneity of the world's coastal zones is considerable. There are as a consequence considerable methodological problems associated with developing global perspectives of the role of this compartment in the functioning of the total Earth system. Identifying and quantifying this role and developing scenarios of change in the coastal compartment of the Earth system under anthropogenic and geocentric driving forces of change demands that a considerable body of research is undertaken to describe:

- The nature of the physical and biological heterogeneity of the world's coastal zones
- The extent to which physical and biological process data and models can be extrapolated or transferred from one area to another
- The nature and extent of variation in the socio-economic conditions driving coastal change
- The nature of and variation in the biological and physical processes currently occurring in coastal areas
- The nature of changes which might be expected to occur under differing scenarios of global change

In addition, the spatial linearity of the domain under consideration places unusual demands, and constraints, on data collection and modelling, which are not comparable for many other Core Projects of IGBP where the two horizontal dimensions are, for the purposes of much process research, equal.

It is clear therefore, that a considerable number of national level research projects will be required in order to merely describe the heterogeneity and complexity of functioning of the coastal systems of the world if global level syntheses and models are to be developed. Managing the outputs from such research will require a correspondingly large investment if the global level goals and objectives of LOICZ are to be achieved.

Costs of Implementing the Individual Activities, Tasks and Sub-tasks Detailed in the Implementation Plan

No attempt is made to produce a costing for the individual Activities, Tasks, and Sub-Tasks described under the various Foci of this Implementation Plan, since the costs will vary considerably according to local in-country costs of equipment, manpower and other resources. In addition different combinations of Tasks and Sub-tasks might be undertaken as single, nationally funded projects contributing to LOICZ. Nevertheless an overview of the Activities, Tasks and Sub-tasks described in the chapters on the four foci would suggest that the costs are substantial. Thus undertaking a cost-benefit and other economic analyses of alternative uses of mangrove ecosystems (Focus 4, Activity 4.1.3) on a globally co-ordinated basis would require, at an absolute minimum, 7 sets of paired studies in Central America, the insular Caribbean, West Africa, East Africa, South Asia, Southeast Asia and the Pacific regions if a global perspective were to be achieved. The costs of a full set of such national level studies could therefore be conservatively estimated at around US$ 350,000. A number of mangrove research programmes are already in place which, with little added cost could produce the additional data required, thus substantially reducing the overall costs at a national level of achieving the LOICZ research goals and objectives.

In funding individual national level research activities which are designated by national IGBP committees as contributions to LOICZ, adequate allowance within the project budget must be made for at least the costs of communication, including the costs of electronic transfer of synoptic data to the Core Project Office or designated research and/or regional node. In addition where specific planned international activities of LOICZ such as the Annual Open Science Meetings are known in advance, the costs of participation of scientists in such centrally co-ordinated LOICZ activities should also be included in the project budget where appropriate. In general terms, such additional costs are likely to be modest in comparison with the overall budget for each project, but a failure to fund these minimal additional activities will seriously compromise the capacity of the Core Project Office to generate the necessary global syntheses and models.

The programme management chapter of this Implementation Plan outlines the proposed mode of operation of the Core Project Office and LOICZ project in achieving the global goals and objectives of the project as a whole. It is envisaged that institutions will be designated as regional and/or research nodes with responsibility for networking and transfer of data and information amongst designated sub-sets of the overall LOICZ network. No adequate mechanism exists within the IGBP framework at present for meeting the costs of such decentralised co-ordination functions. In addition, as discussed below, the funding of the Core Project Office, although comparatively generous for the planning phase, is inadequate for funding the level of activity envisaged once implementation commences.

It is therefore critical that the IGBP Secretariat and SC-IGBP work closely with the Core Project Office and bodies such as IGFA to identify appropriate mechanisms for adequately funding the Project, *prior to the commencement of the Implementation Phase.* Suggestions concerning such a mechanism, including the establishment of a LOICZ Trust Fund, are provided in the Recommendations and Conclusions of this Appendix.

Co-ordination and Management Costs of the Project

The functions of the Core Project Office[22] include *inter alia:*

- Administering the project on a day to day basis, under the long-term guidance of the SSC
- Co-ordination of research efforts, and planning and co-ordinating research campaigns and field programmes
- Maintaining needed connections with relevant national and regional projects
- Ensuring effective co-ordination with other components of the IGBP, and other relevant international research programmes
- Disseminating information and research results

Funding for the Core Project Office was initially agreed by the Netherlands Government at the levels indicated in Table 4. These funds were envisaged as covering the salary and emoluments of the Core Project Manager, a Project Scientist and a full-time Secretary; office operational costs; an appropriation for the organisation of meetings related to project development; communication costs including production of a newsletter; funds for travel by project staff; and funds to support the travel of designated individuals to project and related meetings.

Table 4. Agreed funding of the LOICZ Core Project Office as of 1993 (Nfl 1,000; 1.9 Nfl = 1 US$).

Year	1993	1994	1995	1996	1997
Government grant	400	700	800	800	800
Host Institution	80	160	160	160	160
Total	480	860	960	960	960

Funding for the initial central planning and development of the Project, for network establishment and development of the structure and modalities of operation of the Core Project Office is therefore more than adequately met from this level of appropriation. It was envisaged in the definition study prepared by the Netherlands Organisation for Scientific Research, on behalf of the Netherlands Ministry of Education and Science, that there would be a need for additional staff, in particular a data management specialist and modelling specialist early in the development of the Project, thus bringing the staffing level of the Core Project Office to five full-time staff. Funds for these additional staff are not included in the above appropriation and were envisaged as being sought separately, to a total of 70, 95, 100, and 110 thousand US$ in years 2, 3, 4 and 5 of operation respectively. Total operational costs for the Core Project Office were therefore foreseen as indicated in Table 5.

[22] IGBP,1993. p. 39

Table 5. Anticipated costs of the LOICZ Core Project Office as foreseen in the Core Project Office Definition study. (Nfl 1,000; 1.9 Nfl = 1 US$).

Year	1	2	3	4	5
Government grant	815	890	815	840	865
Additional funds	115	310	375	400	425
Total	930	1200	1190	1240	1290

The Core Project Office opened in November 1993 with the appointment of the Core Project Manager, nine months later than originally envisaged. Despite the initial delay in development of the Project and the Core Project Office, considerable progress has been made to date in defining both the nature of the Project itself and the role of the Core Project Office within the project. The future co-ordination and management roles of the Core Project Office are essentially outlined by the Framework Activities, Programme Management, and Integrative Activity chapters of this Implementation Plan, hence it is possible to define more precisely the financial requirements of the Core Project Office over the next four to five years. The Integrative Activities of "The role of coastal seas in the global carbon cycle" and "Integrated approaches to assessing the economic and social impacts of global change in coastal systems" are budgeted as separate projects and have already been submitted to the United Nations Environment Programme (UNEP) for consideration for inclusion in their work plan for funding under the Global Environment Facility (GEF). Considerable enthusiasm for these projects has been generated within and outside UNEP and the full framework budgets for these activities are provided below.

Future Budgetary Requirements of the Core Project Office

To execute the functions indicated in the Framework Activities and Programme Management chapters of this Plan considerable funds in addition to those originally envisaged as being required must be made available to support the convening of workshops; publication of methods manuals, reviews of current science, syntheses of results; electronic and other communication. Unlike many of the other Core Projects of the IGBP, LOICZ cannot achieve its overall goals and objectives without the active participation of scientists from developing countries; hence financial and other support must be provided through the Core Project to support the research envisaged as being undertaken in such countries which encompass the bulk of the world's tropical coastlines. These coastlines are also those where the rates of anthropogenically driven change are considerably greater than in much of the world's higher latitude coastal areas. It must also be recognised that communication with scientists in much of the developing world will have to be via print media, phone, fax and letter for much of the life of the project since access to means of communication such as e-mail and electronic data transfer is currently, and will remain for the foreseeable future, restricted in such countries.

Table 6 provides an indicative Framework budget for the entire project based on the assumption that all project goals and objectives are to be adequately addressed over the remaining 9 years of the project. These figures represent the total sums required including the budgetary appropriations as currently agreed between the Netherlands Government and the IGBP Secretariat. The following notes relate to the relevant budget lines in Table 6.

Table 6. Framework Budget (1,000 US$) for the Operation of the Core Project Office, based on the assumption that all project goals and objectives are to be adequately addressed over the 9 remaining years of the project.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
Project Personnel	235	285	335	335	335	335	335	315	315	78	2,903
Core Project Manager	120	120	120	120	120	120	120	120	120	60	1,140
Project Scientist Data	60	60	60	60	60	60	60	60	60	-	540
Project Scientist Modeller	-	30	60	60	60	60	60	60	60	-	450
Data entry operators	10	20	40	40	40	40	40	20	20	-	270
Executive Secretary	35	35	35	35	35	35	35	35	35	18	333
Typist/clerk	10	20	20	20	20	20	20	20	20	-	170
Consultants	60	80	80	60	60	60	60	80	80	40	660
Administrative support	-	30	85	85	85	85	85	85	85	18	623
Administrative Assistant	-	20	35	35	35	35	35	25	35	18	273
Secretary/typist	-	10	20	20	20	20	20	20	20	-	150
Temporary Assistance	-	-	30	30	30	30	30	30	20	-	200
Travel	150	180	240	240	240	240	200	150	120	40	1,800
Fellowships	90	120	120	90	48	48	24	24	20	-	594
Sub-contracts	220	240	240	240	260	260	260	260	260	-	2,240
Regional Nodes	100	100	100	100	100	100	100	100	100	-	900
Research Nodes	100	100	100	100	100	100	100	100	100	-	900
Publications & Layout	20	40	40	40	60	60	60	60	60	-	440
Meetings & Workshops	180	295	335	335	380	380	380	380	380	250	3,295
Technical workshops	80	120	160	160	160	160	160	160	160	-	1,320
Regional meetings	-	75	75	75	75	75	75	75	75	-	600
Inter-Regional meetings	-	-	-	-	45	45	45	45	45	-	225
Global Review meetings	100	100	100	100	100	100	100	100	100	250	1,150
Expendable Equipment	15	20	25	25	25	25	25	25	25	-	210
Non-Expendable Equipment	40	50	30	-	-	50	40	-	-	-	210
Premises & Operating Costs	50	50	180	180	180	180	180	180	180	-	1,360
Equipment maintenance	3	5	5	8	10	10	10	10	10	-	71
Reporting costs	139	167	267	415	324	334	334	334	185	-	2,499
Communication costs	30	40	50	50	60	60	80	80	50	-	500
Evaluation costs	-	-	-	-	80	-	-	-	-	120	200
ANNUAL TOTAL	1,212	1,562	1,992	2,063	2,087	2,067	2,013	1,913	1,700	546	17,155
Contingency 5%	61	79	100	103	104	103	101	96	85	27	859
GRAND TOTAL	1,273	1,641	2,092	2,166	2,191	2,170	2,114	2,009	1,785	573	18,014

1. Project personnel

At present the Core Project Office is staffed by a full-time Project Manager and Project Scientist together with a full time professional Secretary. Additional support is currently provided by the Host Institution, NIOZ, in terms of personnel providing computer and electronic backup, assistance with publications and reproduction, and accounting and administration.

To achieve the scientific goals and objectives of LOICZ it is envisaged that at the very minimum one other full-time scientist with specialisation in global modelling will be required from 1996 to the end of the project. A data entry operator should also be appointed to support the project scientist in 1995 and a second operator from 1996 onwards. Already the volume of correspondence is such that a clerk/typist is required to handle the volume of work associated with the substance of the Project.

These additional staff would form the Core Project Office and would be located in the LOICZ Office at NIOZ. They would be responsible to the LOICZ Core Project Manager for the day-to-day operation and management of this Project as a whole. Salary costs are budgeted according to international scales and include allowances and other emoluments.

2. Consultants

It is envisaged that the Chairman and other members of the LOICZ Scientific Steering Committee will be required to devote considerable time on an *ad hoc* basis to the development of various activities and tasks envisaged in this Implementation Plan. Provision is made therefore to fund their full-time participation in project development and implementation for short periods.

In addition, senior professional scientists are envisaged as being employed as consultants on an *ad hoc* basis to provide additional scientific, management and technical advice as required. They would be expected to participate in various regional, inter-regional and global meetings and to undertake travel and to provide advice and assistance to the regional and research nodes as required. Costs are budgeted on the basis of an average of around US$ 300/day, plus international air travel and Daily Subsistence Allowances (DSA). Thus 60,000 US$ allows for around 100 man days per year and five major trips at a cost of US$ 6,000 per travel.

3. Administrative support

At present the Host Institution NIOZ, provides substantial technical and administrative support to the functions of the Core Project Office. It cannot however be expected to provide from within existing resources the additional administrative support required to handle the envisaged volume of work once the project become fully operational. Additional administrative support in terms of a full-time administrative assistant and secretary/typist would be required to handle the accounts, production of publications and their distribution. Some appropriation for part-time and temporary staff is also made to cover holiday periods and periods of peak activity within the Core Project Office.

4. Travel

During the Project it is vital that the staff of the Core Project Office travel extensively and regularly to provide frequent contact with the regional and research nodes once established, to provide project advocacy and to encourage the widest possible participation in the research activities. This budget line includes travel of all senior project staff to meetings, regional nodes and other venues. Travel is budgeted at a rate of US$ 5-7,000 per trip of 7-10 days, including airfares, local transport and DSA. A total of 18 such trips for the Core Project Manager per year and 9 for each of the Project scientists are envisaged once the project becomes fully operational. The Executive Secretary would be required to attend and provide secretariat services to the Annual Open Science Meetings.

5. Fellowships

It is anticipated that scientists from the regional and research nodes and other components of the LOICZ research network will from time to time require training in or. familiarisation with the use of certain equipment and/or models. Provision is therefore made to cover the costs of short visits of around 2 weeks duration for scientists from LOICZ Regional and Research Nodes to visit other LOICZ nodes and or the Core Project Office. Costs are budgeted for air travel and DSA at around 6,000 US$ per fellowship.

6. Sub-contracts

It is envisaged that each LOICZ Regional and Research Node will enter into a formal agreement with the Core Project Office for the implementation of an agreed work plan according to an agreed schedule. Provision is therefore made in the budget to provide, to those nodes requiring such assistance, financial support to execute the agreed functions. Such a sub-contract is envisaged as being a mechanism to provide financial support for, *inter alia*, additional secretarial and administrative assistance, minor equipment items and costs of communications. The precise nature of each sub-contract will vary on a case by case basis but it is intended that the bulk of these funds would be allocated to Institutions acting as nodes in developing countries and countries with economies in transition.

It is recognised that to encourage participation of scientists at sites selected for data collection within each developing country region some provision must be made for the costs of that participation. This budget line allows for a modest sum to be included in the sub-contracts for regional nodes to be transferred to approved institutions having the capacity to undertake the necessary research. These sums are intended to cover the additional costs of data transmission and communications incurred by participation in project research.

7. Meetings

In order to develop the LOICZ networks into functioning collaborative research partnerships directed towards common goals and objectives, it will be necessary to convene regular Annual Open Science Meetings. To ensure adequate global participation in such meetings it will be necessary for the Core Project Office to have access to funds to support the attendance of scientists from less developed countries and countries with economies in transition.

To develop common approaches within LOICZ it will be necessary to develop standardised methods for data collection, management and exchange, and comparable modelling techniques. To develop such common methodologies it will be necessary to convene on a regular basis technical workshops to develop the techniques for wider application throughout the LOICZ network. Given the anticipated research initiatives determined by the overall goals and objectives of the project it is estimated that 4 such workshops will be convened in 1995, 6 in 1996, and 8 in each subsequent year. Each such workshop is costed at around US$ 20,000 and includes the costs of air travel and DSA for between 5 and 10 scientists expert in the subject of the workshop.

Regional meetings are costed at around US$ 25,000 per meeting and include the costs of air travel and DSA for between 10 and 15 LOICZ scientists operating research projects within each region. Such meetings would be convened during the first 4 years, in collaboration with START, as a mechanism to initiate and co-ordinate LOICZ research in regions composed of developing countries and/or countries with economies in transition. During the remaining years of the project such meetings would be used as fora for the comparison of results obtained at different sites within each region. Around 3 such meetings are envisaged annually.

Inter-regional meetings are costed at between 40 and 50 thousand US$ and are envisaged as including representatives (to a total of around 15-20) from two or more regions which are at similar stages of development of the project activities and where the nature of the coastal zones are comparable. One such meeting would be held annually during the last 5 years of the project.

Annual Open Science Meetings are costed at around US$ 100,000 and would include the scientists from all regional and research nodes, a representative selection of scientists from the individual sites and the Scientific Steering Committee (total 30-40 scientists). The Open meeting held in the final year of the Project would review progress and achievements during the course of the ten years of Project Implementation and make recommendations concerning future research and modalities of Implementation.

8. Expendable equipment

Property or equipment purchased for the Core Project Office with a cost per item under US$ 500, for which inventory records are not maintained; e.g., office supplies, books and documents, simpler computer software, etc.

9. Non-expendable equipment

Whilst it is recognised that considerable capacity exists within the Host Institution, the Core Project Office will require access to additional computers, work stations and GIS and other software. Provision is made to equip the Core Project Office with the necessary hardware and software to provide overall co-ordination of database preparation, storage, maintenance and exchange, and for development of models and their distribution throughout the LOICZ research network.

10. Premises and operating costs

This line includes the costs of operating the Core Project Office, including office consumables, heating, lighting, cleaning and space rental. During 1995 and 1996 adequate space is available to the Core Project Office of LOICZ in the host Institute, The Netherlands Institute for Sea Research. Beyond 1996 however additional space would be required, exceeding the existing capacity of NIOZ.

11. Equipment maintenance

Costs of maintenance and repair of equipment purchased for the Core Project Office.

12. Reporting costs

Editing, translating, printing and distribution of reports and publications. It is recognised that an obligation exists to produce the products of LOICZ activities only in English. It would however be advantageous to provide translations at least of summaries of major achievements in other major languages such as French, Spanish, Russian, Chinese and Arabic. The costs of such activities are not included in the present figures.

A number of different types of publication are anticipated as being produced internally by the project during the implementation phase. These range from a regular quarterly newsletter, through meeting and workshop reports to directories, databases, and manuals and guidelines for methods standards and protocols. A summary of the anticipated costs, based on the assumption that all goals and objectives of LOICZ are addressed during the remaining lifespan of the Project is provided in Table 7. Printing costs are based on quotations from printing firms in the Netherlands and these could be substantially reduced by printing through the IGBP Secretariat in Stockholm, or by printing in Singapore or Hong Kong.

Directories of LOICZ scientists and LOICZ research will be produced at regular (biennial) intervals for distribution through the IGBP and LOICZ networks. As of November 1994 the mailing list of LOICZ Corresponding Scientists numbered 1,000 individuals in 124 countries. It is anticipated that at the peak of implementation of the LOICZ Project this listing will extend to some 5,000 active scientists engaged in global change related research in the coastal zone. Production of directories of approved research is a requirement of the IGBP Core Projects, whilst directories of LOICZ Researchers and Corresponding scientists will facilitate direct communication between individuals having similar or related research interests. Costs are estimated on the basis of production and direct mailing of 5,000 copies and bulk mailing of an additional 1,000 copies. Each Directory is estimated at between 60 and 100 pages produced in B4 size.

Quarterly newsletter. As noted in the Framework Activities chapter of this Implementation Plan a quarterly newsletter will be produced in hard copy and electronic form in order to provide the LOICZ network and the wider IGBP network with information concerning developments and activities in the LOICZ Core Project. The first issue is planned for April 1995 and in the first two years 3,000 copies will be printed for bulk and direct mailing rising to 5,000 copies from 1997 onwards. Initial size will be 8 sides of A4 centre folded. Approximate printing and mailing costs are estimated at US$ 2.50 a copy.

Table 7. Anticipated costs (US$) of internal publications during the implementation of the LOICZ Project.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
LOICZ Directories	8,000	8,000	10,000	10,000	12,000	12,000	12,000	12,000	-	84,000
Researchers	8,000	-	10,000	-	12,000	-	12,000	-	-	42,000
Research	-	8,000	-	10,000	-	12,000	-	12,000	-	42,000
Quarterly Newsletter	**22,500**	**30,000**	**50,000**	**50,000**	**50,000**	**50,000**	**50,000**	**50,000**	**50,000**	**402,500**
Meeting Reports	**16,000**	**24,000**	**32,000**	**32,000**	**32,000**	**32,000**	**32,000**	**32,000**		**232,000**
Reports & Studies	**92,500**	**105,000**	**175,000**	**322,500**	**230,000**	**240,000**	**240,000**	**240,000**	**135,000**	**1,780,000**
Data System Plan	17,500	-	-	22,500	-	-	-	-	-	40,000
Databases	17,500	35,000	70,000	105,000	105,000	105,000	105,000	105,000	-	647,500
Syntheses & Reviews	22,500	-	-	90,000	90,000	135,000	135,000	135,000	135,000	742,500
Methods standards & Protocols	35,000	70,000	105,000	105,000	35,000	-	-	-		350,000
Annual Total	**139,000**	**167,000**	**267,000**	**414,500**	**324,000**	**334,000**	**334,000**	**334,000**	**185,000**	**2,498,500**
Contingency	6,950	8,350	13,350	20,225	16,200	16,700	16,700	16,700	9,250	124,925
Grand Total	**145,950**	**175,350**	**280,350**	**435,225**	**340,200**	**350,700**	**350,700**	**350,700**	**194,250**	**2,623,425**

Meeting reports will be produced as technical documents recording the substantive decisions of planning workshops and a record of the discussions. They will be produced on A4 size, side stapled for distribution to LOICZ researchers having identified interests in the subject of the meeting or workshop concerned. It is anticipated that around 1,000 copies of each report will be produced, and it is estimated that during 1995 and 1996 4 and 6 such workshops will be convened and run by the Core Project Office, primarily concerned with developing standards, methods and protocols. From 1997 to the end of the project's main implementation phase in 2002, some 8 workshops or meetings will be held annually to develop the project science, review findings and provide guidance to subsequent actions undertaken within the framework of the Project as a whole. Overall printing and mailing costs are estimated at US$ 4 a copy

Reports and studies containing a variety of materials from guidelines for modelling and standards and protocols for LOICZ approved research, to syntheses of results and reviews of specific areas of LOICZ Science will be produced throughout the life of the project. It is anticipated that approximately 5,000 copies of these documents will be produced and mailed. Production of 60 page documents in B4 size, centred stapled and with 8 pages of colour will be the standard adopted for reviews and syntheses. Approximate costs of production are estimated at around US$ 2.50 a copy, mailing at US$ 2 a copy giving a total of 22,500 US$ per document. For databases and methods colour will not be included and costs of printing and mailing are estimated at US$ 3.50 per copy or US$ 17,500 per document.

13. Communication costs

Given the anticipated size of the network of LOICZ Researchers and Corresponding Scientists it is anticipated that the costs of communication by phone, fax and electronic media will substantially exceed the capacity of the Host Institution. Costs are estimated on the basis of known costs for similar sized offices operating in an international arena and include postage and telecommunications costs, freight and port clearance charges not included under other lines.

14. Evaluation costs

Fees, travel and DSA of consultants hired to evaluate the management and substantive results of the project. A mid-term evaluation is planned in 1998 and a terminal evaluation on completion of the Project. This latter activity is envisaged as also providing a useful mechanism for a review of any subsequent activities which might be planned on the basis of the results of the current project.

15. Contingency

5% of the total costs of the project.

Discussion

The definition study for the Core Project Office commissioned by the Netherlands organisation for scientific research (NWO, 1993) estimated the costs of the Core Project Office as rising to one and a quarter million guilders by 1996. This estimate was based on

the requirements of the science plan, which does not contain details of the modalities of implementation. This estimate included:

- Five staff (Project Manager, Scientific Officer, Data specialist, modelling specialist and one full-time Secretary)
- Staff Travel costs of US$ 100,000 per annum
- Meeting and travel subsidies of US$ 150-200,000 per annum
- Costs of housing and equipping the office of US$ 50-80,000 per annum

The present estimate is based on the further elaboration of the scientific issues and uncertainties outlined in the Science Plan and a more well defined statement concerning the modalities of operation of the Office and Implementation of the Project as a whole. It presents therefore a more realistic estimate of the costs of co-ordinating in an effective and efficient manner the nationally funded research which might be undertaken to address the overall goals and objectives. A failure to fund the Core project Office at this level will severely constrain the ability of the Office to comply with the requirements of the IGBP in terms of realising the goals and objectives of the LOICZ Core Project.

Indicative Framework Budget for the Integrative (Core Research) Activity: "The role of coastal seas in the global carbon cycle"

The following notes correspond to the budget lines highlighted in Table 8.

1. Personnel

A Senior Scientist is required as overall Project Co-ordinator for the duration of this Core Research Activity, supported during the Preparatory and Operational Phases by an Executive Secretary. At the commencement of the First Operational Phase a Project Scientist would be required to provide on-site training in the use of equipment at the regional nodes; technical backup to the implementation of the regional programmes and overall co-ordination of international data management and exchange procedures.

During the second year of Operational Phase 2 (year 7 of this Activity) a scientist will be appointed with expertise in modelling to assist the regional nodes in finalising budget models in preparation for systems modelling, and to collate the global carbon budget data. A systems modeller would be appointed at the end of this year to help facilitate the development of regional systems models by the regional nodes. Both modellers would be retained during Operational Phase 3 to assist in inter-regional model testing and validation and develop global syntheses and models. It is probable that some technical assistance will need to be provided to these modellers in executing these functions.

These staff would form the co-ordination unit for this Integrative (Core Research) Activity and would be located in the LOICZ Core Project Office. They would be responsible to the LOICZ Core Project Manager for the day-to-day operation and management of this Activity. Salary costs are budgeted according to international scales and include allowances and other emoluments.

Table 8. Indicative Framework Budget (1,000 US$) for The Integrative (Core Research) Activity: "The role of coastal seas in the global carbon cycle".

	Preparatory Phase	Operational Phase 1				Operational Phase 2				Operational Phase 3		10 yr. Total
	10 Mths	Year 1	Year 2	Year 3	Year 4	Year 1	Year 2	Year 3		Year 1	Year 2	
Project Personnel	140	210	210	210	210	210	290	290		290	290	2,350
Project Co-ordinator	110	120	120	120	120	120	120	120		120	120	1,190
Project Scientist	-	60	60	60	60	60	60	-		-	-	360
Modellers x 2	-	-	-	-	-	-	80	140		140	140	500
Executive Secretary	30	30	30	30	30	30	30	30		30	30	300
Consultants	60	60	60	60	100	80	60	60		80	80	700
Administrative support	-	55	55	55	55	60	60	60		60	50	510
Admin. Assistant	-	25	25	25	25	25	25	25		25	25	225
Secretary typist	-	20	20	20	20	20	20	20		20	25	185
Temporary Assistance	-	10	10	10	10	15	15	15		15	-	100
Travel	60	120	120	100	120	100	100	120		80	80	1,000
Fellowships	-	150	50	-	-	150	50	-		-	-	400
Sub-contracts	-	500	1,050	1,050	1,050	1,050	1,050	500		300	-	6,550
Regional nodes	-	500	500	500	500	500	500	500		300	-	3,800
Sites	-	-	150	150	150	150	150	-		-	-	750
Ship charter	-	-	400	400	400	400	400	-		-	-	2,000
Meetings	50	250	100	250	100	250	200	200		200	250	1,850
Regional mtgs.	-	250	-	250	-	250	-	-		-	-	750
Inter-Regional mtgs.	-	-	100	-	-	-	200	-		200	-	500
Global mtgs.	50	-	-	-	100	-	-	200		-	250	600
Expendable Equipment	10	25	30	30	30	30	50	50		50	15	320
Non-Expendable Equipment	20	2,660	100	100	100	650	50	100		-	-	3,780
Premises & Operating Costs	100	150	150	150	150	150	180	200		200	200	1,630
Equipment maintenance	-	5	50	60	70	70	70	50		30	20	425
Reporting costs	15	25	25	25	50	30	30	50		20	80	350
Communication costs	15	20	25	30	30	30	30	35		30	20	265
Evaluation costs	-	-	-	-	80	-	-	80		-	100	260
Annual Total	470	4,230	2,025	2,120	2,145	2,860	2,220	1,795		1,340	1,185	20,390
Contingency	24	212	101	106	107	143	111	90		67	59	1,020
GRAND TOTAL	494	4,442	2,126	2,226	2,252	3,003	2,331	1,885		1,407	1,244	21,410

2. Consultants

It is envisaged that an international group of experts of around 5 in number will be retained as scientific and technical advisors to this Activity. They would be expected to participate in various regional, inter-regional and global meetings and to undertake *ad hoc* travel and to provide advice and assistance to the regional nodes as required. In addition senior professional scientists are envisaged as being employed as consultants on an *ad hoc* basis to provide additional scientific, management and technical advice as required. Costs are budgeted on the basis of an average of around US$ 300/day, plus international air travel and Daily Subsistence Allowances (DSA). Thus 60,000 US$ allows for around 100 man days per year and five major trips at a cost of US$ 6,000 per travel.

3. Administrative support

An administrative assistant responsible for records and accounts, and a secretary typist would be required full time during the Operational Phases of the Project, and some allowance is made for temporary support in terms of record maintenance and scientific data entry. Such staff would be located in the Co-ordination Unit. Salaries are budgeted according to local scales and include allowances and other emoluments.

4. Travel

During the Preparatory Phase the Project Co-ordinator will need to visit potential regional nodes and sites in order to select those most appropriate. During subsequent years, travel of all project staff to meetings, regional nodes and other venues is included in this line item. Travel is budgeted at a rate of US$ 5-7,000 per trip of 7-10 days, including airfares, local transport and DSA. A total of 24 such trips for the Co-ordinator and Project Scientist, are covered by the US$ 120,000 budgeted in years 1 and 2 of Operational Phase 1 for example.

5. Fellowships

It is anticipated that scientists and laboratory staff from the regional nodes will require training in or familiarisation with the use of certain equipment in order to carry out the work of the Operational Phases 1 and 2. Provision is therefore made to cover the costs of short visits of 2 to 4 weeks duration for a minimum of 30 such fellowships which would be held at laboratories currently operating the equipment envisaged as being placed in the regional research nodes. During Phase 2 provision is made for training in the use of computer equipment and modelling software where this is required. Such training could be provided under existing bilateral agreements, but reliance on such arrangements could delay the implementation of the first Operational Phase.

6. Sub-contracts

It is envisaged that each regional node will enter into a sub-contract under which they will conduct the necessary research, provide support to selected sites within their regions and participate in the exchange of data, models and results. The precise nature of each sub-contract will vary on a case by case basis, but provision is made to pay part of the salary of the scientist(s) responsible for the operation of each regional node and the salary of at least one laboratory assistant. Additional funds for operating and reporting costs are

also included under this line, but the cost of equipment and repair is listed separately in the budget table. Each node would be responsible for data collection and analysis from between five and ten sites within their region of responsibility.

It is recognised that to encourage participation of scientists at sites selected for data collection within each region, provision must be made for the costs of that participation. This budget line allows for a modest sum to be transferred to approved institutions having the capacity to undertake the necessary sampling to cover the costs of sampling and transhipment of materials to the regional nodes for analysis.

In order to ensure adequate spatial coverage, particularly of off-shore sites, provision is made for ship charter since it is recognised that not all regional nodes will have access to research vessels. Costs of this line could be reduced where such vessels are available and where selected sites correspond to areas being visited for other research purposes.

7. Meetings

Regional meetings are costed at around US$ 25,000 per meeting and include the costs of air travel and DSA for between 10 and 15 scientists operating the selected sites within each region. Inter-regional meetings are costed at between 40 and 50 thousand US$ and are envisaged as including representatives (to a total of around 15-20) from two or more regions which are at similar stages of development of the project and where the nature of the coastal zones are comparable. Global meetings are costed at around US$ 100,000 and would include the scientists from all regional nodes, a representative selection of scientists from the individual sites and the scientific advisory panel (total 30-40 scientists).

8. Expendable equipment

Property or equipment with a cost per item under US$ 500, for which inventory records are not maintained; e.g., office supplies, books and documents, simpler computer software, etc. These costs relate to the operation of the Research Activity Co-ordination Unit.

9. Non-expendable equipment

Whilst it is recognised that regional nodes will, in all probability, already possess some or all of the equipment required to participate in this Activity, a full costing for ten regional nodes is included in the first year of Operational Phase 1. During the Preparatory Phase and first year of Operational Phase 1, provision is made for equipping the Co-ordination Unit with computers, printers, software, facsimiles and other items of non-expendable equipment. During years 2 and 3 of Operational Phase 1 some provision is made for replacement of equipment while in year 4 of Operational Phase 1 and year 1 of Operational Phase 2 provision is made equip the co-ordination office with the necessary computer hardware and software to run the models, and to up-grade a selection of the more advanced regional computing capabilities to ensure their involvement in the development and validation of regional models. All equipment purchased by the Research Activity and installed at the regional nodes would remain the property of the Co-ordinating Unit until the completion of the Research Activity at which time ownership would revert to the institution acting as regional node.

Each regional node will require the analytical equipment detailed in Table 9 for which approximate costings are provided.

Table 9. Costs (US$) of equipping a regional Node to participate in the project "The role of coastal seas in the global carbon cycle".

1 CN element analyser	70,000
1 DOC analyser	70,000
1 infrared spectrometer	20,000
1 computerised potentiometer	20,000
1 self contained CTD	20,000
1 portable winch & water bottles	20,000
2 portable computer, printer	10,000
1 precision photometer	15,000
1 sediment grab	5,000
miscellaneous equipment (filtration etc.)	10,000
TOTAL	260,000

10. Premises and operating costs

This line includes the costs of operating the co-ordinating office, including office consumables, heating, lighting, cleaning and space rental. During the Preparatory Phase it is envisaged that the Core Project Office of LOICZ and the host institute, The Netherlands Institute for Sea Research, would underwrite these costs.

11. Equipment maintenance

Costs of maintenance and repair of equipment purchased as part of this research activity.

12. Reporting costs

Editing, translating, printing and distribution of reports and publications.

13. Communication costs

Postage and telecommunications costs, freight and port clearance charges.

14. Evaluation costs

Fees, travel and DSA of consultants hired to evaluate the management and substantive results of the project.

15. Contingency

5% of the total costs of the project.

Discussion

The indicative framework budget presented in Table 8 is prepared on the basis of the following assumptions:

- That much of the Northern hemisphere would be covered through national activities funded directly by the governments of developed countries (equivalent to fifteen additional regional nodes)
- That ten regional research nodes are required to ensure minimal coverage of areas outside the domain of developed countries
- That no laboratories in developing countries are fully equipped to carry out the analytical work required
- That financial support for participation of scientists from developing countries and countries with economies in transition will be required in order to guarantee their participation
- That no research vessels are available to the institutions selected as regional nodes to be funded through this programme
- That the operating costs of the co-ordination unit, including office space must be met from within the project budget

The Budget is therefore a total costing for de novo establishment and implementation of this Integrative (Core Research) Activity.

Overall costs to the budget of this Activity could be reduced by:

- Provision of ship time through bilateral agreements
- Donation of equipment by governments, through bilateral and multi-lateral aid and assistance programmes
- Provision of fellowships by governments of the host institutions providing the training
- Provision of space and office maintenance costs by the Host Institution

Indicative Framework Budget for the Integrative (Core Research) Activity: "Integrated approaches to assessing the economic and social impacts of global change in coastal systems"

The notes provided below relate to the budget lines highlighted in Table 10 which represents the estimated costs of the Mediterranean regional component of this Activity. Costs for the Southeast Asian and Pacific Regional components are estimated to be between 1.5 and 2 million US$ greater than this component. The Global Modelling Phase is estimated to cost between 2.5 and 3.0 million US$ over 3 years, commencing with a preparatory phase in the year 2000.

1. Personnel

Professional level staff with fixed term contracts; salary scales and benefits calculated according to international scales. The Activity Co-ordinator, and Executive Secretary would be located in the LOICZ Core Project Office, Netherlands Institute of Sea Research, and the Scientist would be out-posted to the Co-ordinating Unit of the Mediterranean Action Plan in Athens.

Table 10. Indicative Framework Budget (1,000 US$) for the Mediterranean regional component of the Integrative Activity (Core Research): "Integrated approaches to assessing the economic and social impacts of global change in coastal systems".

	Preparatory Phase	Operational Phase			46 Mth Total
	10 Mths	Year 1	Year 2	Year 3	
Activity Personnel	**175**	**210**	**210**	**210**	**805**
Co-ordinator 46 mths.	100	120	120	120	460
Scientist 46 mths	50	60	60	60	230
Executive Secretary 46 mths	25	30	30	30	115
Consultants 56 mths	**120**	**300**	**300**	**300**	**1020**
Administrative support	**25**	**85**	**85**	**85**	**280**
Admin. Assistant 36 mths.	-	25	25	25	75
Secretary typist 46 mths	17	20	20	20	77
Temporary Assistance 76 mths	8	40	40	40	128
Travel	**100**	**120**	**120**	**120**	**460**
Sub-contracts	**-**	**350**	**200**	**100**	**650**
Meetings	**50**	**100**	**100**	**100**	**350**
Expendable Equipment	**10**	**25**	**15**	**10**	**60**
Non-Expendable Equipment	**20**	**60**	**40**	**5**	**125**
Premises & Overheads	**110**	**150**	**150**	**150**	**560**
Equipment Operation & maintenance	**5**	**8**	**8**	**10**	**31**
Reporting costs	**25**	**15**	**30**	**200**	**270**
Communication costs	**15**	**20**	**25**	**30**	**90**
Evaluation costs	**-**	**-**	**-**	**30**	**30**
Annual Total	**655**	**1,443**	**1,283**	**1,350**	**4,731**
Contingency	**33**	**72**	**64**	**68**	**237**
GRAND TOTAL	**688**	**1,515**	**1,347**	**1,418**	**4,968**

2. Consultants

It is envisaged that an international group of experts of around 5 in number will be retained as scientific and technical advisors to this Activity. They would be expected to participate actively in various meetings; take an active role in the development of the research agenda; undertake *ad hoc* travel; and provide advice and assistance to the LOICZ Core Project Manager and Co-ordinator on the implementation of the Activity. In addition, senior professional scientists are envisaged as being employed as consultants, through special service agreements, to provide active guidance in the implementation of the research; to participate in the analysis of results; and to provide additional scientific, management and technical advice as required. They will work with small networks of institutions and individuals in the region in the implementation of the various components of the overall work plan. Costs are budgeted on the basis of an average of around US$ 300/day, plus international air travel and Daily Subsistence Allowances

(DSA). Thus 60,000 US$ allows for around 100 man days per year and five major trips at a cost of US$ 6,000 per travel. The total budget line allows for approximately 56 months of consultants time.

3. Administrative support

Support level staff with fixed term contracts or hired as temporary assistance. An administrative assistant responsible for records and accounts, and a secretary typist would be required full time during the Operational Phases of the Activity; the former would be located in the Core Project Office the latter out-posted to assist the Scientist in Athens. Some allowance is made for temporary support in terms of record maintenance and scientific data entry. Such staff would be located in the Co-ordination Unit. Salaries are budgeted according to local scales and include allowances and other emoluments.

4. Travel

During the preparatory phase the Co-ordinator will travel extensively in the Mediterranean to visit organisations and institutions connected with the implementation of the many activities of the Mediterranean Action Plan. During subsequent years, travel of all Activity staff to meetings, institutions and other venues is included in this line item. Travel is budgeted at a rate of US$ 5,000 per trip, including airfares, local transport and DSA. A total of 24 such trips for the Co-ordinator and Scientist are covered by the US$ 120,000 budgeted in years 1 and 2 of Operational Phase 1, for example.

5. Sub-contracts

Contracts with institutions for data compilation, processing, analysis and computer simulations, and for undertaking additional research required to meet the goals of LOICZ Focus 4. The precise nature of each sub-contract will vary on a case by case basis, but provision for personnel and consultancy contracts, purchase, repair and maintenance of equipment, printing and publishing are covered under other budget lines.

It is recognised that in the case of the Southeast Asian Seas and South Pacific Regions this budget line would be substantially larger since the body of existing data in these regions is correspondingly smaller. Therefore additional research would be required and provision will need to be made to cover the costs of such research.

6. Meetings

Regional meetings are costed at around US$ 25,000 per meeting and include the costs of air travel and DSA for around 10 scientists. Costs of participation of project personnel and consultants are included under other budget lines.

7. Expendable equipment

Property or equipment with a cost per item under US$ 500, for which inventory records are not maintained; e.g., office supplies, books and documents, simpler computer software, etc.

8. Non-expendable equipment

Whilst it is recognised that considerable capacity exists within the Mediterranean region, the co-ordinating unit will require access to work stations and GIS software; provision is made to equip the unit with the necessary hardware and software to provide overall co-ordination of data and models.

9. Premises and operating costs

This line includes the costs of operating the co-ordinating office, including office consumables, heating, lighting, cleaning and space rental. During the Preparatory Phase it is envisaged that the Core Project Office of LOICZ and the host Institute, The Netherlands Institute for Sea Research, would underwrite the costs of housing the Co-ordinator and Executive Secretary.

10. Equipment maintenance

Costs of maintenance and repair of equipment purchased as part of this research activity.

11. Reporting costs

Editing, translating, printing and distribution of reports and publications. It is recognised that an obligation exists to produce the final products of this research activity in at least the official UN languages in widespread use in the Mediterranean Region (English, French & Arabic)

12. Communication costs

Postage and telecommunications costs, freight and port clearance charges.

13. Evaluation costs

Fees, travel and DSA of consultants hired to evaluate the management and substantive results of the Core Research Activity.

14. Contingency

5% of the total costs of the Core Research Activity.

Discussion

The indicative framework budget presented in Table 10 is prepared on the basis of an expert assessment of the requirements in the case of the Mediterranean study. It must be recognised that during the Preparatory Phase when the details of the additional research required to meet the goals of LOICZ are better defined the budget could be significantly altered.

Costs for both the Southeast Asian and South Pacific Regions are believed to be considerably higher than those estimated in the case of the Mediterranean since the body of available research and data for these regions is considerably less. It is estimated

therefore that the sub-contracts line would be substantially increased in both cases leading to estimated costs of US$ 5.6 and US$ 6.5 million for these studies. The global modelling phase is estimated to cost between 2.5 and 3.5 million US$. The overall cash flow required for implementation of this Activity is indicated in Table 11.

Table 11. Total cash flow (US$ 1,000,000) required for implementation of the Integrative Activity (Core Research): "Integrated approaches to assessing the economic and social impacts of global change in coastal systems".

Phase	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
MAP	0.7	1.5	1.3	1.4						4.9
SARCS			0.8	1.7	1.5	1.6				5.6
SPREP				0.9	2.0	1.7	1.9			6.5
Global modelling						0.4	0.9	0.8	.0.9	3.0
Total	0.7	1.5	2.1	4.0	3.5	3.7	2.8	0.8	0.9	20.0

Conclusions & Recommendations

The costs of implementing the LOICZ Core Project of the IGBP are substantial, reflecting the spatial heterogeneity of the world's coastal zones and consequently the fact that a greater involvement of developing country scientists is required to achieve the overall goals of this Core Project than for any other IGBP endeavour. Many of the questions and scientific issues of concern to the IGBP in terms of Earth system modelling are of low priority for developing country governments and hence are unlikely to receive financial support from the limited research budgets of such governments.

It is clear therefore that a mechanism must be established which ensures global participation in this Core Project and thus enables the goals and objectives of the Project to be achieved. It is equally clear that the total costs should not be borne by a single government hence it is suggested that a LOICZ Trust Fund be established to be operated in accordance with the financial rules and procedures of the host institution (NIOZ) and the Netherlands Government.

The LOICZ Trust Fund

Operation and management of the fund

A separate LOICZ Trust Fund should be established, subject to the accounting procedures of the Netherlands Government and operated by the Core Project Office. The Fund should be audited annually and the accounts presented to the SC-IGBP and to IGFA.

Decisions concerning the expenditure of the Fund should be the responsibility of the Core Project Manager acting on the advice of a small management group composed of the Chairman and one other member of the LOICZ Scientific Steering Committee, the Director of the Host Institution NIOZ, and the Executive Director of the IGBP or his nominee.

Income

The Trust Fund should be open for the *ad hoc* receipt of funds from any and all sources, including IGBP member Governments, non-governmental organisations, and industrial and commercial concerns. However, reliance solely on such sources of income would inevitably result in a failure to meet the funding targets anticipated in the budgets outlined above.

Since the majority of the costs envisaged in operating the Core Project Office stem from the need to co-ordinate and facilitate collaboration between nationally funded research programmes of global change research in the coastal zone:

> *It is suggested that 1% of the total research budget for all nationally funded LOICZ research projects be designated specifically for support of the international co-ordination functions of LOICZ and transferred to the LOICZ Trust Fund.*

The 1993 IGFA assessment of national government contributions to global change research suggests that participating governments spent a total of 2.24 million US$ on LOICZ research, before the project had even commenced. Once the LOICZ Project reaches full implementation status this figure is likely to be at least comparable to that of JGOFS which reached 42 million US$ in 1993. This source of revenue would therefore generate around 420,000 US$ or 20% of the anticipated requirements. Assuming that the Netherlands Government continues to support the Core Project Office at the originally planned level of approximately 500,000 US$ or 23% of the anticipated requirements, then a shortfall of 57% would remain.

The Framework budget presented above is based on the following assumptions:

- That neither of the Integrative Activities are funded
- That no cost recovery of publications is attempted
- That additional space requirements would have to be rented
- That all meeting costs would have to be met from the recurrent budget

If both Integrative Activities are funded then an estimated 10% of the Core Project Office costs could be saved through a combination of administrative support functions, and redistribution of responsibilities amongst the additional personnel and resources made available to the Core Project Office as a whole.

Between 12 and 20% of the annual budget involves the production and free distribution of publications. If the IGBP policy of free distribution of all publications were to be rescinded and LOICZ internal publications were to be sold to scientists in developed countries, and if the size of print runs were reduced then an estimated 2-5 % of the annual budget could be saved. This option is not recommended, since the success of the LOICZ Project and the IGBP as a whole is dependent both upon wide participation and wide dissemination of information.

The additional space requirements costed above as rented space and included in the premises and operating costs line, represent around 10% of the annual recurrent budget. An initial, one-off investment of approximately 500,000 US$ by the Netherlands Government in expanding the capacity of the host institution would therefore represent an overall saving of 500,000 US$ over eight years, or approximately 3% per annum.

Around 19% of the annual budget represents support to meetings and workshops. It is anticipated that a substantial proportion of this could be raised through *ad hoc* contributions and support from government and intergovernmental sources.

The annual income requirements could thus be generated in the following manner:

	% of annual requirements
Netherlands Government Contribution	23
1% levy on Nationally funded LOICZ research	20
Savings resulting from funding of the Integrative activities	10
Cost recovery of publications	2 - 5
One-off Investment in additional space construction	3
Ad hoc contributions for workshops and meetings	10
Total	68-73%
Anticipated Shortfall	32-27%

Conclusion

If regular contributions were to be made to a LOICZ Trust Fund to the level of the anticipated funding requirements, this would greatly enhance the efficiency of project management by reducing the time expended in seeking small sums of money from a multiplicity of potential donor agencies to support the individual activities envisaged under this Implementation Plan. In the absence of such a trust fund or central funding mechanism it is estimated that less than one quarter of the goals of LOICZ could be achieved in a ten year time frame. Indeed it would be foolish to even attempt to address the entire contents of this Implementation Plan and at best only one focus should be addressed directly, with only those aspects of the other foci most directly related to the selected Focus being undertaken in support of this reduced sub-set of goals and objectives.

It is strongly recommended that if the required funding cannot be guaranteed then the LOICZ Core Project should either be redefined with more constrained and limited goals and objectives or shelved until such time as the funding is made available.

Appendix 5

Terms of Reference for the Scientific Steering Committee of the Land-Ocean Interactions in the Coastal Zone

Core Project of the IGBP

The following terms of Reference were agreed at the third LOICZ-SSC meeting in Texel, June 1994 and subsequently approved by the IGBP Officer's Meeting in September 1994.

The Scientific Steering Committee (SSC) of the Land-Ocean Interactions in the Coastal Zone, (LOICZ) Core Project of the IGBP, is established by the Scientific Committee of the IGBP (SC-IGBP) which shall be responsible for the appointment of the Chairperson, Vice-Chair and members.

The primary functions of the LOICZ Scientific Steering Committee are:

- To provide scientific guidance and oversee the development, planning and implementation of the LOICZ Core Project
- To provide, on request, scientific advice and assistance to the National Committees and START Regional Committees, in the planning of national and regional research which is designed to contribute to the overall goals of LOICZ
- To encourage national governments, regional and international funding agencies to support the implementation of Core Research and the achievement of LOICZ goals through the provision of adequate support to the necessary national, regional and international research
- To encourage collaboration between the LOICZ Core Project and other IGBP and International Programmes and Agencies concerned with the scientific study and assessment of global change in the coastal zone
- To recommend to the SC-IGBP:
  - Members for appointment by the SC-IGBP to the committee
  - A Chairperson for appointment by the SC-IGBP
  - A Vice-Chair for appointment by the SC-IGBP
  - Such amendments to these terms of reference as may prove necessary from time to time

In undertaking these responsibilities the SSC shall collectively:

- Meet approximately every 9 months and at least once a year, to review progress in the development and implementation of the LOICZ Core Project and to advise the Chairperson and Core Project Manager on the scientific developments which should be initiated or undertaken between meetings
- Prepare and revise guidelines for the conduct of meetings, workshops, and conferences designed to assist the Committee in executing its functions
- Prepare and revise, as necessary, criteria for the identification of national and regional research which contributes to the goals of LOICZ as: Core Research; Regional/National Research; or, Relevant Research

- Develop guidelines for the preparation, publication and distribution of substantive and technical reports resulting from Core Research; from the work of the Core Project Office; and from the LOICZ related activities of the Committee, individually and collectively
- Advise the Core Project Manager, on the necessary actions required of the Core Project Office in support of the work of the Committee
- Consider such other matters as individual members, or the Core Project Manager bring to their attention or are referred to them for consideration by the SC-IGBP

Members of the Scientific Steering Committee serve in their individual capacities and are expected to:

- Attend in full the meetings of the Scientific Steering Committee
- Provide the best possible scientific information and advice concerning their field of specialisation as it relates to the goals and Implementation Plan for the LOICZ Project
- Provide scientific advice to the Chairperson and Core Project Manager on the development and implementation of the project
- Represent the scientific interests of LOICZ at relevant scientific meetings
- Provide a written report to the Core Project Office within one month of attendance at a meeting at the expense of the Core Project Office
- Provide a two way channel of communication between the Scientific Steering Committee and the national and where possible, regional and international research community
- Organise, convene, conduct and provide reports for such LOICZ workshops as shall be agreed by the SSC
- Keep the Core Project Office and Chairperson of the SSC fully informed of all actions directly or indirectly related to LOICZ
- Assist in securing financial and other support for the execution of Core Research, adopted and approved by the Committee

The Chairperson of the Scientific Steering Committee is expected to:

- Chair the meetings of the committee
- Undertake advocacy on behalf of the project and enlist wide international participation in the project
- Work closely with the Core Project Manager in implementing agreed activities between meetings of the Committee
- Report periodically to the SC-IGBP on progress in implementing the project and seek the assistance of the SC-IGBP in addressing difficulties encountered in the implementation
- Represent LOICZ at meetings of the SC-IGBP

The Vice-Chair of the Scientific Steering Committee is expected to:

- Chair the meetings of the committee in the absence of the Chairperson
- Undertake advocacy on behalf of the project and enlist wide international participation in the project
- Assist the chair and the Core Project Manager in implementing agreed activities between meetings of the Committee

Appendix 6
Responsibilities of the Core Project Office

The LOICZ Core Project Office (CPO) is established at the *Nederlands Instituut voor Onderzoek der Zee* (Netherlands Institute of Sea Research, NIOZ), Texel, the Netherlands. The Core Project Office will assist the LOICZ Scientific Steering Committee in planning and carrying out new scientific research; it will also serve as a much-needed channel of communication between scientists working in different countries on various aspects of global change in the coastal zone. An important early task of the Core Project Office will be to assist the SSC in collating information on national and regional programmes of coastal research - to ensure that there is no unnecessary duplication of effort, and that the LOICZ project makes effective use of existing knowledge in its analysis of coastal processes and change at global scales.

The general tasks of the LOICZ Core Project Office as identified in IGBP Report No. 25, are as follows:

- Administering the project on a day-to-day basis, under the long term guidance of the SSC
- Co-ordination of research efforts, and planning and co-ordinating research campaigns and field programmes
- Providing project advocacy and promotion, enlisting wide international participation in the project
- Maintaining needed connections with relevant national and regional projects
- Ensuring effective co-ordination with other components of the IGBP, and other relevant international research programmes
- Disseminating information and research results
- Securing support for the operation of the Office
- Co-ordinate the setting up of databases for the LOICZ project, either at the site of the Office or through a networking system

In addition, the Core Project Office is expected to:

- Provide day to day support to the work of the Committee both individually and collectively
- Provide the technical Secretariat for the meetings of the SSC and other meetings convened by the SSC within the framework of the LOICZ Project

Modalities of Operation

In discharging these functions the Core Project Office will provide infrastructural support to LOICZ framework activities, and day to day management and guidance to Integrative Activities (Core Research) undertaken in accordance with this Implementation Plan.

The Core Project Office shall, with the assistance of the LOICZ-SSC as appropriate, and in close consultation with the IGBP Secretariat, take responsibility for raising the necessary new financial and other resources required to implement activities in the Implementation Plan which fall outside the scope of national research activities.

The Core Project Office will have responsibility for maintaining, as appropriate, formal and informal linkages on behalf of the LOICZ Project, with International Organisations, Institutions and Programmes involved in scientific research on Global Change in the Coastal Zone.

The Core Project Office will, on behalf of the LOICZ-SSC, take primary responsibility for maintaining close collaborative linkages with other IGBP Core Projects and Framework Activities and with the Human Dimensions of Global Environmental Change Programme.

Appendix 7
Benefits and Obligations of Participation in the International LOICZ Project of the IGBP

Benefits Derived by National Participation in the International LOICZ Project

- Facilitation of planning National Programmes through the provision of a scientifically sound organisational framework for research
- Adds to value of national research through provision of complementary information, extending the temporal and spatial coverage
- Access to an international, interdisciplinary, global change and coastal scientific network
- Access to internationally agreed standards and protocols for measurement thus permitting data exchange and compatibility
- Access to data sets and liaison with and between national and international data centres and repositories
- Access to the coastal components of other IGBP Core Projects and activities and relevant international organisations
- Access to consolidated data products and scientific reviews

Obligations & Responsibilities Consequent upon National Participation in the International LOICZ Project

- Establishment of an operational national LOICZ focal point for communication with the Core Project Office and to serve as a channel of communication between the CPO and the national research community
- Development of a national LOICZ Programme addressing the LOICZ Goals & Objectives
- Execution of the programme in accordance with agreed methods and protocols where these exist
- Provision of data and products resulting from the national research activities to agreed data centres when established
- Provision of support to the Core Project Office through regular communication, and through the provision of financial and logistic support to data centres and the CPO where and when appropriate

Appendix 8
Guidelines for LOICZ Involvement in Workshops & Meetings

(Adopted by the 3rd LOICZ-SSC Meeting, Texel, June 1994)

In order to foster interest and participation in the development and implementation of the LOICZ project, the LOICZ Core Project Office (CPO), or members of the LOICZ Scientific Steering Committee (SSC) on behalf of LOICZ, will, from time to time, organise workshops, meetings and related activities concerned with global change and the coastal zone. The involvement of LOICZ in workshops, meetings and related activities organised by other agencies, organisations or institutions will take various forms according to the nature of the activity, its goals and the scope of intended LOICZ participation.

Workshops, Meetings and Related Activities Organised by the LOICZ CPO or SSC

Workshops or periodic open science meetings for which the LOICZ SSC and Core Project Office take primary organisational responsibility will be open to co-sponsorship and support by other organisations and or bodies. In such cases:

- **Co-sponsorship,** by another agency, organisation and/or institution would normally involve financial commitments in support of the activity on the part of that agency, organisation or institution, of a magnitude comparable to that of LOICZ

- **Sponsorship,** by another agency, organisation and/or institution would normally involve commitments in support of the activity, in cash or in kind, on the part of that agency, organisation or institution, but of a lesser magnitude than the contributions of LOICZ or other co-sponsors

- **Supporting agencies, organisations or institutions** would be considered to be those, whose goals coincide with those of LOICZ and which send an official representative(s) or participant(s) to the workshop or meeting. Such participation and/or representation being at the expense of the supporting agency, organisation or institution

The technical reports of LOICZ Workshops or meetings will be published by the Core Project Office. Preparation of these reports for publication will be the responsibility of the Core Project Office or SSC member responsible for the organisation of the activity. Publication of the substantive outputs from such activities will be undertaken on a case by case basis.

Workshops, Meetings and Related Activities Organised by Other Agencies, Organisations or Institutions

LOICZ may from time to time, *sponsor, or co-sponsor* workshops, meetings and related activities organised by other agencies, organisations or institutions with which the LOICZ project has clear collaborative links.

In order to receive *endorsement* by the LOICZ SSC, activities proposed and organised by other agencies, organisations or institutions must meet the following criteria:

- The proposed activity should have well defined objectives and products addressing LOICZ questions, goals and research activities, and should not be held simply for the purpose of presenting scientific papers

- The proposed activity should have involved the active participation of a LOICZ SSC member or the Core Project Office in the planning and development of the agenda

- Notwithstanding the above, the LOICZ SSC may choose from time to time to endorse meetings which are well advanced in their planning before such endorsement is sought, provided that the activity is clearly directed towards some aspect(s) of the goals of LOICZ, and where LOICZ research can be seen to benefit from the activity

LOICZ may from time to time, *support* workshops, meetings and related activities organised by other agencies, organisations or institutions when it is clear that the aims and objectives of the activity are likely to lead to some benefit to LOICZ in achieving its overall goals. This support will be limited to support for an official representative to, or another participant in, the activity. Where LOICZ involvement is limited to support, the LOICZ name and Logo may not be used on any materials produced prior to, or resulting from the activity, without the express, prior permission of the Core Project Office, in writing.

LOICZ supported representatives and/or participants to workshops, meetings and related activities are expected to provide the Core Project Office with a brief report of the outcome of the activity, within one month of their attendance.

Appendix 9
Bibliography

The scientific literature on land-ocean interactions and on global change in coastal zones is extremely diverse, not only with regard to the topics that have been investigated but also in terms of the source journals and books. Some aspects are covered by a large body of relevant information, whereas others have received little attention. As part of the planning for the LOICZ project, a set of key references has been compiled. These are given here; however, for the sake of clarity, only a limited number have been individually cited in the preceding text. The edited books all contain important chapters which have not been individually listed.

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No. 23 Joint Global Ocean Flux Study: Implementation Plan. Published jointly with SCOR. (1992)

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No. 25 Land-Ocean Interactions in the Coastal Zone: Science Plan. Edited by P M Holligan and H de Boois. (1993)

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No. 32 International Global Atmospheric Chemistry (IGAC) Project: The Operational Plan. (1994)

No. 33 Land-Ocean Interactions in the Coastal Zone: Implementation Plan. Edited by J C Pernetta and J D Milliman. (1995)

Appendix 12
Acronyms and Abbreviations

AAECP	ASEAN/Australia Economic Co-operation Programme
ACSYS	Arctic Climate System Study
ASEAN	Association of Southeast Asian Nations.
BAHC	Biospheric Aspects of the Hydrological Cycle (IGBP)
CAMP	Coastal Area Management Plan (UNEP/Mediterranean Priority Actions Programme)
CASP	Canadian Atlantic Storms Program
CFC	Chlorinated Fluorocarbon
CLIP	Climates of the Past (UNESCO)
COBSEA	Co-ordinating Body of the Seas of East Asia (UNEP)
COMAR	Coastal and Marine Research (UNESCO)
CONFLUENCE	(Programme investigating the upwelling region and mixing of the Rio Plata into the SW Atlantic)
CoOP	Coastal Ocean Processes
CPO	Core Project Office (IGBP)
DIS	Data and Infomation System (IGBP)
DMS	Division of Marine Sciences (UNESCO)
EAS	East Asian Seas
EASAP	East Asian Seas Action Programme (UNEP)
ECOMARGE	(Programme of the EU)
ELOISE	European Land-Ocean Interaction Studies
ENSO	El Niño - Southern Oscillation
EROS-2000	European River Ocean System (EU)
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organisation of the United Nations
GAIM	Global Analysis, Interpretation and Modelling (IGBP)
GCTE	Global Change and Terrestrial Ecosystems (IGBP)
GEF	Global Environment Facility
GEMS	Global Environment Monitoring System (UNEP)
GESAMP	Joint Group of Experts on the Scientific Aspects of Marine Pollution (UN)
GLORI	Global Land-Ocean River Inputs database (LOICZ)
GOOS	Global Ocean Observing System (IOC-UNEP-WMO)
GPS	Global Positioning System
GRID	Global Resource Information Database (UNEP)
HDP	Human Dimensions of Global Environmental Change Programme (ISSC)
IAG	International Association of Geodesy
IAPSO	International Association for Physical Sciences of the Ocean
IASC	International Arctic Science Committee
ICAM	Integrated Coastal Area Management (methodology developed by MAP/PAP)

ICLARM	International Centre for Living Aquatic Researce Management
ICSU	International Council of Scientific Unions (ICSU)
IGAC	International Global Atmospheric Chemistry project (IGBP)
IGBP	International Geosphere-Biosphere Programme
IGCP	International Geological Correlation Program
IGFA	International Group of Funding Agencies
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IODE	International Oceanographic Data Exchange (IOC of UNESCO)
IPCC	Intergovernmental Panel on Climate Change
ISSC	International Social Sciences Council
IUCN	The World Conservation Union
JGOFS	Joint Global Ocean Flux Study (IGBP)
KEEP	Kuroshio Edge Exchange Processes
KUSTOS	(Near-coast matter- and energy fluxes: the transition between Land/Sea in the southeastern North Sea)
LMER	Land Margins Ecosystems Research (USA)
LOICZ	Land-Ocean Interactions in the Coastal Zone (IGBP)
LOIS	Land-Ocean Interaction Study
LUCC	Land-Use and Cover Change (IGBP)
MAB	Man and the Biosphere Programme (UNESCO)
MAP	Mediterranean Action Plan (UNEP)
MAP/PAP	Mediterranean Action Plan, Priority Action Programme
MASFLEX	Marginal Sea Flux Experiment in the West Pacific (JGOFS)
MBIS	MacKenzie Basin Impact Study
MPI	Max Planck Institute
NOAA	National Oceanic and Atmospheric Administration (USA)
NOWESP	North-West European Shelf Programme
OCTS	Ocean Colour and Thermal Scanner
OMEX	Ocean Margins Exchange (EU)
PAGES	Past Global Changes (IGBP)
PARAT	(A Study of the Transfer of Particulate and Dissolved Phases from Southern South America to the SW Atlantic Ocean)
PCB	Polychlorinated Biphenols.
RCU	Regional Co-ordinating Unit (for COBSEA)
SAFCOM	START Regional Committee for Southern, Central and Eastern Africa.
SARCS	Southeast Asian Research Centre (START)
SC-IGBP	Scientific Committee of the IGBP
SCOPE	Scientific Committee on Problems of the Environment (ICSU)
SCOR	Scientific Committee on Oceanic Research (ICSU)
SeaWIFS	Sea-viewing Wide Field of View Sensor
SEEP	Shelf Edge Exchange Processes
SPREP	South Pacific Regional Environment Programme
SSC	Scientific Steering Committee (IGBP)
START	Global Change System for Analysis, Research and Training (IGBP)
UNEP	United Nations Environment Programme
UNESCO	United Nations Economic, Scientific and Cultural Organisation
USGS	United States Geological Survey
VLBI	Very Long Baseline Interferometry
WCRP	World Climate Research Programme