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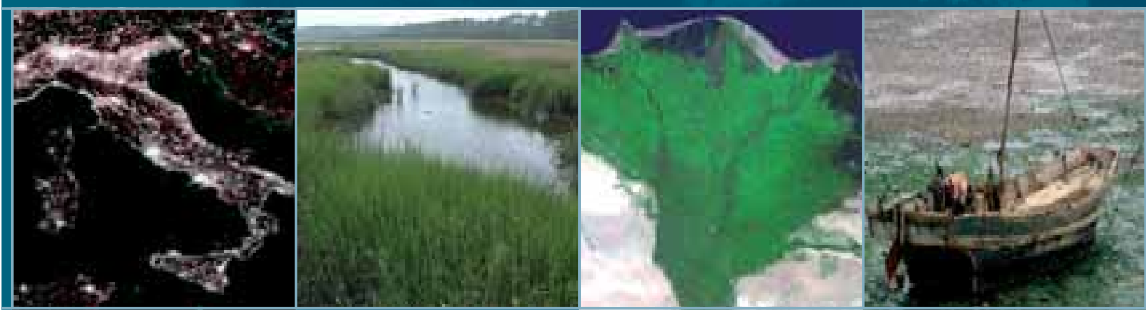
Global Terrestrial Observing System

Coastal GTOS

Strategic design and phase 1 implementation plan



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GEO-SPATIAL DATA AND INFORMATION ENVIRONMENTAL MANAGEMENT ASSESSMENT AND MONITORING [GLOBAL ENVIRONMENTAL CHANGE]

Global Terrestrial Observing System

Coastal GTOS
Strategic design and phase 1 implementation plan

Christian, R.R.,
Baird, D.,
Bowen, R.E.,
Clark, D.M.,
de Mora, S.,
DiGiacomo, P.M.,
Jiménez, J.,
Kineman, J.,
Mazzilli, S.,
Servin G.,
Talaue-McManus, L.,
Viaroli, P.
& Yap, H.

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FOREWORD

Coasts are among the most important areas in the world to humans and one of the most sensitive to anthropogenic impacts at local to global scales. To detect, assess and manage coastal environmental change, there is a clear need for improved environmental and socio-economic information on the coastal zone within the observing system framework.

The issues of the coast are varied and intricately related. The discontinuity between the land and ocean and the transboundary conditions of both source and receiving waters provide complexities that challenge the efforts of global observing systems. Coastal ecosystems and associated habitats and biota provide distinct combinations of valuable ecological goods and services and face intense pressures from human activities such as urbanization, commerce and recreation. Impacts to both human and natural resources come from habitat alteration, increased water use and pollution, erosion and sedimentation, and changing marine waters from storms, tsunamis and sea-level rise.

Coastal management programmes, political instruments, and research activities all require global and regional resource assessments. Information for these efforts comes from *in situ* and remote sensing data collection. But data collection is not enough. There must be an associated data management, model production, and communication infrastructure. This infrastructure needs to provide information freely and in a timely fashion to both developed and developing nations. Capacity is especially needed for the latter nations. The Coastal Module of the Global Terrestrial Observing System (GTOS) is designed to support part of this infrastructure and aid in the capacity building. It is linked to other existing and planned international initiatives including the Coastal Module of the Global Ocean Observing System (GOOS), the Coastal Theme of the Integrated Global Observing Strategy (IGOS) and Coral Reef Sub-theme, and the Global Earth Observation System of Systems (GEOSS).

This document presents a strategy for developing a Coastal Module of GTOS (C-GTOS), describing the design for a mature observing system and contributions to global observation needs. It identifies ways to implement that strategy during the initial phase of the programme through a series of well defined products that are achievable in a relatively short timeframe.

A mature and functioning Coastal Module of GTOS, integrated with other programmes, benefits many. Improved *in situ* and remotely sensed coastal observations and resultant products will provide information for individuals and organizations responsible for global, regional and even local policy-making and environmental management of coastal areas. Validated assessments of condition and change will be made with greater and prescribed accuracy, and the discontinuity of information from land and marine waters will be bridged.

Jeffrey B. Tschirley
Chief,
Environment and Natural Resources Service,
Food and Agriculture Organizaton of the United Nations

ABSTRACT

There is a clear need for information on global and regional change in coastal areas bordering the world's large water bodies. Collection of *in situ* and remote sensing data must be improved and associated data management, model production, and communication infrastructure developed to provide free and timely information to developed and developing nations. To address this need, the Global Terrestrial Observing System (GTOS) has developed a coastal module in collaboration with the Global Ocean Observing System (GOOS), Global Climate Observing System (GCOS), and in combination with the overarching coastal activities of the Integrated Global Observing System (IGOS) and Global Earth Observation System of Systems (GEOSS).

The primary goal of the Coastal Module of the Global Terrestrial Observing System (C-GTOS) is to detect, assess and predict global and large-scale regional change associated with land-based, wetland and freshwater ecosystems along the coast. The approach taken to developing C-GTOS is twofold: a long-term strategic design towards a mature integrated coastal observing system, and the development of a series of five well-defined, priority products achievable in the short term. The mature system focuses on: (i) human dimensions, land use, land cover and critical habitat alteration; (ii) sediment loss and delivery; (iii) water cycle and water quality, and (iv) effects of sea level change, storms and flooding. The five priority products provide proof of concept and help build the mature system.

This document presents the strategy developed by the GTOS coastal panel of scientific experts to establish C-GTOS. The first sections of the document describe the design for a mature observing system and contributions to global observation needs. In the sections following, further details are provided on the five products that implement this strategy during the initial phase of the programme and a discussion of milestones for development of a mature system.

Coastal GTOS Strategic design and phase 1 implementation plan

By Christian, R.R., Baird, D., Bowen, R.E., Clark, D.M., de Mora, S., DiGiacomo, P.M., Jiménez, J., Kineman, J., Mazzilli, S., Servin G., Talaue-McManus, L., Viaroli, P. & Yap H.

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John Latham
GTOS Programme Director

CONTENTS

ACRONYMS

CBD	Convention on Biological Diversity
CEOS	Committee on Earth Observation Satellites
C-GOOS	Coastal Ocean Observations Module of Global Ocean Observing System
C-GTOS	Coastal Module of the Global Terrestrial Observing System
CME	Coastal and Marine Environment
CODAE	Coastal Data Assimilation Experiment
COOP	Coastal Oceans Observations Panel
DLR	German Aerospace Center
DMSP	Defense Meteorological Satellite Program
DOE	US Department of Energy
DPSIR	Driver-Pressure-State-Impact-Response
EEA	European Environmental Agency
EEZ	Exclusive economic zone
ELOISE	European Land–Ocean Interaction Studies
ESA	European Space Agency
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization of the United Nations
GCMD	NASA Global Change Master Directory
GCOS	Global Climate Observing System
GEF	Global Environment Facility
GEO	UNEP Global Environmental Outlook
GEO	Group Environmental Outlook
GEO	Group on Earth Observations
GESAMP	The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GHOST	Global Hierarchical Observing Strategy
GIWA	Global International Waters Assessment
GLOSS	Global Sea Level Observing System
GMA	Global Assessment of the Marine Assessment
GOOS	Global Ocean Observing System
GOSIC	Global Observing Systems Information Center
GPA	Global Programme of Action
GTOS	Global Terrestrial Observing System
HSESDS	Human Systems – Ecological Systems – Delivery Systems
ICAM	Integrated Coastal Area Management
ICAMS	Integrated Coastal Analysis and Monitoring System
ICARM	Integrated Coastal Area and River Basin Management
ICSU	International Council of Science
ICZO	Inland-Coastal Zone-Ocean
IGBP	International Geosphere-Biosphere Programme
IGOS	Integrated Global Observing Strategy
ILTER	International Long Term Ecological Research Network
IOC	Intergovernmental Oceanographic Commission
IPCC	Intergovernmental Panel on Climate Change

ISO	International Organisation for Standardization
IUCN	World Conservation Union
JAXA	Japanese Aerospace Exploration Agency
LaguNet	Italian Network for Ecological Research in Coastal Zone and Transitional Areas
LCCS	Land Cover Classification System
LME	Large Marine Ecosystems
LOICZ	Land-Ocean Interactions in the Coastal Zone
LTER	Long Term Ecological Research Network
LULC	Land use and land cover
MA	Millennium Assessment
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	US National Aeronautics and Space Administration
NEM	Net ecosystem metabolism
NGDC	National Geophysical Data Center
NIMA	US National Imagery and Mapping Agency
NOAA	National Oceanographic and Atmospheric Administration
OECD	Organisation for Economic Co-operation and Development
OLS	Operational Linescan System
ORNL	Oak Ridge National Laboratory
PNEC	Programme National Environnement Côtier
RSP	Regional Seas Programme
SEDAC	Socio Economic Data and Application Center
SIDS	Small Island Developing States
SLR	Sea level rise
SMOS	Soil Moisture and Ocean Salinity
SPA	Specially Protected Areas
SRTM	Shuttle Radar Topography Mission
SSSI	Sites of Special Scientific Interest
TARGETS	Tool to Assess Regional and Global Environment and Health Targets for Sustainability
TEMS	Terrestrial Environmental Monitoring Sites
TOPC	Terrestrial Observation Panel for Climate
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	United Nations Environment Programme
UNEP/DEWA	United Nations Environment Programme Division of Early Warning and assessment
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USCCSP	US Climate Change Science Program
USGS	United States Geological Survey
WCMC	World Conservation Monitoring Centre
WDPA	World Database on Protected Areas
WMO	World Meteorological Organization
WWF	World Wildlife Fund
WSSD	World Summit on Sustainable Development

EXECUTIVE SUMMARY

The primary goal of the Coastal Module of the Global Terrestrial Observing System is to detect, assess and predict global and large-scale regional change associated with land-based, wetland and freshwater ecosystems along coasts.

The coastal zone contains a wide variety of ecosystems that are both important ecologically and highly valued by humans. Biodiversity and productivity are often high, and the processing of energy and materials links terrestrial ecosystems with marine waters and the atmosphere. A significant portion of the human population resides in the coastal zone or uses its resources. Some of the most densely populated areas on earth are along the coast, positioned with high vulnerability to natural disasters.

The coast presents a particular challenge to assessing global change. The discontinuity between the land and ocean provides complexities that challenge the efforts of global observing systems. There is a clear need for information about the coastal zone from an integrated socio-ecological perspective within the observing system framework.

This plan for the Coastal Module of GTOS (C-GTOS) describes the strategic design for a mature observing system and identifies ways to implement that strategy during the initial phase of the programme.

The plan recognizes the need to develop the observing system into a mature and sustainable programme through a series of achievable products. C-GTOS has the following goals:

- Meet the general GTOS mandate.
- Identify users and establish products appropriate to user needs.
- Establish a regime for observing, assessing and predicting global and large-scale regional change for select ecological and associated socio-economic issues.
- Identify a select group of critical, tractable issues to address in the near term, as well as in the long term.
- Link remote and ground-based observations in the coastal zone.
- Provide mechanisms to communicate products to users and receive feedback
- Promote capacity to observe, assess and predict change.

Early efforts by the panel of scientific experts participating in the C-GTOS workshops focused on (i) definitions of the ”coast” and factors that affect differences in definitions and (ii) the selection of appropriate analytical frameworks for choosing critical indicators and assessment tools. Because of the complexity of the environment and the different needs of perceived users, it was decided not to rely on a single definition of the coastal zone, but to maintain definitional flexibility. Potential users variously define the coastal zone in terms of four criteria: (i) management units; (ii) human use dynamics; (iii) area of extent, and (iv) ecosystem functionality. These categories helped structure the design of the plan. The central framework is the Driver-Pressure-State-Impact-Response, which focuses on the interrelationship between human society and environmental issues.

The structure of C-GTOS reflects its interface with the Coastal Module of the Global Ocean Observing System, other research and observing system programmes, and the proposed coastal theme of the Integrated Global Observation Strategy (IGOS). Potential users were identified with consideration of those proposed by the Coastal Module of GOOS. Users, or stakeholders, drive the development of C-GTOS. They are the sources of interest in the issues and variables, the recipients of products from the observing systems and, in some cases, the providers of the observations and financial support.

Observing systems require both field (*in situ*) and remote sensing (satellite and aerial photography) data collected on an ongoing basis. Experts at the workshops selected global and large-scale regional themes and identified a suite of variables and indicators for each. These variables and indicators include (i) human dimensions, land use, land cover and critical habitat alteration; (ii) sediment loss and delivery; (iii) water cycle and water quality and (iv) effects of sea level change, storms and flooding.

Data are harmonized, developed into various information products and communicated to users. At each of these steps, the use of existing and proposed information systems and frameworks is required. The plan identifies these needs, necessary policies and future actions, as well as some first phase implementation products that address data requirements. The GTOS Terrestrial Environmental Monitoring Sites (TEMS) project is one of the information systems identified as central to the identification and cataloguing of data and to the communication of information. TEMS is envisioned as requiring major enhancement to accommodate the needs of C-GTOS. Considerable effort has been made to identify needed enhancements. Many C-GTOS information products will require the distribution and use of geographic information products via the Web, as well as the use of cost-effective PC-based software. C-GTOS will build on existing Web-based information systems such as GeoNetwork of the Food and Agriculture Organization and PC-based products that will also extend information management capacities in developing countries. The volume of data required for C-GTOS and the need to convert those data into information products will require access to advanced informatics techniques and significant capacity development. The information products can be used by stakeholders for policy- and decision-making, and their feedback will provide further information on C-GTOS user needs, in turn providing opportunities for modifications in data collection.

The first phase of C-GTOS will build on a set of readily achievable products that are designed to provide tests of concept for the observing system. These products were chosen based on the needs of the programme and representation of the aforementioned topics of concern. The first phase implementation products are titled as follows:

- enhancement of TEMS;
- distribution and the rate of change of population, urbanization and land use in the coastal environment;
- vulnerability of ecosystem services in deltaic systems;
- management of conservation and cultural sites in the coastal zone;
- distribution of sites appropriate for analyses of delivery systems.

Both initial implementation and development of the mature system have a number of components. Milestones and timelines are proposed for each of the components associated with initial implementation. Beyond these targets, several programmatic elements are required for the development of a mature system. First, it is important to evaluate existing and needed capacity and training in information management, data processing and interpretation (modelling tools), and outreach (including the TEMS and GTOS Web sites). Second, C-GTOS must establish a number of components essential to effective implementation, including a user advisory group, the ability to perform measurements, training and capacity building, product delivery, linkages to other global observing systems and assessments and sustainable funding. Third, the activities of C-GTOS must be integrated with policy and management processes to improve coastal decision-making and resource management. Finally, maintaining programme quality over time will require a process of review and assessment of outcome measures and performance indicators.

Ultimately, the mature C-GTOS is envisioned as being fully interactive and complementary with the coastal activities of GOOS and GCOS. This integration is being fostered through the joint participation of scientific experts involved in the development of the GTOS Coastal Module, and coastal observations within both GOOS and GCOS. In particular, through the development of the integrative Coastal Theme for IGOS. The mature system will require considerable development of capacity in many ways because of the complexity of the landscape and issues of the coast. The approach described in this plan builds on success of priority products to generate the capability, goodwill and enthusiasm of the international community to support a mature observing system.

CHAPTER 1 INTRODUCTION

1.1 NEEDS AND RATIONALE

1.1.1 The coastal zone discontinuity

Coastal ecosystems, found along the margins of the world's large water bodies, are regions of remarkable biological productivity, high accessibility and great importance to society. They have been centres of human activity for millennia. Coral reefs, mangroves, tidal and non-tidal wetlands, sea grass beds, barrier islands, estuaries, peat swamps, lagoons, river reaches, deltas, coastally restricted forests, sea and land ice and other terrestrial ecosystems constitute the integrated, cross-boundary coastal zone. Each of these ecosystems, and its associated habitats and biota, provides its own distinct bundle of goods and services and faces somewhat different pressures from human activity, habitation, commerce and recreation; they provide agricultural products, fish, shellfish and seaweed for both human and animal consumption, and they are a considerable source of fertilizer, pharmaceuticals, consumer products and construction materials (Costanza, 1999; Cohen *et al*., 1997; Jackson, Kurtz and Fisher, 2000; Scialabba, 1998). Valuable ecological services come from a broad range of habitat types harbouring a wealth of species and genetic diversity (Christensen *et al*., 1996; MA, 2003). Coastal ecosystems store and cycle nutrients, filter pollutants from inland freshwater systems, and help to protect shorelines from erosion and storms. Furthermore, near-shore coastal waters provide another suite of ecological goods and services (UNESCO 2003c). Coastal zones are thus among the most important areas in the world to humans and one of the most sensitive to global change.

1.1.2 Global coastal monitoring needs

The global community's early recognition of the importance of coastal ecosystems and monitoring was shown in the outcomes of two conferences: the Convention on Wetlands held in Ramsar, Iran, in 1971, and the UN Conference on the Human Environment held in Stockholm, Sweden, in 1972. In 1992 the UN Conference on Environment and Development in Rio de Janeiro, Brazil, provided an international forum on the concept of sustainable development. The Agenda 21 plan was one of the major resulting products. Chapter 17 of Agenda 21 contained provisions for the protection of oceans, seas, coastal areas and related resources, providing a political instrument for including the sustainable development concept in the management of coastal areas. Commitments to sustainable use of coastal areas have been made since the Rio convention through such global instruments as the UN Convention on the Law of the Sea (UNCLOS), the Convention on Biological

Diversity (CBD), the Barbados Action Plan, the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-Based Activities, and the Food and Agriculture Organization of the United Nations (FAO) Code of Conduct for Responsible Fisheries, and associated action plans (Duda and Sherman, 2002). International organizations and nations alike responded to the new coastal resource management needs in a number of ways. UN agencies developed and endorsed guidelines for Integrated Coastal Area Management (ICAM) (Scialabba, 1998; UNESCO, 2003a; UNEP, 2004). Programmes such as the Regional Seas Programme (RSP) and the Large Marine Ecosystems projects (Sherman and Duda, 1999) drew multinational cooperation, and scientific programmes researched the social and environmental causes of the degradation of coastal resources (GESAMP, 2001).

All of these political instruments, management programmes and research activities require global and regional resource assessments, as well as associated data collection infrastructure. Furthermore, recent environmental targets set by the Millennium Development Goals and the World Summit on Sustainable Development (WSSD) in 2002 emphasize the need for ongoing mechanisms for monitoring coastal areas and strengthening Agenda 21 coastal initiatives. A number of existing and planned international initiatives are being developed in support of these coastal assessment needs. The three global observing systems (Global Terrestrial Observing System [GTOS], Global Climate Observing System [GCOS] and Global Ocean Observing System [GOOS]), in collaboration with their partner global monitoring and research programmes, are addressing this issue through the development of a Coastal Theme for the Integrated Global Observing Strategy (IGOS). This document presents a strategy for developing a Coastal Module of GTOS (C-GTOS) and describes how it will be initially implemented.

1.1.3 Integrating the coastal components of the global observing systems

The coastal zone presents particular challenges to observing systems; the environmental diversity is great, the ecosystems span a wide range of productivities and susceptibilities to disturbance, and human populations are dense in many coastal areas and their activities significantly use and modify habitats (Nixon, 1995; Bijlsma *et al.*, 1996; UNEP, 1997). The oceanographic community conducted early planning efforts through the design of the Coastal GOOS Panel, Living Marine Resources, and Health of the Oceans programmes, under the auspices of the Intergovernmental Oceanographic Commission (IOC). These programmes are currently merged into a common programme using the Coastal Ocean Observations Panel (COOP) (UNESCO, 2000). The COOP strategic plan has been formulated (UNESCO, 2003c), and the implementation plan is being developed for the Coastal Ocean Observations Module of GOOS (C-GOOS). Many of the specific operational activities of these planning efforts are to be implemented through regional and national observing systems. The overall focus is on assessing aspects of global change within the ocean, particularly coastal waters. The land, wetlands and freshwaters are considered important determinants of inputs and boundary conditions for coastal waters. Information about land-based conditions is crucial to C-GOOS, but the acquisition of that information is outside the perceived realm of responsibilities of these oceanographic programmes. Furthermore, assessing socio-economic interactions with global and large-scale change in the coastal zone requires land-based assessments. Therefore, GTOS has initiated the coastal Module, which will be responsible for collecting and managing observations, including socio-economic information, concerning the terrestrial, wetland, coastal freshwater and, when appropriate, transitional water ecosystems.

The development of C-GTOS begins with a vision of its goals (see Section 1.2) and objectives. This vision suggests a strategic design, and details for implementation are established within the context of this design. The Coastal Panel of scientific experts have begun the process of defining goals and objectives for the observing system and establishing steps for its implementation. Several frameworks provide a structure to in which to consider the goals of C-GTOS. The primary one is the Driver-Pressure-State-Impact-Response (DPSIR) framework, which links ecological and human conditions and activities proposed through C-GTOS and the Coastal Theme of the IGOS. Other frameworks provide insight into other complexities of, and interactions within, the coastal zone.

Initially, the C-GTOS Panel of scientific experts identified selected “states” (*sensu* DPSIR) or attributes of the coastal ecosystems associated with state changes. Variables or observations to detect status and change in states were delineated and linked to prospective sources of information on these variables. The C-GTOS Panel members then examined networks of programmes known to sample the coastal environment in ways that can support the observing system. This information was placed in the context of the Terrestrial Environmental Monitoring Sites (TEMS) web database of GTOS, and gaps in our ability to make observations were noted.

Second, the group focused on identifying significant and appropriate questions and priority products for addressing these questions. This iteration narrowed the range of issues of consideration and observations. The group then proposed discrete products to structure the early activities of C-GTOS. These products are designed to provide clear evidence of the value of C-GTOS. Further, the panel members engaged user groups for C-GTOS products. The mature C-GTOS will build upon these initial activities and is envisioned as providing a more systemic approach in collaboration with C-GOOS.

The implementation plan developed through a series workshops and follow-up activities with the GTOS coastal panel of scientific experts. The final writing session and review included contributions from individuals of numerous international coastal management and research organizations. The first workshop occurred at East Carolina University in Greenville, North Carolina, USA, from 15 to 18 October 2002. The second workshop was held at the Joint Research Centre of the Institute for Environment and Sustainability in Ispra, Italy, from 3^{rd} to 6^{th} March 2003. The third workshop was at the La Selva Biological Station, Costa Rica, from 19 to 22 October 2003. Participants at these workshops are listed in the Annex.

1.2 VISION

The primary goal of C-GTOS is to detect, assess and predict global and large-scale regional change associated with land-based, wetland and freshwater ecosystems along coasts. Understanding the coast has particular significance to the international community's ability to make wise policy because it is the focus of intensive human activity and has rich and diverse natural resources. The efforts of C-GTOS will be coordinated with those of other observing systems, particularly the Coastal Module of the GOOS. Products will be readily communicated to and in support of programmes responsible for making and implementing wise coastal policy.

1.3 OBJECTIVES

C-GTOS has the following goals:

- ***To meet the general GTOS mandate.*** GTOS is a programme for observing, modelling and analysing terrestrial ecosystems to support sustainable development. GTOS facilitates access to information on terrestrial ecosystems so that researchers and policy-makers can detect global and regional environmental change and manage responses to it.
- ***To identify users and establish products appropriate to user needs.***
- ***To establish a regime for observing, assessing and predicting global and large-scale regional change for a selected group of critical, tractable issues.*** These issues, which must be addressed in both the short and long term, are:
    - population dimensions, land cover/land use and critical habitat alteration;
    - sediment loss and delivery;
    - water cycle/water quality;
    - effects of sea level change, storms and flooding.
- ***To identify a select group of critical, tractable, priority issues to address in the short and long term.*** This goal recognizes the need for an operational observing system that evolves and matures. Concerns include effects of climate and anthropogenically induced changes to coastal biota, habitats and processing of materials and energy. Thus, topics have human and natural components involve physical, chemical, and biological forcing, and have socio-economic implications.
- ***To link remote and ground-based observations in the coastal zone.***
- ***To provide mechanisms to communicate products to users and receive feedback.***
- ***To promote capacity to observe, assess and predict change.***

1.4 USERS AND NEEDS

1.4.1 Who are the users of C-GTOS?

Users and their needs drive the determination of issues and variables addressed by observing systems. Users are the final recipients of products produced (see Figure 1 for a diagram of the observing system structure). Wise policy on coastal issues depends on information derived from observing systems, and decision-makers make up an important component of G-GTOS users. Further, it is expected that some users may provide funding for operation of observing systems.

Information is required at a range of geographic scales, from local to global levels. Although local- and national-scale users are foreseen for C-GTOS, the majority of users will require regional and global information products, such as the programmes and initiatives identified in Section 2.1, with mandates addressing coastal issues (see Table 2).

The following is neither an exhaustive nor exclusive list of proposed users of C-GTOS. It includes the identified global initiatives, as well as national and non-governmental users who will benefit from the implementation of C-GTOS. The list uses research completed as part of the C-GOOS strategic plan (UNESCO, 2003c). It was modified to meet the objectives of C-GTOS (Christian 2003) and then vetted by the Coastal Panel of scientific experts and at the GTOS Secretariat.

- Conventions (multilateral and bilateral) and policy instruments, including the UN Framework Convention on Climate Change, the United Nations Convention on the Law of the Sea, the Ramsar Convention on Wetlands, Agenda 21, the Convention on Biological Diversity, the GPA for the Protection of the Marine Environment from Land-Based Activities, various regional seas agreements and the Barbados Action Plan.
- International organizations and their activities with a coastal focus, such as those of FAO. These include, for example, the GPA coordination office, Code of Conduct for Responsible Fisheries, Sustainable Fisheries Livelihood Programme, Sustainable Development Department coastal management initiatives such as the Integrated Coastal Analysis and Monitoring System (ICAMS), initiatives within the United Nations Environment Programme (UNEP) (e.g. the RSP and the World Conservation Monitoring Centre [UNEP-WCMC]) and programmes within the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (e.g. IOC, ICAM).
- GTOS and other observing system programmes themselves, particularly those associated with coastal waters as part of the IGOS Coastal Theme and C-GOOS (e.g. GOOS regional alliances and the Global Sea Level Observing System [GLOSS]).
- Research, modelling and assessment programmes associated with global and regional coastal change and coastal issues: coastal components and projects of the Global Assessment of the Marine Environment (GMA), Millennium Assessment (MA), Global International Water Assessment (GIWA), Global Environmental Outlook (GEO), Earthwatch, the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), Scientific Committee on Problems of the Environment (SCOPE), Land-Ocean Interactions in the Coastal Zone (LOICZ), UNEP-WCMC, Global Environment Facility (GEF)-funded Large Marine Ecosystems (LME) projects and the International Council of Science (ICSU).
- Individual scientists and members of the research community, including those belonging to programmes such as the European Land-Ocean Interaction Studies (ELOISE) and the International Long Term Ecological Research Network (ILTER). This also includes modellers working at scales ranging from particular species populations of economic or social value to global climate change and

biosphere response such as those involved in the project Tool to Assess Regional and Global Environmental and Health Targets for Sustainability (TARGETS).

- Suppliers of information to policy-makers and environmental managers responsible for large-scale systems (e.g. European Environment Agency, National Oceanic and Atmospheric Administration of the USA (NOAA), National Aeronautics and Space Administration [NASA] and the European Space Agency [ESA]).
- Non-governmental organizations for industry, transportation, tourism, agriculture, fisheries and environmentalism (e.g. European Chemical Industry Council, Wetlands International, Birdlife International).
- National governments involved in both transboundary decisions and national policy-making and implementation.

The C-GTOS Panel has actively sought the inclusion of representatives of potential user groups in its deliberations. Representatives of GIWA, LOICZ, COOP, Ramsar Convention on Wetlands, NOAA and UNEP GPA have participated or are active members of the Coastal Panel. Users will be engaged throughout the development of each of the phase 1 implementation products and the advancement of a mature C-GTOS.

1.4.2 Linking C-GTOS to the IGOS Coastal Theme

Numerous national and international agencies, systems and programmes are dedicated to acquiring or utilizing multidisciplinary coastal zone observations. These include Committee on Earth Observation Satellites (CEOS) members (e.g. NASA, Japanese Aerospace Exploration Agency (JAXA), NOAA, German Aerospace Center (DLR), ESA), the coastal components of the GOOS and the GTOS, as well as the LOICZ Project of the International Geosphere-Biosphere Programme (IGBP) and the UNEP GPA for the Protection of the Marine Environment from Land-Based Activities. Independently, these and other related efforts are making important contributions to the global coastal science and management communities. Accordingly, the IGOS Partnership is in the process of developing a Coastal Theme to integrate the activities of the various programmes, particularly to ensure continuity across the land, sea and air coastal interface.

In particular, the IGOS Coastal Theme will coordinate and strengthen coastal observational capabilities (both *in situ* and space-based) and the attendant decision-making process by promoting the development of an integrated, sustainable global measurement strategy for the coastal zone. This effort will be an inclusive, coastal community–driven approach that brings together data providers and data users (e.g. space agencies and observing systems and programmes). A suite of objectives has been defined focusing on both research and applications, with a particular need to develop and sustain operational capabilities to support and integrate the activities of Coastal GOOS and Coastal GTOS, and related international programmes. The overall goal of this effort is to *"develop a strategy for integrated global observations that will provide improved understanding of earth system variability and change in the coastal zone, with a particular emphasis on propagation of change and variability across the land-sea interface."* (IGOS 2003)

TABLE 1

Links between C-GTOS priority products and IGOS Coastal Theme priorities

C-GTOS PRIORITY PRODUCTS	Coastal hazards and public safety	Coastal urbanization and public health	Coastal ecosystem health and productivity	Coastal hydrological and biogeo-chemical cycles
Enhancement of TEMS	•	•	•	•
Distribution and rate of change of population, urbanization and land use in the coastal environment	•	•	•	•
Vulnerability of ecosystem services in deltaic systems	•	–	•	•
Management of cultural and conservation sites	•	•	•	–
Distribution of sites appropriate for analyses of delivery systems	–	•	•	•

IGOS COASTAL THEME PRIORITIES

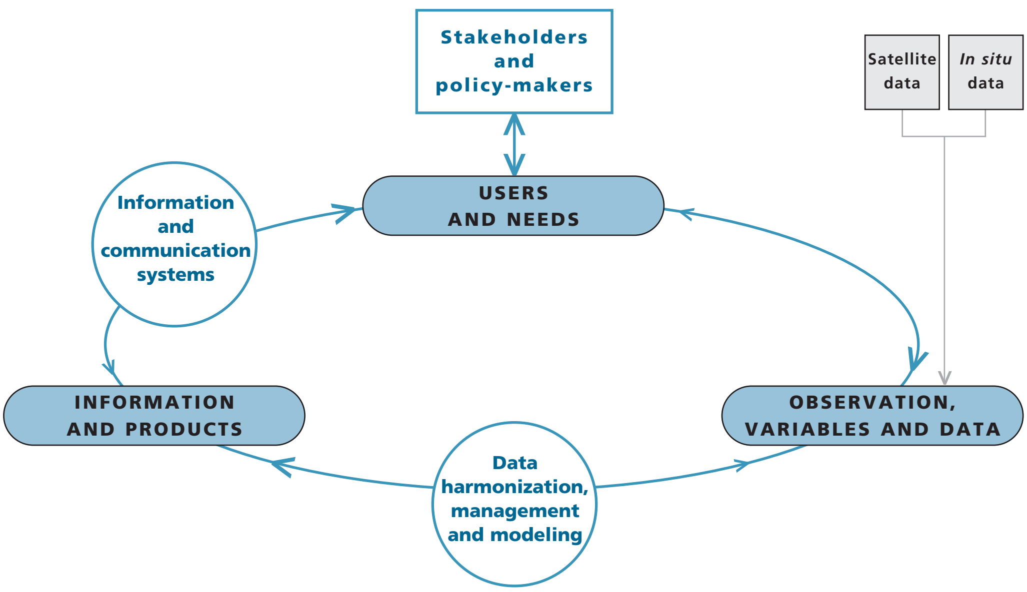
C-GTOS and the IGOS Coastal Theme are closely coupled, ensuring that the observing needs of C-GTOS are met, and placing C-GTOS within the context of the other observing programmes described above. For context of the interaction is shown in Table 1. The five priority C-GTOS products (discussed in Chapter 4) are considered in the context of the four key coastal user issues identified by the IGOS Coastal Theme. Each priority product addresses at least two of these key issues, with the human dimension and land-use and land-cover (LULC) products addressing all five. Thus these initial C-GTOS products will offer considerable added value and returns. Further, the IGOS Coastal Theme has identified the need for a strong C-GTOS programme to help implement the *integrated* coastal observing strategy it will put forward and thereby ensure effective management of coastal regions. Consequently, C-GTOS will have a continued incentive and need to expand upon this initial suite of products to support the growing needs of coastal users. One of the key means to promote integration is the establishment of the Coastal Data Assimilation Experiment (CODAE), a project to develop and test the various integrative activities of the coupled observing systems.

1.5 STRUCTURE

An observing system should be user-driven, or "end-to-end" in structure, providing the products required by the organizations and individuals who will use the data (GTOS, 1998a; UNESCO, 2003c). C-GTOS users (see Section 1.4.1) require products that provide information on conditions or changes in the coastal zone on a regional or global scale. The structure of C-GTOS is envisioned as a cycle that allows feedback between the various parts, especially allowing users to drive the identification and modification of observations and data collected (see Figure 1). Observations are linked through a series of processes to the final communication of products to the users and stakeholders for the purposes of policy decision-making, i.e. an "end-to-end" structure. Observing systems make field (*in situ*) and remote sensing (satellite) observations through the collection of data. The data are developed into various information and products required by users and stakeholders, and delivered through Web and PC-based information and communication systems. Information systems are central to the harmonization, management and modelling of data, and to the subsequent production of information products and their communication to users (see section 3.7). Frameworks have been used to determine the appropriate variables to include in observations and will be used to integrate this information and help communicate it to users. Subsequent chapters reflect this observing system structure.

FIGURE 1

The structure of the C-GTOS system



The structure of the C-GTOS system includes observations, variables and data, which are transformed into information and products to provide for users and their needs. In turn, users and their needs provide feedback influencing the further development of observations, variables and data. Each of these stages is dependent on additional components, shown in the white box and circles.

CHAPTER 2

DEFINING THE COAST AND FRAMEWORKS

One of the first challenges for those designing studies and protocols directed at global coastal systems is to determine (i) the factors driving the definition of the coastal area, and (ii) the selection and articulation of analytical frameworks needed to select critical indicators and assessment tools. Neither task is simple, straightforward or without the controversy of choosing among myriad options.

2.1 THE COASTAL SYSTEM

Defining the coastal system is an early and obvious task for any effort like the design of the Coastal GTOS Module. Nevertheless C-GTOS has not accepted one definition of the coastal zone. Rather it has reviewed the definitions and approaches adopted by potential users. The review has been summarized by categorizing users into three groups or hierarchical levels: multilateral environmental agreements, international organizations, and global/national assessment initiatives dealing with coastal issues. A range of definitions of the coastal area and ecosystems can be found in Table 2. Although these vary in extent and characteristics, four discrete approaches to defining coastal area can be derived. Those views can be categorized through descriptions of the coast from the perspective of:

- *Management Units:* Integrated Coastal Management is a decision-making approach now broadly embraced by a majority of national governments and international organizations. However, while the basic principles of integrated management hold some measure of broad agreement, there is no consensus on a clear and precise definition of the coast. One view of the coastal zone is associated with management provisions and coastal jurisdictional lines, such as states, provinces, counties or cities.
- *Human Use Dynamics:* Coastal areas can be defined by the particular social use value they support. Coastal recreational zones, zones with intense human population dynamics or intense urbanization, coastal agricultural areas and coastal transportation nodes all bring different dynamics to the task of defining interesting coastal areas.
- *Area Extent of the Coastal Zone:* Perhaps the most common definition driving a determination of coastal areas is based on geography. Here the definition can be as simple as 100 kilometres from the beach to more refined approaches focused on coastal watersheds.
- *Ecosystem Functionality:* The coastal zone may be most broadly viewed through linked system functions focused at the land–sea interface. Here, the coast is directly tied to scientists' understanding of the value of coastal habitats. These areas of unique diversity and ecological value deserve more acute and directed attention.

TABLE 2

Definitions of coastal areas and ecosystems used by international organizations and initiatives with coastal management mandates (direct quotes are shown in italics)

MULTILATERAL ENVIRONMENTAL AGREEMENTS	
International initiatives with coastal mandates	**Definitions of coastal areas or associated ecosystems and habitats**
The United Nations **Millennium Assessment (MA)** is an international work programme designed to meet scientific information needs concerning the consequences of ecosystem change and available options for response. **Documentation:** MA (2003); http://www.millenniumassessment.org/	The **Millennium Assessment** reports on ecosystems and ecosystems services within reporting categories. The coastal zone is one of six reporting categories defined by (i) a central concept and (ii) boundary limits for mapping. *Central Concept: interface between ocean and land, extending seawards to about the middle of the continental shelf and inland to include all areas strongly influenced by the proximity to the ocean. Boundary Limits for Mapping: area between 50 m below mean sea level and 50 m above the high tide level or extending landward to a distance 100 km from shore. Includes coral reefs, intertidal zones, estuaries, coastal aquaculture and sea grass communities.* MA reporting categories are not mutually exclusive. For example, *a wetland ecosystem in a coastal region may be examined both in the MA analysis of coastal systems as well as in its analysis of inland water systems.* Some differentiation is made between the coastal zone and other adjacent reporting categories based on the definition of boundary limits for mapping. For example, the coastal zone has a shared boundary with boarding marine systems (> *50 m depth*). Permanent inland waters of inland water systems are also separated spatially from respective coastal systems (*permanent water bodies inland from the coastal zone*).
The Ramsar Convention on Wetlands held in **Ramsar**, Iran, in 1971, covers all aspects of wetland conservation, recognizing wetlands' extreme importance for biodiversity conservation and the well-being of human communities. **Documentation:** Ramsar Convention on Wetlands (1971) and associated key documents (Articles 1.2 and 2.1); http://www.ramsar.org/	The **Ramsar** definition of wetlands accounts for a wide variety of coastal habitats. The Ramsar Classification System for Wetland Type lists the following types of coastal wetlands: *permanent shallow marine waters; marine subtidal aquatic beds; coral reefs; rocky marine shores; sand, shingle or pebble shores; estuarine waters; intertidal mud, sand or salt flats; intertidal marshes; intertidal forested wetlands; coastal brackish/saline lagoons; coastal freshwater lagoons, and karst and other subterranean hydrological systems.* Under the original Convention on Wetlands, wetlands are described as: *areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres...* [Wetlands] *may incorporate adjacent riparian and coastal zones, islands or bodies of marine water deeper than six metres at low tide lying within the wetland.*
Agenda 21 was adopted at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, in 1992. It is one of the key documents for integrated coastal area management and led the way for subsequent coastal area agreements and legal instruments. **Documentation:** UNCED (1992); http://www.un.org/esa/sustdev/	Chapter 17 includes seven major programme areas that relate to coastal areas and management, of which the first is *integrated management and sustainable development of coastal areas, including Exclusive Economic Zones.*

INTERNATIONAL ORGANIZATIONS	
International initiatives with coastal mandates	**Definitions of coastal areas or associated ecosystems and habitats**
The United Nations Environment Programme (UNEP) is developing a module for the Assessment of the **Coastal and Marine Environment (CME)** as a contribution to the planned **Global Marine Assessment (GMA)**. This contribution encompasses and is expanding upon existing assessment initiatives for the major coastal and marine ecosystems. Multiple other coastal-related initiatives have been or are being conducted, such as the programme on **Integrated Coastal Area and River Basin Management (ICARM)** relevant to the terrestrial coast. **Documentation:** UNEP (2004); UNEP/MAP/PAP (1999); http://www.unep-wcmc.org/marine/	An exact definition and spatial extent is not specified for coastal habitats that are part of the **CME** assessment. Instead an adaptable approach is proposed to determine the scope, based on existing assessment methodologies: *the geographical structure of the assessment has to be flexible and based on natural, political and institutional realities. Existing geographical and programmatic structure … should be used where appropriate.* The large variety of habitats in coastal waters is noted, including *coastal wetlands, estuaries and deltas, mangrove, coastal reef and seagrass beds.* **ICARM** guidelines identify the area of concern as encompassing *the catchment, the coastal zone and the nearshore coastal waters.… Four interacting zones are taken into consideration: coastal waters, the coastal strip, estuary, and the coastal plain.*
The United Nations Education Scientific and Cultural Organization (UNESCO) has numerous coastal initiatives relating to coastal assessments. These take place primarily through the Intergovernmental Oceanographic Commission (IOC), which (as with many UN coastal initiatives) collaborates routinely with **Small Island Developing States (SIDS)**. **Integrated Coastal Area Management (ICAM)** is one such programme, which is currently developing indicators for assessment of the coastal area. **Documentation:** UNESCO (2003a); http://www.ioc.unesco.org/	A recent guide to the use of indicators for **ICAM** states that catchment management deals with land usages in the coastal stream and river runoff areas for lagoons, bays and estuaries.
The **Food and Agriculture Organization (FAO)** of the United Nations has multiple initiatives that cover coastal areas, their management and the production of relevant guidelines, such as the Code of Conduct for Responsible Fisheries. **Documentation:** Scialabba (1998); FAO (1995); http://www.fao.org/	The **FAO** ICAM guidelines state: *an ICM programme embraces all of the coastal and upland areas, the uses of which can affect coastal waters and the resources therein, and extends seaward to include that part of the coastal ocean that can affect the land of the coastal zone. The ICM programme may also include the entire ocean area under national jurisdiction (Exclusive Economic Zone), over which national governments have stewardship responsibilities under both the Law of the Sea Convention and UNCED*

GLOBAL/NATIONAL ASSESSMENT INITIATIVES	
International initiatives with coastal mandates	**Definitions of coastal areas or associated ecosystems and habitats**
The Coastal Ocean Observations Module of the Global Ocean Observing System (C-GOOS) has been developed with the goal of monitoring, assessing, and predicting the effects of natural variations and human activities on the marine environment and ecosystems of the coastal ocean. **Documentation:** UNESCO (2003c); www.ioc.unesco.org/goos/coop.htm/	Coastal, as defined for use in the Coastal Module of **GOOS**, refers to *regional mosaics of habitats including intertidal habitats (mangroves, marshes, mud flats, rocky shores, sandy beaches), semi-enclosed bodies of water (estuaries, sounds, bays, fjords, gulfs, seas), benthic habitats (coral reefs, sea grass beds, kelp forests, hard and soft bottoms) and the open waters of the coastal ocean to the seaward limits of the Exclusive Economic Zone (EEZ),* i.e. from the head of the tidal waters to the outer limits of the EEZ. The definition of coastal zone is adopted from Nicholls and Small (2002): *the land margin within 100 km of the coastline or less than 100 m above mean low tide, which ever comes first.*
The International Geosphere-Biosphere Project's (IGBP) mission is to deliver scientific knowledge to help human societies develop in harmony with earth's environment. The mandate of **Land-Ocean Interactions in the Coastal Zone (LOICZ)**, as a core project of IGBP, is to address global change in coastal systems and to inform earth system sciences on the relevance of global change in coastal systems. **Documentation:** IGBP Secretariat (2004); http://www.loicz.org/	**LOICZ** includes in its statement of major goals the following reference to the costal zone and scales of activity: *to provide a framework … and to act as a means to focus on key issues concerning human activity and resource use in the coastal zone by applying the full water-continuum scale including the river catchments and the EEZ as spatial scales of major human interventions.*
The Global International Waters Assessment (GIWA) assesses international waters and associated basins to provide information needed by the **Global Environment Facility (GEF)** for work in international waters. A GEF objective for this focus area is to serve primarily as a catalyst to the development of a more comprehensive, ecosystem-based approach to managing international waters and their drainage basins. **Documentation:** Pernetta and Mee (1998); UNEP (1999); http://www.giwa.net/ http://www.gefweb.org/	International waters and their drainage basins, which include coastal areas, are one of four priority areas identified by **GEF** and assessed by **GIWA**. These combined areas often include many different coastal habitats (*comprising marine, coastal and freshwater areas, and surface waters as well as groundwaters*). The main determining factor for this geographic delineation was the *integrity of each unit in terms of encompassing the major causes and effects of environmental problems associated with each transboundary water area, whether river basin, groundwater, lake or sea. In many cases, a drainage area and associated marine basin (often a large marine ecosystem, LME) were the most appropriate units.*
The World Conservation Union (IUCN), National Oceanic and Atmospheric Administration (NOAA) and other organizations that assist developing countries in implementing ecosystem-based strategies use Large Marine Ecosystem (LME) as the principal assessment and management units for coastal ocean resources. **Documentation:** Sherman and Duda (1999); http://www.iucn.org/ http://www.noaa.gov/	LMEs include multiple coastal habitats as they *are regions of ocean space encompassing coastal areas from river basins and estuaries to the seaward boundary of continental shelves and the outer margins of the major current systems. They are relatively large regions… characterized by distinct bathymetry, hydrography, productivity, and tropically dependent populations.*

Ultimately, C-GTOS products will need to be structured in the context of the users' definitions of the coast, taking into account the four common approaches identified for defining coastal areas. A general trend over time can be seen in the change of approaches for many types of organizations managing coastal areas (Table 2). Earlier definitions focused on geography and management units (e.g. EEZ and various ICAM guidelines). More recent coastal management initiatives have had a greater focus on ecosystem functionality and also include interaction with human use dynamics. The ecosystem approach has been endorsed by the Convention on Biological Diversity (CBD) and the Millennium Ecosystem Assessment (MA), and other current global assessments are consistent with this. The approaches presented here are not mutually exclusive. To meet user needs fully, C-GTOS does not define the coast in a single way. Rather, it attempts a strategic approach that highlights the need for understanding the diversity of views and the potential for diversity in user needs (see Section 1.4.1).

2.2 FRAMEWORKS OF ORGANIZATION

Efforts to define the extent of the coastal area cannot be effectively conducted without the input and influence of associated analytical frameworks. These frameworks aid in both the precise determination of that extent, and critically in the understanding of the function and value of such areas. A review of needs in various coastal assessments led to a focus on four dominant frameworks. They connect most explicitly with the view of coastal areas and contribute most directly to the building of a linked network of programmes and practices as envisaged in Coastal GTOS.

These four frameworks will be developed in this section:

- Driver-Pressure-State-Impact-Response (DPSIR). This framework, which has been broadly used, can be viewed as contributing most directly to management- and use-based views of the coastal environment. It provides a vehicle to establish linkages between social and environmental dynamics.
- Inland-Coastal Zone-Ocean (ICZO). This view focuses on distinguishing appropriate physical boundaries. It has been used by those focused on the area extent of the coastal zone and by those interested in use and coastal ecosystem function.
- Human Systems – Ecological Systems – Delivery Systems (HSESDS). This is an emerging framework focused on ecosystem functionality, but it is viewed as holding promise for enhancing understanding of coastal systems and applicable management choices.
- Functional Clustering. This helps to integrate different ecological functions, together with goods and services of ecosystems, in a way that promotes coordinated management.

2.2.1 Driver-Pressure-State-Impacts-Response (DPSIR)

DPSIR highlights human components of the system, coupling socio-economics with environmental observations. DPSIR does not provide explicit recognition of the complexity of ecological interactions. The DPSIR framework provides a general view of the nature of large-scale influences on the state of the environment and on the need to understand and address consequential social impacts driven by environmental conditions. DPSIR serves as a tool to manage change based on clearly identified societal and environmental benefits. The constituents of the DSPIR framework are defined below and exemplified in a C-GTOS-relevant context in Table 3.

- Drivers: changes in large-scale socio-economic conditions and sectoral trends, such as an increased number of tourists, growth and development in the industrial sectors in the coastal zone or large-scale changes to human population dynamics.
- Pressures: processes and mechanisms provoking changes in the natural environment, such as coastal construction altering coastal wetlands or the introduction of agricultural contaminants and nutrients into the coastal watershed.
- State: environmental or ecological changes as a result of the imposed pressures, generally illustrated using a set of readily determined parameters or environmental quality indicators. Examples include enhanced sedimentation in harbours, decline in the biodiversity of salt marshes and saline intrusion into groundwater.
- Impacts: measurable changes in social benefits and values resulting from environmental changes, such as the cost of maintaining coastal transportation systems due to siltation, decline in property values resulting from coastal erosion, and loss in agricultural income from salinization of soils.
- Responses: changes in policy and management practices to mitigate the socio-economic impacts of environmental degradation, such as better management of wastewater treatment and improved agricultural practices.

TABLE 3

The DPSIR framework exemplified using population growth as a driver. Values are examples taken from northern Italy

DRIVER	PRESSURE	STATE	IMPACT	RESPONSE
Population growth	■ Increased water extraction (upstream) ■ Increased wastewater release (downstream) ■ Higher loading of pollutants	■ Deterioration of water quality ■ Changes in water level ■ Variations in river discharge, current velocity ■ Enhanced turbidity	■ Community changes ■ Pollution ■ Sediment accumulation ■ Reduced infiltration	■ Water conservation management ■ mplementation of wastewater treatment
Increase of 1000 inhabitants	■ Water extraction (150 litres per inhabitant) ■ Change in BOD[1] (54 g BOD/ [inhabitant x day])	■ Groundwater level falls by 150 m^3 per inhabitant ■ Coastal water receives 150 m^3 x 54 kg BOD/ [inhabitant x day]	■ Change in landed value of local commercial fishing ■ Changes in recreational value to bathing beaches	■ Water savings (extraction falls from 150 to 100 litres per inhabitant) ■ Wastewater treatment leads to 80% uptake of BOD ■ BOD release decreases (100 x 54 x 0.2 g BOD/day)

1. BOD refers to biochemical oxygen demand, a measure of water quality and the amount of organic pollution.

2.2.2 Inland – Coastal Zone – Ocean (ICZO) physical boundaries

The geographic framework clearly designates the coastal zone as the boundary region between continents and oceans or inland seas. The ICZO structure places C-GTOS into a broader context rather than helping to delineate its components. The coastal zone is the interfacial region between the inland and oceans. Both inland and ocean exert a direct influence on the coastal zone through the transfer of energy, material and information. Accordingly, the coastal zone is distinguished by having a strong gradient of parameters that can be either continental or oceanic in origin. By this reasoning, the inland and ocean boundaries are delineated by the limits of oceanic and continental influences, respectively. For C-GTOS purposes, the extent of the coastal zone is further described in section 4.1.

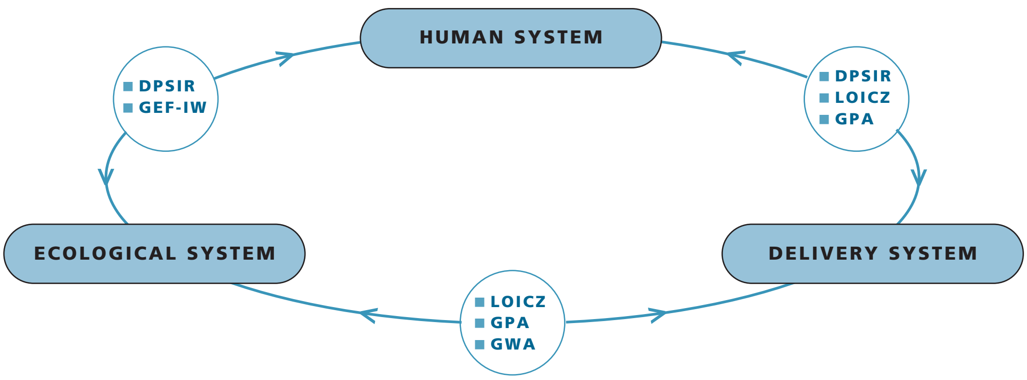
2.2.3 Human Systems – Ecological Systems – Delivery Systems (HSESDS)

Beyond these two more established frameworks, two additional views are presented as vehicles to focus on the dynamic interactions particularly prevalent in the coastal zone. The third framework focuses on three interactive components in the coastal zone, categorized as HSESDS. This triad is illustrated in Figure 2. Here, the concept of human systems refers to all aspects of societal impacts and activities in the coastal region. Two key considerations include land-use patterns and human population dynamics. Ecological systems comprise land cover and habitat, including both terrestrial and aquatic coastal environments. Delivery systems focus on the water cycle, with consideration of both delivery and quality. The delivery systems incorporate the materials (nutrients, sediments and pollutants), energy and information transferred. Moreover, atmospheric pathways must be included.

Whereas some issues of interest and concern may be largely contained within one system, others can arise due to the interactions between systems. The DPSIR approach can be readily incorporated to describe the relationships between the human and ecological systems. The strategies of international programmes can be included in this framework. LOICZ products, such as biogeochemical modelling, link the delivery system to the other two components. Potential users, such as GPA and GIWA, can also be placed into this context. The framework and linkages with DPSIR and some potential international users are shown in Figure 2.

FIGURE 2

Human Systems - Ecological Systems - Delivery Systems



2.2.4 Functional Clustering

This is the most novel and perhaps the most complex framework to be used by C-GTOS. C-GTOS intends to maintain a broad functional definition that is not strictly defined by geography. This approach has led to a framework based on the interaction and overlapping of functional attributes of ecosystems. This is also the framework that best allows the introduction of informatics into the observing system process. Because of the complexity and novelty of the topic, this section describes the functional framework in more detail than others. The level of technicality may not be necessary to all readers. Some may find the following paragraphs sufficient to obtain a sense of this framework.

To address C-GTOS goals, an identification of the commonalities of functions within coastal ecosystems, based on their underlying components (i.e. functional clusters) would be useful on a global or regional scale. The concept of functional clusters implies that admittedly unique systems may nevertheless share some general functions that are aggregates of otherwise different processes and structures. A generic set of such functions can be defined irrespective of their implicit geographic distributions, on the basis of different system components that make them up. The terms of reference of C-GTOS can best be matched by this functional approach, which comprises the following tasks:

- identification of critical ecosystem-maintaining functions and their underlying components in different kinds of coastal environments;
- identification of coastal ecosystem functions in terms of goods and services provided to humans, directly and indirectly;
- the clustering of these functions according to ecosystem types;
- identification of manageable phenomena, or threats and opportunities that may affect ecosystems (National Academy of Sciences, 2000a);
- assessment of potential impacts on the relevant ecosystems, in terms of scenarios that may be of use to decision-makers, and
- assessment of the status of particular ecosystems from an integrated perspective, including how well functions are maintained and how impairment of function might be mitigated.

A functional view of the coastal zone can be described for C-GTOS purposes in terms of the following kinds of functions:

- processes and functions that determine the physical, chemical and biological structure of coastal ecosystems necessary for maintaining ecological integrity and natural sustainability;
- processes and functions related to phenomena of relevance to C-GTOS globally (including land-cover change, land-use conversion, habitat destruction and endangered species protection);
- processes and functions from which humans derive goods and services (directly and indirectly) and that humans particularly value (such as renewable and non-renewable resources including tourism, aesthetic values, development opportunities and living space, recycling of waste and pollutants, erosion control and genetic resources), and

- processes and functions producing useful indicators and predictors of ecosystem change, health, stability and integrity and other important metrics for forecasting and managing ecosystem functions (such as short-term blooms, indicator organisms, keystone species, productivity and other rate indicators).

Functional "clusters" may be defined by specific organism and environmental interactions and assessed through informatics techniques. An inventory of these ecologically necessary resources and processes could be the first step to identifying such functional units. From this inventory one may be able to identify clusters of functions (not in the geographical sense) that relate to important issues in coastal ecology and that define a useful classification of eco-units for research and management purposes. These clusters can be cross-linked to show interactions between processes, sustainability and goods and services and to relate them to traditional ecosystem definitions.

An inventory of ecosystem types has yet to be produced from such a functional point of view. The inventory would produce multiple data layers, or maps, that could be overlaid upon one another. But these maps would not necessarily be of physical features; rather they would represent the ecological functions of ecosystems and the consequent goods and services. Such an approach may lead not to a unique classification of an ecosystem or landscape, but to multiple possible classifications (typologies) that can be tailored to more specific uses. The classification depends on criteria, questions, scale, underlying data and other forms of knowledge, captured as basic models of the functional ecology that can subsequently be mapped for specific needs. This approach is made feasible by the use of relatively common spatial mapping technologies, the relatively new branch of science called informatics, and improved availability of fundamental data, from satellite and *in situ* observations, on which to base such functional models. Informatics promotes the identification of patterns and arrangement of information from large data sets into new formats through computational techniques. This branch of science helps improve understanding and should significantly contribute to the capabilities of observing systems.

DEFINITION OF TERMS IN THIS SECTION

Ecosystem function: What an ecosystem does as an outcome of system behaviour. We refer to two kinds of functions: those that maintain ecosystems and those that provide goods and services to humanity.

Ecosystem process: How the ecosystem does something, internally.

Ecosystem component: A subsystem that is also describable as an ecosystem.

Functional typology: Classification of the different types of functions or functional clusters.

Spatial extent: The spatial relationship between different functional types or clusters.

Ecological functions exist in relationship to observable structures (processes and states) that also determine rates of productivity and resilience and resistance to anthropogenic or natural perturbations. Similar functions may be performed by different structures, and some functions can be defined at a hierarchically higher level and may apply generally in all coastal zone ecosystems. The C-GTOS Panel members identified seven major ecological functions that it believes are generally inherent in all coastal ecosystems (Table 4). Conversely, some functions are ecosystem specific. Both sets of functions (and their supporting structures) exist in harmony to maintain the operation of an ecosystem.

Many examples of ecosystem-specific functions can be listed, such as the following:

- The functioning of estuaries, or mangrove systems, is largely influenced by the rate of freshwater inflow (i.e. quantity, regularity, sustainability) whereas ecological functions in sandy beaches or sea grass meadows are not.
- A maritime forest may perform a specially adapted function of trapping moisture from fog imported to the system by physical processes related to onshore winds. This may be the case for one coastal forest but not another.
- While all savannahs may have some common environmental and physiographic characteristics, some, like East African savannahs, may be more strongly influenced and adapted to indigenous fauna. The relationship between plant and animal functions partly determine the structure of the ecosystem and corresponding functions in relation to goods and services available to humans.

TABLE 4

General and major ecological functions common to all ecosystems and their components

MAJOR FUNCTION	SUPPORTING STRUCTURAL ATTRIBUTES, PROCESSES AND MEASURES (MECHANISMS VARY BETWEEN SYSTEMS)
Transporting and storing **materials**	Biogeochemistry (chemical transformations, nutrient cycling, absorption, nitrification, denitrification, etc.)
Transferring and storing **energy**	Entropy, dissipation, energy storage, primary and secondary production, etc.
Ensuring availability and quality of **air and water**	Hydrologic cycles, filtering, cleansing, flows/circulation, BOD, eutrophication, etc.
Ensuring **habitat availability**	Land conversion, climate change, anthropogenic alterations, landscape or waterscape pattern and process, community structure, substrate dynamics
Generating **biological resources**	Diversity (number, richness, etc.) and distribution of keystone species, endangered and threatened species, invasive species, genetic resources, etc.
Building **trophic networks**	Predator-prey interactions, decomposition
Enhancing **security** (through **sustainability**)	Response to perturbation (resilience, stability, vulnerability, disturbance, etc.); intrinsic value (integrity, ascendancy, genericity, emergy, etc.)

Ecosystem-specific processes are identified at the regional and systems level by the relevant managers or researchers. Although not all possible systems can be described here, some examples are given in Table 5.

Influences on ecosystem functions, structures, processes and characteristics can be classified in two categories:

- those that characterize the general conditions and trends of ecosystems, as observed from monitoring and assessment programmes; these include global conditions and may be subject to global change, and their management requires concerted international efforts, and
- those that represent specific threats or opportunities that can be identified clearly enough to be the subject of local and regional management and policy decisions.

Fluctuations in broad-scale forcing functions that have occurred over millennia are the subject of various global research programmes, for example, to predict the effects of global warming, sea level rise, changing weather patterns, etc. on the biosphere and its major ecosystems. Those priorities need not be repeated here. Conversely, there has been inadequate information to assess ecosystem conditions (processes, structures and functions) and potentially manageable phenomena (threats and opportunities) in the coastal zone in any detail (World Resources Institute, 2002; Burke *et al*., 2001). To complement current assessments (MA, 2003) and outline information for future ones, we have made an initial attempt to identify phenomena that may be in the greatest need of observation in example ecosystems in the coastal zone (Table 4; Table 5). Table 4 classifies the general functions and their underlying processes that we believe are general to all coastal ecosystems. Disruptions or perturbations (anthropogenically induced or not) of any one these will have adverse impacts on any type of ecosystem to some degree or the other; hence observations related to these functions are most critical. The universal and system specific functions for each of the coastal ecosystem types identified are listed in Table 5:

- The first column divides the table into ecosystem types, traditionally defined.
- The second column of the table refers to processes and functions that are ecosystem specific and form a functional cluster in harmony with the major functions shown in Table 4. Together they define the performance of each specific type of system.
- The third column shows which of the manageable phenomena can have an impact, positively or negatively, on the integrity, health and provision of goods and services of a specific ecosystem type.
- The fourth column identifies the goods and services (directly and indirectly) each particular type of system provides.
- The last two columns give a preliminary qualitative assessment of how sensitively the system may respond to local management by humans. These assessments could be refined through adaptive management approaches

Table 4 and table 5 thus identifies clusters of universal and system-specific functions for any type of ecosystem in any environmental regime and provides a functional classification (typology) of the coastal zone. Not all of the functions and processes are of equal importance, nor do they all act with the same intensity in the same or different climate regimes. Fluctuations and differences on small spatial scales are inevitable. Expertise and knowledge at the local scale backed up by existing databases are essential in identifying the importance of system processes and the degree to which the functioning of the system has been or will be impaired by manageable phenomena. It is also only at the local scale that the degree of management required to sustain a system within the limits of change can be assessed.

TABLE 5

Functional clusters and ecosystem types

		UNIVERSAL ECOSYSTEM PROCESSES AND FUNCTIONS				
		Ecosystem-specific processes and functions	*Manageable phenomena (threats and opportunities)*	*Goods and services*	*Resistance[1] to manageable phenomena*	*Resilience[2] to manageable phenomena*
ECOSYSTEM TYPES	**Coastal wetlands, salt marshes and swamps**	■ Filtering capacity ■ Water pulsing ■ Export of organic material	■ Habitation/ urbanization ■ Introduction of non-native species ■ Water extraction	■ Water waste treatment ■ Habitat (system-specific biota) ■ Erosion control ■ Tourism	High	Low
	Estuaries	■ Absorptive capacity ■ Tidal pulsing ■ Habitat/nursery ground ■ Export of organic and inorganic material	■ Exploitation (fish, bait org) ■ Eutrophication ■ Chemical pollution ■ Water extraction catchments ■ Urbanization ■ Input of human pathogens	■ Subsistence food production ■ Transportation ■ Recreation ■ Habitats ■ Property/ habitation ■ Tourism	High	Low to moderate
	Mangrove forests	■ Tidal pulsing ■ Export of organic material ■ Substrate biogenesis	■ Exploitation ■ Water extraction ■ Aquaculture ■ Urbanization	■ Existence value (unique plants and animals) ■ Erosion control ■ Soil formation ■ Habitats	High	Low
	Sea grass meadows and kelp beds	■ Water movement/ currents ■ Habitat/refuge ■ Organic detritus production	■ Harvesting ■ Eutrophication ■ Sediment deposition ■ Erosion	■ Biological control ■ Erosion control ■ Habitats/refuge	High	Moderate
	Sandy beaches and coastal dune/ desert systems	■ Filtering capacity ■ Wave regime ■ Export of organic material ■ Fog belts	■ Mining ■ Introduction of non-native plant species ■ Habitation/ harbours/seawalls ■ Breakwaters ■ Artificial dune stabilization	■ Habitat (system-specific biota) ■ Erosion control ■ Storm attenuation ■ Tourism ■ Raw materials (precious metals, diamonds)	Moderate	High
	Coastal forests and grasslands	■ Water cycle ■ Soil formation ■ Refuge (terrestrial biota)	■ Exploitation (deforestation) ■ Urbanization ■ Introduction of non-native species (plants and animals) ■ Construction (highways, dams)	■ Water regulation and supply ■ Habitat ■ Waste treatment ■ Oxygen and carbon cycles ■ Storm attenuation ■ Tourism ■ Raw material (wood, seeds, grazers)	Moderate	Low to moderate

1. Resistance is defined as the response of an ecosystem to human-induced perturbations (i.e. manageable phenomena). "Low" resistance implies that the system is susceptible to these perturbations/activities and will be negatively affected.
2. Resilience is defined as the ability of the system to respond positively to the curtailment or amelioration of manageable phenomena. "Low" means that the system's ability to "recover" is permanently impaired and that it will probably continue to exist in a different ecological state than before.

CHAPTER 3

FROM OBSERVATIONS TO PRODUCTS

The mature C-GTOS will require numerous steps to provide products from observations. These steps will include identifying issues of concern, their context and their associated variables and indicators, which make up the database. These data will be incorporated and harmonized into a management system based on TEMS that will require significant enhancement. Derived metadata and information products will be communicated to users, again through TEMS, GeoNetwork and other platforms. Finally, all of these steps require significant increased capacity. This section summarises these steps.

3.1 THE CONTEXT OF ISSUES

An important goal of C-GTOS is to ensure that land-based, wetland and freshwater conditions of the complex and important coastal region are adequately represented within the global observation system. As such, the key issues within observation systems can be divided into five categories (Christian, 2003):

- those whose effects contribute to global change;
- those whose effects contribute to large-scale regional change;
- those for which global change produces significant local response;
- those for which large-scale regional change produces significant local response, and
- those that occur so ubiquitously that the result is of global importance.

C-GTOS focuses on environmental issues most directly linking terrestrial, freshwater and wetland ecosystems determined within the context of integrating frameworks (see section 2.2). These key issues are represented herein by critical, linked systems and associated measures of change. An initial list of issues (related to states in the DPSIR framework) has been developed to include (i) human dimensions, land cover, land use and habitat alteration; (ii) sediment loss and delivery; (iii) water cycle and water quality, and (iv) effects of sea level change, storms and flooding. The human dimension is so important to the condition of the coast that additional effort is being made on the socio-economic condition of coastal populations in coordination with C-GOOS.

Addressing these issues is foreseen as occurring in two phases. First, a small and select group of priority topics will be addressed to establish proof of concept. Then a fully mature observing system will be developed to provide the ability not only to detect change associated with the key issues, but also to predict it and provide essential reporting products to assist in management and mitigation.

All of ecology operates at the interface between organisms and their environments, and hence, ecological processes begin at the fine scale. Some of these processes, such as denitrification (conversion of nitrate to gaseous nitrogen) or respiration, can have a global influence (Seitzinger and Kroeze, 1998) despite functioning at the local level (Smith *et al.*, 1991; Jenkins and Kemp, 1984). Certain processes operate at landscape scales, and they are not simple aggregations of finer-scale ecology (e.g. energy flow through a food web), nor are they simply parts of a global pattern. Ecosystems, or landscape units, can be seen as living units with their own ecological interactions. Table 6 below illustrates how certain processes can be aggregated within a range of scales, but there can also be major distinctions between scales where ecological processes take on a whole aspect. Interactions between these major scale divisions must be understood by linking models, and not just aggregating data, as can be done within a scale range.

TABLE 6

Example of major scale divisions (expressed as hypothetical resolution of data)

MODELS			
1 mm - 10 m ⟷	10 m - 100 km ⟷	100 km -1000 km ⟷	1000 km - globe
Plot patch organism	Landscape community ecotype	Region country continent	Continent world

It is likely, then, that some observations may need to be made at each of these scales, even if the ultimate goal is to develop a regional to global synthesis. The spectrum of spatial scales of variables is coupled with temporal scales of variation, with small-scale variables tending to change more rapidly. The Global Hierarchical Observing Strategy (GHOST) used by GTOS recognizes these scale differences and addresses how sampling can accommodate them (GTOS, 1997b). GHOST includes an array of sampling plans, from intermittent and continuous *in situ* sampling at discrete points in the landscape to satellite measures of large areas. Moreover, some phenomena cannot be scaled up except by coupling models.

Issues (changes in state) can be assessed by a large number of conservative and non-conservative physico-chemical, biological and socio-economic indicators and variables. The C-GTOS Panel identified variables that can either indicate the status of each issue (an indicator) or help quantify an important aspect of the issue (an environmental variable). The collection of data on these indicators or variables is not done directly by C-GTOS. Rather C-GTOS assimilates data from various sources to address these issues. Many of these sources are listed in TEMS, but not all. Sources have been identified in general, but specific ability to provide the appropriate data requires further evaluation. The purpose of this section is to describe the nature of these key issues for which observations will be made and data collected.

3.2 HUMAN DIMENSION, LAND COVER/LAND USE AND CRITICAL HABITAT ALTERATION

Recent assessments estimate that roughly 3.2 billion people, or more than half the current global population, live on or within 200 km of a coastline. By 2025 that number is expected to increase to 6.3 billion or 75 percent of the then global population (UNESCO, 2003b). Changing population is reflected in changing land-use patterns derived from land-cover data, including an apparent increase in urbanization and alteration to critical habitats. Once the initial state of the dynamic population is understood, key variables, which are indicators of the response of the coastal ecosystem to a wide range of human-related activities, can be recognized, and observing systems can be optimized. The impact of population growth on coastal ecosystems will be a major issue this century (Cohen *et al.,* 1997; Nicholls and Small, 2002; Wickham *et al*., 2002).

The rate of change in land use and land cover in the coastal environment will significantly outpace the steady increase in population in the coastal region. Land-use and land-cover change are significant to a range of themes and issues central to the study of the coastal environment. Habitat modification is important and occurs through effects on both the quality of soil and water and changes to the biota. Alterations in the earth's surface contribute to changes in biodiversity, biogeochemical cycles, hydrological cycles and ecological balances and complexity (Jackson, Kurtz and Fisher, 2000; Seitzinger and Kroeze, 1998; Vitousek *et al*., 1997). Through these environmental impacts at local, regional and global levels, land-use and land-cover changes driven by human activity have profound regional environmental implications, such as alterations in surface runoff dynamics, lowering of groundwater tables, impacts on rates and types of land degradation, and reduced biodiversity.

Table 7 provides a list of indicators and variables to assess the status of, and change in, coastal human populations, land use, land cover (including important components such as impervious surfaces), and habitat quality. Some, but not all, of these variables are currently measured at sites in the TEMS network, but no concerted effort exists within GTOS to incorporate these variables into an operational observation network. In addition, there may be further issues of scale and data availability that will require further evaluation. The categorization of issues of concern throughout this chapter does not create a listing of mutually exclusive variables. Thus, tables in the following subsections provide variables and indicators that are germane to these topics.

Human dynamics in, and anthropogenic forcing upon, coastal areas constitute themes central to the implementation of both GTOS and GOOS. However, the myriad environmental variables and indicators of the influence of humans are not easily parsed between the two observing systems. Given the evolving nature of programmatic implementation in both efforts, it is suggested that a shared system of programme responsibility should be built. This system could be driven by the needs for indicator identification and ranking at both the global and regional level.

Two approaches are taken with respect to socio-economic variables. First, several variables have been listed within TEMS, but they are largely inactive, with many not yet applied to any aspect of GTOS. C-GTOS is taking the lead on socio-economic observations by including these variables in the C-GTOS observing system. Table 7 summarizes some of the important socio-economic variables listed within TEMS and identifies the need for their application to the coastal zone.

TABLE 7

Socio-economic variables and indicators included in TEMS and evaluation of stated resolutions in TEMS and resolution needs for application to coastal issues

Variable	Temporal resolution	Spatial resolution	Source and comments
DEMOGRAPHICS/HUMAN WELL-BEING			
Human development index	Annual (1-yr lag)	National	TEMS[2]
Population density	Annual (1-yr lag)	Subnational	TEMS[2,a]
Population living below the poverty line	Annual (?-yr lag)	Subnational	TEMS[2,a]
Urban population (fraction)	Undetermined	Subnational	TEMS[2,a,c]
ECONOMICS/ENERGY/TECHNOLOGY			
CO_2 emissions	Annual (?-yr lag)	National	TEMS[2,a]
Energy use	Annual (?-yr lag)	National	TEMS[2,a]
Genuine domestic savings	Annual (1-yr lag)	National	TEMS[2,a]
Gross domestic product	Annual (1-yr lag)	National	TEMS[2]
Primary energy production	Annual (1-yr lag)	National	TEMS[2]
HUMAN HEALTH			
Calories available	Annual (2-yr lag)	National	TEMS[2]
Government expenditure on health care	Annual (2-yr lag)	National	TEMS[2]
Health care	Annual (3-yr lag)	National	TEMS[2]
Malnutrition prevalence	Annual (3-yr lag)	National	TEMS[2]
Safe water (access)	Annual (1-yr lag)	National	TEMS[1,a]
Sanitation (access)	Annual (3-yr lag)	National	TEMS[2a]
Water-borne and food-borne diseases	Undetermined	National	TEMS[2,a,c]
INDUSTRIAL/URBAN			
Hazardous waste	Undetermined (3-yr lag)	National	TEMS[2,a,c]
Industry sector	Annual (2-yr lag)	National	TEMS[2]
Motor vehicle ownership (per capita)	Undetermined	Subnational	TEMS[2,a,c]
Municipal waste	Undetermined	National	TEMS[2,a,c]
Pollution abatement and control expenditure	Biennial (?-yr lag)	National	TEMS[2,a]

Notes:
1. Terrestrial Ecosystems Monitoring Sites (environmental variables): http://www.fao.org/gtos/tems/variable_list.jsp.
2. Terrestrial Ecosystems Monitoring Sites (socio-economic variables): http://www.fao.org/gtos/tems/socioeco_list.jsp.
a. Observations required from C-GTOS.
b. Shorter lag required.
c. Requires recurring measurements.

Variable	Temporal resolution	Spatial resolution	Source and comments
NATURAL RESOURCES/RURAL			
Agricultural production index	Annual (2-yr lag)	Subnational	TEMS[2,a]
Arable land	Annual (2-yr lag)	Subnational	TEMS[2,a]
Deforestation	Biennial (1-yr lag)	Subnational	TEMS[1,a]
Fertilizers	Annual (2-yr lag)	National	TEMS[1,a,b]
Habitat conversion	Annual (2-yr lag)	National	TEMS[1,a,b]
Habitat fragmentation	Annual (2-yr lag)	National	TEMS[1,a,b]
Irrigation potential	Undetermined	National	TEMS[2,a,c]
Labour force in agriculture	Annual (1-yr lag)	National	TEMS[2,a]
Land area protected	Annual (3-yr lag)	National	TEMS[2,a,b]
Land cover	Annual (2-yr lag)	National	TEMS[1,a,b]
Land use	Annual (3-yr lag)	National	TEMS[1,a,b]
Pesticide use	Annual (1-yr lag)	National	TEMS[2,a]
Total forest area	Biennial (1-yr lag)	Subnational	TEMS[2,a]
Vegetation cover and height class	Annual (2-yr lag)	National	TEMS[1,a,b]
Water withdrawal by sector	Annual (< 1-yr lag)	National	TEMS[2,a]
Wood for fuel and charcoal	Annual (1-yr lag)	National	TEMS[2,a]

Notes:
1. Terrestrial Ecosystems Monitoring Sites (environmental variables): http://www.fao.org/gtos/tems/variable_list.jsp.
2. Terrestrial Ecosystems Monitoring Sites (socio-economic variables): http://www.fao.org/gtos/tems/socioeco_list.jsp.
a. Observations required from C-GTOS.
b. Shorter lag required.
c. Requires recurring measurements.

Second, C-GOOS has produced a strategic design plan and is currently developing an implementation plan taking account of both global and regional programme efforts (UNESCO, 2003c). As part of the implementation effort, a draft protocol for ranking priority socio-economic indicators has been prepared and will be extended and refined during the plan development process. This protocol is linked to that developed within the strategic design plan to rank common variables to detect and predict change in coastal environmental conditions (UNESCO, 2003c). This exercise is viewed as holding equal value for both GOOS and GTOS in identifying and ranking common and critical socio-economic indicators. It is expected that all environmental variables will, in the future, also be assessed to determine links with the IGOS Coastal Theme. Thus, this protocol is seen as the means for incorporating socio-economics into the observing systems.

3.3 SEDIMENT LOSS AND DELIVERY

Human activities within watersheds have dramatically altered the delivery of sediments to the coast, with significant ecological and economic consequences. These activities have altered the amount, timing, quality and composition of transported sediments. A variety of land-use changes have contributed to increased sediment delivery to coastal ecosystems through enhanced erosion. These land uses include agriculture, silviculture, dredging, and urban development. In contrast, construction of dams and levees has decreased sediment delivery. Sediment contamination may result from the nutrients and chemicals used in agriculture and the myriad activities of modern society. While most research and policy initiatives addressing alterations to sediment loss and delivery from human activities focus on upstream sources, seaward sources may also be important. Sediments, some contaminated, accumulate in coastal beaches, wetlands and lands as a result of normal tidal delivery and storm events. Dredging and structural changes to shorelines affect this source of sediment supply. The ubiquity of these alterations makes this issue a global one, as the IGOS Coastal Theme recognizes (IGOS, 2003).

Alterations in the quantity and quality of sediment loss and delivery have numerous impacts. The geomorphology of shorelines, and indeed whole coastal regions, may depend on the amount and timing of delivery. This geomorphology is closely linked to human use of these regions, from habitation on deltas to recreational use of beaches. Considerable economic investment depends on a predictable, and often stable, shoreline. Silting of ports and waterways can threaten the safe operation of shipping. Whereas dredging operations have direct economic consequences, the dumping of dredge spoils has indirect consequences, for instance, on environmental quality. The productivity of coastal ecosystems is also affected by increased sediment loss and delivery through enhanced turbidity, associated nutrient loading and the toxic effects of contaminants.

A number of indicators and variables of sediment loss and delivery are already measured by TEMS sites, while others will need to be added through C-GTOS, complementing the needs of other observing systems and assessments (see Table 8). However, many of these measurements cover a limited geographic area. Table 8 focuses on aspects of water flows to the coast (e.g. water discharge) and delivery of particulate matter carried within water bodies.

3.4 WATER CYCLE AND WATER QUALITY

Human activities within watersheds have directly altered hydrology and hydrochemistry of both superficial water bodies and groundwater aquifers (Alexander *et al.*, 2000; Howarth *et al.*, 1996; Nixon, 1981; Smith *et al.*, 2003). The hydrological cycle is forced by both upstream and seaward phenomena. Furthermore, climate changes have induced modification in the permanent ice cover, as well as in frequency and quantity of wet deposition. A variety of land-use changes have contributed to increased modifications in the watershed structure. Construction of dams and levees, variations in the hydraulic regime, wetland reclamation, agriculture and urban development are responsible for changes in the hydrographic networks and delivery of pollutants to coastal ecosystems. The urban development of coastal areas is also responsible for direct contamination of the near-shore system. Reclamation of coastal wetlands and mangroves and exploitation of inshore and near-shore waters for tourism, shipping, aquaculture, etc. also cause relevant losses of ecosystem functions, such as the

TABLE 8

Indicators and variables for sediment loss and delivery

	Observation variables/indicators	Source
CURRENT VARIABLES	Soil annual loss from erosion	TEMS[1]
	Soil erosion from gullying	TEMS[1]
	Topography	TEMS[1]
	Water discharge	TEMS[1]
	Water sediment load	TEMS[1]
	Water storage fluxes	TEMS[1]
	Water runoff	TEMS[1]
	Water turbidity	TEMS[1]
PROPOSED VARIABLES	Accretion rates	USGS[3]
	Currents	C-GOOS[2]
	Elevation changes	USGS[3]
	Number and size of dams	SEDAC[7]
	Particulate C and N	C-GOOS[2]
	Sedimentation	EEA[8]
	Solid wastes	GIWA[4]
	Surface waves	C-GOOS[2]
	Suspended sediment (organic matter)	C-GOOS[2]
	Suspended sediment size	C-GOOS[2]
	Suspended sediments contaminants	OECD[6]
	Suspended solids	GIWA[4]
	Total suspended solids	C-GOOS[2]
	Water yield	MA[5]

Associated organization and source for description of the variables:
1. Terrestrial Ecosystems Monitoring Sites: http://www.fao.org/gtos/tems/variable_list.jsp.
2. Coastal Module of Global Ocean Observing System: http://ioc.unesco.org/goos/.
3. United States Geological Survey: http://www.nwrc.gov/set/.
4. Global International Water Assessment: http://www.giwa.net/.
5. Millennium Ecosystems Assessment: http://www.millenniumassessment.org/en/index.aspx.
6. Organisation for Co-operation and Development: http://www.oecd.org/home/.
7. Socio Economic Data and Application Center: http://sedac.ciesin.org/.
8. European Environmental Agency: http://www.eea.eu.int/.

retention of or buffering against pollutants (De Wit *et al*., 2001; Valiela and Cole, 2002) and loss of fish nursery habitats affecting associated productivity of off-shore commercial fisheries and coral reef biomass and resilience (Mumby *et al*., 2004). From the seaward side, two major phenomena are of growing interest: the ingression of saline water into the coastal groundwater reservoirs and the rise in sea level. The increased salinity of waters in the coastal areas is detrimental for human uses (agriculture, industry and drinking purposes) (King, 2004; Pilkey and Cooper, 2004). The sea level increase is expected to have direct effects mostly in the reclaimed and subsiding lands (Zhang, Douglas and Leatherman, 2004), but it can also affect coastal waters – for example, by limiting light penetration in the benthic system, by changing vegetal communities and by affecting oxygen distribution in the water column. The ubiquity of these alterations makes this a global issue. The impacts of altered quantity and quality of water delivery are numerous. Changes in the freshwater-to-saline water ratio can not only have the above-mentioned impacts, but also affect the aquatic biota and ecosystem productivity. The increased concentration of phosphorus and nitrogen is responsible for eutrophication and dystrophy of coastal waters. Persistent pollutants can accumulate in sediments and aquatic food webs. These quality changes are closely linked to human use of these regions (urban areas, fishery, aquaculture, recreation and tourism). Productivity effects can be witnessed through symptoms of eutrophication, dystrophy and fishery losses. Economic consequences of these changes can be directly monitored through fishery catch, aquaculture production, tourist numbers and related revenue. Scientists believe these changes may significantly threaten coastal productivity and critical resources or cause irreversible alterations, the effects of which cannot be predicted.

TEMS provides information on water cycle processes and on some indicators of water quality (see Table 9).

However, the resolution of information and its specificity to the coastal zone requires further evaluation. Some of the identified indicators and variables are not currently found within TEMS, and will need to be added through the implementation of C-GTOS.

3.5 EFFECTS OF SEA LEVEL, STORMS AND FLOODING

The state of sea level is perhaps more dependent on global climate than any other issue highlighted by the Coastal GTOS Panel. It has been the focus of an international assessment of global change under the auspices of the Intergovernmental Panel on Climate Change (IPCC), which recently predicted an adiabatic global sea level rise (SLR) of an average of 50 cm by 2100, with a range of 20 to 90 cm (McCarthy *et al.*, 2001). It has also been the source of intense controversy concerning the causes, rates and methods of observation (Antonov, Levitus and Boyer, 2002; Cabanes, Cazenave and LeProvost, 2001; Miller and Douglas, 2004). The largest contribution to the observed rise in global SLR is the thermal expansion of warming oceans associated with global warming (McCarthy *et al.*, 2001). SLR is assessed as part of the coastal components of GOOS and GCOS (UNESCO, 2003c). In addition to the melting of land-fast sea ice, causes of SLR that originate in terrestrial environments are also significant and GTOS-relevant. These include the melting of glaciers and mountain ice caps and changes in human storage and connectivity of terrestrial water (King, 2004; Miller and Douglas, 2004). These estimates could change dramatically upon consideration of significant ice melt or shifts in ocean circulation. Regionally and locally, relative sea level can differ markedly from global estimates (Church, 2001; Kerr, 2001). Sea level may decrease in areas of postglacial rebound or tectonic activity, and sea level rise may be greater in areas of subsidence.

TABLE 9

Indicators and variables of the water cycle and water quality

	Observation variables/indicators	Source
CURRENT VARIABLES	Biogeochemical transport from land to ocean	TEMS[1]
	Evapotranspiration	TEMS[1]
	Groundwater fluxes	TEMS[1]
	Groundwater storage fluxes	TEMS[1]
	Precipitation	TEMS[1]
	Rainfall chemistry	TEMS[1]
	Soil infiltration rate	TEMS[1]
	Soil structure	TEMS[1]
	Soil texture	TEMS[1]
	Soil type	TEMS[1]
	Water cation concentration	TEMS[1]
	Water discharge	TEMS[1]
	Water heavy metals	TEMS[1]
	Water inorganic nutrient content	TEMS[1]
	Water organic contaminants	TEMS[1]
	Water trace elements	TEMS[1]
	Water potability	TEMS[1]
	Water runoff	TEMS[1]
	Water storage fluxes	TEMS[1]
PROPOSED VARIABLES	Agricultural/industrial organics	TEMS[2]
	Groundwater conditions	TEMS[2]
	Inland freshwater dams	TEMS[2]
	Municipal waste	TEMS[2]
	Size and distribution of dams	SEDAC[3]
	Water balance	TEMS[2]
	Water organic nutrient content	TEMS[1]
	Water use intensity	TEMS[2]

Associated organization and source for the description of variables:
1. Terrestrial Ecosystems Monitoring Sites: http://www.fao.org/gtos/tems/variable_list.jsp.
2. Terrestrial Ecosystems Monitoring Sites (socio-economics variables): http://www.fao.org/gtos/tems/socioeco_list.jsp.
3. Socio Economic Data and Application Center: http://sedac.ciesin.org/.

The impacts of SLR, storms and flooding may be substantial on both natural and human-dominated ecosystems (King, 2004; Pilkey and Cooper, 2004; Zhang, Douglas and Leatherman, 2004). Increased sea level may cause the following situations:

- loss of property due to flooding;
- increased costs of maintenance of shorelines;
- wetland movement and loss, and
- decreases in water availability for human use.

These impacts come from both the long-term propensity for intrusion of seawater into the terrestrial environment and the increased frequency of storm water flooding. The measurements of sea level and sea state are a commitment of C-GOOS, but the effects of SLR, terrestrial-derived sources of freshwater influx and the indirect influence of land-use change on SLR by global warming are all quite appropriate to C-GTOS, and identified variables are included in this section, as well as those for the water cycle (see section 3.4) and human dimensions (see section 3.2) issues. A limited number of variables have been identified, and most are either listed within TEMS or LOICZ, but these generally relate to sea state and land conditions (see Table 10). Variables measuring the effects of seawater on terrestrial ecosystems, including human-dominated ecosystems, are found in the other sections of this chapter – for example, habitat alteration, land-use and land-cover change.

TABLE 10

Drivers, related variables and indicators of sea level, storms and flooding. Many variables related to resulting effects are associated with other identified issues within this chapter, and are tabled within the corresponding sections

	Observation variables/indicators	Source
CURRENT VARIABLES	Glacier mass balance	TEMS[1]
	Glacier change in length	TEMS[1]
	Topography	TEMS[1]
	Water discharge	TEMS[1]
	Water surface temperature	TEMS[1]
	Wind velocity	TEMS[1]
	Atmospheric pressure	TEMS[1]
	Wind velocity	TEMS[1]
PROPOSED VARIABLES	Bathymetry	USGS[3]
	Height of dykes	TEMS[2]
	Length of dykes	TEMS[2]
	Sea level height	CEOS[4]
	Upwelling	FAO Fisheries Glossary[5]

Associated organization and source for the description of variables:
1. Terrestrial Ecosystems Monitoring Sites: http://www.fao.org/gtos/tems/variable_list.jsp.
2. Terrestrial Ecosystems Monitoring Sites (socio-economics variables): http://www.fao.org/gtos/tems/socioeco_list.jsp.
3. United States Geological Survey: http://www.nwrc.gov/set/.
4. Committee on Earth Observation Satellites: http://www.ceos.org/
5. Food and Agriculture Organization of the United Nations:
http://www.fao.org/figis/servlet/static?dom=root&xml=glossary/index.xml.

3.6 CONTEXT FOR CHANGES IN STATE

The issues of concern described above will be foci for C-GTOS. The number of issues addressed and the depth and breadth of their assessment will increase as C-GTOS develops and matures. The issues are placed into the observation system context in Table 11. One can consider that each issue represents an environmental state or condition, and the observing system goals are to assess changes in these states and conditions. As can be seen, all of the issues within coastal ecosystems relate to more than one category of context of observation systems. Some are involved in feedback loops in which global or regional changes effect change within the coastal zone, and the resultant changes affect global or regional conditions.

TABLE 11

Relationships between changes in states of interest to C-GTOS and scale

		Effects are global	Effects are regional	Response to global change	Response to regional change	Ubiquitous
CHANGES IN STATES	Human dimension, land use/ land cover and critical habitat alteration	●	●	●	●	●
	Sea level, storms and flooding	–	–	●	●	●
	Sediment loss and delivery	–	–	–	●	●
	Water cycle and quality	●	●	●	●	●

Interactions may be complex and encompass multiple issues, as well as scales. For example, global phenomena (e.g. atmospheric carbon dioxide concentration changes and climate) may affect the coastal states with respect to land use, land cover, habitat integrity, water cycle and sea level. All states are considered affected by regional forcing, and all are considered local. However, the local changes are ubiquitous (Bijlsma *et al*., 1996, Marsh, 1999). Conversely, local but ubiquitous and regional changes may affect larger-scale phenomena. For example, widespread changes in sediment loss and delivery or land use may in turn affect the availability and quality of habitat for waterfowl whose migrations are trans- or intercontinental (Michener *et al*., 1997; Thompson and Patterson, 2000) and local wetland sustainability (Christian *et al.,* 2000). The state changes that directly affect global processes are seen only as human activities and alterations to the water cycle.

3.7 DATA AND INFORMATION MANAGEMENT

With the identification of critical indicators comes the need for data acquisition, data management and the integration and analysis capabilities to interpret indicators and develop useful information products for science and decision-making. GTOS has developed an operational system in TEMS that could be extended and refined as part of a distributed network of databases and web portals for related metadata and data. Other information management infrastructures (such as readily accessible data archives) are necessary parts of a mature observing system and are detailed in the GTOS Data and Information Management Plan (GTOS, 1998b).

A draft framework specific to C-GTOS data and information needs is summarized below as a first step towards the development of a complete document. It is based on the GTOS Data and Information Management Plan (GTOS, 1998b), updated to include recommendations in preparations by the Committee on Data for Science and Technology in the Priority Assessment on Scientific Data and Information (ICSU, in preparation). It is divided into a number of basic elements, not totally independent, but intended to provide a convenient structure for presentation and discussion.

3.7.1 User requirements

C-GTOS aims to supply data and information products to address both science and policy needs in each user community. The importance of identifying the needs of the different types of users for each of these issues has been already emphasised and will be a continuing process as C-GTOS develops. There will be new users and new issues, and experience shows that users' requirements will change with time. The definition of user needs must drive data collection and information production.

Policy and actions

- C-GTOS datasets should be collected, developed and managed to meet the known, inferred and predicted needs of the user communities.
- A user needs analysis should precede any major programme of data collection to clearly identify data and information requirements and the core dataset requirements.

3.7.2 Custodianship and quality control

A custodian is the body responsible for the development, maintenance and quality of a dataset, and for arranging access to it while reducing redundancy of data collection and maintenance. Most important, a custodian should have the scientific and technical knowledge and expertise to be in the best position to assess and ensure data quality and to indicate the appropriate uses and limitations of the data. C-GTOS will ensure that there is sufficient documentation associated with any data and information to allow the user community to make a quality assessment; a dataset judged to be of acceptable quality for one user group may be unacceptable for another.

Policy and actions

- As part of the end-to-end information management framework, all C-GTOS datasets will have a designated data custodian.
- Detailed minimum requirements for a GTOS dataset custodian in the form of a pro forma custodianship agreement will be developed.
- Procedures will be established for assigning, managing and reviewing custodians.
- All C-GTOS datasets will be provided with adequate metadata, enabling potential users to assess to judge if the data or information is of acceptable quality.
- Registration procedures will be established for datasets and information products.

3.7.3 Metadata

Metadata are "data about data", describing such things as the general content, intellectual property, geographic nature and quality of the data. They constitute documentation covering all aspects of the end-to-end data management process. Metadatabase systems are systems specifically designed to manage metadata, i.e. to provide facilities for discovery, exploration and exploitation. Such systems may be used within a single institution to organize and maintain its own data holdings. They are also used on a broader level and can then provide a mechanism through which data producers can ensure that potential users are made aware of existing data, their nature and how they might be obtained.

Metadata is an integral component of the desired high-quality data and information products C-GTOS plans to deliver to users. Metadata will facilitate data distribution and access, enable quality assessments to be made and allow for archiving. To assess the metadatabase system needs, the relatively new science of informatics and its appropriate technologies must be applied.

Policy and actions

- All C-GTOS data and information must have metadata in accordance with GeoNetwork and ISO guidelines (ISO, 2003).
- Metadata requirements must be identified at the directory level and guidelines produced.
- Metadata harmonization methods will be built.
- Minimum generic metadata requirements at the dataset level for different data types will be identified.
- Appropriate informatics techniques will be applied, and new approaches developed.

3.7.4 Equitable, free and open access

Existing organizations and institutions that enter into partnership with C-GTOS can be regarded as a loosely coupled distribution system through which data and information can be made available to the user community. At the first level, users must be able to find out what data are available through metadatabases or data catalogues, e.g. TEMS, Global Change Master Directory, and GeoNetwork. The next level involves finding out more detail about potentially useful datasets by examining the associated metadata. Finally, if a dataset appears to be suitable for the intended use, then a simple order-and-delivery process should be available. Ideally, C-GTOS aims to provide data and information in an unrestricted fashion and free of charge while acknowledging situations when a data provider may restrict access to respect individual and national privacy, security and confidentiality.

Policy and actions

- C-GTOS data and information should be made available in a timely and unrestricted fashion at zero (or minimum) cost.
- C-GTOS data and information should be easily accessible in a variety of forms to meet the requirements of the user community.
- Pro forma agreements are needed as a starting point for any necessary bilateral negotiations.
- Guidelines for metadata requirements will be developed to enable user browsing and ordering.

3.7.5 Interoperability

The ability to use data and information collected over long time periods and to integrate data from disparate sources to create new datasets is dependent upon the interoperability of data, software and hardware. By promoting data harmonization and commonly accepted international standards, C-GTOS will seek to bring together various types, levels and sources of data in such a way that they can be made compatible and comparable.

Policy and actions

- C-GTOS datasets should be harmonized, to the extent possible, to allow integration of national and regional datasets into a usable global information resource.
- An inventory will be developed and maintained of all of the principal international standards, organizations and international scientific bodies active in harmonizing environmental data relevant to the scope of C-GTOS.
- Priority areas will be identified where lack of harmonization is hindering the potential usefulness of C-GTOS data.
- International expert meetings will be facilitated and sponsored to develop harmonization techniques in key sectors relevant to C-GTOS.

3.7.6 Archiving

The preservation of data and information to enable use over the long term is intrinsic to the concept of C-GTOS. Archiving is also an essential element of the end-to-end data management framework, and custodians will be expected to have archival procedures in place. C-GTOS could designate specific custodians as “archive facilities” and ensure that every data holder is associated with one such facility to which copies of all material to be archived should be forwarded. Even if it is possible to archive all data and information, it might be neither practical nor economically feasible. Again, informatics approaches are needed to aid decision-making. Thus C-GTOS should consider the cost of archiving, which includes the preservation of data integrity and the upgrading of databases as the software and hardware technologies advance.

Policy and actions

- All C-GTOS data and information must be securely archived, along with all relevant metadata.
- An appropriate number of custodians will be designated C-GTOS data archive facilities.
- Guidelines will be developed for archival requirements for C-GTOS products.
- All data holders will have archival procedures in place that are consistent with GTOS guidelines.

3.8 CAPACITY BUILDING

Challenges exist for C-GTOS. The challenge faced by much of the terrestrial ecosystem monitoring community, and C-GTOS in particular, is at least partly due to the following factors:

- The community is very diverse and fragmented in terms of disciplines and research priorities. (in some ways this contrasts with C-GOOS, where many researchers and management programmes are devoted specifically to coastal waters).
- Inadequate national resources and political commitment are available for long-term research, especially in developing countries.
- Most regional and international collaboration experience is limited (this is contrary to the atmospheric and ocean communities, where such collaboration is long-standing and reasonably effective).

These challenges must be faced by the terrestrial ecosystem monitoring community and TEMS before data starts being more freely exchanged, assembled and assimilated in large-scale datasets. Even so, these are only the initial challenges. Integration and analysis of data to generate useful products for decision-makers presents an even greater challenge. All of these challenges can be met through the building of capacity in one form or another.

This plan does not outline a definitive capacity-building plan. The principles for capacity building for observing systems have been discussed elsewhere (GTOS, 1998a; UNESCO, 2003c), as have details. We identify here issues that are considered of special importance to C-GTOS, recognizing that considerable effort is needed to ensure successful maturation and sustainability of the observing system. The mechanisms for this effort require future consideration.

First, there is a need to intensify the harmonization, standardization, and quality of long-term coastal data by developing and disseminating methodologies and supporting education and training efforts. These efforts must be sustained and reinforced, especially in developing countries.

Second, it is important to increase the visibility of terrestrial ecosystem research in the context of the coastal zone by underscoring the central tie between socio-economic factors and ecological changes. Most efforts in coastal observations have been from the oceanographic and marine science community. This is because a significant portion of this community identifies itself with coastal and estuarine waters. Coastal wetland scientists and managers often have a history in marine science. The oceanographic community has provided a political constituency to advance C-GOOS. No comparable community exists for terrestrial science. The terrestrial and freshwater coastal zone is not perceived as unique from other terrestrial and freshwater environments. This cultural difference needs to be addressed, and special effort is needed to develop a labour force and intellectual base for the non-marine environments of the coastal zone.

Finally, there is a need to foster more cooperation between national and international ecosystem monitoring networks and stations through concrete activities such as C-GTOS. This cooperation can be achieved through greater recognition of the relevant transboundary (nutrient discharges, bird migration and mangroves as well as fish nurseries) and global issues (carbon flux, coastal erosion). An opportunity to promote this cooperation is presented through the implementation of C-GTOS as described here.

CHAPTER 4

PHASE 1 IMPLEMENTATION PRODUCTS

4.1 RATIONALE FOR INITIAL IMPLEMENTATION

Developing a mature C-GTOS will not occur in a short time. Because it is interfacial between GTOS and GOOS, the plan for C-GTOS has had to take elements of both observing systems. GTOS programmes have tended to focus on ambitious but discrete products, such as estimates of the global flux of carbon or net primary production on land, i.e. terrestrial carbon observations and net primary productivity. GOOS programmes are developing more as systems of numerous measurements and products. C-GTOS promotes a mixture of both methodologies, with the goal of creating a limited systems approach. To achieve this long-term goal, however, C-GTOS must establish credibility through well-defined initial products. Collectively, these products can be considered the phase 1 implementation of the C-GTOS.

This chapter describes a set of proposals for initial products within the Coastal Module of GTOS. These products address aspects of the issues or changes in states of interest identified previously (Chapter 3), assess capacity in certain areas, promote improved capabilities to enact the mature C-GTOS. Thus, products are seen as spanning the range of research from pre-operational and pilot project to operational. The issues include the following: (i) human dimensions, land use, land-cover and critical habitat alteration; (ii) sediment loss and delivery; (iii) water cycle and water quality, and (iv) sea level change, storms and flooding. Capacity will be assessed throughout the process of developing these products, and improved capabilities will be required to achieve the proposed products. Described in detail in subsequent sections, the initial products are as follows:

- enhancement of TEMS;
- distribution and rate of change of population, urbanization and land use in the coastal environment;
- vulnerability of ecosystem services in deltaic systems;
- management of conservation and cultural sites in the coastal zone;
- distribution of sites appropriate for analyses of delivery systems.

In terms of rationale for project selection, the products are designed to provide tests of concept for the observing system, determine the initial array of variables and indicators to be sampled and improve needed components and capabilities. Also, such initial products provide inroads into the accessibility of data needed for the more mature C-GTOS.

Three principles underpin phase 1 project selection. First, TEMS is seen as a key tool for programmatic delivery by serving as a central platform for facilitating and coordinating C-GTOS activities. A fundamental consideration is therefore the requirement to reinforce TEMS, with the role of fostering or improving communications between data providers and end users, including the dissemination of products and models. Second, research has been recognized as a valid component of C-GTOS, whereby such efforts are focused on proof of concept or developing products to improve information and technology transfer to developing countries. Third, a global or large-scale regional perspective is necessary in product development. While the global context of some of the phase 1 products is obvious, this is probably not the case for a study of deltaic systems. Nevertheless, this project aims at a proof of concept and provides a venue for developing informatics for C-GTOS. The end product should not only be transferable to other deltaic systems, but be adaptable to other ecosystems.

Explanation of each priority product is given in the following Sections in the form of a project proposal. Note that these explanations are written with a greater degree of detail and technicality than previous sections. The style reflects the need to demonstrate appropriate scientific rigor. We advise readers, who do not wish to delve into the details, to focus their attention on introductory, objectives and "importance to" subsections and not read the methods subsections.

4.2 ENHANCEMENT OF TEMS

4.2.1 Overview

TEMS was created in the late 1980s by the Global Environment Monitoring System Programme Activity Centre of UNEP as an international registry of terrestrial observation sites that access, measure, monitor and catalogue ecological data.

Since 1996 the GTOS Secretariat in Rome, Italy, has managed and developed the database with technical support from the FAO. It now contains approximately 2050 sites, 40 networks and 1300 contacts, all of whom are surveyed annually for updates. Site, network and variable information can be accessed through the TEMS Web site, which includes metadata, maps and variables methodology sheets (see http://www.fao.org/gtos/tems).

The TEMS database is a GTOS-led effort to enhance monitoring site collaboration and provide a framework for researchers, resource managers and decision-makers who seek data and information to support their efforts at the regional and global level.

The overall objectives of this proposal are to enhance TEMS to meet new coastal user needs by (i) improving TEMS geographical coverage through registration of relevant coastal networks and sites; (ii) developing new coastal monitoring variables and indicators and facilitating access to scientific datasets; (iii) integrating satellite images with ground measurements, and (iv) enhancing the outreach of TEMS.

4.2.2 Introduction

The core of the TEMS database consists of the research sites, which actively carry out, collect, distribute or own large time-series datasets. To be registered, the sites must be committed to long-term research, systematically monitor a suite of variables and express interest in international collaboration, as demonstrated by the presence of openly accessible or at least partially accessible datasets and data sharing. Finally, the sites should be well established in their area of study and degree of involvement with the international community to ensure the quality of the data they provide. Sites' efforts should directly relate to at least one of the five key GTOS issues: (i) changes in land quality; (ii) availability of freshwater resources; (iii) loss of biodiversity; (iv) climate change, and (v) impacts of pollution and toxicity.

All variables included within TEMS have an associated datasheet or methodology. A brief description of the existing GTOS environmental and social variable methodology and data sheets is included below.

Environmental variables methodology sheets

New site managers using the TEMS software select the most relevant coastal variables that best describe the observations made at their site. For coastal sites there are three groups of variables, described in Chapter 3, which will guide site managers in measuring and monitoring the following coastal environmental issues:

- sediment loss and delivery;
- water cycle and water quality;
- effects of sea level, storms and flooding.

Each variable (e.g. soil moisture, water pH) is accompanied by a methodology sheet that sites can use as a basis to start monitoring activities. These methodology sheets focus on identifying terrestrial observation requirements, assisting the establishment of coastal terrestrial observing networks and assessing their adequacy, providing guidance on observation standards and facilitating access to terrestrial data (GTOS, 1997b).

Socio-economic data sheets

In a similar fashion to the environmental variables, data sheets have been developed for the preliminary C-GTOS socio-economic variables identified (section 3.2) to facilitate the integration of coastal environmental and socio-economic issues. These will guide site managers in the selection of variables that best describe the ongoing observations taking place at their sites.

Need for a TEMS Coastal Module

Early in 2002 a user survey was carried out to assess the use of the TEMS database and the adequacy of geographic coverage and to identify future user requirements. The survey also assessed the utility of specific features within the Web site, such as the thematic modules (biodiversity, coastal, forest and hydrology). The research sites reported that 19 percent of respondents included coastal monitoring as part of their site research (Tschirley, Servin and Sessa, 2003). Table 12 shows the distribution of all member sites of TEMS, and their distance from the coast. One of the first steps in developing the new coastal component of the TEMS system will be to identify a subgroup of coastal sites and networks that would most benefit from this new initiative.

TABLE 12

Distribution of current TEMS sites with distance from the coast

Distance from the coast	Number of sites	Cumulated number of sites	Percentage of total sites
Less than 5 km	160	160	10
Between 5 km and 10 km	213	373	14
Between 10 km and 50 km	497	870	32
Greater than 50 km inland	700	1570	44
All sites	**1570**	**1570**	**100**

Note: This information was derived from a representative subset of the registered TEMS sites at the time of publication.

Sites located within 50 km of the coast will include the majority of members suited to the coastal subgroup, but sites up to 100 km from the coast will be contacted to facilitate access to data useful to coastal studies with broader geographical boundaries (Bryant *et al*., 1998; Cohen *et al.,* 1997; Scialabba, 1998; Nicholls and Small, 2002). Sites will also be identified based on the type of data they deliver for specific coastal user needs. Coastal variables can be cross-referenced with the existing sites to identify areas of under representation.

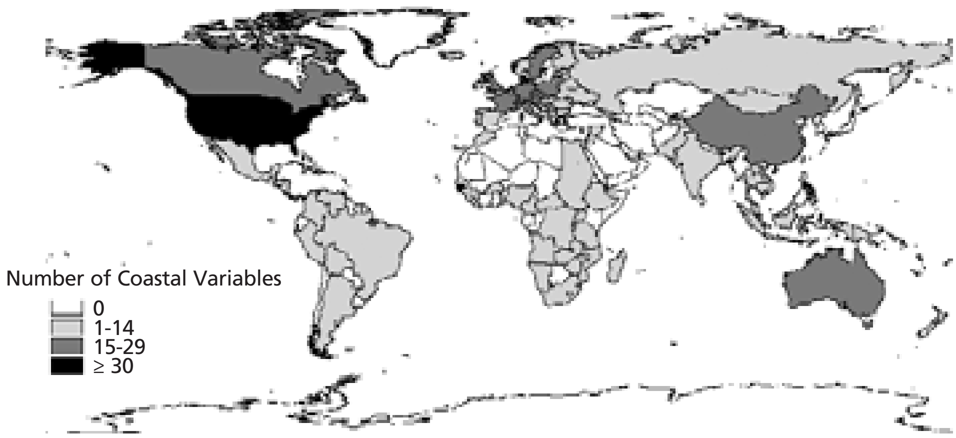
Figure 3 shows the global distribution of variables addressing coastal issues, monitored at current TEMS sites. Although this analysis shows only the presence or absence of variables within each country, it does identify the necessity for an expansion of current TEMS coverage, focusing on the regions of Africa, South America, Asia and Oceania, to ensure comprehensive coverage of coastal variables for C-GTOS as described below. It should be noted that some landlocked countries are shown to have the presence of low numbers of coastal variables monitored. This is because some coastal variables are the same parameters measured for other GTOS monitoring themes, such as hydrology and biodiversity, within these countries. Further analysis of site distribution and variables measured addressing specific issues, such as sediment loss and delivery (see Table 8) or water cycle and quality (see Table 9), will aid in identifying gaps in country coverage on C-GTOS focus issues. Methods of engaging and maintaining dialogue with existing and new TEMS members are described in the following outreach section. Cooperation with GOOS and IOC will be necessary in identifying and registering sites.

4.2.3 Objectives, proposed products and methods

The proposed Coastal Module of TEMS has been designed to close the gaps between global environmental and socio-economic data for coastal ecosystems. This module will allow users to search solely through the coastal sites and thus provides easier access to information on nutrient and sediment transport, land use and land cover, habitat quality monitoring and assessment, as well as socio-economic and human population data for coastal regions. The successful development and wide utilization of TEMS are largely due to the programme's focus on a few key outcomes and objectives, and all planned enhancement of TEMS for C-GTOS will use the same approach to cater for the needs of

FIGURE 3

Between The global distribution of current coastal variables measured at TEMS sites in each country. The number of coastal variables measured at one or more sites within each country is shown ranging from 0 to equal or greater than 30



new users from the coastal community. The following activities will provide a substantially enhanced TEMS but will not provide the full capacity to convert data to information products within the mature C-GTOS, which will depend on further development of the informatics capacities of C-GTOS, GTOS and IGOS. The proposal in section 4.4 on deltaic systems will begin the process of developing appropriate informatics techniques for C-GTOS.

Improve geographical coverage

Networks registration: Terrestrial ecosystem monitoring is expensive and difficult to sustain if it does not meet specific policy and management priorities. Therefore a long-term commitment may not be the first priority of governments, especially in developing countries, where poverty, hunger and health issues may be more critical. This is part of the reason why 85 percent of the sites are located in Europe and North America. A continuous effort is needed to identify and register networks and sites working on coastal issues, geographically located within the coastal zone (see Table 12) or areas associated with user definitions of the coast (see section 2.1). Analysis of existing TEMS data, such as the global distribution of current coastal variables shown in Figure 3, will be used as a tool to direct efforts to recruit new coastal site members. It can assist in filling the gaps in the geographical distribution of sites, identifying regions where coverage is inadequate, particularly in Africa, Asia, Latin America, and Oceania. It can also help to identify gaps in the coverage of the monitoring variables, principally in areas where a more complete geographic coverage exists. Among new sites and networks to be contacted, government and university-affiliated organizations will be given priority. In addition, it will be valuable to seek new partnerships with intergovernmental private institutions and non-governmental organizations. As noted in section 1.4.1, various coastal conservation sites may be enticed into the TEMS network, as both providers and users of data. COOP, IOC and GEO will play integral roles in this process.

Development of monitoring variables and access to data

Organize a workshop of experts to further characterize the variables following the Terrestrial Observation Panel for Climate (TOPC) methodology (GTOS, 1998c) and determine their value in detecting, assessing and understanding global and regional changes in the coastal zone. In order to achieve this, the following subactivities will be carried out and supported by the C-GTOS Panel scientific experts: (i) obtain feedback from users and coastal networks on the preliminary list of 54 environmental and 37 socio-economic variables identified for C-GTOS (Chapter 3); (ii) finalize C-GTOS variables; (iii) assess the selected environmental and socio-economic variables using the COOP ranking methodology; (iv) refresh and update the variables sheets and review the identified primary and secondary data holders by performing a quality assurance/quality control assessment, and (v) identify any new variables of major interest and create the appropriate variable sheet following the same methodology.

Data matrix development: In collaboration with the Global Observing Systems Information Center (GOSIC), GTOS developed a data matrix prototype (see http://www.gosic.org/ios/GTOS_observing_system.asp) based on GHOST hierarchy (see http://www.fao.org/gtos/GHOST.html). The GHOST hierarchy has five tiers, each with unique characteristics and roles, although existing facilities often straddle more than one tier. On the macro level a few variables are measured regularly in a large number of places, and on the micro level a large number of variables are measured in a few locations for a limited period. The relevant datasets of interest will be extracted from NASA's Global Change Master Directory (GCMD) using the following criteria: variables/keywords, spatial extent (regional and global level) and long-term duration (more than five years). Additional key datasets will be registered in GCMD. These datasets will be available through the data matrix interface, increasing the monitoring site information accessible to the TEMS user and providing a conduit for future translations of GCMD and TEMS variables. To further enhance the accessibility of information across the two information servers, additional development will involve a dynamic link between the TEMS Web site and GCMD site data. This will be a prototype for the integration of TEMS products with other global information systems, enabling live GCMD search capacity and links for users to jump directly to view GCMD datasets.

Metadata registration: Metadata provide detailed and standardized descriptions to understand the data published and support interoperability and sharing within and among organizations. Recently, the GTOS Secretariat has been considering the registration of metadata, using the GeoNetwork system, for the scientific datasets collected and owned by TEMS sites, complying with global standards and guidelines being developed including ISO (ISO, 2003), GEO (GEO, 2003), and UN-endorsed spatial data standards such as those used by GeoNetwork and Dynamic Atlas products. Forty-four percent of the respondents to a questionnaire addressing this issue expressed their interest in registering their datasets in a metadata directory (Tschirley, Servin, and Sessa, 2003). As a pilot project to address metadata standards within TEMS all new coastal variables and data sheets will comply with current metadata standards. Assistance will be provided to new coastal sites to record complete metadata information on registration.

Software development: simplicity, efficiency and accessibility

Inherent in the TEMS vision is the need for simplicity and speed. The platform independent architecture of the TEMS information system has a low maintenance cost and enables both users and site managers to quickly access the information they need from the Internet through a user-friendly interface using search engines and dynamic Web maps. Registered site managers can update their own site data online with a username and password.

Compliancy and integration with existing spatial data management initiatives

The GeoNetwork initiative is the cornerstone of FAO's spatial data infrastructure development (see http://www.fao.org/geonetwork). The purpose of GeoNetwork is to

- improve access to and integrated use of spatial data and information;
- support decision-making in agriculture, forestry, fisheries and food security;
- promote multidisciplinary approaches to sustainable development, and
- enhance understanding of the benefits of geographic information.

It is a fully operational system for the formulation, management and dissemination of metadata and data. In addition, it provides dynamic access to certain datasets through an ArcIMS-based map server. The expert user can also gain access to GeoNetwork datasets from desktop geographic information system (GIS) software and overlay them with local data. All spatial products produced as part of C-GTOS, such as the TEMS dynamic maps of coastal sites, will be compliant with current ISO metadata standards (ISO, 2003). Products will be made available to a wide audience of users through the GeoNetwork web portal but can also be made accessible to those without Internet access in future projects through the development of stand-alone products using the FAO publishing software Dynamic Atlas (GTOS, 2003).

Integrate remote sensing measures

Remote sensing data access: Since 1998, the GTOS Secretariat has been developing a few projects linking ground measurements (e.g. land cover, leaf area indices and net primary productivity) with satellite-derived remote sensing data. Using sensor data collected from a single source provides complete, globally consistent measurements, temporally and spatially, which can then be compared and refined using the ground-based measurements. The database will include links to existing similar projects under the resources heading, to alert users to the utility of linking *in situ* and satellite measurement. TEMS is already providing, in the variables section, a link between the variable measured and its equivalent in the CEOS - World Meteorological Organization (WMO) database. It allows users to find which satellite sensors and missions are measuring particular variables. An interface will be developed so that users can identify imagery relating to their site of interest according to individual specifications (e.g. sensor, frequency, repetition rate, resolution). This is also a step towards delivering spatial data directly to users, a service that is possible through the future integration with other spatial web services such as GeoNetwork.

***In situ* validation of remote sensing products:** Collecting data at the global level using satellite sensors not only is far less expensive and faster than intensive field, i.e. *in situ,* observations, but also covers very large areas in a short time frame. However, variables measured by satellite are rarely compared with ground measurements. *In situ* networks provide invaluable validation data to assess and improve the accuracy of satellite products. The links between these two observing methods tend to be sporadic and weak. TEMS provides direct links to the joint CEOS/WMO database that contains information about the variables measured by various satellite missions and instruments. The system is seen as a potential tool to bridge these two data-collecting methods by linking the precision, accuracy and consistency with which land-based sites can measure certain variables to the larger-scale assessments that are possible on satellite platforms. The implementation of C-GTOS, and collaborations with other observation systems as part of the IGOS Coastal Theme, will further develop links between *in situ* and satellite observations with specific products for coastal areas. This includes planned missions such as the Soil Moisture and Ocean Salinity (SMOS) of the ESA, and programmes such as COASTWATCH and COASTCHART, which will provide satellite-derived products to the Coastal IGOS and GTOS coastal community.

Enhance outreach

Increase visibility: The key question that future developers of TEMS must address is not how to make the Web interface easier to use, but how to increase the use among existing members and how to attract potential new users based on an outreach strategy. As there is already an existing base of members who measure coastal variables (see Figure 3), these member sites and networks will be the first contacted to form a subgroup of coastal member sites for C-GTOS. To aid the development of the Coastal Module, this group will be invited to participate in the review process for the enhancements in its embryonic stages and to provide feedback on this and other components of C-GTOS. Follow-up correspondence with the coastal member groups will involve mechanisms for interactive feedback on TEMS through the Web site and via e-mail. Participating coastal members will also be asked to identify sites within their own region that should be approached to fill gaps in coastal data coverage. This request will be made through tailored mailings containing information particular to their geographic location and area of specialization. To engage new sites and attract users looking for coastal data, collaboration will be pursued with identified coastal networks (see section 1.4.1) such as IUCN and NetCoast. The presence of C-GTOS and TEMS will be publicized through network newsletters and mailing lists, international meetings and conferences and scientific publications.

4.2.4 Importance to GTOS and importance generally

Many challenges remain to be faced by the terrestrial ecosystem monitoring community before data can be more freely exchanged, assembled and assimilated in large-scale datasets. Enhancing TEMS will enable GTOS to contribute in several ways to global and regional monitoring of coastal environmental change. It will

- improve harmonization, standardization, and quality of long-term terrestrial data;
- increase the visibility of terrestrial ecosystem research by underscoring and acknowledging the central tie between socio-economic factors and ecological changes, and
- foster greater cooperation between national and international ecosystem monitoring networks and stations through the realization of concrete activities in coastal areas.

4.2.5 Timeline and implementation options

- Coordinate with other observing programmes that have a coastal focus (such as IGOS partners) to access, manage and process satellite and remotely sensed data: 2-5 years.
- Ensure access and complementary cross-institutional management of coastal data by coordinating with other coastal observing programmes in the development of variables, metadata and data sharing matrices: 2-5 years.
- Redefine the content and presentation of coastal data in C-GTOS according to users' needs, and develop access to sites and information based on these needs: 1 year.
- Identify and register more coastal sites into TEMS with special emphasis on including "marine" laboratories that sample land-based, freshwater, wetland and estuarine ecosystems and sites from underrepresented regions: 1-5 years.
- Define and characterize new and previous coastal and socio-economic variables in a manner similar to that done for other variables of TEMS: 2 years.
- Enhance spatial data capabilities and adopt open data standards to provide information products to users via the Web and through stand-alone GIS software: 2-5 years.

4.3 DISTRIBUTION AND RATE OF CHANGE OF POPULATION, URBANIZATION AND LAND USE IN THE COASTAL ENVIRONMENT

4.3.1 Overview

Currently, 1 billion people live in urban areas, and 3.2 billion people, or more than half the current global population, live on or within 200 km of a coastline. By 2025 that number is expected to increase to 6.3 billion or 75 percent of the then global population (UNESCO, 2003b). While these statements are open to debate, they underlie the fundamental questions about coastal population, land use and urbanization. The effects of the growing coastal population, and increase in urbanization both on the coast and further inland, drive changes in land use affecting the sustainability of the coastal ecosystem and reshape our current concept of the coastal environment.

Key questions

To begin to address these issues and formulate a plan of action to offer possible solutions to these problems, we need to answer four key questions:

- What is the distribution of population in the coastal zone?
- What is the distribution of urbanization in the coastal zone?
- What is the distribution of land use in the coastal zone?
- What are the rates of change for these variables?

4.3.2 Introduction

GTOS has developed a module responsible for the information concerning the terrestrial, wetland and coastal freshwater ecosystems appropriate to observing system needs. This land-based module of GTOS leads towards integrating terrestrial observations with marine observations to understand better the dynamics of change and the magnitude of its impacts. One of the fundamental parameters in determining the effects of the terrestrial portion of the coastal ecosystem is the extent of the human population, the scope of human activity and the socio-economic activity associated with the current and future increased population.

The population in the coastal zone is a major factor in assessing the health of the coastal ecosystem. The distribution of population is reflected in the types of coastal land use, and changes to these indicators are key elements in predicting their effects on coastal systems, e.g. loading of nutrients, sediments, pollutants or pathogens and resulting biological or ecological response in coastal waters. It is proposed that coastal databases of these key indicators be developed using existing, non-proprietary datasets for broad application in global coastal studies. These databases can then be tied in with existing coastal marine ecosystem and water quality assessments, e.g. UNEP GPA, to understand and predict the impact of human population growth in coastal regions and promote improved management.

4.3.3 Objectives and proposed products

It is proposed that an initial product be created showing the distribution of the coastal population and the extent of urbanization and land use in the global coastal regions. Periodic updating and recompilation of these datasets for different time periods will allow a spatial and temporal assessment of the dynamics of the changing coastal population and its effects on land use. These periodic updates will be secondary products, the value of which will increase in proportion to the number of temporal epochs developed.

Fully describing and understanding the coastal ecosystem requires the population dynamics to be accurately described and understood. Changing population is reflected in changing land-use patterns, including an apparent increase in urbanization. Once the initial state of the dynamic population is understood, key parameters, which are indicators of the response of the coastal ecosystem to a wide range of human-related activities, can be recognized, and observing systems can be optimized or designed.

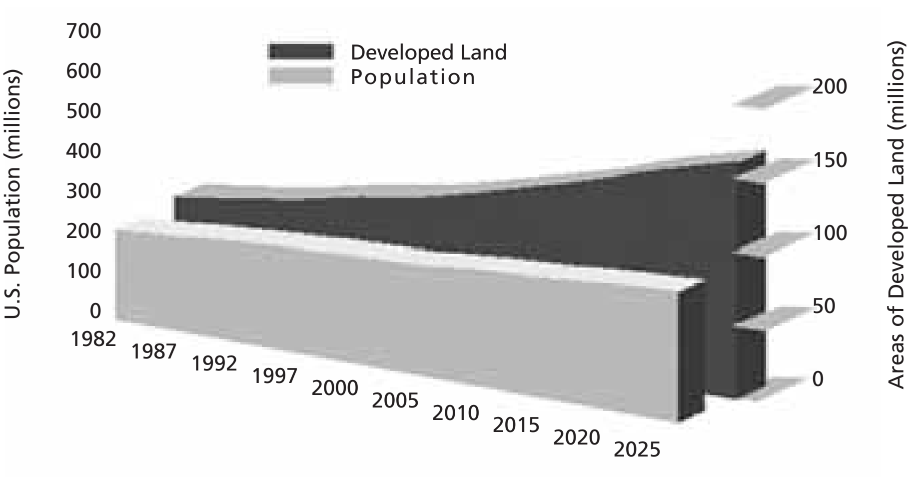
4.3.4 Significance to GTOS and beyond

The impact of population on the coastal ecosystem will be a major issue in this century. The rate of change in land use in the coastal environment will significantly outpace the steady increase in population in the coastal region.

For example, land in the United States has been developed at more than twice the rate of population growth since 1982. This increase is a result of a consistent decline in development densities over the past several decades. If the trend continues through the year 2025, the nation will consume another 68 million acres (25 million hectares) of rural land for urban development (see Figure 4).

FIGURE 4

A comparison of historical and projected population and developed areas in the United States (PEW, 2000)



4.3.5 Methods

- Identify and describe a representative set of indicators and methods of measurement for global coastal population, coastal population density and land-use/land-cover pattern and composition.
- Derive a "best set" of global population distribution, urbanization and land use/land cover using the current best available data. The best available datasets are described in section 4.3.6 below. A definition of the coastal zone will be determined for this initial assessment according to the requirements of C-GTOS, as appropriate, recognizing that effective choice of these indicators and methodological approaches will be driven by the context of use. Therefore the Coastal Panel of scientific experts present the case that assessment be carried out in light of the following:
  - Differing geographic properties and dimensions evolve from alternative definitions of the coastal zone. These differences in spatial context would, for example, vary if the coastal zone were defined by (i) simple and traditional

distance from the coast definitions (e.g. 100 km from high mean water); (ii) functional, sectoral or use-based descriptors; (iii) watershed dynamics, or (iv) political or regulatory boundaries.

- Policy questions involving coastal areas, population and land-use dynamics are context driven. For example, large-scale social characteristics such as level of economic development or political boundary conditions will certainly be different in different parts of the world, thus potentially requiring different views and uses of alternative indicators and methods.
- Human dynamics in the coastal zone have a temporal dimension ranging from the question of resident versus seasonal coastal population to decadal changes in urban sprawl.

- Determine and rank indicator choice, methodological approaches and data sources according to a set of assessment criteria designed to distinguish their value in addressing these questions of context.
- An effective assessment of criteria will cull or expand upon such categories as indicator type, spatial extent, variables required, linkage value, spatial resolution, temporal resolution, start date, update frequency, data sources, accuracy or precision, reliability and validity.
- Changes in the temporal and spatial distribution of population, urbanization and land use/land cover will be assessed as the datasets are developed for different time periods. This assessment will be an ongoing aspect of this project. Some of the data sources are periodically updated as part of ongoing operational efforts, so the use of these datasets will greatly facilitate this aspect of the project.

4.3.6 Datasets to be considered

A number of databases will be used to develop these products; these should be unrestricted, non-proprietary datasets in the public domain. A preliminary list of available products is included below, from which the appropriate datasets will be selected for the project. The selection will be based on both the functional use products and data interoperability issues that may arise owing to the use of multiple datasets.

DOE Landscan Ambient Population

The Landscan Global Population Project was developed as part of the US Department of Energy (DOE) Oak Ridge National Laboratory (ORNL) Global Population Project. It is a worldwide population database at 30" X 30" resolution for estimating ambient populations at risk. Best available census counts are distributed to cells based on probability coefficients, which, in turn, are based on road proximity, slope, land cover and nighttime lights. Verification and validation studies have been conducted routinely for all regions and more extensively for portions of the Middle East and the Southwestern United States. The dataset has been used for estimating ambient populations at risk. Files are available via the Internet in Environmental Systems Research Institute (ESRI) grid format by continent and for the world. The dataset is updated yearly.

DMSP Nightlight database and Nightlight change database

The U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) has a unique capability to collect low-light imagery. The DMSP is a polar-orbiting satellite and views a 3000 km swath with a 2.7 km ground sample distance. The satellite possesses two spectral bands: visible and thermal. There is nightly global coverage. The programme has been operating since 1972, and digital data are available from 1992 and will continue until around 2012. To derive the stable nighttime light database, algorithms were applied to about 1000 orbits of data covering the same time period to generate the first digitally derived global map of nighttime lights. Four different types of lights were distinguished: (i) human settlements; (ii) gas flares; (iii) fires, and (iv) heavily lit fishing boats. Two global datasets were derived – one for 1992-93 and one for 2000. In 1995 the National Geophysical Data Center (NGDC) researched the calibration of the OLS low light imaging data and in 1996 conducted experiments with the gain settings on the OLS. It found that it would be possible to generate a radiance-calibrated nighttime lights product. It was found that three gain settings are required to cover the full dynamic range of observable light from human settlements. A preliminary global product was made using 28 nights of data from 1996-97. This preliminary product does not have an atmospheric correction applied and suffers from low numbers of cloud-free observations in many parts of the world.

Global Landsat mosaic (1990, 2000)

NASA formally donated to UNEP (and to the wider UN) the 1990 and 2000 Global Landsat datasets developed and orthorectified by Earthsat as part of a Science Purchase Program. Once processed, the data were delivered to NASA's Stennis Space Center, which then passed them on to organizations responsible for distribution, such as the USGS Distributed Active Archive Center and the University of Maryland Global Land Cover Facility. The two mosaics consist of: (i) 1990 mosaic - 7 bands/30 m resolution/7500 scenes, and (ii) 2000 mosaic - 9 bands/1 at 15 m/8500 scenes (this is currently being compiled with 2500 scenes already available).

The compilation process took the best available image (i.e. most cloud free) for the year in question and combined these into an orthorectified mosaic for the entire earth's land surface covered by Landsat. Online access to single scenes and Red Green Blue images (bands 7, 4 and 2) of the 1990 and 2000 mosaics is already possible. Mosaics are available to view at full resolution (30 m) and can be downloaded in 5 ° tiles in MrSID format (http download at 70 Mb per tile).

Shuttle Radar Topography Mission

The Shuttle Radar Topography Mission (SRTM) is a joint project between the US National Imagery and Mapping Agency (NIMA) and NASA. The objective of this project is to produce digital topographic data for 80 percent of the earth's land surface (all land between 60° north and 56° south latitude), with data points located every 1-arc-second (approximately 30 m) on a latitude/longitude grid. The absolute vertical accuracy of the elevation data will be 16 m (at 90 percent confidence). This will result in the most accurate and complete topographic map of the earth's surface ever assembled.

Even though the mission will generate a 30 m resolution Digital Elevation Map, it is not yet clear whether this will be made generally available for the whole world at low or no cost. Alternatively, it is planned that a slightly reduced resolution (90 m) will be made available free of charge. This resolution is sufficient for draping 30 m Landsat imagery and creating perspective. The ability to create three-dimensional perspective views helps with interpreting the Landsat imagery, especially in the creation of land-use/land-cover spatial distributions.

Moderate Resolution Imaging Spectroradiometer (MODIS)/Terra Global 1 km Land Cover/GLOBCOVER

The MODIS Land Cover Classification product, MOD12Q1, identifies 17 classes of land cover in the IGBP global vegetation classification scheme. This scheme includes 11 natural vegetation classes and three developed land classes. One of these is a mosaic with natural vegetation, permanent snow/ice and barren or sparsely vegetated land, and water. Additional Science Data Set layers for other classification schemes include the University of Maryland modification of the IGBP scheme, the MODIS LAI/fPAR (MOD15) scheme, and the MODIS Net Primary Production (MOD17) scheme. These classes are distinguished with a supervised decision tree classification method.

The MOD12 classification schemes are multitemporal classes describing land-cover properties as observed during the year (12 months of input data). Successive production of this “annual” product allows us to make new land-cover maps with increasing accuracies as both classification techniques and the training site database mature. For land-cover change, users should use the Vegetation Cover Conversion product, MOD44, or the Land Cover Dynamics product, MOD12Q2. The data are available for the global extent of land area in 317 HDF-EOS file format files in nominal 10° tiles in Integerized Sinusoidal Grid projection.

The GLOBCOVER initiative will develop services for a global land-cover map for the year 2005, using the same thematic legend as the FAO Land Cover Classification System (LCCS) that was used for GLC-2000. The product will be derived from MERIS sensor data improving on the previous GLC-2000 dataset through a finer resolution (300 m).

Further development and application of MODIS vegetation continuous fields and MODIS urban products will be made. These represent new and improved efforts to address urban contributions to landscape conditions and should be considered as one of the combination of data sources needed for the product.

4.3.7 Limitations of the data

The DMSP nighttime lights have their limitations. At present, these data are the best available on a global basis and are available without restriction. However, there are particular applications or assessments for which higher resolution, greater accuracy, different time scale and other human dimension indicators will be needed for a particular application or assessment. This proposed effort is to provide reference or baseline datasets for population, urbanization and land use/land cover from which gaps in the data related to particular applications can be determined. As already noted, the quality of the data used to derive these indicators needs to be assessed in relation to its application. Nighttime light imaging provides useful insight. In some areas, there will be problems with the data.

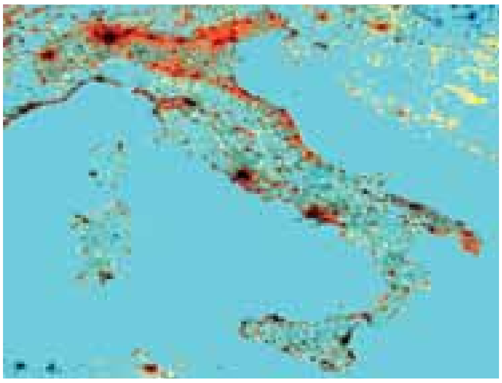
Indeed, for many applications it is clear that the spatial or temporal resolution of nighttime light data holds remarkable value in determining population dynamics, where lights can be taken as an indicator of density. Below are two images of Italy (see Figure 5). The image on the left shows that a sizable amount of change has occurred over seven years. This has been described as urban sprawl, which indicates changes in land-use patterns and population density and distribution. Specific methods need to be developed for deriving land use data from these data, possibly using ancillary sociological data. There are, however, challenges to this approach in areas where population density is not reflected by nighttime power use (e.g. impoverished areas of the globe or areas of significant cultural differences).

The changes in human population and the resulting changes in land use may be the single most influential factor in understanding coastal ecosystems. These datasets will be useful to a wide variety of users, including researchers, land use managers, emergency response planners, and policy-makers. Many of the limitations found with DMSP nighttime could be overcome with higher spatial resolution and on-board calibration.

FIGURE 5

DMSP nighttime lights change detection results (1992-93 versus 2000) in Italy (C.D.Elvidge, NOAA-NGDC)

LEGEND
Red: Lights brighter in 2000
Cyan: Lights brighter in 1992-93
White: Lights saturated in both periods



LEGEND
Red: Lights brighter in 2000
Yellow: New lights in 2000
Blue: Lights brighter in 1992-93
Blue/Grey: Dim lights detected in both years
Black: Lights saturated in both periods

FIGURE 6

High resolution nighttime lights of Las Vegas, Nevada acquired from a NASA aircraft (C.D. Elvidge, NOAA-NGDC)

See Figure 6, showing nighttime lights of Las Vegas, Nevada acquired at 1.5 meter resolution from a NASA aircraft. With high resolution it is possible to discern major streets, detect lights from individual buildings, and discriminate developed versus undeveloped land with high accuracy. High resolution nighttime lights may be quite useful for tracking the expansion of development if acquired routinely from a NightSat.

4.3.8 Timeline and implementation options

The source datasets are available now. Development of the coastal databases of population, urbanization and a change product would need at least 1 person-year, and land use interpretations can then follow. Development of a land-cover database would take an additional person-year. This work would complement existing marine assessment activities and as such would have considerable value added in this context.

TABLE 13

Web sites for additional information

Web site	URL
Population Reference Bureau	http://www.popnet.org/
The World Gazetteer	http://www.world-gazetteer.com/home.htm
World Resource Institute	http://www.wri.org/
CIESIN	http://www.ciesin.org/datasets/cir/gpopdb-home.html
UNEP/DEWA -North America	http://grid2.cr.usgs.gov/globalpop/
NASA GISS	http://www.giss.nasa.gov/data/landuse/
EDC - Land Use DAAC	http://edcdaac.usgs.gov/glcc/glcc.html
NGDC - DMSP	http://dmsp.ngdc.noaa.gov/pres/sprawl_042502/sprawl/page8.html
DOC Landscan	http://web.ornl.gov/sci/gist/landscan/

4.4 VULNERABILITY OF ECOSYSTEM SERVICES IN DELTAIC SYSTEMS

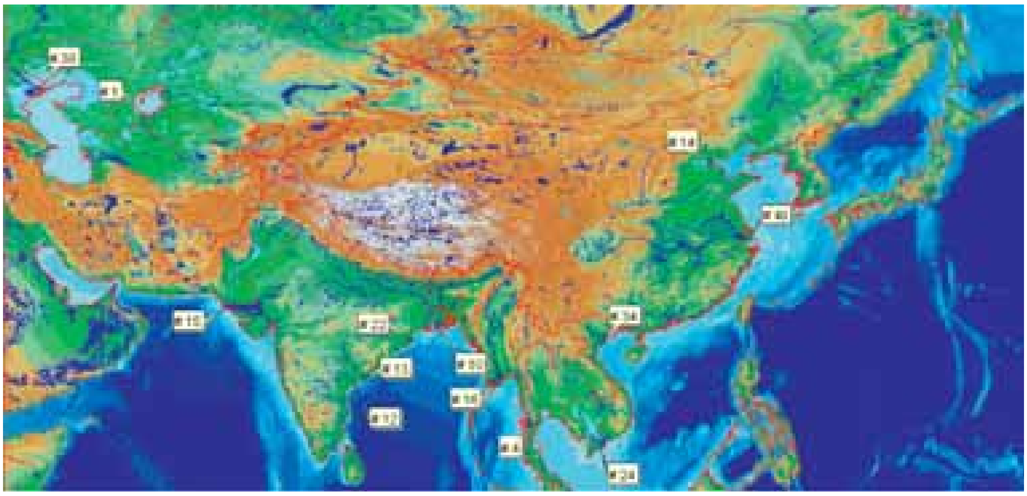
4.4.1 Overview

The information age has brought the capability to generate huge datasets in almost every area of human endeavour – business, government, genetics and health care, to name a few. The very existence of global observing systems is proposed based on the collection, management, analysis and communication of such datasets. The need to process the vast streams of data has resulted in the development of a new science – the science of informatics. This discipline uses modern computational tools to examine large datasets for patterns, to classify and arrange data and information, to improve understanding of this information and to communicate this in improved and novel ways. This priority product assesses some necessary aspects of informatics for observing system needs through the example of deltaic systems and functional typologies.

A recent study (Coleman, Huh and DeWitt, 2003) suggests that deltaic systems around the world may be losing land at a global rate of 16 percent per decade owing to a combination of factors. If true, this will have significant implications for human ecological

FIGURE 7

Position of major deltas for which extensive datasets exist



and socio-economic systems and large numbers of people. The drivers of this change seem to be cumulative and include climate change and processes affecting sediment dynamics (e.g. changes in river discharge and hydrologic base level due to dams, sea level and energy change, land-cover change and other factors). Changes in organic production due to climate change may be responsible for the observed land loss, which is occurring mostly in the interior part of deltas (Coleman, personal communication, 2004). The expected impact of sea level rise would be to increase the rate of land loss through coastal erosion and accelerated subsidence. Hydrologic diversions, for example from dams, decrease sediment delivery and thus further tip the scales towards land loss. The world may be losing many of its deltas and along with them many important coastal ecosystem functions.

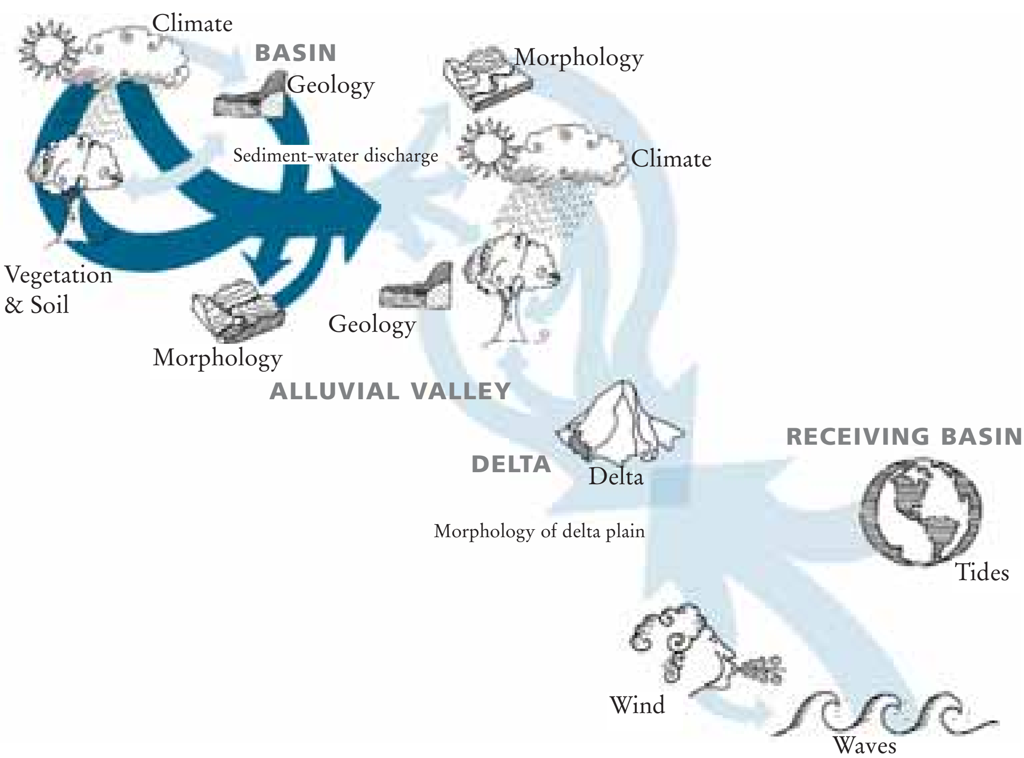
Data associated with these studies (Hart, 2001; Coleman, Huh and DeWitt, 2003) provide a valuable resource for: (i) development of informatics tools, and (ii) assessments of impacts on ecological services (system-level functions of importance to humanity) and related land use. We propose a series of digital maps, constructed through informatics models, showing the vulnerability of ecological services (and/or opportunities) associated with land use in deltaic systems worldwide, in relation to actual and projected effects of climate and sea level change and alteration of sediment regimes due to the presence of dams. The effort would focus on a subset of the approximately 50 deltaic systems identified for global assessment, for which there are suitable data available (approximately seven to ten deltas at this time). Distribution models will be developed to estimate the extent and kind of potential impacts from combined pressures, in terms of vulnerability and suitability of specific functions in each delta (e.g. goods and services from mangroves, aquaculture, agriculture and other delta-specific land uses). A general cluster of ecological services (functions) related to traditional land use should also be produced, to provide a comparative index of ecological vulnerability for deltaic regions. This project would thus support and demonstrate the overall DPSIR and functional typology frameworks of C-GTOS (presented earlier).

4.4.2 Introduction

According to the latest IPCC report: *"deltas that are deteriorating as a result of sediment starvation, subsidence, and other stresses are particularly susceptible to accelerated inundation, shoreline recession, wetland deterioration, and interior land loss (Bijlsma et al., 1996; Day 1997). River deltas are among the most valuable, heavily populated, and vulnerable coastal systems in the world. Deltas develop where rivers deposit more sediment at the shore than can be carried away by waves. Deltas are particularly at risk from climate change, partly because of natural processes and partly because of human-induced stresses. Human activities such as draining for agricultural development; levee building to prevent flooding, and canalization, damming, and dyking of rivers to impede sediment transfers have made deltas more vulnerable to sea level rise. Where local rates of subsidence and relative sea level rise are not balanced by sediment accumulation, flooding and marine processes will dominate...In the case of largely regulated deltas...significant land loss on the outer delta can result from wave erosion... If vertical accretion rates resulting from sediment delivery and in situ organic matter production (for example in mangrove systems) do not keep pace with sea level rise, water logging of wetland soils will lead to death of emergent vegetation, a rapid loss of elevation because of decomposition of the belowground root mass, and, ultimately, submergence and erosion of the substrate (Cahoon and Lynch, 1997). In some situations, saltwater intrusion into freshwater aquifers also is a potentially major problem."* (Excerpts from IPCC report, Chapter 6: McCarthy *et al.*, 2001).

FIGURE 8

Conceptual model of a deltaic system (Coleman, Huh and DeWitt, 2003)



The effects of anthropogenic alterations of freshwater flow and sediment transport on integrated functions are inadequately modelled in most development plans affecting deltas (Kingsford, 2000). These effects combine with those of climate and sea level change (McCarthy *et al.*, 2001) to increase risks to ecological services and land use potential on which many people depend. Deltas have been identified by the IPCC as ecological areas that are among the most vulnerable to climate-induced sea level change. Furthermore, in perhaps no other system is the C-GTOS functional definition of "coast" better met than in deltas, which are systems that exist as a result of the equal dynamic influence of land and sea processes.

Whereas it is common to classify, analyse, and map ecosystem units on structural criteria (Allee *et al.*, 2000), integrated science may benefit more from the perspective of functional units, whereby geographic extent is not specified as a fixed boundary in the unit definition but is predicted from a model representing functional classifications. Mapping functions of interest in this way can more effectively support assessment of multiple impacts because it can generate highly adaptive information. It also represents an opportunity to apply informatics to the observing system process by modelling patterns and developing visualization schemes for those patterns. Establishing a flexible functional mapping capability would benefit integrated ecosystem research and assessments related to climate change, as identified in the goals of the IPCC and corresponding national programmes. Such assessments seek to characterize systems from an integrated physical, ecological and societal perspective (Pulwarty, 2000), and as a result they require innovative and flexible tools (Huston, 2002; MA, 2003).

4.4.3 Project description

The main product will be a series of digital maps that demonstrate informatics and spatial modelling methods for estimating ecological functions. A limited group of deltas will be modelled and mapped, but the number will grow as part of an effort to promote data sharing and international cooperation. Mapping will then be instituted as an operational part of the mature C-GTOS by being periodically and systematically updated. Thus, this project begins as a research effort but is intended to evolve into an operational component of C-GTOS.

Mapping and analysis will produce indices of condition of deltas. A spatial index of land loss or gain potential can be produced considering actual and projected effects of climate and sea level change, changes in organic deposition, stabilization by land cover, and alteration of sediment loss and delivery and hydrological base-level change resulting from the presence of dams and other water diversions. This index, with other constraints, can then be used to model and map vulnerability and suitability of land use practices in deltaic systems, within various scenarios of sea level change and dam development. For example, this approach can show the feasibility of promoting certain land uses that increase organic deposition or substrate stabilization and that may thereby partly compensate for conditions of deltaic deterioration.

FIGURE 9

Landsat imagery of deltaic system

A general cluster of ecological services (functions) related to traditional land use will also be produced to provide a comparative index of ecological vulnerability for deltaic regions. Such an index could be added, for example, to UNEP Division of Early Warning and Assessment's (DEWA) proposed "Coastal Vulnerability Index".

Available data and modelling tools make it feasible to do vulnerability analysis for a subset of factors influencing sustainability of ecological services and those deltas for which consistent data have been compiled. This capability will be extensible in the future as new data are organized and made available. Data for this project are available from an initial World Deltas Database, the World Commission on Dams and other sources of important contextual data on elevation, climate, tides, etc., as described below. All project data will be made available from C-GTOS partners and/or the TEMS database.

This effort would help establish a standard set of measures for deltaic systems, focusing on local geologic environments (state variables), natural habitats, human land use, ecosystem services, and significant system drivers. These measures would quantify specific processes of water flow, salinity, sediment loss and delivery, geology and hydrology, organic deposition, stabilizing vegetation, wave and tidal energy, etc., to support future assessment and monitoring. The project would aim at establishing international collaboration on data sharing and research for continuing integrated studies and assessments of deltaic systems. Additional models may be developed as the database grows, to map the suitability and vulnerability of more specific deltaic functions in each delta (e.g. goods and services from mangroves, aquaculture and agriculture, industrial development, habitation, and other delta-specific land uses) under different conditions. This work is needed in view of the cumulative effects of environmental change and human pressures, which may be particularly severe in deltaic regions and for which deltas may be suitable sentinel or early-warning systems.

4.4.4 Methods

Methods exist and are being enhanced to model and map ecosystem functions based on Habitat Suitability Modelling techniques (Rubec *et al.*, 1999; Kineman, 2004). Functions, unlike geographic entities, have only implied geography based on the distributions of their determining or limiting factors and the means by which these factors interact and change over time. They are naturally complex, highly variable, and both context and system dependent; yet we must know them to assess impacts of climate change and human activity on those things that matter most to society. The number of functions of interest is not fixed but is determined by the intersection of natural ecology, human ecology and scientific or management interests. These definitions are dynamic, and hence the most suitable method for mapping them is to employ a model that is not restricted by prior classifications, including geographic units, and that as a result is easily iterated with changing conditions and criteria.

A functional taxonomy (or typology) can be developed for deltas in keeping with the general recommendations in the C-GTOS plan. The desired indices (representing functions of interest) can be modelled and mapped from a generalized "niche" model, using observational data to define the niche dimensions, or controlling variables. This approach requires data for multiple semi-independent variables that define the suitability for ecological functions. Statistical estimates or other available knowledge (including expert knowledge) are used to define mathematical response functions for each controlling variable, which are then combined by the model. Functional response and niche theory (Heglund, 2002; Pykh and Pykh, 2000; Hirzel *et al.*, 2002; Guisan and Zimmermann, 2000; Austin, 2002; Bernert *et al.*, 1997) can be applied to expand the concept of Habitat Suitability Modelling (Schamberger and O'Neil, 1986) for this purpose, combining GIS and spatial modelling capabilities (Peterson and Vieglais, 2001; Rubec *et al.*, 1999).

The proposed project adapts such methods to mapping generalized functional classifications, demonstrating this as a new operational capability. It will produce a corresponding series of maps showing the potential distribution of land use suitability in deltaic ecosystems, as well as integrated indices of their comparative vulnerabilities to the combined drivers stated above. A limitation of this approach is that it does not model dynamics directly, although certain kinds of dynamical changes will be estimated by iterating the technique on those factors that provide feedbacks (such as land cover). Advantages include model simplicity, the integration of data and statistical measures with expert knowledge, and high adaptability and extensibility of the technique.

FIGURE 10
Land cover in the Nile delta

The steps for this project include:

- identifying the functional cluster to be mapped and its component functions (as described above), documenting definitions;
- decomposing the selected function into the physical, biotic and societal factors that most efficiently determine or indicate the spatial (and temporal) distribution of that function in the study region;
- determining physical, biotic and societal response functions for each component controlling the distribution and obtaining the needed data sets;
- constructing niche models for each of the functional components using a suitability model approach;
- linking component models to constitute the functional cluster model;
- producing desired maps from the models, iterating where spatial constraints interact;
- preserving these steps in automated procedures employing appropriate off-the-shelf software.

4.4.5 Data availability

World Deltas Database

Approximately 42 major deltas of the world have been surveyed, and seven of these have been studied in depth with respect to their structural and functional characteristics, natural and cultural land use and processes that determine their stability with respect to sediment loss and delivery and/or sea level change. These data are being made available for general use through national and world data centres. In a typical deltaic analysis, physical subenvironments, drainage basins, land use and other factors are identified and mapped, and hydrologic and sediment balance analyses are performed. The figures in this proposal show examples from currently available data for world deltas, which, combined with other data sources listed below, provide the foundation for the proposed project (Figure 7; Figure 8; Figure 9; Figure 10).

World Commission on Dams

Data on the location, properties, and effects of dams on river flow and sediment loss and delivery are available from the World Commission on Dams.

Digital Elevation Models

Elevation data are currently available from public sources as follows:

- 30 arc-second topography for Antarctica, Asia, Australia, China, and India.
- 3 arc-second (~90 m) coastal elevation and bathymetry for the United States (National Ocean Service/Geophysical Data System).
- 3 arc-second (~90 m) topography for the United States, Canada, Greenland, Europe, Russia, coastal Africa (except 30 sec for Libya, Somalia, and Ethiopia).
- 1 arc-second (~30 m) topography for Hawaii and Alaska.

Other Data Sources

This effort should be pursued in collaboration with other national and international centres and sources of data, both scientific and cultural, such as the LOICZ delta initiative (http://www.deltasnetwork.nl).

The TEMS Database

Considerable relevant data are accessible through TEMS, and further data will be added by this effort. As TEMS is a metadata server, links from the Web site directly to the primary custodians of the data are provided as part of the TEMS system.

4.4.6 Desired products

- A Web site for world deltas data and research products, presenting applications and examples from this demonstration effort, the general strategy for functional analysis of coastal deltas, and interactive maps with downloadable data.
- Digital maps for a representative number of deltas around the world showing vulnerability of specified ecosystem services (related to land use), to the combined impact of sea level rise and alterations in hydrology and sediment delivery due to dams.
- Models that produce each of the above maps and that can be altered to test assumptions, incorporate new data or ask new questions.
- A full report of methods, results and recommended development pathways. This includes an assessment of the application of informatics to observing system processes.
- Routine periodic updates of products and analysis of change. The maps and indices will be periodically updated as part of an operational, mature C-GTOS.

4.4.7 Importance to GTOS

Functional ecology is the basis for ecosystem geography at all scales. Process and pattern have mutually reinforcing aspects, such that one cannot be determined without the other. The US National Academy of Sciences report *Global Change and Ecosystems Research* (National Academy of Sciences, 2000b) determined that "changes in the structure and function of natural ecosystems," particularly in response to changes in the distribution of human population, are among the most significant changes requiring investigation. The recent US Climate Change Science Program (Moss *et al.* , 2002) strategic plan for "Improving Connections Between Science and Society" identifies a range of ecosystem research and data needs, emphasizing the question: "how do natural and human-induced changes in the environment interact to affect the structure and functioning of ecosystems at a range of spatial and temporal scales, including those functions that can in turn influence regional and global climate?" Illustrative research questions in the USCCSP emphasize "the effects of multiple environmental changes on the structure, functioning, and biodiversity of terrestrial and aquatic ecosystems..." Regarding modelling needs, it emphasizes the need for: "spatially explicit ecosystem models capable of representing complex interactions between diverse ecosystems and the physical/chemical environment" – particularly "for examining the impact of management and policy decisions on a wide range of ecosystems..." The recent IPCC report (McCarthy *et al.*, 2001) recommends priority research into "adaptation options and (adaptation) capacity for coastal zones and marine ecosystems". These programmes are speaking with one voice to recommend stronger ecosystem studies aimed at the functional level. This recommendation represents the evolution of global change science to its current stage, where cumulative effects of complementary causes must now be considered and appropriate tools for doing that must be developed.

4.4.8 Importance generally

Land and sea are linked together in the coastal zone in an intricate network of cross-boundary interactions that underlie ecosystem function. Recent assessment reports (World Resources Institute, 2002; Gitay, 2001; The Heinz Center, 2002) indicate that high rates of change in coastal ecosystem function are of major concern both internationally and nationally as anthropogenic and natural change combine inharmoniously to disrupt and either temporarily or permanently degrade ecosystem goods and services. The human-altered mosaic of coastal ecosystems increasingly restricts policy and management options for responding to these changes.

The World Resources Institute summarized the status of information on coastal ecosystems in their report *Pilot Analysis of Global Ecosystems* (Burke et al., 2001), making the following recommendations:

- Information on the location and extent of coastal ecosystems is very incomplete and inconsistent at the global level.
- Historical data describing previous extent of habitats, against which we might hope to measure change, are very limited. Where no historical data exist, the possibility of predictive mapping should be considered, using existing climatic, oceanographic and topographic data combined with biogeographic information.

- There is an urgent need for better and more consistent classification schemes and datasets characterizing the world's coasts.

These problems are typified in the problems facing the sustainable management of deltaic systems, which represent microcosms and early warning systems for many of these issues.

4.4.9 Anticipated users

The unique combination of data resources and methodological development represented in this demonstration effort is intended to catalyse or support an international focus on assessment of deltaic ecosystems that will continue to develop data and model sharing as an evolving community. Many of these potential users have been previously identified for C-GTOS (section 1.4.1). Finally, users of the general approach are expected from other science and management communities involved in the coastal zone, and methods should be applicable to similar mapping needs for ecosystems in other biomes.

4.4.10 Timeline and implementation options

The proposed demonstration should be feasible as a short-term (1- to 2-year) effort conducted by a small spatial ecological modelling team. The participants in this C-GTOS planning effort are familiar with, and in several cases represent, suitable capabilities and facilities for producing the proposed product and can thus either participate in production or help guide it. Work may also be combined with existing projects to explore such informatics needs for regional integrated ecosystem assessments. Management of the deltas database is currently being discussed. Various proposals have been submitted to develop the proposed spatial modelling capabilities for other applications. Synergistic support can thus strengthen a request for proposals on this topic. The efforts will continue throughout the development of C-GTOS through the periodic (every 5-10 years) updating of maps and indices.

TABLE 14

Web sites and organizations providing additional information on deltas

Web sites and organizations	URL
World Commission on Dams	http://www.dams.org/
Smithsonian Deltas-Global Climate Change Program	http://www.nmnh.si.edu/paleo/deltas/
NASA Geomorphology from Space (Ch. 5: Deltas)	http://daac.gsfc.nasa.gov/www/geomorphology/
Indian Deltas (Prof. G.F. Hart)	http://www.geol.lsu.edu/deltaweb/
	http://www.geol.lsu.edu/deltaweb/INDIARPT/india.htm
World Conservation Monitoring Centre	http://www.unep-wcmc.org/
Ramsar Convention on Wetlands	http://www.ramsar.org/
World Resources Institute	http://www.wri.org/
San Francisco Bay - Sacramento/San Joaquin Delta GIS	http://www.regis.berkeley.edu/baydelta.html
Environmental Atlas of the Lake Ponchetrain Basin	http://pubs.usgs.gov/of/2002/of02-206/index.html
Louisiana Statewide GIS	http://atlas.lsu.edu/search/searchAtlas.htm

4.5 MANAGEMENT OF CONSERVATION AND CULTURAL SITES IN THE COASTAL ZONE

4.5.1 Overview

This proposal advocates the creation of a multilayered Web-based information system for the management of conservation and cultural sites in the coastal zone, and the organization of an international collaborative effort to meet these data needs. This effort extends those of UNEP-WCMC and the FAO's GeoNetwork and puts them into the observing system context. By definition, these conservation and cultural sites constitute places that people have, for various reasons, specially designated as worthy of preservation and protection, such as marine parks and UNESCO World Heritage Sites. These may serve as sentinel sites for many aspects of global change. The first two layers of the system feature an interactive map of sites, distinguished by category, giving ready access to additional information about the site in the second "encyclopaedia" layer. Subsequent layers provide regional and global syntheses of data collected. Key outcomes relating to improved global and regional information on conservation and cultural site management include the extension and validation of existing global datasets; gap analysis of site management issues within (and between) regions, and communication and reporting tools for sites and national governments that assist them in meeting international conservation convention requirements. The coupled development of this and other phase 1 products of C-GTOS will also add a particular focus on transboundary issues, with respect to both natural and human threats across the land–sea interface.

4.5.2 Introduction

The project focuses on sites that have high "human" values. It is worth noting that the rationales for protecting sites span a variety of scientific and socio-economic reasons. Thus, coastal parks may be designated for reasons of natural beauty, because they have important fossil sites or because they represent key biomes. Heritage sites are designated on the basis of historical and cultural importance.

Adequate governance of reserves and parks has been recognized internationally as a key component in the protection of marine and coastal environments (WSSD, 2002; IUCN, 2003; CBD, 2004). Significant advances have been made towards collecting information to quantify what is "adequate" coverage, most notably through the World Database on Protected Areas (WDPA), which was created by a consortium of international organizations (including UNEP-WCMC, IUCN, and others). Funding is being sought to further develop WDPA to meet the needs of international conventions, with a particular focus on improved ability to quantify the coverage of habitat type within reserves. This will be a large step towards meeting CBD targets set in 2004; "to effectively conserve ten percent of the world's ecological regions by 2010" (CBD, 2004). In addition to necessary ecosystem information for reserves, a collaborative effort is required to expand corresponding information about management of protected areas. This will be achieved through building on existing efforts and provide new information and tools to users through the planned activities described in this proposal, and other related C-GTOS phase 1 products.

4.5.3 Objectives and proposed products

This project is a Web-based information system envisaged with multiple "layers" of information, content and complexity. The different layers would be aimed at differing subsets of potential users and can be supported by different sponsors. These layers are identified below as (i) map, (ii) encyclopaedia, (iii) interpretation, and (iv) monitoring and reporting. They represent the order of complexity and maturity of the products, as the first two layers will be produced through the collection and synthesis of data and the latter two layers will be products derived from this work, producing improved outputs as the system matures.

Map products

The map itself constitutes only the first layer of the overall project design. Clearly a modular approach would allow various maps to be added as required, depending on users, priorities and sponsors. Map elements could be classified according to various schemes. The following categories (key features) make up a non-exclusive list of elements in which management boundaries will be mapped:

- marine parks, reserves and sanctuaries;
- coastal terrestrial parks and forests;
- UNESCO World Heritage Sites;
- Ramsar Convention wetlands;
- LTER sites;
- UNESCO Biosphere Reserves;
- sites of scientific importance such as type specimen locations;
- key geological features and fossil sites;
- in Antarctica: Antarctic Heritage sites, Specially Protected Areas (SPA) and Sites of Special Scientific Interest (SSSI).

Interactive maps will be displayable in various ways to meet particular user needs, including by category, region, monitoring activities, socio-economic indicators or vulnerability index where available. The map layer will provide the primary user-friendly graphical interface by which users will be able to "drill" down to locate further information from the other product layers and connect to additional information from TEMS and other collaborating data providers. Other state-of-the-art GIS mapping functions will be used in the interface, building on existing tools such as those provided by UNEP-WCMC and the FAO's GeoNetwork (GTOS, 2003).

Encyclopaedia product

The second layer would be an encyclopaedia product, whereby individual features on the map will be linked to a database of appropriate site-specific information. All information will be presented in Web pages to enable users to select and further explore related information using standard Web-browsing software. Features include the following:

- importance of site (e.g. why selected);
- relevant convention or agreement, if applicable;
- site management plan;

- socio-economic indicators and statistical information (e.g. number of international, national and local visitors);
- links to adjacent conservation and cultural sites (within and between categories);
- links to data providers, sponsors and the sites themselves (e.g. other GTOS and GOOS themes, UN Atlas, UNEP-WCMC, UNEP-Regional Seas Programmes, FAO fisheries, LOICZ, GEF-International Waters projects); where possible, links will be made directly to the related data and tools within the organizations' Web sites.

As with sites registered in TEMS, managers of individual conservation or cultural sites will be able to administer their own information directly through the Web interface, ensuring the same sustainable data management strategy implemented by TEMS. Some data may be sensitive and not accessible to all users, while managers may wish to share other information, encouraging promotion of best management practices across geographic and national boundaries. The information system underpinning this initiative will need to provide this functionality and, in doing so, will create a strong basis for future global and regional user forums for information sharing on conservation and cultural sites.

Interpretation product

The third layer, reflecting a major potential value added from C-GTOS, is interpretation. A holistic approach permits gap analysis within the different categories and allows an assessment of the relationships between sites, their management strategies and influences of other sites and management practices (including terrestrial management practices provided by TEMS). Thus, a first order of interpretation would be regional gap analysis of data available from the mapping and encyclopaedia products. The questions to be considered initially relate to coverage:

- Is there sufficient regional (and eventually global) coverage of sites within a given category?
- Do adjacent terrestrial and marine parks or reserves exist?
- What is the coverage of sites that cross the land-sea interface?
- What are the major transboundary issues influencing sites?

Thereafter, the task is to identify gaps in site management within particular regions:

- Do sites within the category have equally robust management plans? Thus, there is the potential for cross-fertilization of best management practices for similar types of sites or those that may be geographically close.
- Is the marine-terrestrial interface adequately taken into account, particularly with respect to adjacent terrestrial and marine sites?
- What is the level of community participation and financial sustainability of sites within categories?
- For a given location, does the management plan consider coastal vulnerability issues (e.g. natural hazards, pollution threats, offshore shipping, coastal erosion, sea level rise) or have access to information and support for such studies?

A third facet would be the cross-fertilization of socio-economic considerations.

- What lessons with respect to public outreach campaigns could be transferred from one site to another within, and between, regions?
- Would sites consider twinning arrangements, leading to reciprocal scientific exchanges or tourist activities within or between regions?

Monitoring and reporting product

A fourth layer of complexity relates to monitoring and reporting products derived from the previous layers that provide value-added services to managers of sites. Conservation and cultural sites should collect environmentally relevant information to evaluate the success of site management in maintaining the rationale for which the feature was designated for protection. In this way, the viability of the site management plan can be continually assessed. Moreover, these sites would be expected to need an early warning system for site protection, on the understanding that prevention is preferable to mitigation. These sites would also collect a range of socio-economic data (e.g. number of visitors, number of employees, budget and contributions to scientific knowledge). Overall, these sites may serve a highly important role for the observing system. As sentinel sites that may monitor critical variables, these can act as early warning systems for global change in the broader sense once their data are harmonized and integrated.

These sites will be linked through the planned information system to global environmental monitoring initiatives such as TEMS and WDPA, thereby acting as sources of environmental data for the global database and initiating contact with new sites not yet incorporated into global coverage. Several parameters are likely to be of importance to individual sites, as well as national and global monitoring needs. A non-exhaustive list includes general meteorological measurements (GCOS linkage), several oceanographic parameters (GOOS linkage), and C-GTOS site-specific information (coastal erosion, local land use changes, biodiversity indices). The tables in Chapter 3 provide a non-exhaustive listing of variables and indicators associated with the key issues of the mature C-GTOS.

The site indicators incorporated in the system, and the reporting of final synthesised data, can be tailored to meet the needs of individual site, national and global reporting requirements. This feature will aid countries in meeting their national reporting requirements under related global conventions. The same tools will be a valuable resource for site managers to commence vulnerability mapping exercises and for the relevant international or regional agencies to disseminate information and obtain data.

4.5.4 Methods

This product depends on the creation of a multilayered Web-based information system and collaboration with other international agencies. Parts will be relatively fast to develop, based on existing datasets and products. This requires the collaboration and support of both donors and relevant data and information services providers (see Table 15). Therefore, organising a collaborative effort among the appropriate international agencies will be the first step in developing the product. The first two product layers (map and encyclopaedia) require the production of GIS-based spatial databases and the development of Web-based as well as desktop-based information systems to house all product layers. Subsequent interpretative layers would be longer-term developments and are dependent on data collected from the initial two layers.

Additional information will be needed to validate and improve the current datasets of management information. A concerted effort will be made to engage individual sites to review and contribute information directly. This outreach effort will facilitate the widespread utilization of the information products in site management, as well as encourage the cross-fertilization of ideas and best management practices between sites. Outreach strategies also need to be developed for national and regional networks and associated governing agencies, for in many cases data may be available only through their participation.

4.5.5 Importance to GTOS

Given that sites of special significance are featured, this project has some outputs with potentially high visibility for C-GTOS that could be produced quickly at relatively low cost, particularly through the mapping and encyclopaedia products. The coastal zone is featured and thereby can serve to emphasise coast-relevant issues and problems. A global perspective is required to make certain that adequate coverage is extended worldwide for key features, and the interpretation and monitoring components of the project will contribute as the programme matures. A holistic view across the land-sea interface will ensure that sites in either domain are protected from threats across the land-sea interface. Subsequent capacity building will extend global coverage of the terrestrial sites registered in the TEMS database (section 4.2).

4.5.6 Importance generally

Educators and civil society are likely to be most interested in the map and aspects of the encyclopaedia, while environmental managers make up the main target group of regular and substantive use of the interpretive products. Engagement should stimulate cross-fertilization of site management strategies and potential twinning arrangements. As the project matures, nations responsible for reporting data to conventions, and the conventions themselves, will benefit from the outputs. Users of related regional and global data, such as modellers, will benefit from improved monitoring that will expand global coverage of databases. Lastly, sites and organizations responsible for networks of sites can place their efforts in a larger context.

4.5.7 Timeline and implementation options

Because parts of this product are based on existing datasets, they can be developed quickly. A modular design for both categories of sites and interpretation would permit evolution of the product, driven by user needs and appropriate sponsors. Development of the first two layers could be expected within a six-month time frame, if built on existing resources through collaborations with data providers (see Table 15). Subsequent interpretative layers would be a longer-term project and would preferably be linked to the outreach activities of C-GTOS, TEMS and other collaborators.

TABLE 15

Summary table for the phase 1 implementation product: management of conservation and cultural sites in the coastal zone

Product	Management of conservation and cultural sites in the coastal zone
Users	Civil society, educators, researchers, site managers, tour operators, ecotourists, GTOS meeting planners
Possible sponsors	FAO, UNEP, UNESCO, Ramsar Convention on Wetlands, others
Variables/indicators	Meteorological, oceanographic, biodiversity, socio-economic
Spatial extent of data	Global/regional/national/subnational
Data sources	Sites of special interest
Data providers	Sites of special interest, UNEP-WCMC, IUCN, WWF, and others
Spatial resolution (GTOS)	Variable
Accuracy/precision of data	Variable, non-harmonized
Reliability of data	Variable and patchy
Spatial extent of use	Global
Linkage values	High (GTOS-TEMS, GCOS, GOOS, others)
Start year/date	2004
Update frequency	Annual for sites; ongoing for new categories (data providers and users) and sites

TABLE 16

Web sites and organizations with additional related information

Web sites and organizations	URL
World Conservation Monitoring Centre	http://www.unep-wcmc.org/
Terrestrial Ecosystem Monitoring Sites	http://www.fao.org/gtos/tems/
World Database on Protected Areas	http://sea.unep-wcmc.org/wdbpa/
Ramsar Convention on Wetlands	http://www.ramsar.org/
World Resources Institute	http://www.wri.org/
Environmental Protection in Antarctica	http://www.cep.aq/

4.6 DISTRIBUTION OF SITES APPROPRIATE FOR ANALYSES OF DELIVERY SYSTEMS

4.6.1 Overview

This proposal selects a network of sites, across a range of geographical, socio-economic and environmental conditions, to analyse the delivery systems and provide focused and timely support to the Coastal Module of the GTOS. This kind of network will take advantage of already existing national or regional initiatives with the aim of enhancing their integration in a worldwide context and filling information gaps. The network aims at comprehensively representing different regions, covering a range of climatic and ecosystem characteristics and ensuring that multiple anthropogenic pressures and water pollution problems are considered. "Delivery system" fits the HSESDS framework described in section 2.2.3.

4.6.2 Introduction

A variety of land uses have contributed to increased changes in the watershed structure, hydrographic networks and the delivery capacity of the coastal zone (Turner, Adger and Lorenzoni, 1997; Söderqvist, Mitsch and Turner, 2000). The urban and agricultural development of coastal areas is responsible for direct contamination of the near-shore system. Reclamation of coastal wetlands and mangroves and exploitation of inshore and near-shore waters for tourism, shipping, aquaculture and other uses also cause relevant losses of ecosystem functions, such as the capacity to retain or buffer against pollutants (De Wit *et al.*, 2001; Valiela and Cole, 2002) and loss of fish nursery habitats affecting associated productivity of off-shore commercial fisheries and coral reef biomass and resilience (Mumby *et al.*, 2004).

Altered quantity and quality of water delivery have numerous impacts. Changes in the freshwater-to-saline water ratio can have the above-mentioned impacts, but can also affect the aquatic biota and ecosystem productivity. The increased concentrations of phosphorus and nitrogen are responsible for eutrophication and dystrophy of coastal waters. Persistent pollutants can accumulate in sediments and aquatic food webs. These quality changes are closely linked to human use of these regions (e.g. urbanization, fishery, aquaculture, recreation and tourism). Economic consequences of these changes can be directly monitored through fishery catch, aquaculture productivity or tourist numbers and related revenue. There are direct and documented human consequences, including matters relating to public health.

Boundary conditions of the delivery system

Material and pollutants are delivered to coastal waters through a complex system that is made of different components, both upstream and seawards. The most reactive part is indeed located in the coastal zone itself, where most of the biogeochemical processes occur (see De Wit *et al.*, 2001). The structure of the coastal zone as identified by the LOICZ project (Gordon *et al.*, 1996; Turner, Adger and Lorenzoni 1997) is an acceptable (even broad) framework, within which one can identify the main components of the delivery system:

- inland areas, which affect the oceans mainly via rivers and non-point sources of pollution;
- near-coastal lands and wetlands where human activity is concentrated and directly affects inshore and near-shore waters, and
- transitional waters - generally estuaries, lagoons and shallow waters - where the effects of land-based activities are dominant and where the sea level increase might have relevant effects.

The marine component can also influence the delivery system through waterborne transports (e.g. oil transport), waste dumping, fishery, etc.

The identification of components and their boundaries is relevant in order to select and prioritize the features of the delivery system and the related indicators. The combination of all these features calls for an integrated observational system of watershed–coastal zone–open sea. However, we consider it a priority to focus on the so-called transitional waters, whose dominion is very narrow and shallow. Here, biogeochemical sedimentary processes are important, since the water volume to sediment surface ratio is low (for example, in comparison with the deeper continental shelf). As a consequence, in shallow coastal ecosystems macrophytes, microphytobenthos and benthic fauna play major roles.

Status of monitoring networks and sources of information

Monitoring programmes in coastal waters should be based on how best to address the relevant issues and specific controversial problems. Most often, the issues to be analysed are complex and cannot be resolved by considering only simple variables and linear relationships. To be suited to monitoring programmes, indicators should be quantitative, based on scientific consensus and sound methodologies, validated, sensitive to changes in time and space, appropriate in scale, cost-effective and user friendly.

Numerous networks that may have monitoring components are available. Observational networks for consideration are the Regional Seas and Action Plans, many of which are UNEP sponsored. Many have their own Websites but can be accessed through the central portal: http://www.unep.ch/seas. Another series of related projects stem from GEF-IW (Global Environment Facility International Waters). There is a Web site at GEF (http://www.gefweb.org/), which links to its resource network (http://www.iwlearn.org) and the implementing agencies (UNDP, UNEP, World Bank).

At present, there are also good examples of networks and projects aiming to assess the delivery capacity of the coastal system, namely the LOICZ project (http://www.loicz.org), the ELOISE (http://www.nilu.no/projects/eloise/) cluster of projects, ILTER and several national activities. Additional sources can be supplemented by national environmental agencies.

4.6.3 Objectives and proposed products

This proposal aims to:

- identify a selected number of sites among those that are available in existing monitoring networks, project networks, core projects, etc.;
- assess the suitability of the selected sites for distinguishing and monitoring variables that depend upon (i) local factors and impacts within the coastal zone; (ii) watershed-based factors and impacts, and (iii) global issues;
- promote common approaches, methodologies and techniques for monitoring the delivery through the coastal system;
- implement a guidance document for carrying out studies and monitoring of the delivery system in the coastal zone;
- develop a common and harmonized database of water quality and quantity parameters that can provide support to assessment and management of system delivery and inherent policy applications.

4.6.4 Methods

Proposed activities are structured in three phases described in the sections following. Clearly a modular approach would allow various deliverables to be added as required, depending on users, priorities and sponsors. By definition, the systems that can be potentially considered constitute sites specially designated as worthy of monitoring local to global issues.

Specific tasks for achieving the above-mentioned objectives would be the following:

- to provide a forum for discussion and cooperation between research groups, agencies and institutions that are developing monitoring programmes in coastal and transitional aquatic ecosystems;
- to evaluate available information and present understanding of flows of carbon, nutrients and pollutants across the transitional and coastal waters under different anthropogenic pressures and threats;
- to promote an agreed common approach to studies of biogeochemical and ecological processes that are relevant for implementing monitoring programmes of the delivery systems, and
- to develop a network of sites for achieving the above-mentioned goals that can be maintained for the foreseeable future.

4.6.5 Variables and indicators

Observational variables and related indicators of water quantity and quality can be organized in groups of selected key variables. As an initial listing we suggest:

- reservoir characteristics, type, morphometry and geomorphology;
- hydrodynamics and related indicators (e.g. tidal range, residence time, riverine discharge);
- meteorological data (precipitation and evaporation);
- infiltration and intrusion into the groundwater aquifers (saltwater intrusion);
- water extraction, uses and discharge of contaminated waters;
- exchange rates and water fluxes between reservoirs;
- exchange rates and material fluxes between reservoirs;
- physicochemical and biological transformations within reservoirs;
- carrying or buffering capacity (ecological sustainability);
- chemical quality of waters;
- microbial quality of waters.

A first attempt to give an inventory of key observational variables and indicators is given in Table 17. Indicators were chosen to address both issues in the context of what is measured currently by various entities. Most of these variables are included in monitoring programmes of developed countries (see, for example, the US Clean Coastal Act and the EU Water Framework Directive). Tentative criteria for prioritization are also given in terms of feasibility and scientific consensus. At a first instance, most of the geomorphic, hydraulic and meteorological variables, as well as nutrients and chemical oxygen demand (COD), can be proposed for global monitoring. These variables are easy to measure, and for this reason there is often some redundancy in this kind of data. Measurements of organic nitrogen, major ions and metals present an intermediate level of difficulty because of equipment and technical expertise requirements.

Only certain variables are easily determined at low monetary or time cost using standardized techniques. Most of the variables require ground-based measures, but satellite imaging and remote sensing have strong potential to address some issues for observing system needs. Many of these variables are related to those in tables in Chapter 3.

TABLE 17

Preliminary inventory of key variables to be used for assessing the delivery capacity of the system

Variable	Level of difficulty	Remote sensing	Scientific consensus and information provided
Alkalinity, CO_2	Low	No	High
BOD5 and/or COD	Low	No	High
Carbon (DOC, POC)	High	Yes	Some discrepancies among techniques
Direct sewage discharge	Low	No	High
Dissolved reactive Silica	Low	No	High
Freshwater discharge	Low	No	High
Inorganic Contaminants (mostly heavy metals)	High	No	High
Major ions (Na^+,K^+,Mg^{2+}, Ca^{2+}, Cl^-, HCO_3^-, SO_4^{2-}, CO_3^{2-})	Intermediate	No	High
Metals of biological interest (Fe, Cu, Zn, Mo, Mn)	Intermediate	No	High
Nitrogen species	Low	No	High
Organic contaminants (nonpersistent and POP)	High	No	High
Organo-metallic compounds (MeHg, TBT)	High	No	High
Pathogen bacteria (coliforms and faecal matter)	Intermediate	No	High
Phosphorus species	Low	No	High
Radionuclides	High	No	High
Salinity	Low	Yes	High
System depth	Low	Yes	High
System surface area	Low	Yes	High
Viruses	High	No	High
Wet deposition and evaporation	Low	No	High

To assess changes (intensity, direction, reversibility, etc.) in the delivery system, one needs a “reference system” that has pristine or minimally altered conditions, is uncontaminated or has not been transformed). The major questions are: do such reference systems exist? Are the reference systems site-specific, or, in other words, how generalized can a reference system be? This is one of the main issues raised by the European Commission when starting the implementation plan of the Water Framework Directive.

4.4.6 Proposed activities

TASK 1. Identification of the existing sites

The identification of existing sites that are appropriate for achieving the above-mentioned objectives will begin with consideration of the LOICZ approach to the C, N and P biogeochemistry in the coastal zone. The suitability of each site will be assessed according to the following criteria for prioritizing them:

- representativeness of different geographical zones, coastal ecosystems/typology, socio-economic conditions and anthropogenic impacts;
- existing knowledge and research and monitoring skills and facilities;
- perspectives of a long-term monitoring programme and its management.

The LOICZ approach can be considered a first step in implementing the analysis of the delivery system within the Coastal Module of GTOS. Three major points are to be considered for further developments:

- The LOICZ project started some biogeochemical budgeting activities in about 170 coastal sites in all continents (see Table 18). By now coverage of the world coastal systems is almost well distributed. Other sites are known to exist but are not part of the LOICZ network.
- The LOICZ budget approach considers basic data related to the river basin (riverine water discharge, N and P loading, direct sewage discharge, etc.), atmospheric inputs of P and N, water quality of the coastal system and the adjacent seas and oceans.
- At the meetings at The Hague in 1997 and 2001, assessments of coastal typology were started considering climate features, population index, oceanographic data, etc.

By now, most of these activities can be considered “snapshots” representing “spots” of the coastal system and related river basins. However, they are very promising exercises because they were developed with the LOICZ cooperative network which involved and helped local teams of scientists. Most of the LOICZ sites (or regional cluster of sites) can potentially have a self-evolving structure that can be implemented step-by-step. Moreover, the LOICZ approach does not need “sophisticated” tools and data, but only requires data that are already available also for the developing countries (see the various LOICZ reports). This approach has some weakness, which are the assumptions and the simplifications made for allowing the budgeting exercises with very few and primitive data.

The LOICZ approach can be used for answering two major questions:

- What are the distribution and coverage of sites appropriate for analyses of delivery systems?
- What is the existing knowledge of the functional typology of the coast in order to evaluate the distribution of homogeneous functional units?

An assessment of relationships between sites and site management strategies is then necessary in order to evaluate redundancy, coverage degree and potential gaps. The questions to be considered initially concern coverage:

TABLE 18

Tentative inventory of the sites monitored in the LOICZ project. Other sites are also indicated based on knowledge of C-GTOS Panel members. Several sites would not be considered coastal using certain definitions (e.g. some sites are > 50 m depth and others are > 50 m elevation)

Region	Subregion	National network	LOICZ sites	Other sites
North Polar			4	0
North America	West		3	6
	East		6	5
North-Central America	Mexican system	Mexico	22	0
Central-South America			15	4
Pacific Ocean			3	0
Europe	Baltic Sea	Denmark	9	0
		Sweden	3	
		Poland	2	0
		Baltic-Kattegat	1	0
		Bothnian Sea	1	0
		Gulf of Finland	1	0
		Gulf of Riga	1	0
		as a system	1	0
	North Sea	as a system	1	0
	Irish Sea	as a system	1	0
	Europe-Atlantic coast		3	2
	Mediterranean Sea	LaguNet-Italy	17	5
		PNEC-France	1	13
		PlaNet-Portugal	0	7
		ElNet-Greece	2	10
	Black Sea		4	1
Africa	Mediterranean coast		1	0
	Atlantic ocean		6	2
	Indian ocean		4	0
	South Africa	South Africa	11	5
Australia and New Zealand	Australia	Australia	10	1
		Great Barrier Reef	1	0
		Subtropical	1	0
	New Zealand	New Zealand	3	0
India		India	2	0
East Asia and Japan		North Korea	1	0
		South Korea	2	0
		Japan	5	0
		Russia	1	0
		China	1	1
	East China Sea		1	0
	Yellow Sea		1	0
Southeast Asia		China	4	0
		Philippines	11	0
		Taiwan	4	0
		Vietnam	5	0
	Gulf of Thailand		8	0
		Indonesia	1	0

- Is there sufficient global coverage of sites within a given typology?

Thereafter, the task is to identify gaps in site management:

- Do sites within a given typology have equally robust management and monitoring plans? Thus, there is the potential for cross-fertilization of management practices for similar types of sites or those that may be geographically close.
- For a given site, does the monitoring plan adequately consider coastal vulnerability issues (e.g. natural hazards, pollution threats, offshore shipping, coastal erosion, sea level rise)?

As a preliminary step, to avoid redundancies or gaps, the existing LOICZ and additional sites (e.g. ELOISE, ILTER, etc.) will be organized in homogeneous cluster according to typology.

Task 1 is expected to produce maps, features and site-specific information. These will be based on the following:

- importance of the site;
- system typology;
- demographic, socio-economic and statistical information;
- biogeochemical budgets based on the LOICZ approach and the related database;
- relevant convention or agreement, if applicable;
- site management plan, if existing.

TEMS is expected to aid these efforts with identification and coordination of: organizations providing data, datasets and metadata (Section 4.2).

TASK 2. Selection and validation of permanent sites and implementation of national/regional networks

Subsequent interpretative and validation exercises would be a longer-term project. LOICZ, UNEP, TEMS, ILTER, ELOISE and other networks could provide an opportunity to involve site managers in the project. Initially, site managers would participate as data providers, but with the anticipation that engagement would lead to direct communication between sites and cross-fertilization of ideas with respect to site management.

The involvement of local scientists, end users and stakeholders will be also required in order to achieve a common and agreed approach on the coastal typology definition. As a matter of fact, coastal sites that are expected to contribute to system delivery are quite different for hydrogeomorphology (they span coastal lagoons, wetlands, estuaries, bays, upwelling areas, etc.), communities (they span microphytobenthos, phytoplankton, sea grasses, seaweeds, kelp, etc.), and tidal amplitude (microtidal, mesotidal, macrotidal, nontidal).

If applicable, a system of networks would be proposed as a neuronal system with local and national networks connected to a regional node, which is connected to a subcontinental/continental node, which in turn is connected to the GTOS secretariat office. For example, some networks in Europe may still be working in this direction, such as the Networks for Ecological Research in Coastal Zone and Transitional Areas which were developed in Italy (LaguNet), Greece (El-Net), Portugal (Pla-Net), and the Programme National Environnement Côtier (PNEC) in southern France. Others are developing through a bottom-up approach, such as those in Spain and Eastern Europe. These networks can potentially form a network of the European Mediterranean region (the Southern European Arc Network). In parallel a Baltic network should be developed, along with a North Atlantic network. The three regional networks should be connected in the European network (continental level), etc. An assessment of the feasibility of this kind of network is necessary.

Task 2 is expected to provide the organization for the network of delivery systems. Contact among representatives of individual sites and smaller networks will be made through a series of forums (Web-based), meetings and workshops. This bottom-up approach was developed in the Water Framework Directive and is currently being pursued as a national exercise in Italy with the LaguNet (http:// www.dsa.unipr.it/lagunet) and a forum on the definition of coastal typology (http://www.ecologia.ricerca.unile.it/).

TASK 3. Optimization of strategies and planning and implementation of common methodologies

Parts of this product would be relatively easy to create, based on existing sites and data (see task 1). Further development of local and regional networks would permit evolution of the product but requires the implementation of common strategies and methodologies. The LOICZ approach was first developed through the application of a common biogeochemical model for carbon, nitrogen and phosphorus (Gordon *et al.*, 1996) and the organization of regional workshops. The analysis of the delivery system for other pollutants will require a similar approach, specifically:

- the implementation of a guidance book dealing with the pollutants to be considered and incorporation of the information into TEMS;
- the organization of regional workshops for training local experts in use of the guidance book and its application;
- assurance of continued reliable and operational monitoring.

The implementation of the guidance would require an optimization between the top-down and bottom-up approaches to improve the skills and building capacity of the local and regional stakeholders and actors. An example of this approach is also given by the development of the Water Framework Directive of the European Union.

4.6.7 Importance to GTOS

Given that sites of special significance are featured, this project represents an output with potentially high visibility for C-GTOS that could be quickly achieved at relatively low cost, at least for Tasks 1 and 2. The land-ocean boundaries are considered, and thereby outputs can serve to emphasise issues and problems that are relevant for coastal systems. Among these, the existing data that are relevant for the analysis of the delivery systems are:

- superficial freshwater discharge in the coastal zone;
- direct wet deposition;
- water exchanges with the adjacent ocean;
- N and P loadings;

- derived ecosystem functions, especially the net ecosystem metabolism (NEM) that is a measure of ecosystem behaviour (C, N and P sink or source for the adjacent ocean).

These products will be integrated and communicated through TEMS. They also provide an increase in the number and enhancement of TEMS variables. A global perspective is required to make certain that adequate coverage is extended worldwide for key features.

4.6.8 Importance generally

The creation of a network of well-monitored sites in the coastal zone will allow a range of short- and medium-term assessments of:

- relations between anthropogenic input (organic matter, nutrients, chemicals), retention and release during their transfer across the coastal zone, and the potential evolution in the adjacent ocean;
- calibration and validation of models, e.g. for assessing diffuse sources of nutrients, sediment transport, pollutant release from sediments and their transfers to the coastal waters;
- impact of preventive and remedial measures and environmental policies on those polluting effects (DPSIR approach).

Such a network could also contribute to the implementation of environmental policies under different economic and political conditions and help develop a common and harmonized database as a support for decision- and policy-makers. Also, such a network would provide a direct opportunity for interaction with C-GOOS.

4.6.9 Timeline and implementation options

Task 1. Identification of the existing sites (Years 1-2):

- A report will give an inventory of the site and a summary of information regarding its suitability for the delivery system of C-GTOS.
- A mid-term report will be circulated among the Coastal Panel members.
- Contact will take place with scientists and stakeholders involved in site management. An evaluation of their interest in the C-GTOS initiative will be conducted.

Task 2. Selection and validation of permanent sites and implementation of national and regional networks (Year 3): This task includes meetings and workshops with those who are interested in the initiative, giving an opportunity to start building up a network.

Task 3. Optimization of strategies and planning and implementation of common methodologies (Years 3-10):

- Phase 1: assessment of feasibility.
- Phase 2: organization of regional workshops for starting the network of sites for the analysis of system delivery.
- Phase 3: creation of active network.

CHAPTER 5

MILESTONES FOR DEVELOPING A MATURE SYSTEM

5.1 GENERAL IMPLEMENTATION ISSUES

Throughout this document we have identified issues that can act as foci for the development of C-GTOS, variables or indicators addressing these phenomena, some initial sources for the information and potential products. We have described frameworks that integrate the phenomena into broader contexts and identified potential users who are expected to provide more information on what products may aid them best.

C-GTOS will be established in two phases. In phase 1 TEMS will be enhanced and used to develop several discrete products. The mature observing system will come in a second phase, requiring further consideration. We expect a limited second round of efforts, in association with the IGOS coastal theme and C-GOOS, to extend the strategic design for the mature C-GTOS into implementation. We expect the mature system to be well integrated into other coastal initiatives and GTOS components.

Implementation has a number of components. Each of the components of the observing system has proposed milestones and timelines. Beyond these are several programmatic considerations. First, an assessment of feasibility involves evaluation of all of the following: existing and needed capacity and training, information management (TEMS), informatics and modelling tools, and a GTOS Web site for education and outreach (TEMS). Second, C-GTOS must establish a number of components essential to effective implementation of a GTOS module, including a user advisory group, the ability to perform measurements, an information management structure, training and capacity building, product delivery, linkages outside C-GTOS and funding. Third, the activities of C-GTOS must be integrated into policy and management support (see Figure 1). Finally, a process of review and assessment of outcome measures and performance indicators must be established to maintain quality over the extended length of time of the programme.

This section describes milestones for several aspects of system development requiring implementation. These include milestones for user identification and involvement, frameworks, observations, variables and data acquisition and management priority products.

5.2 MILESTONES FOR USER IDENTIFICATION AND INVOLVEMENT

- Distribute an implementation plan to potential users, requesting evaluation of issues and priority proposals of interest (Year 1).
- Organize a workshop of selected users focused on an issue and priority proposal with high interest to initiate implementation (Year 1).

- Link to activities of GEO (Years 1-2).
- Participate in IGOS Coastal Theme process, including the establishment of CODAE (Year 1 on).
- Establish an advisory committee with user representation to foster maturation of C-GTOS and integration with C-GOOS (Year 2 on).

5.3 MILESTONES FOR FRAMEWORKS

The frameworks provide organization for instituting C-GTOS. There is no need to develop frameworks out of context of other activities. Thus, their development will be associated with milestones described in other sections (see Table 19). Of note, however, is the importance of DPSIR in the establishment of socio-economic variables and indicators and functional typology for the priority proposal on deltaic systems.

5.4 MILESTONES FOR OBSERVATIONS, VARIABLES AND DATA ACQUISITION AND MANAGEMENT

- Evaluate extent of coverage, specificity to the coastal zone and reliability of indicators and variables within TEMS for issues of concern (1-2 years).
- Evaluate extent of coverage, specificity to the coastal zone and reliability of indicators and variables for issues of concern within other Web sites (1-3 years).
- Coordinate with C-GOOS on establishing relevant socio-economic indicators (1-2 years).
- Produce priority products to serve as examples of the capability of C-GTOS (2-10 years).
- Establish reliable data collection on initially selected issues (10 years).
- Establish reliable data collection on all issues (20 years).

5.5 MILESTONES FOR PHASE 1 IMPLEMENTATION PRODUCTS

The implementation products described in Table 19 represent the first series of results that will directly meet user needs. Each proposed product has a timeline that includes demonstrable accomplishments within 1 year of initiation, as well as longer-term goals and products (Table 19).

These proposals can be initiated independently. Thus, milestones for each are dependent on the conditions and timing of its initiation. We do expect, however, that at least one or two of the proposals will begin within the first year of the programme.

TABLE 19

Summary of C-GTOS priority products milestones

Timeline for product development	Enhancing TEMS	Human dimensions	Informatics and deltaic vulnerability	Management of conservation and cultural sites	Delivery systems
1 year	Identification and registration of coastal sites and variables	Initiation of population and land use/land cover estimates	Data collection and synthesis	Identification of sites, map and encyclopaedia	Identification of existing sites and addition of new sites
2-5 years	Development of cross-institutional data management with organizations focusing on coasts	Provision of validated estimates for coastal zone	Development of habitat classification, modelling and mapping products	Enhancement of network and interactions	Selection and validation of permanent sites
5-10 years	Establishment of recurring monitoring and reporting of change, enhancement of data service	Establishment of recurring and formal reporting of change	Establishment of recurring and formal reporting of change	Enhancement of network, interactions and monitoring	Establishment of an active network
>10 years	Continued and extended use	Continued and extended use	Continued and extended use	Continued and extended use	Continued and extended use

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CONTRIBUTORS

Mr Martin Adriaanse
UNEP - GPA Coordination Office
P.O. Box 16227 - 2500 BE The Hague, The Netherlands
Tel: +31 70 311 4466 - Fax: +31 70 345 6648
E-mail: m.adriaanse@unep.nl

Dr Dan Baird
Department of Zoology
Nelson Mandela Metropolitan University
P.O. Box 77000 - Port Elizabeth 6031, South Africa
Tel: +27 415 04341 - Fax: +27 418 04237
E-mail: dan.baird@nmmu.ac.za

Prof. Robert E. Bowen
Environmental, Coastal and Ocean Sciences Dept.
University of Massachusetts, Boston
100 Morrissey Blvd. - Boston, MA 02125 3393, USA
Tel: +1 617 287 7443 - Fax: +1 617 287 7474
E-mail: bob.bowen@umb.edu

Prof. Peter Burbridge
The Orchard, House of Ross
Comrie, Perthshire, Scotland PH6 2JS, UK
Tel: +44 1764 670900 - Fax: +44 1764 670981
E-mail: Peter_Burbridge@Yahoo.com

Dr Robert R. Christian
Biology Department
East Carolina University - Greenville, NC 27858, USA
Tel: +1 252 328 1835 - Fax: +1 252 328 4178
E-mail: Christianr@mail.ecu.edu

Mr David M. Clark
National Geophysical Data Center &
World Data Centers - Boulder
NOAA/NESDIS
325 Broadway, Code E/GCx1 - Boulder, CO 80303, USA
Tel: +1 303 497 6215 - Fax: +1 303 497 6386
E-mail: David.M.Clark@noaa.gov

Mr Dag Daler
Scientific Director
UNEP GIWA Co-ordination Office - SE-391 82 Kalmar, Sweden
Tel: +1 46 480 447353 - Fax: +1 46 480 447355
E-mail: Dag.daler@giwa.net

Dr Stephen John de Mora
International Atomic Energy Agency
Marine Environmental Laboratory
4 Quai Antonine 1er - MC 98012, Monaco
Tel: +377 979 77272 - Fax: +377 979 77276
E-mail: s.de_Mora@iaea.org

Dr Paul M. DiGiacomo
Scientist, Ocean Science Research Element
Jet Propulsion Laboratory
California Institute of Technology
MS 300-323, 4800 Oak Grove Drive - Pasadena, CA 91109-8099, USA
Tel: +1 818 354 8189 - Fax: +1 818 393 6720
E-mail: pmd@pacific.jpl.nasa.gov

Dr Jorge Jiménez
Organization for Tropical Studies
Oficina Centroamericana
Apartado 676 - San Pedro, 2050 Costa Rica
Tel: +506 240 6636 - Fax: +506 240 6783
E-mail: jjimenez@cro.ots.ac.cr

Prof. Dale A. Kiefer
Dept. Biological Sciences
University of Southern California
3616 Trousdale Pkwy, AHF342 - Los Angeles, CA 90089-0371, USA
Tel: +1 213 740581 - Fax: +1 213 7408123
E-mail: kiefer@usc.edu

Mr John Kineman
NOAA National Geophysical Data Center
UCB Cooperative, Institute for Research in the Environmental Sciences
E/GC1 Room 1B158, 325 Broadway - Boulder, CO 80303, USA
Tel: +1 303 497 6900 - Fax: +1 303497 6513
E-mail: John.J.Kineman@noaa.gov

Mr John Latham
GTOS Programme Director
c/o FAO, SDRN
Viale delle Terme di Caracalla - Rome 00100, Italy
Tel: +39 06 5705 54026 - Fax: +39 06 5705 53369
E-mail: john.latham@fao.org

Mr Stefano Mazzilli
GTOS Secretariat
c/o FAO, SDRN
Viale delle Terme di Caracalla - Rome 00100, Italy
Tel: +39 06 5705 3519 - Fax: +39 06 5705 3369
E-mail: stefano.mazzilli@fao.org

Dr Michael K. Orbach
Duke University Marine Laboratory
Nicholas School of the Environment
135 Duke Marine Lab Road - Beaufort, NC 28516 9721, USA
Tel: +1 252 504 7606 - Fax: +1 252 504 7648
E-mail: mko@duke.edu

Ing Géraud Servin
Environment Officer
c/o FAO, SDRN
Viale delle Terme di Caracalla - Rome 00100, Italy
Tel: +39 06 5705 2655 - Fax: +39 06 5705 3369
E-mail: geraud.servin@fao.org

Dr Ashinbindu Singh
UNEP/DEWA-North America
USGS/EROS Data Center
Sioux Falls - South Dakota 57198, USA
Tel: +1 605 594 6117 - Fax: +1 605 594 6119
E-mail: singh@usgs.gov

Dr Liana Talaue-McManus
Division of Marine Affairs Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway - Miami, FL 33149, USA
Tel: +1 305 361 4760 - Fax: +1 305 361 4675
E-mail: lmcmanus@rsmas.miami.edu

Mr Jeff Tschirley
Chief
c/o FAO, SDRN
Viale delle Terme di Caracalla - Rome 00100, Italy
Tel: +39 06 5705 3450 - Fax: +39 06 5705 3369
E-mail: Jeff.Tschirley@fao.org

Mr L Brennan Van Dyke
UNEP
Regional Office for North America
1707 H. Street, N.W., Suite 300 - Washington, DC 20006, USA
Tel: +1 202 785 0465 - Fax: +1 202 785 4871
E-mail: Brennan.Vandyke@rona.unep.org

Prof. Pierluigi Viaroli
Dipartimento di Scienze Ambientali
Universita di Parma
Parco Area Delle Scienze 33A - 43100 Parma, Italy
Tel: +39 05 21 905683 - Fax: +39 05 21 905402
E-mail: pier@dsa.unipr.it

Prof. Helen Yap
The Marine Science Institute
University of the Philippines Diliman
Quezon City 1101, Philippines
Tel: + 63 2922 3959 - Fax: + 63 2924 7678
E-mail: hty@upmsi.ph

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The complexity and intensity of human use of coastal ecosystems represent a challenge to earth observations. This document presents the strategy developed by a panel of scientific experts to establish a Coastal Module of the Global Terrestrial Observing System (C-GTOS) to meet this challenge. The primary goal of C-GTOS is to detect, assess and predict global and large-scale regional change associated with land-based, wetland and freshwater ecosystems along the coast.

The first sections of the document describe the design for a mature observing system and integration with other systems, contributing to global management programmes, political instruments and research activities. In the sections following, details are provided on the five products that implement this strategy during the initial phase of the programme and a discussion of milestones for development of a mature system are also described.

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