IGBP REPORT 47

GLOBEC REPORT 13

Global Ocean Ecosystem Dynamics (GLOBEC)

Implementation Plan

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INTEGRATING ACTIVITY

ACTIVITY 9.0 Towards a GLOBEC Synthesis: Ecosystem Comparisons

Introduction

The synthesis of the results of GLOBEC research needs to start at the beginning of the programme, not at the end. Many GLOBEC programmes are now on-going (some for several years), and there is considerable information available for some regions from other programmes. A synthesis of this information needs to begin now, in order to track progress, compare experiences among projects, and recognize and act upon surprise events as they occur rather than decades later (for example, shifts between "regimes" or "ecosystem states"). Synthesis provides a constant opportunity to evaluate increasing understanding of the structure and functioning of global ocean ecosystems, as derived from the national and regional programmes, and tracks improvements in predictive capabilities. The synthesis phase uses these studies to build a broad assessment of the responses of marine ecosystems to global changes, including extension to areas that are poorly studied. It also attempts to identify early indicators of large and qualitative system changes that may result from global changes.

Overall objectives

The overall objectives of this synthesis Activity are the:

- Development of marine ecosystem typologies and classification of ecosystems into these typologies
- Identification of key ocean systems not presently being studied by GLOBEC activities, and encouragement of programmes in these regions
- Synthesis of the responses by characteristic "ecosystem-types" to large-scale global changes.

The GLOBEC approach

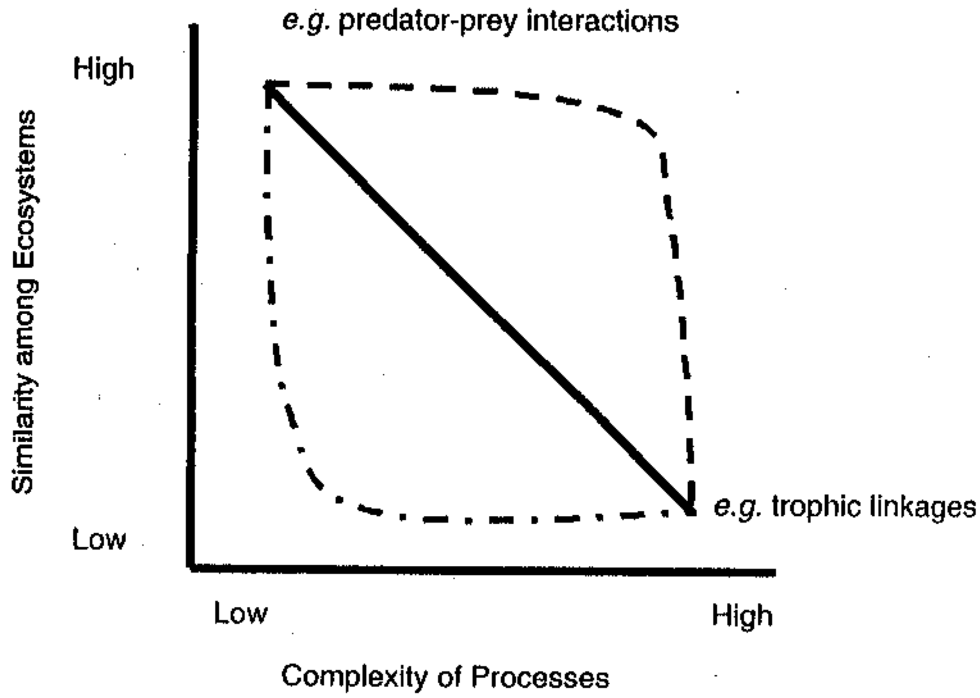
Marine ecosystems are integrated complexes of physical, biogeochemical, and biological interactions. At the very basic levels of ecosystem processes, such as predator-prey interactions, there is likely to be a high degree of similarity among ecosystems with respect to the dynamics of these interactions (*e.g.* the effects of turbulence). However, more complex processes, such as trophic linkages which embody species diversity, energy flow, turnover rates, *etc.*, are likely to be quite diverse and to have much lower similarity among ecosystems (Figure 37). Ecosystems such as tropical Atlantic coral reefs and temperate Atlantic continental shelves may rapidly decrease in similarity as the complexity of the processes increases (*e.g.* the dashed curve in Figure 37) whereas ecosystems such as temperate Atlantic and temperate Pacific continental shelves may maintain a high degree of similarity as the complexity of the processes increases (*e.g.* the dotted curve in Figure 37). Identification of the dominant change in slope of such relationships may identify critical processes at which the similarity among ecosystems begins to diverge.

The current Regional programmes of GLOBEC were selected to represent major marine ecosystems. However, a formal categorization of marine ecosystem types has been developed only for the lower trophic levels, and that only very recently (Longhurst 1998). In addition, there may be other important marine ecosystems which are not presently being investigated by the regional, multi-national, or national programmes. For example, it might be argued that the oligotrophic ocean (*e.g.* South Pacific and Indian Ocean tuna environments), coral reefs, or monsoon-dominated systems should also be areas in need of GLOBEC research. This integrating Activity will provide comparisons among marine ecosystems through development of characteristic system typologies. Its goal is to synthesize and generalize knowledge and information among (what may be considered as similar) marine ecosystems around the globe, and also to identify substantive differences. This will determine the extent to which generalized responses to perturbations can be predicted for various marine ecosystems, rather than having to describe responses in each ecosystem separately. It will also permit extension of predicted responses to similar but less-well studied ecosystems, reflecting the very real constraints on limited personnel, funding, and time which prevent detailed study of all important systems.

Synthesis activities will also involve comparisons of processes within and among marine ecosystems, and comparisons of ecosystem responses to large-scale forcings (both natural, such as climate variability, and anthropogenic, such as fishing). Understanding and prediction of the different responses by these "ecosystem-types" to such large-scale forcing is a core objective of GLOBEC which involves local, regional, and global concerns. Models, and formal methods for comparative analyses (meta-analyses), are the central approaches by which the syntheses will be conducted. A key outcome is expected to be identification of "early-warning" indicators of large-scale ecosystem changes, and to what extent they may be similar among a variety of ecosystem types. Identification of potential indicators early in the GLOBEC programme would provide for their monitoring and assessment throughout the duration of GLOBEC field and modelling activities. Further key outputs of these syntheses should include evaluation of what the effects of changes in marine ecosystems may be to global biogeochemical processes (*e.g.* Focus 4) and to human social systems (*e.g.* interactions with the GECHS project, see 7.5.1, above).

Figure 37

Relationships between the complexity of ecosystems processes, and the similarity among ecosystems. For example, the dynamics of predator-prey interactions are expected to be similar among most ecosystems, whereas the details of trophic linkages (including species composition, energy flows, turnover rates, *etc.*) are likely to differ greatly among ecosystems as different as tropical coral reefs and temperate shelf systems. The dashed line represents systems which diverge very quickly with increasing complexity of the ecosystem process being considered; the dotted line represents systems which maintain high similarity as complexity of the process being considered increases. The location of the major change in slope represents a characteristic complexity at which similarity among ecosystems diverges.



Task 9.1

Development of Marine Ecosystem Typologies and Classification of Ecosystems

Rationale

Concern about the impacts of climate variability and anthropogenic forcing of marine ecosystems is global. However, resources are insufficient to study each local system in order to understand the local responses to global changes. Development of marine ecosystem typologies and classification of ecosystems is one approach to extrapolate the predicted responses to global changes to less-well studied or unstudied systems. It is also an attempt to synthesize results from local and regional GLOBEC programmes to larger spatial and temporal scales.

Objective

- The objective of this Task is the development of marine ecosystem typologies, and classification of marine ecosystems into these typologies.

Implementation

Development of system typologies, and ecosystem comparisons, should consider a variety of approaches. Simplest may be the "whole ecosystem level", such as the Bering-Barents-Okhotsk Seas; upwelling Eastern Boundary Current systems; Kuroshio/Oyashio and Gulf of St. Lawrence/Labrador Sea; *etc.* Longhurst (1998) provides a classification of pelagic marine environments based primarily on physical processes and the responses of planktonic algae. The Large Marine Ecosystem concept provides additional starting points for the initial definition and comparison of systems at this level. However, within the whole ecosystem level, or perhaps as an alternate approach, the focus also could be placed on comparing similar physical processes and or species in different systems, *e.g.*, the effects of sea ice in the Southern Ocean and Bering Sea; upwelling vs downwelling processes; shelf-deep ocean exchange processes; or Calanoid copepod or gadoid comparisons, for example between the North Pacific and North Atlantic ecosystems. A key point here will be the evaluation of links between energy characteristics of physical processes (*i.e.* available potential energy and kinetic energy) and the structural-functional characteristics of the ecosystem.

Several methodological problems occur immediately in such an exercise to compare and type marine ecosystems. Meta-analytical methods are a logical framework for this approach, however, to date these methods are better developed for experimental rather than the observational approaches which generally must be used in the marine sciences. A standard suite of processes or parameters to measure, using a common set of methodologies or at least acceptable conversions among measures, will also greatly facilitate ecosystem comparisons (see the Measurement and Modelling Framework Activity; also the PICES CCCC programme has recommended a common set of processes to measure in studies around the North Pacific). Other concerns include the definition of response variables, within and between study variance, and choice of replicates and contrasts. One approach, moving from simple and perhaps more readily available ecosystem information to more complex analyses and finally to interactive ecosystem simulation models, is presented in Table 1.

Table 1

Overview of approaches for comparisons among ecosystems, structured from more simple to more complex in both approach and information requirements (After Gaedke, U. 1995.

Observational basis	Concepts and techniques	Potential insights
abundances and body mass (biomass spectra)	biological species, allometric relationships, time-series analyses, biomass size distribution, trophic continuum concept	species list, quantitative importance of species with respect to biomass (and process rates), size conversion efficiency, variations in time and space
abiotic parameters	regression analyses	potential abiotic impacts
trophic interactions (binary web)	aggregation of species into trophic guilds, food web analyses	food web structure, connectance, linkage density, potential direct interactions
process rates (*e.g.* production, respiration), diet compositions, trophic webs	population dynamics, flow analyses, network analyses, trophic level concepts	mass-balance flow diagrams, trophic transfer efficiencies, trophic structure and function (direct and indirect effects)
regulation of flows	dynamic simulation models	direct and indirect effects and dynamic interactions
adaptability, adaptive interaction web	fully reactive and predictive simulation models with a flexible community structure	prediction of community structure and function for different environmental scenarios

The IPO, in consultation with the SSC, will be tasked with drafting an initial definition of an ecosystem typology, drawing upon existing information from ongoing GLOBEC, Large Marine Ecosystem, and other studies. Workshops will then be held on groupings of potentially similar ecosystems attended by experts in those systems in order to compare, contrast, and refine typology definitions to identify levels of similarity among the systems. This certainly should include extrapolation to less-well studied ecosystems. Results of these workshops are to be published in the scientific literature.

Outputs

- Initial definitions of marine ecosystem typologies, and classification of ecosystems into these typologies
- Workshops on sets of potentially similar ecosystems, to compare, contrast, and refine classifications, and to extrapolate to poorly-studied systems where warranted
- Publication of workshop proceedings.

Task 9.2 Identification and Prediction of Responses of Marine Ecosystem Types to Global Changes

Rationale

The goal of the GLOBEC synthesis is to determine the responses of marine ecosystems to global changes. Having identified characteristic marine ecosystem types and classified ecosystems, understanding their responses to global changes is the next step. The advantage of using ecosystem types for this Task is that similar ecosystems should respond in broadly similar ways; identification of divergences from predicted responses will be even more informative. Identification of "early warning" indicators of large scale system changes within and across ecosystem types will greatly help prediction and possible mitigation of the effects of global changes.

Objectives

- To identify and characterize components of the major marine ecosystems which are likely to be affected at an early stage by global changes (*i.e.* early-warning indicators)
- To understand the responses to global change of each component of the ecosystem, focusing on both zooplankton and fish
- To use ecosystem models to identify and compare predicted and observed responses of marine ecosystem types to global changes.

Implementation

Success in achieving this Task will depend critically on retrospective analyses of systems (*i.e.* comparisons of how similar and different system-types responded to past global changes) and modelling of system processes (*e.g.* modelling system responses to hypothetical global changes). The collection of ecosystems within a typology will serve as replicates to compare responses. The retrospective and modelling analyses will also identify parameters and system variables that may serve as early warning indicators of qualitative changes in system states. From this point of view it may be worthwhile to link ecosystem characteristics to a system of ocean-atmosphere parameters. These could include: sea surface temperature, sea level pressure, and latitudinal and longitudinal positions of the atmospheric Centres of Action (COAs) (*i.e.* Icelandic Low, Azores High, Aleutian Low, *etc.*). For instance, the North Atlantic Oscillation has been shown to be related to zooplankton abundance in the North East Atlantic. However, the NAO represents the oscillation of mass between two semi-permanent atmospheric pressure systems, the Azores High in the subtropical Atlantic and the Icelandic Low in the subpolar Atlantic region. A relationship between zooplankton and the individual COA is more likely to be useful because it localizes the region of climatic influence on the main ecosystem. Each COA affects the atmospheric and oceanic circulation in its own sphere of influence. In order to make quantitative comparisons between the COAs in observed and simulated fields, it is useful to define objective indices for the intensity, latitude and longitude of a COA at a given time. Variations in the intensity of COAs should be reflected in mesoscale changes of physical and biological characteristics. Comparisons between the intensity of COAs and mesoscale variability of physical and biological characteristics of ecosystems, through different regions, should improve understanding of the interactions among scales. These analyses will follow from identification and comparisons of ecosystem typologies, and may be a component of the workshops discussed in Task 9.1, depending on the state of retrospective and modelling studies for these areas.