A Global Ocean Biogeographic Information System (OBIS) for the Census of Marine Life

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Introduction

Recent breakthroughs in remote sensing and in situ observation technologies now allow a detailed understanding of many of the ocean's biogeochemical and physical processes on regional and global scales. These databases allow us to explore the processes determining the life histories, habitats, abundance, and distributions of marine species. To pursue this research, intensified studies of biogeography, systematics, taxonomy, and the natural history of marine organisms are needed (National Research Council, 1996). The Alfred P. Sloan Foundation has sponsored a series of "Census of Marine Life" workshops which have sought to define an international program of research. At one of the workshops (Grassle, 1997), authorities on marine benthic taxa, community ecology, conservation biology, and biological statistics called for internationally-recognized specialists on marine taxa to work with information specialists and oceanographers to produce an online, electronic atlas of marine life. This digital atlas of species' distributions and associated marine habitats would guide sampling designs for a "Census of Marine Life" and generate hypotheses concerning the origin and maintenance of diversity of life in the oceans.

Current state of marine species data

While great advances have been made in our understanding of the life in the oceans, it is clear that we are only beginning the process. Discoveries of large numbers of undescribed species have been made from all marine environments, but particularly from continental shelves (Poore and Wilson, 1993; Gray, 1994; Coleman et al., 1997), deep-sea sediments (Hessler and Sanders, 1967; Sanders, 1968; Grassle and Maciolek, 1992; Lambshead, 1993; Blake and Grassle, 1994; Gooday, 1999), and coral reefs (Reaka-Kudla, 1997). These advances indicate that present estimates of the richness of marine species are far too low (National Research Council, 1996; Snelgrove et al., 1997). The discovery of previously unknown hydrothermal vent and cold-seep ecosystems (Grassle, 1986; Tunnicliffe, 1991; Tunnicliffe et al., 1998) have further altered conventional views on the richness of life and ecosystem processes in the oceans. Changes in community structure and abundance of even the most common, well-known species add a sense of urgency to measurement of the present composition and limits of marine life.

While the distribution of certain taxa may be relatively well understood a global perspective on biodiversity is lacking. The only map of species richness per unit area (Valentine and Moores, 1974) recognizes just 12 shallow-water geographic areas and 6 levels of relative species richness; no absolute diversity estimates are given. The UNEP Global Biodiversity Assessment includes only two maps for marine biogeography. One, based on surface-water distributions of pelagic species, defines six classes of "Oceanic Realms" (UNEP, 1995). The other classification excludes the open ocean and deep sea and recognizes 49 "Large Marine Ecosystems" (Sherman, 1993; UNEP, 1995). Longhurst (1998) summarizes the biogeography of the surface layers of the ocean in a map of 51 ecological provinces, and notes that even the most extensive compilation of distribution maps "remind us how far we are from achieving a comprehensive, species-based geography of the pelagic ecosystem and how little we have progressed since the early maps." We are even further from achieving a species-based geography that includes the benthos from coastal, continental shelf, and deep-sea regions of the ocean.

The need for species-level data

Understanding oceanic ecosystems depends on well-documented, species-level information on the existence, abundance, geographical distribution, and mode of survival of marine organisms. There is general agreement that the species is the basic unit for studying ecological and evolutionary relationships. Without species-level data, basic processes such as food web relationships, population interactions, evolutionary history, habitat specificity, and biogeographic distributions cannot be studied. Identification of exotic, introduced species and the siting of marine reserves are not possible without reliable information on species distributions. Numerous theories have been proposed to explain species diversity patterns, but the lack of global species distribution data summarized in appropriate geographic frameworks has slowed progress.

Species-level data are also key to understanding human impacts and making management decisions. The species composition of well-sampled locations provides the most sensitive measure of changes in biological characteristics over decadal spans of time (Barry et al., 1995; McGowan et al., 1998). Toxic effects are observed as declines in sensitive species. Intrusions of exotic species can result in loss of native species. The patch structure and distribution boundaries of species provide essential information for describing habitats and the potential for interaction among species. To sustain fisheries, data on spatial and temporal interactions among species are needed to define habitat and to improve management recommendations.

Despite these data needs, many major interdisciplinary marine science programs have measured marine life only as density and/or biomass of major taxa. Because consistent species-level identifications usually require the involvement of expert systematists, reliable studies of species composition and abundance are few and far between. Most marine environments are not known well enough to identify whether less abundant or rare species are present or not, and many introductions go unnoticed. Yet, despite minimal research support, systematists and taxonomists have described new species at rates comparable with the growth of the scientific literature as a whole (Winston and Metzger, 1998).

The Ocean Biogeographic Information System (OBIS)

The Sloan Foundation-sponsored workshop in October 1997 asked a panel of benthic systematists, community ecologists, conservation biologists, and mathematical ecologists to identify research areas with the greatest potential to advance the understanding of patterns of life in the oceans. The panel unanimously agreed on two related priorities: first to fund systematists and taxonomists to assemble species-based distribution datasets for a variety of taxa. The recent marked increase in numbers of species described in many important taxonomic groups suggests that a contemporary synthesis of existing data will yield important new insights. A cross section of leading marine systematists, including those represented at the workshop, undertook to redirect their efforts to produce global, geo-referenced databases for Families or Orders of major marine taxa. Groups that could be completed within a year or two with a relatively small additional investment of funds included molluscs, crustaceans, polychaetes, echinoderms, corals, anemones, and bryozoans.

The second priority was to develop an information system capable of integrating multiple distribution datasets and environmental coverages for analysis. Existing good-quality distribution data are stored in a wide variety of formats and media, many of which are not compatable. Comparing datasets, or relating them to distribution data, requires a substantial effort to re-format and re-process the data. The workshop participants called for a central system where datasets could be found, mapped, analyzed, and overlaid with environmental data. New data created by the Census of Marine Life would be compatible with the system, and existing distribution and environmental data would be included.

Utility of the Ocean Biogeographic Information System

Because OBIS will only include identifications checked by a single authority for each group, these data would be ideal for doing research on species ranges, species/area relationships, and habitat boundaries. The distribution of species richness and zoogeographic boundaries would be used to compare the distributions of major taxa and to make new global biogeographic maps. In addition, overlays of environmental data such as bottom topography, sediment types, kinetic energy and storm tracks, climatic oscillations, nutrient fluxes, dissolved oxygen concentrations, and patterns of temperature and salinity variation would be developed. Maps of surface productivity, export production, and biomass of organisms would provide additional overlays for comparison with species distributions. New analytical approaches would be explored for using the geographic information systems (GIS) databases to test ecological and zoogeographic hypotheses (similarities and differences in boundaries and ratios of diversity across taxa, species/area relationships, local vs. regional species richness, etc.). Systematists would continue to set the standards for species identifications in the Census of Marine Life. Systematics and species-level information would play a central role in the design of future studies, thus revitalizing this area of marine science.

Global Ocean Observing Systems – future projections

The technological capability of ocean observing systems is growing exponentially. We are in the early stages of assimilating data from a growing array of satellite-based sensors. Improved surface moorings or bottom stations, satellite and underwater cable communications, and breakthroughs in design and reduction in cost of unmanned underwater vehicles (equipped to accommodate the full range oceanographic instruments) have already revolutionized the study of physical and chemical processes and primary productivity in the ocean (von Alt et al., 1997; Grassle et al., 1998). The most rapid advances are yet to come as we increase the ability to distinguish and identify species remotely and learn how to automate at least some aspects of the Census of Marine Life. OBIS would provide the framework for development of new conceptions of species distributions, the design of more efficient sampling programs, and the retrieval of biological data in the context of a comprehensive ocean data management system.

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