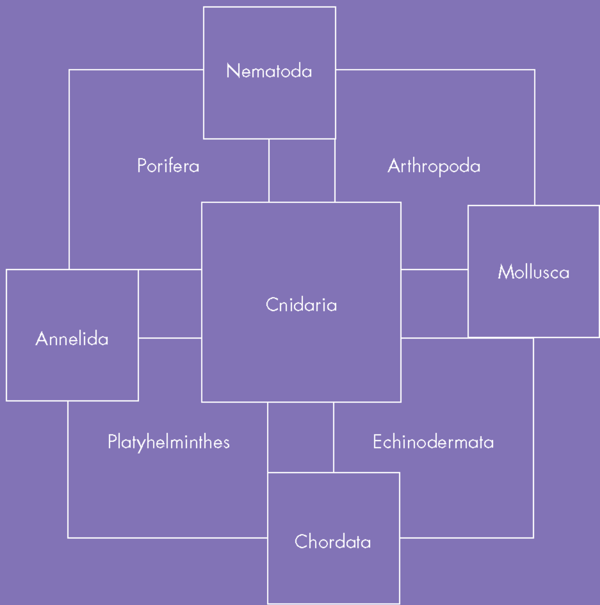
Research Plan

CENSUS OF MARINE LIFE

Version January 2005



Cover Images

Annelida: Marine polychaete, *Polychaeta* (Serpulidae). Photo: Sea Studios Foundation, Monterey, CA.
Arthropoda: Armed hermit crab, *Pagurus armatus*. Photo: Doug Pemberton
Chordata: Orbicular burrfish, *Cyclichthys orbicularis* (Diodontidae). Photo: Karen Gowlett-Holmes
Cnidaria: Horned stalked jellyfish, *Lucernaria quadricornis*. Photo: Strong/Buzeta
Echinodermata: Daisy brittle star, *Ophiopholis aculeata,* Photo: Dann Blackwood
Mollusca: Deep-sea scallop, *Placopecten magellanicus*. Photo: Dann Blackwood
Nematoda: Non-segmented nematode, *Pselionema* sp. Photo: Thomas Buchholz, Institute of Marine Biology, Crete
Platyhelminthes: Unidentified pseudocerotid flatworm. Photo: Brian Smith
Porifera: Stove-pipe sponge, *Aplysina archeri*. Photo: Shirley Pomponi

The Census of Marine Life Research Plan is written and distributed by the Census of Marine Life International Secretariat. It has undergone several iterations of review by the International Scientific Steering Committee, chairs of national and regional implementation committees, and the leadership of OBIS, HMAP, FMAP, and the Ocean Realm Field Projects.

The Census of Marine Life Executive Summary

In a world characterized by crowded shorelines, oceanic pollution, and exhausted fisheries, only an encompassing global marine census can probe the realities of the declines or global changes in ocean resources and the extent of our ignorance. Archives spanning centuries, technologies empowering exploration, and communications connecting scientists open opportunities for such a census. In the year 2000, the Census of Marine Life (COML) began, led by an International Scientific Steering Committee of experts in diverse forms of life, habitats, and technologies.

Mission: *Assess* and *explain* the changing *diversity, distribution, and abundance* of marine *species* from the past to the present, and project future marine life.

Scope: Global marine life since fishing became ecologically important, from icy polar to warm tropical waters, from tidal zones shared by humans to obscure trenches 10,000 meters deep, from microscopic plankton in the light and sea lions plunging into the dark to worms in abyssal sediments, from organisms shifting on the slopes of seamounts to ones tolerating fiery oceanic vents, the 5 percent of the ocean that is fairly regularly visited and the 95 percent of the ocean whose life is largely unexplored.

Strategy: Through 2010, scientists worldwide will exploit and organize what is known, shrink the unknown, and minimize diversion into the unknowable. Three large questions define the tasks of the Census: What did live in the oceans? What does live in the oceans? What will live in the oceans? Globally, scientists collaborating in COML are mining historical and environmental archives, typically since about the year 1500, to write a History of Marine Animal Populations (HMAP), quantifying how fishing and environmental fluctuations changed what lived in the oceans. Fourteen cooperative international Ocean Realm Field Projects as well as affiliated national efforts are exploring the diversity, distribution, and abundance of what lives in six ocean realms from tidal zones to deep trenches. The observers in the field projects, as well as HMAP, deposit their data in the Ocean Biogeographic Information System (OBIS), a global georeferenced database about marine species, accessible on the web with tools for visualizing relations among species and environments. The Future of Marine Animal Populations (FMAP) network integrates the extensive Census-generated data in mathematical models to predict how environmental and human influences will change what will live in the oceans.

Progress: In its first four years, COML planned its research and outreach, formed management at national, regional, and international levels, entered partnerships with major international organizations concerned with marine biodiversity, raised funds, and got in the water. Researchers from more than 70 nations are working together. In 2003, its Baseline Report provided a filter for explorations likely to yield the great surprises. HMAP completed case studies of southeast Australia and southwest Africa. The Mid-Atlantic Ridge project collected 80,000 specimens from this undersea mountain range. OBIS is on track to serve 10 million records covering all known marine species by 2007. FMAP charted evolving biodiversity hot spots for fish in the open ocean.

Completion: After passing established milestones in 2005 and 2007 and concluding in 2010, COML will have shrunk the unknown with a census of diversity, distribution, and abundance. It will grant legacies of improved methods for biological sensing for the Global Ocean Observing System, access to data on marine life in OBIS, information for wise management of marine resources, and a better informed public.

More information: The COML portal at http://www.coml.org/.

Preface

From its beginning in 2000 until its conclusion a decade later in 2010, the Census of Marine Life (COML) pursues the mission of assessing and explaining the diversity, distribution, and abundance of marine life from microbes to mammals, from pole to pole, and from the ocean's nearshore to its darkest depth. COML's large tasks are answering three questions: What did live in the oceans? What does live in the oceans? What will live in the oceans?

The table of contents of this Research Plan manifests COML's strategy for answering the three questions. (1) Create an accessible database and analytic tools. (2) Study archives for environmental and human impacts, generally since about the year 1500. (3) Observe present life through explorations in six realms that encompass all major forms of life and ocean habitats. (4) Foresee what will live in the oceans by integrating the data in the accessible system and employing it in models.

This plan builds on COML's Baseline Report of 2003. This plan updates the Research Plan of 2003 and Decker and O'Dor (2002), incorporating a full statement of COML's "Goals, Scope, and Strategy," also available separately. After stating the Goal and Baseline of each component task and field project of COML, this Research Plan summarizes the progress and expenditures by 2005, tells plans for reaching milestones during 2006-2009, and concludes with the culminating accomplishments planned for 2010.

Scientific staff members and associates of COML's International Secretariat drafted this plan for discussion and adoption at the joint meeting of COML's International Scientific Steering Committee and the chairs of the national and regional implementation committees, 2-3 December 2004 in Paris, France. Most of the information was abstracted from the detailed plans and proposals of COML's component tasks and projects. For a few projects still in development, the draft anticipates likely major goals and directions.

This plan describes each task and project briefly. For greater detail, readers should refer to www.coml.org to reach individual project Web sites and principal investigators. In the age of the Web, this plan is a living document that will be frequently updated as COML accumulates achievements and addresses challenges.

This plan focuses on the cooperative international efforts of COML. Along with these large international efforts, single nations make important contributions, especially within their jurisdictional waters. Their surveys and research will ultimately flow into the global database and form a global picture as the importance of ocean influences and resources is more widely recognized. COML gratefully acknowledges these efforts, as well as the many research efforts in allied domains of ocean science that help COML accomplish its mission, crucially.

A list of COML and other international marine program acronyms is provided at the end of this document.

Ronald K. O'Dor, Senior Scientist

International Secretariat, Census of Marine Life

CONTENTS

I. The Goal, Scope, and Strategy of the Census of Marine Life

Evaluation of reports of crowded shorelines, oceanic pollution, and exhausted fisheries as well as more than a billion cubic kilometers of unexplored water requires a systematic, global census of marine life. Only an encompassing census can probe whether the reports reveal regional declines or global changes, and the extent of our ignorance. Fortunately, archives spanning centuries, technologies empowering exploration, and communications connecting scientists make such a global undertaking feasible. Accordingly, in the year 2000 the Census of Marine Life (COML) began under the leadership of an International Scientific Steering Committee (SSC) now encompassing nations on five continents.

Censusing many trillions of moving organisms belonging to millions of diverse species in the three-dimensional oceans of the world challenges marine scientists. To cope with this challenge, the SSC defined a goal for the Census, sharply. It set a scope for the work. It devised a strategy.

1. Goal: *Assess* and *explain* the changing *diversity, distribution, and abundance* of marine *species,* from the past to the present, and project future marine life. Going beyond a search for unknown species to being a census, the Census of Marine Life encompasses the diversity of species as well as the abundance and geographic distribution of each species.

2. Scope: Consider global marine life since fishing became important, typically about the year 1500, and some decades into the future. The scope encompasses realms from icy polar to warm tropical waters and from tidal zones shared by humans down to dark trenches 11,000 meters deep. It encompasses microscopic plankton in the light and sea lions plunging beneath, down to worms in abyssal sediments. It encompasses organisms that shift on the slopes of seamounts and others that tolerate fiery oceanic vents.

3. Strategy: For the world's few thousand marine scientists to progress beyond exploration to a global census requires wise strategies or else decades could pass while interesting work falls short of the cumulative progress possible. The SSC devised the following strategies.

A. Focusing on the knowable unknown.

Explorers selecting strategies for discovery reason which paths have the highest probability of success. Nature will make the final selection between open avenues and blind alleys, but distinguishing among known, unknown, and unknowable is a basic preselection filter. The known is easiest to filter out. Stone tablets, libraries, and now the electronic Web have accumulated a vast inventory of the known. A standard scientific report first reviews literature to draw a baseline of the known and to preselect against its reexploration.

Filtering unknowable from unknown is harder. The profit of avoiding fool's errands and focusing instead on the knowable unknown justifies the hard reasoning. Some hard reasoning concerns the causes of unknowability because too fine a filter might preselect against great discovery. Still some things are intrinsically unknowable – the weather weeks hence and the exact number of fish in a bay a decade from now. Such intrinsically unknowable things seem safe to filter out.

Some things are unknowable because search is impractical. For example, a sea to be explored is inaccessible, specimens explode or otherwise deteriorate when brought to the surface, or cost and tedium overwhelm. Because boundaries of practicality between the unknown and the unknowable can be breached, as by submarines and high-throughput DNA analysis, the filter for removing the practically unknowable must be revised frequently and kept up to date.

Opportunity for the Census lies in the knowable unknown. To begin concentrating effort there by establishing the known, the SSC examined the known (O'Dor, 2003, 2004). After reasoning, the SSC set the unknowable aside and focused on the tasks and projects described below to investigate the knowable and enlarge the known.

B. Ten-year life, 2000-2010

Limiting lifetimes concentrates minds. Accordingly and strategically, the SSC fixed the life of the Census as 2000-2010, the first decade of the millennium.

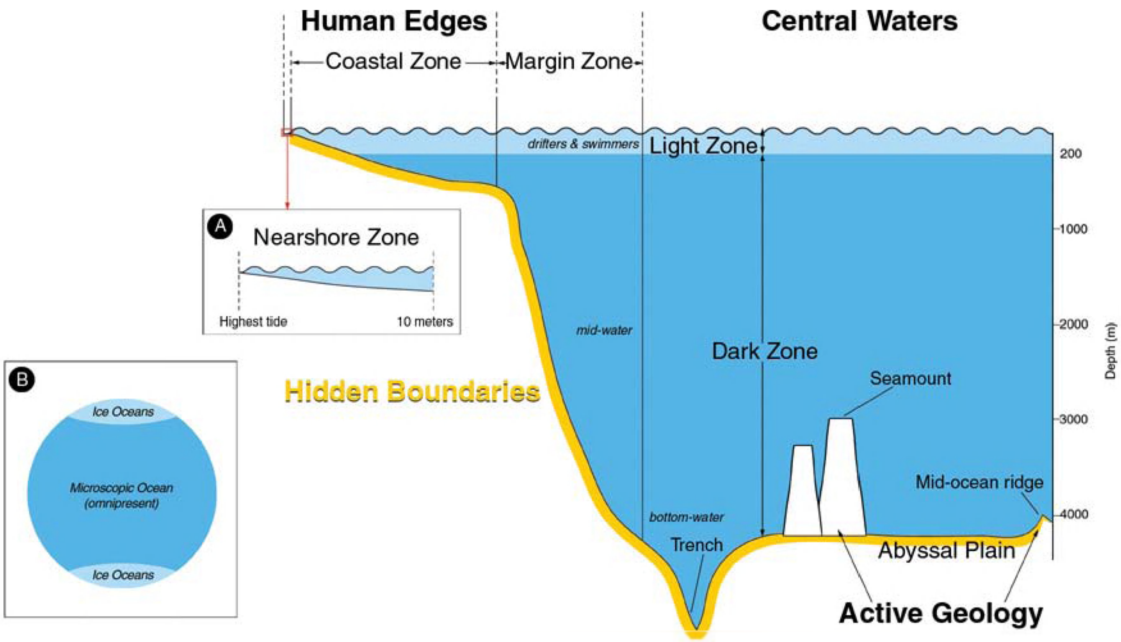


Figure 1. An ocean basin cross section illustrating the realms and zones of the world oceans as defined by the Census of Marine Life. The insets depict (A) the nearshore zone of the human edges and (B) the realms of ice oceans and the omnipresent microscopic ocean (O'Dor, 2003).

C. Six realms

A census of the life in the vast oceans begins with a strategic division into parts that can be grasped. Freely flowing currents render division among bordering nations or even among oceans illogical. On the other hand, dividing exploration among the six realms and subsidiary zones diagrammed in Figure 1 makes strategic sense. The realms and zones are practical as they correspond to the difficulty and technology of their exploration. The realms and zones make biological sense as light, pressure, and temperature confine species to a few realms or zones.

The six realms and subsidiary zones named in Table 1 encompass all life from the surface of the nearshore to the bottom of the deep ocean. The realms and zones help reveal the diversity, distribution, and abundance of marine life. In the nearshore zone and on continental shelves and slopes, fish, shellfish, and lobster abound. In the light zone of the ocean's central water, drifting microbes photosynthesize food that miniature shrimp and swimming fish eat. In the dark of central water, jellyfish swarm, and in the sediment snowed from above onto the abyssal plain, microbes and worms prosper. Around active seafloor vents, heat-resistant microbes survive. In polar oceans, algae photosynthesize inside the sea ice. The small, drifting organisms that photosynthesize all the primary food make up almost all the 145,000 million tons of marine biomass. Small animals like krill account for most of the animal mass, while prominent large animals, like fish and whales, constitute only a small, crucial percentage. In all oceanic realms, finding and naming species of animals show unflagging progress as well as opportunity.

Realm	**Zone**	**Area %**	**Crucial Unknowns**
1. Human Edges	Nearshore Coastal	2 10	Distribution Abundance
2. Hidden Boundaries	Margins Abyssal Plains	7 84	Species Species
3. Central Waters	Light *Drifters* *Swimmers* Dark *Mid-water* *Bottom-water*	90 90 90 90	Distribution Distribution Species Species
4. Active Geology		2	Species, Distribution
5. Ice Oceans		7	Species, Distribution
6. Microscopic Ocean		100	Species

Table 1. Six ocean realms distinguished environmentally and by the techniques and difficulty of their exploration. Some are divided into zones. Although vastness alone challenges explorers in some realms, all present challenging unknowns for discovery.

D. Three tasks

The scope of global marine life from the year 1500 into the future requires strategic division into eras and corresponding tasks. The SSC chose the tasks of answering three big questions. What did live in the oceans? What lives in the oceans now? What will live in the oceans of the future?

1. The History of Marine Animal Populations (HMAP)

History in the form of past trends of oceanic environment, human harvest, and marine life can give a head start to perceiving trends through the present into the future. So an important strategy is mining the archives of biology to the limits of recorded history, typically around the year 1500. HMAP pursues the goal of extending time series with historical data to clarify the dynamic interplay of human and natural factors in the changes in commercial marine life and thus improve prediction by mathematical models of economics and oceanography as well as biology.

Historical data divides itself into periods. First and nearest to the present, many nations have collected fishery records since roughly 1900, the "statistical" period. These data are generally printed, and scientists are increasingly using them to examine multidecadal changes during the twentieth century. The data, however, generally need validation because their collection differs from country to country and from decade to decade.

Second, archival material, chiefly in the port and customs archives of European, American and colonial states, survives from 1850 to 1900, the "proto-statistical" period. These materials can be compared with, and integrated into, the published data of the statistical period to extend measures of fish stocks back to the mid-nineteenth century.

Third, data are scarcer and more difficult to interpret for the "historical" period before 1850. Yet some historians have devised indices of catch and fishing effort that can be aligned with records from the protostatistical and statistical periods to yield evidence of long-term changes in marine ecosystems.

Finally, natural "archives" in fossils and sediments constitute the data for the paleoecological period. Methods for reliably determining ages and thus consistency between parallel samples are needed. Nevertheless some reliable time series, especially of clupeid and anadromous species, have been developed from 1500 to the present.

The strategy for using the archival data begins with the development of estimates or indices of catches and fishing effort in major commercial fisheries over the period 1500-2000. It includes using, for example, annual reports of fishery leases to derive more refined measures of catches and fishing effort in a few highly regulated, high-priced inshore finfish and shellfish fisheries from 1750 onwards. It also includes projecting back the known catch statistics of the protostatistical period (1850-1900) to test indices from the historical period.

Three centers make up HMAP. With support from the Danish Research Councils, the center at the University of Southern Denmark is responsible for coordination among researchers and students from more than 18 countries and a range of disciplines. The center at the University of Hull manages HMAP data. Much of the historical data assembled by the case study research teams has been rendered accessible in a common format that makes diverse data a coherent whole available online. The center at the University of New Hampshire encompasses the Departments of Natural Resources and of History and has taken a leading role in analytical methods and modeling.

A regional project strategy gives focus to HMAP. The regions include the South West African Shelf; Caribbean Sea; Gulf of Maine, Newfoundland, Grand Banks, and North East Atlantic; White and Barents Seas; South East Australian Shelf and Slope; and World Wide Whaling. The steering group for the Baltic and North seas exemplifies coordination with 22 members from Russia to England. It identifies historical data and develops fisheries and maritime history in seas that have traditionally contributed to the cultures and economies of their surrounding countries. Written records and archaeology show fishing along these coasts since well before the Middle Ages.

An analysis of marine life in the Baltic Sea and the Skagerrak since 1200 AD exemplifies HMAP projects in the human edges realm. Early fisheries appear driven by climate, but during the twentieth century when more data were available, changes in cod, sprat, herring, seals, and porpoises as well as environment defied a simple assignment of blame to climate, fishing, predation, or pollution.

2. Ocean Realm Field Projects

The link between what lived and what will live in the oceans is "What lives in the oceans now?", the question to be answered by field projects exploring the ocean realms and zones (Table 1). In each realm and zone, one or more projects develops and then implements oceanic exploration. National and regional implementation committees broaden the projects' coverage of realms by encouraging and promoting common approaches globally to ensure that results exploit the opportunity to visualize global patterns and thus test global hypotheses. Each project pursues a goal that is an adaptation to its realm of the COML goals of assessment and explanation.

The field projects will discover new species or estimate abundance and distribution of known species. To go beyond assessing diversity to censusing where each species is distributed and how abundant each species may be requires use of standardized, internationally recognized protocols of sampling. The samples need to be validated and verified using scientifically accepted techniques. Given the vastness of the ocean and the scope of COML, all surveys will be undersampling. Nonetheless, techniques should be "best practices" for representing both the local and total populations using recognized statistical techniques. In using the baseline data to make projections, the assumptions and methodology used need to be identified, discussed, and shared widely and be consistent, linking local population estimates to independently produced global ocean populations estimates. Proper protocols are key to ensuring the legacy of COML as a foundation for future global assessments.

The field projects reflect the SSC's strategy of "known-unknown-unknowable" (KUU) workshops. Identifying what is already known and what is unknowable with current technology allowed the workshops to design projects that apply efficient sampling over the largest possible scale. The projects and their principal investigators from more than 70 nations span the globe (Figure 2), and explore all the realms and zones (Table 2).

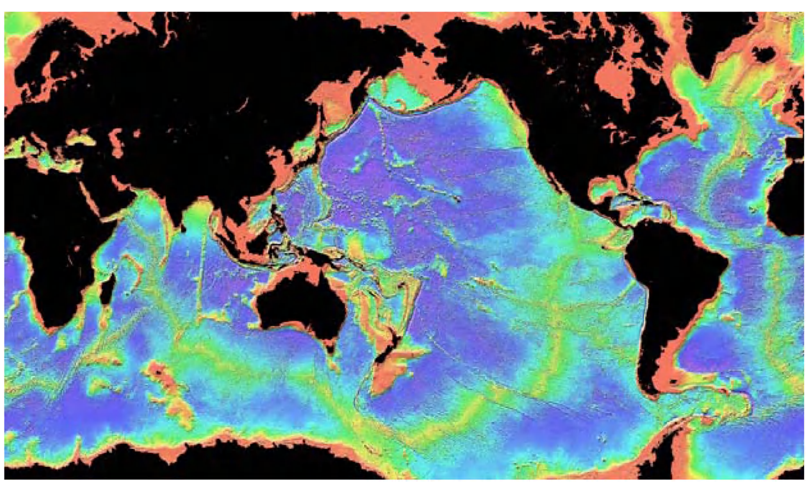


Figure 2. This map displays the bottom realms targeted by the projects, some still regional but many now nearly global – pink nearshore and coastal zones, yellow seamounts and geologically active ridges above blue abyssal plains. Other projects focus on the waters of light zones above and on the kilometers of mid-water depth. Image courtesy of W.H.F. Smith, NOAA (Smith and Sandwell, 1997).

Realm	**Zone**	**Field Projects**
Human Edges	Nearshore	Soft-Bottom Communities: algae and sea grass (Natural Geography in Shore Areas – NaGISA) Global Census of Coral Reef Ecosystems (GCCRE)
	Coastal	Regional Integrated Ecosystem Studies (Gulf of Maine Area Program – GOMA) Coastal Migrants (Pacific Ocean Shelf Tracking – POST)
Hidden Boundaries	Margins	Continental Margin Ecosystems (CoMarge)
	Abyssal Plain	Census of Diversity of Abyssal Marine Life (CeDAMar)
Central Waters	Light *Drifters*	Census of Marine Zooplankton (CMarZ)
	Swimmers	Tagging of Pacific Pelagics (TOPP)
	Dark *Mid-water*	Patterns and Processes of Ecosystems in the Northern Mid-Atlantic (MAR-ECO)
Active Geology		Biogeography of Chemosynthetic Ecosystems (ChEss) Census of Seamounts (CenSeam)
Ice Oceans		Arctic Ocean Diversity (ArcOD) Census of Antarctic Marine Life (CAML)
Microscopic Ocean		International Census of Marine Microbes (ICOMM)

Table 2. Realms and zones, as defined by the COML, and their corresponding field projects. All project Web sites are accessible through the COML portal, www.coml.org.

The implementation plan accompanying the present document reports the goals, scope and strategy of each project as well as the principal investigators. Principal investigators encompass universities, natural history museums, and laboratories in a dozen countries.

Here the National Geography in Shore Areas project (NaGISA) illustrates. Although the accessible nearshore has been studied in minute detail in many locales, it stretches millions of kilometers around all oceans, across latitude, and across climates. Further, because the locales of the nearshore realm are linked, spawning in adjacent or even remote bays influences recruitment in other bays. Testing hypotheses about nearshore ecology requires researchers linked similarly across latitude, climate, and ecosystems. From a beginning around the Pacific Rim, NaGISA pursues the goal of linking researchers across latitude and climate in all oceans to first assess and then visualize and explain diversity patterns in the nearshore. The principal investigators work from a laboratory at the University of Kyoto and with nodes in other regions. NaGISA training for field sampling and sorting is under way in throughout Asia. North and South American and European NaGISA initiatives will complete the Pacific circle and eventually encircle the Atlantic. The NaGISA approach has attracted scientists in more than thirty countries around the Pacific Rim, who committed themselves to using NaGISA protocols and raising local funds. By 2005 NaGISA will have completed work in some of the 30 established sites from Alaska to Thailand, with scientists and funding committed to complete investigations in initial sites at 300-kilometer intervals. In 2006 NaGISA will begin east-west pattern comparisons in the Pacific Rim sampling for east-west pattern comparisons. Comparisons between basins are the goal for 2010.

3. The Future of Marine Animal Populations (FMAP)

Censusing requires strategic sampling of the history and present state of the oceans. Next, prediction requires integration of the samplings of history and the present into models. Then coming full circle, attempting to model the future tests the adequacy of the sampling scheme. Modeling helps define what is known and how firmly, defines what may be unknown but knowable, and defines what is likely to remain unknowable. Accordingly, FMAP pursues goals of data exchange formats for easy model use, of survey designs, and of modeling the consequences of global fishing and climate change on marine life.

Five themes provide FMAP's tactics for reaching its goals: Statistical Design, Data Exchange and Model Interface, Model Development, Data Synthesis, and Prediction. Three centers on the Atlantic and Pacific make up FMAP. The center at Dalhousie University in Canada coordinates the service function of FMAP to the field projects, OBIS and HMAP in providing modeling and statistical advice, and linking to modelers to further the goals of the COML. Funds from the Pew Charitable Trust help demonstrate that models of the abundance, distribution, and population dynamics on a global scale are knowable in the important taxonomic group of sharks. The Yokohama National University brings expertise in fish population dynamics and linkage with NaGISA. The center at the University of Iceland has established an ambitious project to model entire communities of highly mobile marine organisms by incorporating high-tech biological tags that provide trajectories data on individuals. These will be useful for POST and TOPP. Joint modeling workshops with NaGISA, POST, CMarZ, and CenSeam show the way for other projects. FMAP logically extends time and space analyses of HMAP and OBIS.

E. The Ocean Biogeographic Information System (OBIS)

The infrastructure of an information seaway called OBIS constitutes COML's strategy for melding the data from COML's investigations and explorations and from other marine databases around the world. OBIS pursues the goal of a dynamic, global digital atlas for explanation of relations in the oceans with species, location, and abundance, all integrated with environmental data, maps, and model outputs on the Internet.

OBIS begins with authoritative information contributed by experts about the location of species on a map of the oceans. OBIS further incorporates other georeferenced species-level data sets such as the catches from continuous plankton recorders – sampling along millions of kilometers, fisheries surveys, and the world's natural history museums. OBIS also integrates data from environmental protection agencies to be used for environmental baselines. Databases accessible through the OBIS portal encompass the microscopic ZooGene, an international partnership to develop a zooplankton genomic barcode of DNA sequences for calanid copepods and euphausiids (Hebert et al., 2003; Stoeckle, 2003). They reach the largest sea creatures with SEAMAP (Spatial Ecological Analysis of Megavertebrate Populations) for the biogeography and ecology of whales, turtles, seabirds, and other large marine vertebrates worldwide. They include the physical environment with archives of oceanographic observations and products.

Both the Internet and the organization to take advantage of such opportunities can be considered new technologies that make the plethora of data more practical to analyze. OBIS passed the milestone of locating fully 40,000 species with 5 million records in October 2004 (Figure 3). Everyone with a connection to the Web can access the data. A visit to http://www.iobis.org/

shows the progress and promise of OBIS. At the portal enter, for example, the common name *cod*. The 417 matches begin with the red-flushed rock-cod (*Aethaloperca rogaa*). OBIS will draw a quick global map of the 60 collections of that cod and also tell the catalog number and depository of the collections plus the author who named the species and date. (This species was named in 1775!)

The OBIS International Committee includes members from Australia, Belgium, Canada, Germany, Japan, New Zealand, the United Kingdom, and the USA**.** The chair works in New Zealand, and the OBIS portal is directed at Rutgers University in New Jersey.

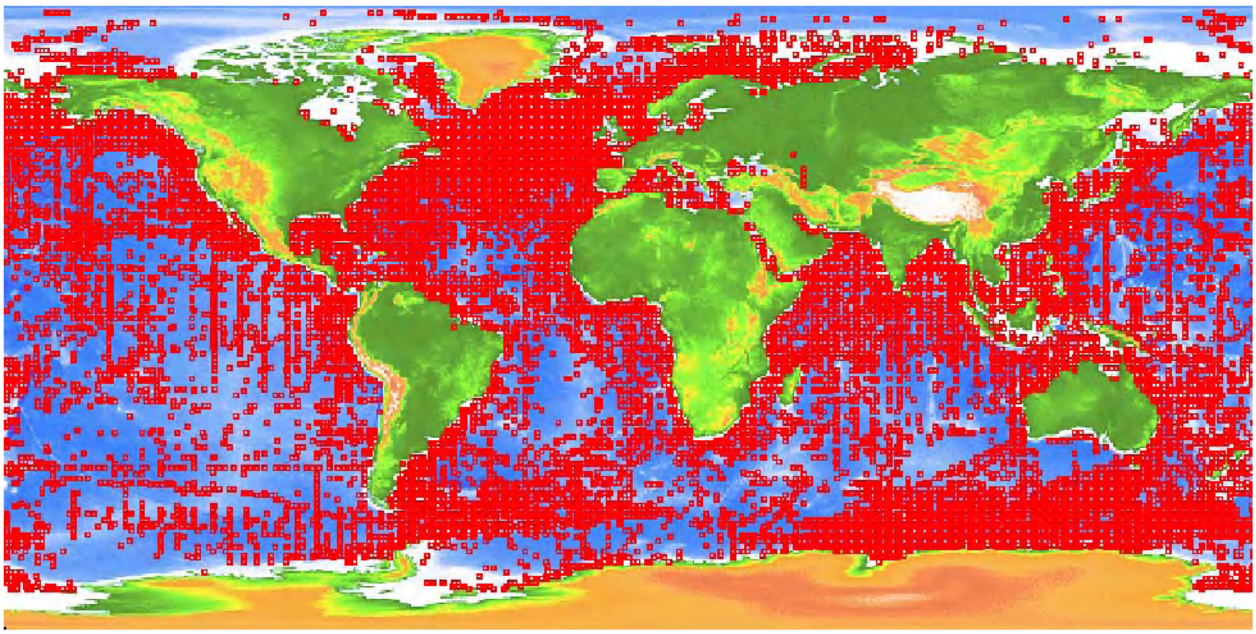


Figure 3. Horizontal spatial distribution of the locations derived from over 5 million data records for 40,000 known marine species available in OBIS in 2004 (http:www.iobis.org).

F. Governance

After two years of feasibility workshops with more than 300 scientists, a small group of senior marine scientists from around the world met in June 1999 and agreed to form a SSC to make the Census of Marine Life actually happen. The program assumed its basic contours at a meeting of the SSC at the Intergovernmental Oceanographic Commission (IOC) in Paris in 2000. The SSC that governs the COML currently has members from Australia, Canada, Chile, Denmark, France, India, Japan, Malaysia, Netherlands, and USA. National or regional implementation committees range from Venezuela and Australia to Russia and Japan.

The COML has received and established cooperation with the all the main intergovernmental and nongovernmental international organizations and programs concerned with the oceans. Among its valuable partners are the Global Biodiversity Information Facility (GBIF), IOC, the United Nations Food and Agriculture Organization (FAO), the United Nations Environmental Program (UNEP), World Conservation Monitoring Centre (WCMC), Global Ocean Observing System (GOOS), Scientific Committee on Oceanic Research (SCOR), DIVERSITAS, International Council for the Exploration of the Seas (ICES), North Pacific Marine Science Organization

(PICES), International Association of Biological Oceanographers (IABO), Partnership for Observation of the Global Ocean (POGO), and the International Union of Biological Sciences (IUBS).

Concepts and research priorities for projects are developed primarily through "known-unknown-unknowable" workshops. Identifying what is already known and what is unknowable with current technology selects projects applying efficient sampling techniques at the largest scales. The SSC has favored proposals with these characteristics:

- Has the potential to change present perspectives
- Is structured on the "known, unknown, unknowable" framework
- Is at least regional in scope
- Utilizes novel technologies or applications
- Presents opportunities for discovery of new taxa
- Focuses on species distributions
- Incorporates education and capacity building
- Makes data available through OBIS
- Contributes to 2010 report

G. Legacies

The most immediate legacy of the program will be the 2010 Census itself, an unprecedented assessment and explanation of the changing diversity, distribution, and abundance of marine species from the past to the present, and projection of future marine life. Realistically, of course, it will be what a coordinated and systematic census can attain within a decade. It will go beyond a search for unknown species to being a census, a Census of Marine Life encompassing the diversity of species, where each species lives and how abundant each species is. Interim or progress reports will be issued in 2005 and 2007 as well as annual highlights reports. Every project will of course post and publish many scientific reports offering detail in its field.

The COML is intended to produce three other legacies. One is the functioning information seaway about marine life, OBIS, whose utility will guarantee its continuity and growth. OBIS will prove an attractive and invaluable tool for management, education, and outreach as well as research. The next legacy is technology for observing marine life. COML is the test bed for many of the technologies and systems to form the biological components of the GOOS. Finally, COML should bequeath a set of international linkages that make future censuses of the global oceans much easier and more complete. The institutions and networks developed by COML, and the scientists apprenticed during all the COML projects, will strengthen marine science as a means of understanding change in the global component that is most vast.

II. Implementation Plan

A. Ocean Biogeographic Information System (OBIS)

http://www.iobis.org/portal.html

Goal. *The goal of the Ocean Biogeographic Information System is to be the primary, authoritative source of data on the distribution of marine species of the world and to provide these data with online quality control (e.g., taxonomy), mapping and analysis tools, including* *correlating distributions to environmental parameters. The data are to be high quality, spatially referenced, historic and newly collected, about all forms of marine life delivered through an online, dynamic, global 4-D (the three dimensions of space plus time) atlas of biogeographic information. The data should be readily visualized and useful for the range of stakeholders concerned with marine life, including public and private managers of marine resources, navies, scientists, educators, and students. The online, digital atlas is expected to provide a fundamental basis for societal and governmental decisions on how to harvest and conserve marine life. It is the central component of COML that links biological survey data with environmental data, maps, and model outputs, in a single location, to enable explanation of the relationship of species, their location, and abundance, to ocean processes. Synthesis of this information aids understanding of collective patterns in biodiversity, such as species relationships, food web structure, and effects of climate change on ecosystems.*

Baseline. OBIS begins with authoritative information about the presence or absence of the relevant species on a map of the oceans. OBIS incorporates other georeferenced species-level data sets such as the catches from continuous plankton recorders, sampling along millions of kilometers, and from fisheries surveys and the world's natural history museums. OBIS also integrates data from environmental protection agencies to be used for environmental baselines. The Internet and the associated new field of biodiversity informatics are new technologies that make analysis of the plethora of data practical.

By 2005. OBIS is providing to its end users around the world a wide-ranging suite of data and data services, including taxonomically and geographically resolved data on marine life and ocean environment; data from museums, fisheries, and ecological studies; data from all ocean environments – seabed to plankton, coastal to deep sea; interactivity with many other databases, including other online databases; access to physical oceanographic data at regional and global scales; and software tools for checking species names, mapping, modeling, and biogeographic analysis. For the period 2002-2006, about US$18 million has been invested in OBIS.

By October 2004, OBIS, the marine component of the Global Biodiversity Information Facility (GBIF), served over 5 million records for nearly 40,000 known species to anyone with a connection to the World Wide Web. This was five times the number of records available one year earlier, and was ahead of its schedule to serve 6 million records in 2005. These records were "harvested" with the cooperation of almost 40 OBIS data sources around the world using automated and standardized online services and a schema adopted by OBIS for data interoperability.

The OBIS portal shows the promise of OBIS, which will grow through 2010 (and beyond). Visit the portal, entering, for example, the common name *squid*. The portal promptly returns a list of all the squid species names contained within it. Alongside each species name comes a button labeled "Quick map." Clicking on *Quick map* in the row for a species of squid, *Architeuthis dux*, for example, takes the browser to a global map showing that Atlantic giant squid specimens are recorded twice, once off Newfoundland and again off the coast of the Carolinas in the United States. Along with mapping capabilities, OBIS offers a growing suite of tools for analysis and projection, for example, of habitats that might be suitable for a particular species.

OBIS is closely associated or working with many international organizations, including the Global Biodiversity Information Facility, Intergovernmental Oceanographic Commission (IOC), Global Ocean Observing System (GOOS), International Oceanographic Data and Information Exchange (IODE), Scientific Committee on Oceanic Research (SCOR), DIVERSITAS, International Council for the Exploration of the Seas (ICES), North Pacific Marine Science Organization (PICES), International Association of Biological Oceanographers (IABO), and the International Union of Biological Sciences (IUBS). Each of the COML Ocean Realm Field Projects (www.coml.org) contributes to OBIS when it serves data through the OBIS portal. Rutgers University (New Jersey, USA) hosts the OBIS portal and OBIS Secretariat. The University of Auckland (New Zealand) hosts the OBIS Executive Office.

2005-2007. OBIS will grow by adding species names and their locations. Based on scheduled addition of data sets, OBIS will serve at least 10 million records covering marine species and their location by 2007. As the Consortium for the Barcode of Life (CBOL) develops, OBIS will become interoperable with its databases. CBOL plans to include all known marine fish by the end of 2007. OBIS will work with Species 2000, Integrated Taxonomic Information System (ITIS), the European Register of Marine Species (ERMS), GBIF, and others to complete a Catalogue of Marine Life that will form the species name authority file for OBIS (i.e., the taxonomy quality control system).

OBIS will formalize its management structure. It will develop 10 regional OBIS nodes (RONs) to ensure and sustain global coverage. It will develop and formalize agreements (memoranda of understanding) with international and national organizations, data providers, and end users to strengthen the authority and mandate of OBIS globally. It will develop a long-term funding strategy with the RONs, data providers, and end users. It will develop a diverse funding base in conjunction with the RONs and data providers, including sources that could provide recurrent, routine funding.

OBIS plans to provide value-added services through the portal, such as time-series search capability and fisheries-related search criteria (working with the Department of Fisheries and Oceans in Canada, FAO Fisheries Global Information System, FMAP, and others). It will further integrate mapping services with state-of-the-art physical oceanographic information, including ocean climate, and further develop for the data served by OBIS a system of quality assurance procedures that are scientifically defensible, credible, and apparent to users. This will develop options such as automated methods for tracking errors and an independent peer-review system. OBIS will establish mirror sites to minimize risks of interruptions in service and expand the present OBIS information services in education and outreach. Connections to additional species information including images, sound, and molecular and ecological knowledge will be provided. Analyses using the OBIS portal will demonstrate to researchers and teachers the value of a distributed, publicly accessible source of global marine biological data.

OBIS will lead the efforts in developing master lists for marine taxa, especially invertebrates. The most critical data quality issue for OBIS is to “get the names right”. Although organizations such as Catalogue of Life have devoted major efforts to collect and standardize taxonomic names, the marine master lists remain incomplete or outdated. OBIS will take the lead in promoting standardized names for marine taxa, with joint efforts from ITIS, Species 2000 and other taxonomic name organizations. OBIS will also develop tools and algorithms to quality control spatial and temporal data. These data are core OBIS information and essential to answering the basic questions of marine biodiversity. Expert knowledge from domain scientists and modern data cleaning techniques will be integrated to assess OBIS data quality. OBIS will measure and improve system (portal and nodes) performance as part of the quality control efforts.

Additionally, OBIS will encourage and promote sharing of quality-related metadata. Quality assurance in dynamic online publications such as OBIS is a critical issue for scientific credibility that demands different approaches compared to static paper publications. An OBIS editorial board of scientific authorities will oversee quality control as do editorial boards of conventional publications. This editorial board will include recognized authorities in taxonomy, ecology, and technical aspects relevant to OBIS, with responsibilities for the quality of data served through the OBIS portal similar to those of conventional journal editors.

Other major marine science programs will be growing in concert with OBIS. Real-time physical and chemical data from GOOS and the Ocean Observatories Initiative, combined with OBIS data, will foster research on previously inaccessible space and time scales, leading to rapid advancement in interdisciplinary marine science. OBIS will be leading development of international marine biological standards and protocols through GBIF, the Intergovernmental Oceanographic Commission IODE, and GOOS. A culture is developing in which scientists will be able to trust biological data that they have not collected themselves. As occurred in physical oceanography or astronomy, community data sets will become the basis for scientific breakthroughs in areas such as spatial ecology and relationships between biodiversity and ecosystem function.

To address the COML goal of answering the question “What did live in the oceans?” OBIS will assimilate many georeferenced records of life in the oceans gathered over the past few hundred years. At the same time, to answer COML's central question of “What does live in the oceans?” OBIS is preparing to assimilate the huge data streams associated with Ocean Realm Field Projects, which are just now beginning and will be extensive during the next 4-5 years. To answer COML's final question of “What will live in the oceans?” OBIS will be an accessible tool for the long run to many analysts and modelers. The utility of OBIS is already widely recognized in the marine science community and is receiving many offers of new information from outside the COML projects. OBIS will be the most tangible legacy of COML.

OBIS will collaborate with major initiatives on distributed ocean data and virtual ocean data systems on data integration and on data discovery standards and data archiving (2005). OBIS will also, working with GOOS, lead biological geospatial data modeling and integration development (2006) and a biological data gathering and mining initiative (2007), including the global IODE and GOOS networks, and IOOS in USA. This will include biological geospatial data modeling and integration development, and biological data mining.

Key partnerships are GBIF and IODE. OBIS is an Associate Member, and the primary marine component, of GBIF. OBIS seeks to bridge GBIF and IODE, two prominent "megascience" initiatives, one aiming to produce an encyclopedia of life and the other archival and delivery of oceanographic data. OBIS will optimize mutual growth with GBIF by, for example, adopting existing products developed or endorsed by GBIF to ensure GBIF support for OBIS.

2008-2009. OBIS will have obtained stable sources of funding and a governance and management structure that ensure continuity and reliability as well as equity for its various stakeholders. Reaching forward from assessment to the mission of explanation, OBIS meanwhile begins to visualize relations among species. It also shows correlations among such physical parameters as salinity and sea surface temperature at the locations reported for a species. In due course, OBIS will integrate biological, physical, and chemical data from multiple sources to explain the diversity, distribution, and abundance of species. OBIS will, through its portal, facilitate the exchange of, and access to, genetic information on marine species, which includes those available from the GenBank and Consortium for the Barcode of Life programs. While it is compiling results from the initial COML projects and other sources, OBIS will also open to researchers, students, and environmental managers a dynamic view of the four-dimensional ocean world.

2010. The atlas must be three-dimensional to recognize the depth of the ocean and, to be dynamic, it must add the fourth dimension of time. The final report of the COML will be a dynamic global atlas of ocean biology – the Ocean Biogeographic Information System – accessible online and analyzable to test hypotheses and make predictions about diversity, distribution, and abundance of marine life. This data will be used in ocean management, including fisheries, conservation planning, and invasive species risk assessment. Although the research program called the Census of Marine Life expects to culminate in 2010, OBIS should live on as a major legacy of COML and a self-supported informatics infrastructure for managing, researching, and educating about living marine resources. Its regional development, as exemplified by the establishment of RONs, will ensure that it can serve these needs both locally and globally.

B. What lived in the ocean? History of Marine Animal Populations (HMAP)

Humanity has interacted with the marine and aquatic environments since the earliest times. While animals of all kinds have been harvested from the oceans, the welfare of human communities has been influenced by changes in the marine environment. The history of marine animal populations is one of today's great unknowns, but recent advances in scientific and historical methodology are expanding the known and the knowable.

Goal. *Clarify the dynamic interplay of anthropogenic and natural factors in the evolution of marine ecosystems, extending time series about changing animal populations and improving predictive capacity of mathematical models of economics and oceanography as well as biology; build the worldwide picture of the oceans before fishing became important, typically about 500 years ago.*

Baseline. With skill and insight, historical records can extend trends backward from the baseline of the present. Paleoecologists build a complementary history, for example, from evidence of abundance of traces of fish in sediments. In the race to detect trends from the baseline of the present into the future, the extension backward gives a head start. Scientific fishing records give a short head start for many species and permit a search for causes of fluctuations beginning in about 1920. Connecting other historical observations of climate, eutrophication, and predatory marine mammals allows exploration of the causes of the fluctuations. History documents the causes of natural and human-induced perturbations to make forecasting changes of fish and ecosystems easier and more certain.

By 2005. HMAP was the first COML project approved by the SSC in 1999. It has well-established centers at the universities of Hull (UK), New Hampshire, and Southern Denmark, engaging more than 100 historians and scientists from 18 different countries in 12 case study research teams with more coming (Figure 4). The Australian study is complete. The centers build the field of marine environmental history and its infrastructure. A sophisticated data management system links to OBIS. Seventy research students from 10 countries have participated in three HMAP summer schools and a range of graduate programs. Tangible outputs include more than 75 conference papers and journal articles, plus some 20 Web publications and OBIS data sets available through the HMAP portal, and a volume of proceedings from HMAP Workshop I, published as Holm, Smith and Starkey (eds.), *The Exploited Seas: Essays in Marine Environmental History*. A 2004 conference in Barcelona organized by the European Implementation Committee to increase southern European interest in HMAP started three new Mediterranean and Black Sea case studies led from Turkey. About $5.5 million has been invested in the three centers.

2005-2009. With demonstrated feasibility through seven pilot projects, HMAP continues five of these projects and an additional 8-12 projects for a global overview by 2007. A popular book on "the oceans before fishing" will be prepared for the autumn 2007 all-program meeting of COML. Meanwhile, HMAP will collaborate closely with OBIS to encourage development of FMAP, to strengthen the base of reliable projections in 2010. The components of HMAP are as follows:

<u>Centers</u>

University of Southern Denmark. Strong support from the Danish Research Councils has created a growing program in biohistory at the center of the HMAP project that includes researchers and students from more than 18 countries and a range of disciplines.

University of New Hampshire. Graduate students in the marine environmental history and marine ecology programs, exposed to the interdisciplinary approach fostered by HMAP, contribute to research effort in their dissertation work.

University of Hull. A renovated center houses the data management strand of HMAP, which includes environmental, paleoecological and economic indicators, together with qualitative information in GIS visualizations and mapping.

<u>Case studies by Realm: Human Edges - Nearshore</u>

Caribbean Mega-mollusks. Indigenous peoples harvested many large snails and bivalves in waters less than 10 meters deep. This Venezuelan-led project looks at records of their shells from middens and from trade through history and prehistory.

Caribbean Coral Reefs and Vertebrates. Ecological analysis of historical data progresses well at the Scripps Institution of Oceanography, but a welter of archival source material discovered in various repositories of European colonial powers will greatly extend its scope and value. Reef fisheries, turtles, and seals are all traceable.

<u>Human Edges - Coastal</u>

Northwest Atlantic. The North West Atlantic case study has four subprojects. A postdoctoral ecologist is analyzing the substantial time series that have been compiled, melding the four together. In the western Atlantic, cod was king, but other species do get mentioned.

Southwest Pacific. Two subprojects examine impact of indigenous fishing of Maori people on the fish stocks of the inshore waters of the South Island, New Zealand, and of a continental shelf and slope trawl fishery off the southeast coast of Australian starting in 1914.
White and Barents Seas. A Russian team from St. Petersburg, Archangelsk, and Moscow has White and Barents Seas projects on historical reconstructions of Atlantic walrus, salmon, and herring populations. Abundant records and initial modeling exercises promise collaborative work with Norwegian partners to elucidate the full Barents Sea ecosystem.
Baltic Sea. Long-term ecosystem dynamics involving the forcing of the ecosystem through the North Atlantic Oscillation, saline intrusions, and human impacts are indicated in Mackenzie et al., 2002. The ecosystem is well covered by modern fisheries and oceanographic data, but enigmas remain, especially with regard to the occurrence and fluctuation of marine mammals, cod, and herring. The challenges of political barriers and linguistic diversity are successfully overcome through identified partners in all Baltic countries.
South West African Shelf. Benguela Current physical forcing may have caused dramatic changes in productivity of this fishery, dominated by small pelagics like sardines and mackerel over the last century. Historical data from government-generated sources are now compiled in a volume of analytical papers to develop models to test these hypotheses.
North Sea. This major appraisal of the complex dynamics of one of the world's most exploited ecosystems is gathering support for assembling and collating data from a wide array of identified historical sources. Major fisheries include cod and herring, but the coastal mudflats housed a rich diversity from invertebrates to birds and mammals.
Mediterranean. Eastern Mediterranean researchers are linked by a funded Black Sea project, and the sea as a whole will be connected by ancient trap fisheries for highly migratory tuna.
Northeast Pacific. A 200-year northeast Pacific Rim fishery ramped up to industrial scale in the last 50 years. The missing links in this well-studied system are historical archives of human interactions with species from salmon to sea otters over the past 500 years from California to Alaska.

<u>Central Waters: Swimmers</u>
Pelagics. Many of the early studies around the world discovered extensive records on large wide-ranging species like tuna, walrus, and whales. This new study would link these records and connect them to recent research to create a global synthesis for the open seas.
World Whaling. Foci include (1) organizing and making twentieth-century whaling data available on line, (2) defining and describing whale fisheries worldwide, and (3) estimating nineteenth century humpback whaling in the North Atlantic. Over 28,000 whales were caught by more than 30 separate fishing operations in the North Atlantic in peak years around 1900. Catches of sperm, humpback, and right whales by "Yankee whalers" from the seventeenth to the twentieth centuries and estimates of catches in other pre-1900 fisheries will be assembled and made available on line.

Results of the studies will be ultimately disseminated in refereed journal papers, and 2008-2009 will focus on integration and a sustained modeling exercise in collaboration with FMAP.

2010. HMAP will provide a synthesis of the worldwide picture of the oceans before fishing became important and publications with concerted public outreach. It will add a forth dimension to field project outputs in the realms of the human edges and central waters by quantifying and explaining shifting baselines related to historic advances in fishing technology. The heart of this project is institution and discipline building to create a sustained capacity to discover how human activities have changed ecosystems through time. This is in contrast to field projects that focus on accelerating adoption of new technologies by existing institutions.

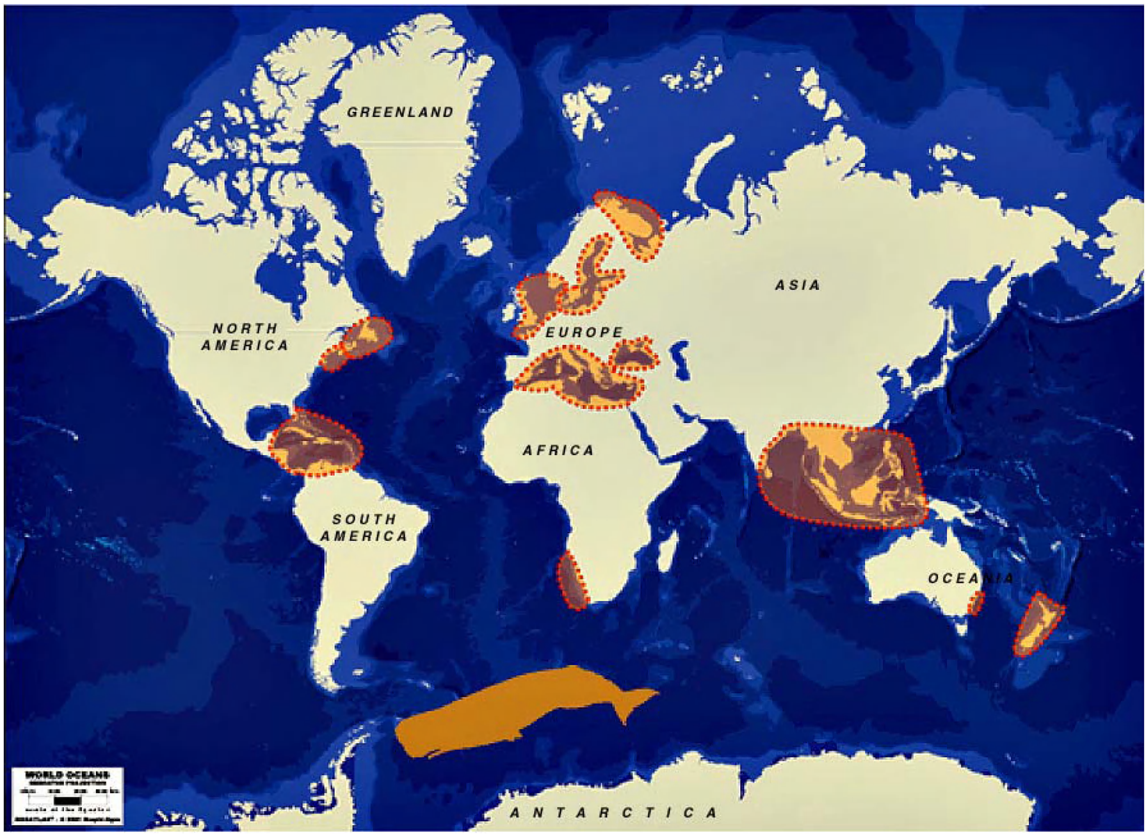


Figure 4. This map on the HMAP Web site (www.hmapcoml.org) shows regions where case studies are under way. HMAP records and documents are available here, but also searchable through OBIS.

C. What lives in the oceans now? Ocean Realm Field Projects

In each realm described above (Table 2), one or more projects are developing an efficient approach to exploration. Regional and national implementation committees will broaden the projects' coverage of realms by encouraging and promoting common approaches globally to ensure that results exploit the opportunity to visualize global patterns and thus test global hypotheses. Each project pursues a goal that is an adaptation to its realm of the COML goal of assessment and explanation. All projects will incorporate their data in OBIS.

1. Human Edges

In Figure 2, pink continental shelves, only 10 percent of ocean area, contain most known biodiversity. Shelves, most important to and impacted by humanity, lie mostly within the exclusive economic zones of nations. These human edges have nearshore and coastal zones.

Nearshore

The accessible nearshore has been studied in minute detail in many locales. The nearshore, however, stretches millions of kilometers around all oceans, across latitude, and across climates. Further, because the locales of the nearshore are linked, spawning in adjacent or even remote bays influences recruitment in other bays. Testing nearshore ecology hypotheses requires similarly linked researchers across latitude, climate, and ecosystems, the essentials of COML.

Natural Geography in Shore Areas (NaGISA)

Goal. *From a beginning around the Pacific Rim, link researchers across latitude and climate in all oceans to assess and then visualize and explain nearshore biodiversity patterns.*

Baseline. Mussels, oysters, and their kin proliferate in the rich region where winds and tides deliver food from the phytoplankton pastures offshore, and streams deliver nutrients from the land. The nearshore including estuaries and bays, and the diverse ecosystems of coral reefs, rocky shores, and kelp forests provide breeding and nursing places for marine life. The abundance of seabirds tells sailors that the shore is near. More than half of humanity lives within 50 kilometers of the coast, and waste from people and their influences reach the nearshore first. Although the nearshore is only about 2 percent of the ocean's area, it contains more than 6 percent of the known species, in part because of intense study of locales. Because it is only meters wide but stretches for millions of kilometers, the character of elongation across latitude and climates distinguishes the nearshore zone.

By 2005. Accepted by the SSC in 2002, NaGISA is demonstrating on the Pacific Rim the power of international collaboration to sample along the elongated nearshore. From its inception, NaGISA used international workshops to create simple, efficient standards for running and recording transects from shore to 10 meters depth using SCUBA and minimally destructive manual sampling techniques focused on the benthos. These protocols are readily available on the Web through the COML portal. NaGISA produces an extensive, consistent database on nearshore biodiversity to supplement and enhance intensive, idiosyncratic ones focused on local problems.

Building on site-selection criteria and sampling protocols developed during the International Biodiversity Observation Year (IBOY), NaGISA aims to achieve wide coverage with standardized techniques for future comparisons. Figure 5 shows the span of the project, 360 degrees around the equator through the Pacific, Indian, and Atlantic Oceans and, north to south, over 160 degrees from the Arctic Ocean to McMurdo Sound in Antarctica's Southern Ocean.

Nagisa means "coastal environment" in Japanese, and a center at Kyoto University coordinates the project. NaGISA initially focused on biodiversity gradients along the western Pacific coastline, but now it has established 30 sampling sites in seven countries and four oceans from Alaska to Indonesia to Florida. Scientists and funding is committed to complete initial investigations in sites in a dozen 20-degree squares. Training for field sampling and sorting is under way throughout Asia, and experts for the explorations are identified. The NaGISA approach has attracted scientists in more than 30 countries, who committed to using NaGISA protocols and raising local funds. South American and European NaGISA initiatives are completing the Pacific circle and eventually will encircle the Atlantic. Over $1 million has been committed to NaGISA to date, plus thousands of hours of volunteer effort.

2005-2009. NaGISA will begin east-west pattern comparisons for major taxonomic groups in the Pacific Rim by 2006. The Web site that provides the essential communication link amongst participants, and the NaGISA database will contribute to OBIS as samples are processed. Comparisons between basins should be possible by 2010.

NaGISA's feasibility is proven, and it is committed to establishing at least three sites in the 130 20-degree squares on the planet that contain shoreline (Figure 5). Its Japanese center will complete the Pacific Rim first, and the European center makes it likely that the North Atlantic will be completed soon afterwards, followed by South America, Africa, the Indian Ocean, and southern Oceania. The methods require no sophisticated or expensive ships or equipment, allowing scientists in developing countries or supervised volunteers to run them. They can be easily incorporated into existing protocols, adding capacity for large-scale comparisons to any nearshore experiment or most effectively be incorporated into monitoring of local areas, thus allowing current project managers to benefit from international taxonomic expertise. Protocols for macrophyte and sea grass habitats will work on selected coastlines from Arctic to Antarctic to provide a baseline for testing hypotheses about latitudinal variation in marine biodiversity. Additional protocols can add rocky and sandy shores, and NaGISA will work closely with the developing coral reef project.

2010. NaGISA seems poised to be the first fully global census completed. By 2010, the samples from the Pacific Rim should be in place for testing hypotheses explaining differences in diversity from north-to-south, east-to-west and between basins. Although NaGISA emphasizes wide-scale, one-time global sampling in seasons of maximum diversity in areas of minimum human impact, it will bequeath a legacy of baselines for long-term monitoring by local and seasonal transects. Japan plans to repeat transects at core sites every five years for 50 years, so global warming can be expected to create a natural experiment to study the impacts of temperature on large-scale biodiversity patterns along the north-south gradient.

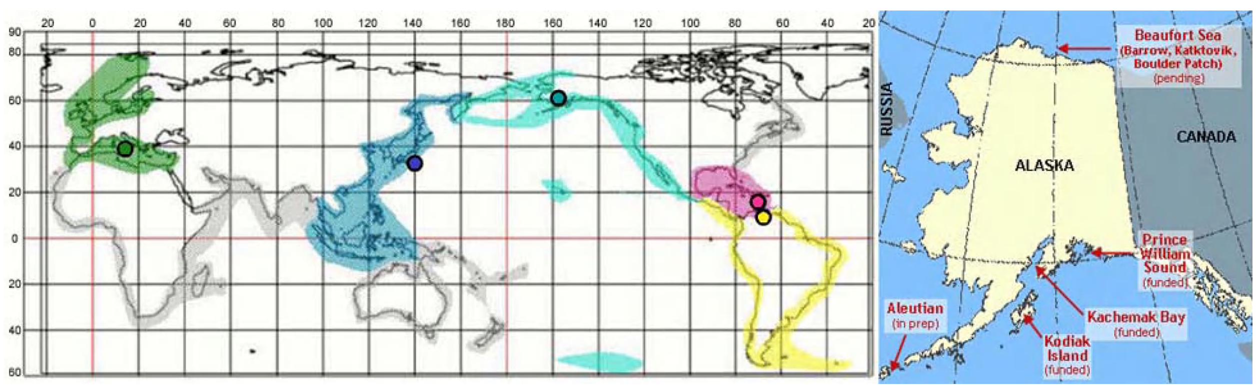


Figure 5. (Left) NaGISA aims to sample at least three sites from high tide to 10m depth in each of these 20-degree squares using its regional centers (dots) to build up a global map of low-tech biodiversity. Areas in gray are in planning for 2006. (Right) The current sampling areas in Alaska. Greater detail is encouraged, but global coverage is the principal goal.

Global Census of Coral Reef Ecosystems (GCCRE)

Goal. *To link researchers across latitude and climate with standardized approaches for the complex habitats created by corals, analogous to those of NaGISA, to assess, visualize, and explain diversity patterns before they are further affected by global changes.*

Baseline. Estimates suggest that there could be anywhere from 1 million to 10 million species on coral reefs, most of which are unknown, but these estimates are based on extrapolations from the numbers of insects in a rainforest or from partial counts of species in aquariums. We do know, however, that though they represent less than 0.2 percent of the area covered by oceans, coral reefs are the most diverse of marine environments. A 3-cubic-meter sample carved out of hundreds of kilometers of coral reef off New Caledonia in the South Pacific contained 130,000 mollusks alone belonging to 3,000 species, many not described. Globally, mollusk species are being described at 300 per year. If all the taxonomists in the world describing mollusks worked on the 3-cubic-meter sample above, they would all be retired before it was finished. Although coral reefs have been studied for centuries, statistical models cannot yet even predict how many samples would be necessary to collect all the species, let alone document their distributions.

Regional-scale patterns of biodiversity among dominant taxa on coral reefs provide a framework for examining biogeographic patterns, based on species composition rather than total generic or species richness. The number of species on a coral reef is less revealing than (a) which species are present, (b) which species are common and which are rare, and (c) their functional ecological roles. The task of acquiring multiscale quantitative biogeographic data on species abundances and functional characteristics is formidable, but essential.

Being among the most threatened of marine environments – by both climate change (Figure 6) and direct human impact – many interests (government, conservation, etc.) are at play in coral reefs. Groups such as the Global Coral Reef Monitoring Network produce periodic status reports on coral reefs of the world. Such efforts need to be combined so that results are comparable on a global scale and expanded to cover many more taxonomic groups and the deeper reaches of reefs.

By 2005. In 2003, COML endorsed the development of a global Ocean Realm Field Project on coral reefs. At the national (Australia, USA), regional (Caribbean) and international levels, leading coral reef scientists have convened to identify the major goals of a coral reef project:

(1) collection and synthesis of existing taxonomic and ecological information on coral reef organisms, (2) development of new technologies, particularly DNA-based, to greatly speed up characterization and understanding of coral reef biodiversity, (3) new initiatives in the taxonomy of diverse but under-studied groups – especially sponges, octocorals, mollusks, echinoderms, decapods, polychaetes, tunicates, seaweeds, (4) assessment of sampling devices to characterize the diversity and resilience of reefs that differ in human disturbance intensity, (5) populating OBIS with newly collected and synthesized data, (6) estimating risks to biodiversity associated with various scenarios for future reef health, and (7) establishing a well-funded global coral reef initiative to address key knowledge gaps.

2005-2009. Though scientists who study coral reefs have had several opportunities to meet and agree on the goals and structure of a COML field project, major international workshops are still needed to outline specific activities and engage dataholders around the world. These will take place in 2005, and the reef project will establish its organizational structure, governance, schedules for research and reporting, and obtain its initial key financial commitments.

Field expeditions in 2005-2007 will tentatively sample sites in Mexico, the Philippines, Heron Island, Hawaii, Okinawa, and Puerto Rico. Collections will be made, photographed, and vouchered, including DNA samples for barcoding. Existing checklists and distribution data will be utilized and verified to produce a journal review of coral reef ecosystem biodiversity. Sampling devices will be deployed on degraded and healthy reefs at each of the sites to assess diversity and resilience (as measured by recruitment) and censuses for invasive species will be made. Technology development will be a major focus, using laser scanning, barcoding, and other DNA-based technologies to determine reef health, species, and abundances. Finally, workshops will be held to synthesize all of the information for use in models and distribution by means of OBIS.

2010. Reef biodiversity will be summarized based on globally consistent approaches in a reef ecosystem synthesis publication. OBIS will provide an ongoing framework for frequent reporting on these rapidly changing zones.

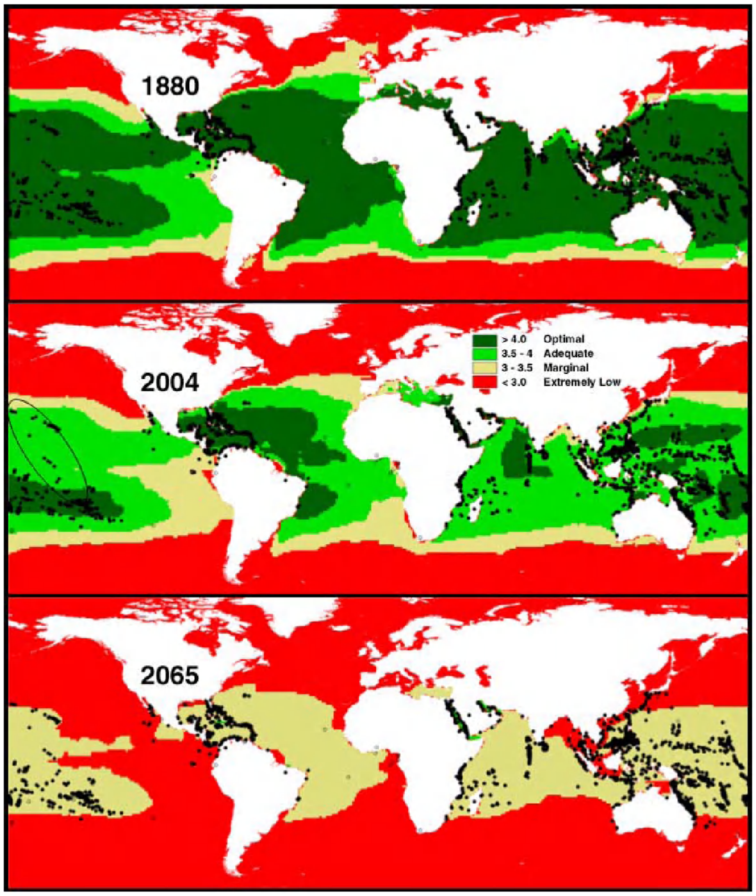


Figure 6. The area optimal for coral growth in terms of ocean chemistry, controlled by atmospheric carbon dioxide levels and temperature, has already dropped to a third of preindustrial levels. Most regions become marginal for coral growth in models of the future, which could be crucial to future management of biodiversity (Buddemeier, 2002).

Coastal

Because 90 percent of the ocean harvest comes from the coastal shelves between the nearshore and the continental margins, studies have concentrated on them. For a few hundred commercial species, national agencies have long surveyed fisheries, and the FAO has collated the catch globally. Recent crises in fisheries forced a reexamination of the management of single species and evolution of new strategies for management, including transboundary species in most coastal nations. Governmental agencies recognized at an early stage the potential contributions that the Census of Marine Life could make as an independent research program. COML recognized that its program for assessing and explaining diversity, distribution, and abundance—especially of noncommercial species—could accelerate and increase knowledge for management of commercial species at the same time it added to museum collections and subtracted from sampling cost. COML initiated two coastal projects, one in the Gulf of Maine distinguished by assessment from seabirds above down to clams at the bottom and the other in the northeast Pacific distinguished by tracking migrations along the shelf.

Gulf of Maine Area Project (GOMA)

Goal. *On a coastal shelf where interests, scientists, and resources congregate, identify and collect the biological knowledge necessary for ecosystem-based management in a large marine environment. GOMA will advance knowledge of both biodiversity and ecological processes over a range of trophic levels – plankton to whales and even birds – and habitats.*

Baseline. With a steep latitudinal gradient in the atmosphere and the ocean, the Gulf of Maine is a potential sentinel for the effects of climate change. As a semi-enclosed sea on the edge of an ocean, the gulf has steep gradients of temperature and tidal amplitude and diverse submarine and coastal habitats. The study area includes all of the Gulf of Maine and Bay of Fundy, Georges Bank, the southern half of the Scotian Shelf, the adjacent Slope Sea, and the New England Seamounts. The Scotian Shelf and Slope Sea influence physical conditions and biota in the gulf. Although some of the gulf may seem pristine, it has a long history of fishing and shipping. Profitable species such as mackerel, herring, and lobster have flourished at times, but haddock and cod fisheries have now collapsed and wild salmon are endangered.

The Gulf of Maine holds a transition between northern and southern biota. The food chain of marine life runs from microscopic algae through 1-gram krill to 100-ton blue whales. Billions of tiny worms and crustaceans live in the accumulated food on the bottom, missed by animals in the upper layer.

Both Canada and the United States have long histories of surveys and management in the Gulf of Maine and now focus advanced technologies on monitoring its physical and biological characteristics. The continuous change of water at a place in the ocean demands measurements of oceanographic properties as well as geographic location. For the requisite oceanographic and geographic context (Figure 7), acoustical and optical devices deployed from boats or operated remotely can be integrated with the Gulf of Maine Ocean Observing System, one of the most advanced "underwater weather" systems in the world. The gulf's long historical record telling what used to live there can complement the census of what lives there now and models of future trends. Areas like the Gulf of Maine can be modeled in four dimensions, integrating the historical, biological and environmental databases. "State-of-the-ecosystem" models such as these are now a recognized requirement for managing sustainable living resources.

By 2005. In 1999 COML initiated the Gulf of Maine Area Project with a series of workshops and meetings focused on assessing biodiversity, which was surprisingly poorly known despite or because of, the concentration of commercial species. In 2002 the program expanded to encompass oceanographic, physiological, ecological, and population dynamics to explain the patterns of biodiversity and predict their change. It also expanded to applying discovery to protect the gulf ecosystem by improved management.

GOMA integrates policy and science perspectives and represents a binational collaboration with the Canadian Department of Fisheries and Oceans (DFO) and the U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries (National Marine Fisheries Service) supporting the effort, including sharing costs and data to create the Gulf of Maine Biogeographic

Information System (GMBIS). GMBIS is now online as the first regional component of OBIS, interoperable with historical data from HMAP and serving data from trawl surveys, pelagic and benthic habitat characterization, and high-resolution bathymetry allowing the development of the first biophysical maps of the gulf.

In the water column, fishers contribute fish-finder records. The GOMA project and the Gulf of Maine Ocean Observation System (GOMOOS) provide continuous information about ocean physics that allows relation of biological samples both to geographic location and to concurrent observations of water temperature, salinity, currents, etc. Relating biology to water conditions is crucial because most ocean life is associated with a water mass, not a place. All GOMA sampling is being evaluated in the context of GOMOOS to ensure that the techniques standardized by the COML can contribute to OBIS' role as a key biological data framework for the Global Ocean Observing System (GOOS).

Although much sampling in the Gulf of Maine can be done in association with routine fisheries surveys conducted by two cooperating national agencies, extending the study to the New England Seamount Chain added a GOMA exploration. Two NOAA Ocean Exploration cruises did biological sampling for GOMA, while testing gear for MAR-ECO. Published species lists from Bear Seamount include 183 species of fishes (including at least one new species), 33 species of cephalopods, and 152 other invertebrates. An interesting pattern is emerging of endemic species and long-range migrants, but many more gulf cruises are needed to understand its true diversity. About $5.5 million has been committed to date.

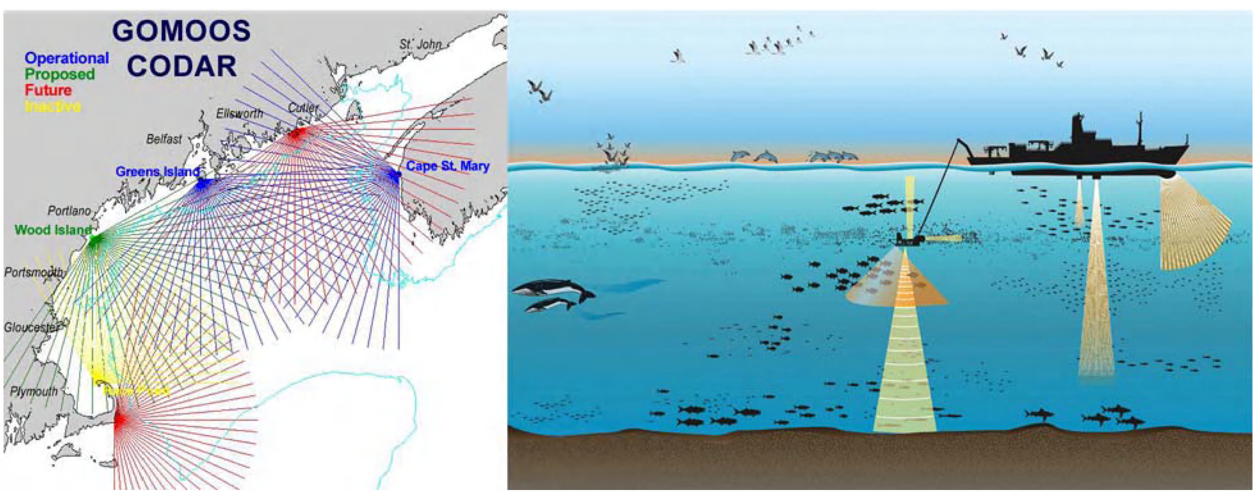


Figure 7. (Left) The Gulf of Maine Ocean Observation System is one of the most advanced operational oceanography systems (GOMOOS/U. Maine PhOG). Combined with the advanced technology from nearby research centers (Right), this makes the Gulf of Maine an ideal spot to test the limits of all aspects of the marine census approach, a test bed for linking physical and biological sampling in GOOS and for developing ecosystem management approaches (WHOI Graphic Services and Foote, 2002).

2005-2009. GOMA will develop both historical reconstruction and predictive tools through two funded projects: HMAP and FMAP in the Gulf of Maine. GMBIS will continue to integrate existing local data sets, through a new Gulf of Maine Ocean Data Partnership, and evolve into a dynamic digital atlas including access to remote data providers. Further field expeditions will contribute to the atlas. Observations in a "Biodiversity Corridor" along the Canada-U.S. border stretching from the shore to the nearest seamounts will focus effort and captivate the public.

The U.S. Implementation Committee for COML has made development of integrated GOMA-like projects in the Gulfs of Mexico and Alaska a priority. In both cases ocean observation systems are developing in parallel, so this will not only build new research capacity, but also further illustrate how coastal monitoring systems can develop internationally. GOMA will serve as an example for regional ecosystem surveys.

2010. GOMA will deliver its Dynamic Atlas, plus the results of HMAP and FMAP work, and a "state-of-the-ecosystem" report for the Gulf of Maine. The legacy includes a tested model of a gulf regional ecosystem survey. The practical consequence of the model will be a sediments-to-seabirds ecosystem management plan and a cleaner, more sustainable and productive gulf.

Pacific Ocean Shelf Tracking (POST)

Goal. *Build a permanent acoustic tracking array for juvenile Pacific salmon and other species as small as 10 grams along the west coast of North America as a prototype for other coasts.*

Baseline. Although young salmon migrate down rivers to the ocean before our eyes, few return. The life of Pacific salmon in the sea is almost entirely hidden and thus unknown. Knowing the routes of specific stocks in the ocean, where they reside and, especially, why some die and some survive in the ocean is crucial if humanity is to act wisely to conserve them.

Each salmon population appears to have two "zip codes" – or postal addresses – sending it not only back to its river of birth, but probably also to specific feeding grounds in the ocean. One can ask where the poor marine survival affecting many Pacific salmon occurs? Some species have had consistently high ocean survival—up to 20 percent, while other stocks of the same species have had survival as low as 0.5 percent; a fortyfold difference in the numbers returning from each spawning parent. At the same time, record returns in recent years to some of these weak stocks speak to the importance of the ocean in determining the success of conservation efforts. These improvements correlate chiefly with climatic effects that increased the productivity of the ocean, and not with changes in river flow. To determine where they die, however, one must know where salmon go, what they do when they get there, and how they return to spawn in their home rivers. The oceanic zip code for a population may be as specific as that of their rivers of origin. Learning the unknown zip code at sea and the routes to it and back to the river requires a tracking technique.

Fortunately, a baseline of known suggests a strategy. After entering the ocean from freshwater, Pacific salmon smolts generally move north and curve around the west coast of North America following the continental shelf. All juveniles caught during eight years of study remained over the continental shelf north to the end of the Alaskan Peninsula (Figure 8). The narrowness of the continental shelf restricts the migration to a long thin corridor that can be monitored relatively inexpensively. Tags showed that some groups of salmon swam swiftly north, some remained over the shelf and some even swam south. Identifying which groups move where would help predict marine survival.

By 2005. Scientists from Canada's DFO and the U.S. NOAA initiated POST, and in 2001 the SSC accepted it. Based at the Vancouver Aquarium, POST's new management board is chaired by the Canadian Commissioner to both the Pacific Salmon and North Pacific Anadromous Fish Commissions. Its membership encompasses both federal and state or provincial branches of Canadian and U.S. governments, as well as foundations, fisheries commissions, and NGOs. The scientific steering group for POST is drawn from North American salmon experts as well as others from Australia and the North Atlantic.

The high survival observed during field studies in 2002-2003 showed that the survival problem for salmon is likely not close to the river mouths and therefore calls for the deployment of a more extensive acoustic array. This demonstration of successful tagging and detection with strategically placed lines encouraged assembling a consortium of researchers from many sectors for the next phase. They envision the continental scale array of tracking stations in Figure 8. Because the West Coast shelf is often narrower than 20 kilometers, a string of 20-30 acoustic receivers across the shelf should detect all tagged animals crossing each line. With over 90 percent efficiency, these acoustic curtains have tracked and identified smolts, immature or maturing shelf-resident salmon, and sturgeon stocks passing them.

A focused array was built in the large "Salish Sea" enclosed by Vancouver Island. The Salish Sea tracking demonstrated detailed measurements of residence timing, movement, and marine survival for multiple species of salmon within the Georgia Strait ecosystem and then along the open continental shelf. Within Georgia Strait, two smaller arrays in Howe Sound and Saanich Inlet tested POST's earlier findings that after leaving freshwater, salmon survival is initially high. Confirming this finding is important because it will encourage development of the extensive array envisioned in Figure 8. With further collaborators, POST deployed an array in 2004 in south Puget Sound, which will soon be followed by the Hood Canal region and along the coastal shelf north of the Columbia River. POST and allied programs raised nearly $6 million to assist with the purchase of acoustic tags, deployment of the array, and administration of its work during 2004-2005.

2005-2009. Tracking of a spectrum of animals implanted with acoustic tags from squid to eels to whales implanted with acoustic tags is planned for 2005 in a skeleton continental-scale acoustic array from Washington to Alaska to demonstrate effective monitoring of several types of large-scale migrations.

A permanent seabed node to host multiple instruments is being developed and tested to make the existing deployment strategy for the acoustic receivers less costly and laborious and more reliable. POST is collaborating with commercial manufacturers to develop these seabed receivers, which will be capable of remotely uploading the collected data using underwater acoustic modems, much the way early computers were linked acoustically through telephone lines.

During 2005-2006, in cooperation with the Neptune North cabled undersea observatory, POST will build one or two lines of additional acoustic receivers using fiber optic lines across the Straits of Georgia and Juan de Fuca. This collaboration will supplement the Salish array and access a refined data management system to provide a continuous data stream. Still other collaborators plan arrays in Monterey Bay, California. In Australia, a similar South West Pacific system is developing. Compatible satellite-linked acoustic receivers are also being deployed on fish aggregating devices in mid-ocean, so these systems may eventually be linked. Data on the migrations of a wide variety of species will eventually be compiled and made available in OBIS.

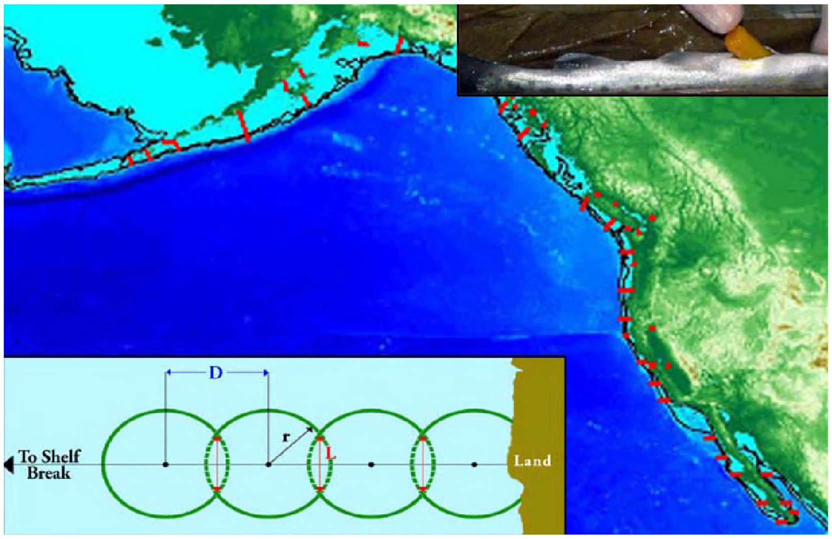


Figure 8. One-third of this array of "listening curtains" was in place in 2004, from the Columbia River to the Alaska panhandle. It monitored the migrations of over a thousand salmon smolts, as well as some unexpected sturgeon that had been tagged in local studies in California rivers. The insets show a schematic the overlapping radii of a line of acoustic receivers (bottom left) and the surgical implanting of an acoustic tag, which can be placed in an animal as small as 10 grams.

2010. POST will have tested and demonstrated continental-scale acoustic tracking by a consortium of salmon researchers, as well as applying the array to other species during their coastal migrations. It will establish the time and locations of oceanic salmon mortality and clues to its cause. It will enter the accumulated migratory tracks in OBIS and contribute to the COML dynamic atlas. POST's legacy will be an international network of listening devices stretching from the shore to the edge of the coastal shelf and stretching along a continent, and it will have stimulated similar systems on many of the other shelves seen in Figure 2. The POST arrays will be a coastal component of GOOS.

2. Hidden Boundaries

Continental Margins

Although their distance from shore and depth inhibited exploration of the margins until recently, we now know that the sloping margins are often unstable and changing. Improving technologies for fishing and oil exploration have pushed down the slopes to reveal challenges few imagined a decade ago. Sonar and seismic images of the lower margins reveal that apparently uniform slopes hide mixtures of rock, sand, mud, and methane hydrates. Underwater landslides that alter local habitats and powerful currents mix water layers and scrub the bottom. These energy-rich areas are likely to have high biodiversity but have been poorly sampled until recently.

Continental Margin Ecosystems on a Worldwide Scale (CoMargE)

Goal. *Establish biodiversity baselines in areas still untouched by commercial exploitation, collecting evidence of changes from such activities in vast areas of margins, and learning the slope's role in the evolution and distribution of species in zones above and below.*

Baseline. Continental margins bound the sides of the wide oceans. Although fewer species are named on continental margins than on the coastal Edges where fishers gather, the margins support many of the same species as well as others from deeper waters. Along the continental margin, powerful currents circulating against the edge of the vast oceanic bowl fertilize a whole complex of life, which changes gradually downslope. Complicated habitats are a likely realm for new species to evolve, and canyons support dense and abundant assemblages. Oddities like the deepest plant and large, old corals and sponges living in trenches and canyons extend the range of species. Although difficult to explore, canyons and trenches cannot be considered in isolation from the less dramatic expanses of the margins. New technologies and exploration for oil have revealed unstable habitats that are a likely source of diversity below. The first hints of this came as the oil explorers began detailed mapping around the world and sampled promising sites for life that might be damaged by oil extraction. The potential to discover new life along with new oil in this realm is perhaps the greatest in the oceans. Integrating such priceless samples collected by oil companies into OBIS is itself a new technology.

By 2005. A KUU workshop in August 2003 developed basic information and concepts, which contributed to the development of Hotspot Ecosystem Research on the Margins of European Seas (HERMES), recently funded by the European 6th Framework Programme. IFREMER in France, a HERMES partner, will host the COML global margins project with strong partnerships in other regions. There is valuable synergy between the participants and interests of the margins project and other COML projects, including ChEss, CeDAMar, and ICOMM, which will help to identify and describe the many new species to be found in this poorly studied realm. Indeed, many fundamental questions about marine biodiversity hinge on the interactions of these realms. The major interest in, and access to, the margins stems from oil exploration. Thus, the initial focus is on benthic diversity, but great potential for new species also exists in the highly productive near-bottom waters and the mid-waters above, as demonstrated by increasing fishing activity.

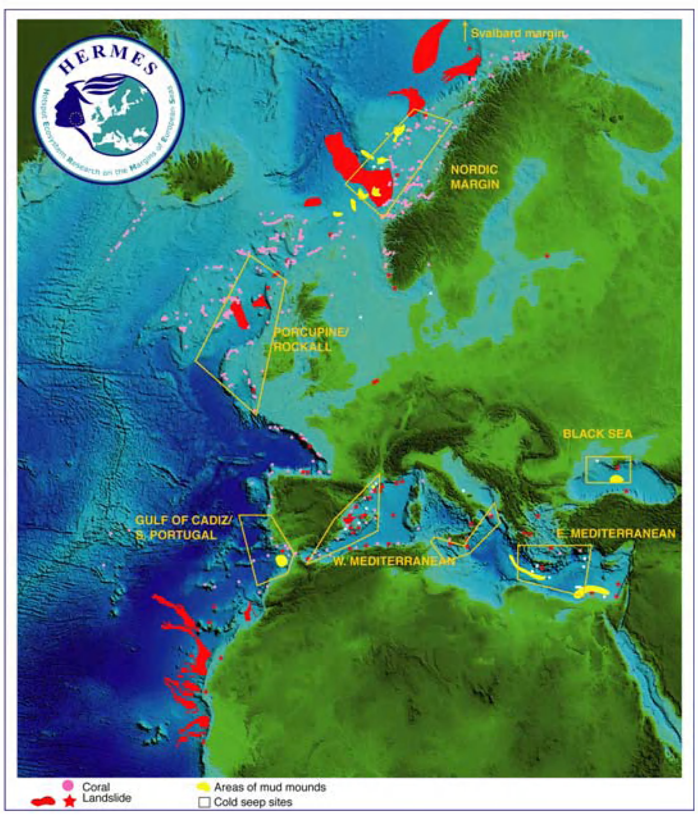


Figure 9. Regions for COML collaboration with the new European HERMES project will provide key initial sampling for the margins project (modified from Weaver et al., 2004).

2005-2009. By May 2005, the margins project will have established its organizational structure, governance, and schedules for research and reporting, and obtained its initial key financial commitments. Figure 9 shows the planned cruise schedule for HERMES. An early goal of the scientific steering group for the margins project will be to identify parallel opportunities in other regions to provide a comparative database. Commercial activity may return far more samples from the margins than research cruises, so aggressive efforts will be made to ensure a quick flow of such samples. OBIS will play a key role in integrating data, and regions where ChEss and CeDAMar are already active have a priority because the margins are thought to be sources of the biodiversity in these other realms.

2010. The margins project will provide the first global biogeography of this realm, describing both the known and the unknown, which will remain large in this time frame. Nevertheless, there are opportunities for the OBIS database to serve as a management tool as human exploration has increasing impact on this previously dark and mysterious realm.

Abyssal Plain

Census of Diversity of Abyssal Marine Life (CeDAMar)

Goal. *Describe the actual species diversity of the abyssal plains and learn what factors cause it to vary in time and space in and on the sediments.*

Baseline. The spectrum of species in abyssal silt is rich in small organisms like protists, crustaceans, and various worms, but poor in larger animals like fish. The accumulation of marine snow in the abyssal silt, its sheer volume, and its relative stability for millions of years allowed diversity and abundance to develop. The variation of the diversity from place to place plus the extent of the plain make it a happy hunting ground for new species. The hunting should be especially good for mollusks, tiny crustaceans and the roundworms called nematodes. Every technological improvement in sampling gear will improve hunting in the darkness of the abyssal plain at the bottom of the ocean.

Hard nodules formed by bacterial action and enriched in heavy metals - such as manganese, iron, nickel, cobalt and copper - litter the surface in some areas of the plain. Unusual, ancient chemical reactions nourished the bacteria, and easily extractable metals accumulated in the nodules. Although undersea miners have collected many samples, scientists have analyzed few of the samples for new species. The richness of the silt in the abyssal plain beckons the explorer.

By 2005. Coordinated from the Senckenberg Research Institute's German Centre for Marine Biodiversity Research (DZMB), CeDAMar is a dynamic part of COML, contributing impressively to workshops and program development. CeDAMar has a global scientific steering group that has successfully unified significant abyssal projects in major ocean basins. It has taxonomists for the most common abyssal fauna in two oceans and has developed a fellowship program for other taxa and other oceans. This network supports and benefits from projects like NaGISA, ChEss, ArcOD, ICOMM, and seamounts that sample organisms in sediments.

CeDAMar has now completed two abyssal plain sampling cruises using benthic grabs and sleds in three oceans, DIVA and BIOZAIRE in the South Atlantic, ANDEEP I and II in the Southern Ocean, and KAPLAN and NODINAUT in the North Pacific (Figure 10). Results from these cruises were integrated at two workshops and have produced more than 70 publications. DZMB's established specimen sorting center has added hundreds of new species to its archives and will soon add them to OBIS. Five additional cruises are funded for the North Atlantic, Southern Ocean, and Indian Ocean. About $22 million has been committed so far.

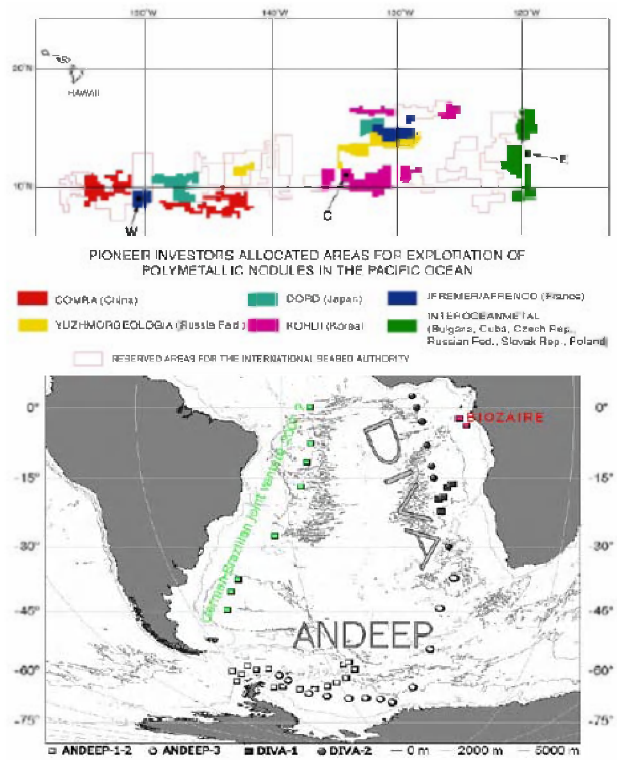


Figure 10. CeDAMar sites. Comparing benthic biodiversity in the (top) Pacific (Adrian Glover and Craig Smith, unpublished) and (bottom) Atlantic and Southern Oceans.

2005-2009. Deep-sea sampling is costly. Volunteer observing ships sample millions of liters of surface water for plankton for not much more than the cost of netting. A couple of liters of mud from the Antarctic abyssal plain, however, can cost $100,000 for salaries and steaming time. Thus, building a global network to exploit samples of the abyssal plain widely and in many ways is critical. The CeDAMar network is focusing on capturing and coordinating as much sampling as possible to create a global synthesis in this difficult-to-explore realm at the bottom of the ocean. To test hypotheses about such factors as productivity and latitude causing high biodiversity in the abyssal sediments, CeDAMar must first perform the challenging task of sampling the abyssal plain at several localities. This local sampling is aimed at revealing the distribution of seemingly widespread species. This knowledge of global patterns of abyssal diversity will be related to conditions in the overlying water zones. Funding in deep-sea sampling ranges from measuring carbon fluxes into sediments to geological drilling studies to nodule mining.

Crustaceans are numerous in both the abyss and the light zone, so there are synergies between the genetically oriented Global Census of Marine Plankton (CMarZ) and CeDAMar. Comparisons between biodiversity encouraged by latitudinal and productivity differences in the plankton of the light zone and in the realm of the abyssal plain could give new insights into vertical transfer of energy and carbon between the water column and the bottom. Genetic comparisons between light zone and abyssal crustaceans could reveal interesting evolutionary patterns. CeDAMar will furnish samples for ICOMM.

2010. CeDAMar will make one of the largest additions to known species in the 2010 report from its unknown realm, but it certainly will not have exhausted the potential for discovery among rare species. The central unknown the abyssal will reveal is whether its common species are truly cosmopolitan and globally distributed. CeDAMar will bequeath a legacy of a global network of experts with the habit of exploiting costly abyssal samples.

3. Central Waters

Light Zone (drifters and swimmers)

At least 40 percent of the world's primary production of biomass occurs in the open ocean, and much of this production is consumed by a community dominated by planktonic crustaceans. These organisms are relatively well studied, and many are assumed to be cosmopolitan. The focus among the light drifters is on the question of whether this community is consistent globally, or merely convergent in a zone that requires highly constrained lifestyles. This question requires molecular tools and global assessment of populations throughout the ocean.

In contrast, there is now no question about the basinwide or even global connections among the large pelagic animals in this zone. Individual recognition, tagging and now real-time tracking of many species leaves no doubt of the scale on which these top predators must be studied. We cannot sum the whale counts in Alaska and Mexico or the tuna counts in Mexico and Japan to get a census – they are all the same individuals! New technologies are now making it possible to provide realistic estimates of the global distribution and abundance in this realm. Even animals themselves are identifying the "ocean oases" where they concentrate to feed on smaller species taking advantage of these production hot spots.

Census of Marine Zooplankton (CMarZ)

Goal. *Global-scale analysis of all marine zooplankton groups using new and emerging technologies including molecular, optical, and acoustical imaging, and remote detection, initially focused on DNA 'barcoding' of existing specimen collections, to identify cryptic species among cosmopolitan groups.*

Baseline. Planktonic organisms dominate the oceans in terms of abundance and biomass and are exceptional in their widespread, frequently circumglobal, biogeographic distributions. The metazoan and protozoan plankton are also exceptional in the degree to which new species remain to be discovered. Despite decades of sampling the oceans, comprehensive understanding of plankton biodiversity has eluded oceanographers because of the fragility, rarity, small size, or systematic complexity of many taxa (Figure 11). Many planktonic groups remain poorly known and problematic for taxonomic and systematic studies, with long-standing questions of species identification, systematic relationships, and biogeography.

Archived collections of preserved plankton samples are a storehouse to be mined for new information on biodiversity of the plankton. Recently, many samples have been appropriately preserved for molecular and biochemical analysis. Widely-distributed, cosmopolitan, and circumglobal species need molecular systematic assessment across their geographic range, particularly with systematically complex and morphologically conserved groups. Tropical waters with low production have higher species diversity, yet the species are poorly explored or characterized even by traditional techniques. Effort is needed throughout the water column to the twilight zone and below, in biodiversity hot spots, centers of speciation (e.g., Banda Sea), and in novel and productive environments in remote regions.

By 2005. A KUU workshop in early 2004 brought together an international partnership using ships of opportunity and a coordinated international network of technicians, taxonomic experts, and biological oceanographers. The project conceived there includes centers in Germany, Japan and the United States and draws on a wide variety of research platforms globally, including the ships of opportunity of the Sir Alister Hardy Foundation for Ocean Science. CMarZ has nine cooperating projects – including six oceanographic cruises – launching in the first year. DNA barcoding is under way in CMarZ laboratories in Japan and the United States. CMarZ is coordinating globally synoptic sampling, with strategic and statistical advice from FMAP.

2005-2009. Field collections, taxonomic analysis and data analysis will be carried out by cooperating projects, ranging from annual surveys in the U.S. exclusive economic zone by the NOAA Fisheries to three months in the Weddell Sea on the *Polarstern*. Training workshops will increase taxonomic capacity, ensuring accurate and consistent identification of specimens. This coordinated multinational effort seeks to complete morphological and DNA barcode analysis of at least the approximately 6,800 described species of marine metazoan and protozoan plankton by 2010 (Figure 11). The CMarZ database will integrate with OBIS. New cooperating projects will be added as opportunities and funding arise to expand sampling to less known realms and use advanced sampling technologies (e.g., remote, autonomous, and manned submersibles). CMarZ will analyze collections from other COML projects sampling the pelagic realm.

2010. CMarZ will provide the first global synthesis of the biodiversity and biogeography of the species that make up the greatest animal biomass on the planet. It is likely to double the number of known zooplankton and will provide DNA barcodes for reliable, fast identification of zooplankton species. It will provide accurate and comprehensive assessment of relationships among light zone plankton in the world ocean, reveal new relationships to those that live in the dark zone, and inform studies of marine food webs, in which zooplankton play a pivotal role.

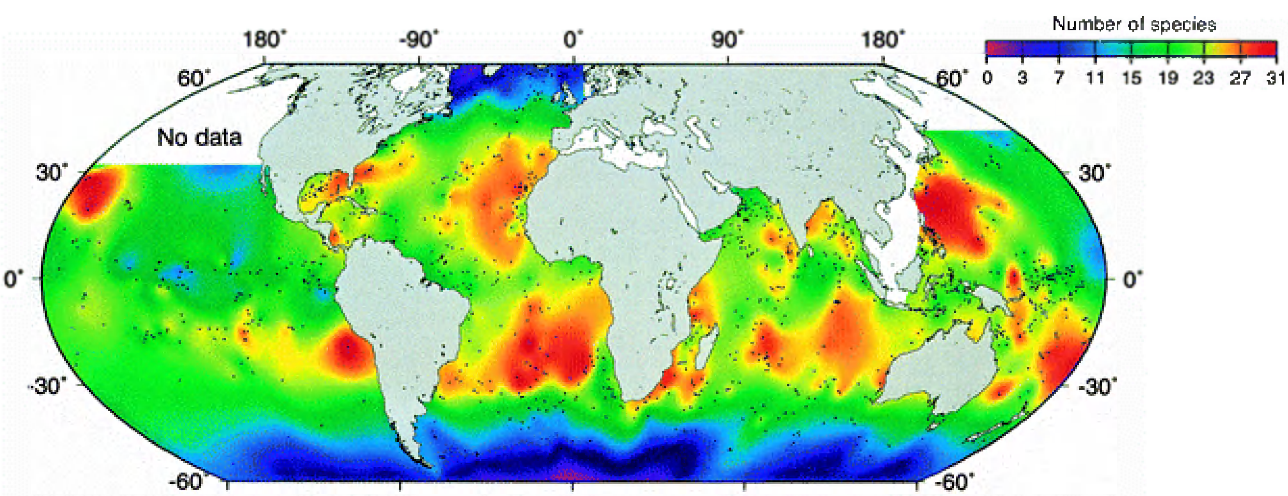


Figure 11. Global patterns of diversity of planktonic foraminifera (Rutherford et al., 1999).

Tagging of Pacific Pelagics (TOPP)

Goal. *To ally with animals as observers to create a view of vast open ocean habitats as seen by the animals themselves, especially top predators. Knowing the behavior of the top predators allows inferences about the distribution and abundance of much else that lives in the ocean, for example, where prey species accumulate. Beginning in the North Pacific, the project provides an example and advice for similar collaborations in other regions.*

Baseline. At their cruising speed of 20 kilometers per hour, whales could circle the globe several times in a year. Tuna traverse both the Atlantic and the Pacific Oceans, some annually! For this dynamic component of ocean life, the questions are less about species and more about distribution and abundance. If the same moving animals are counted on both sides of the ocean, catching one subtracts two from the misleading double count. Wherever the ocean is productive, predators evolve to find and feed on the marine life. If some top predator is not going somewhere, there is little biology to know. Shadowing predatory animals finds concentrations of organisms, and improved telemetry by satellites has made them full allies in our discovery of the oceans. Until recently, we have had a fragmentary picture of the distribution and movements of top predators.

By 2005. Headquartered in California's Monterey Bay (Hopkins Marine Station, Monterey Bay Aquarium, and the University of California) and guided by an international scientific steering group, TOPP scientists have tagged 19 species from albatross to albacore to elephant seals (Figure 12). More than 40 investigators conduct projects in eight countries. By October 2004, over 1500 electronic tags of various designs were deployed and methods developed to capture, handle, and attach a number of different tag types to pelagic allies, including Humboldt squid, a previously untagged species.

While performance of electronics is critical, success also requires reliable attachment of tags, and high levels of retention and recovery. Researchers working with leatherback sea turtles in Costa Rica developed attachment methods for new tags to ensure long-term retention, expanding the tagging options and providing more environmental data. Another key is to tag sufficient numbers of animals to allow statistical analysis of patterns and modeling of movements. Net pen and bait boat releases deployed 131 tagged Pacific bluefin in just four days in early 2003. Archival tags recovered yielded extensive data on tuna movements and the structure of the California Current.

Performance tests of electronic tags in the field, including double tag studies on salmon sharks, compared different geolocation methods: day length to estimate latitude and longitude against Argos satellite transmitters. A new generation of ocean sensor tags has been deployed, improving salinity, light, temperature, and depth measurements. Adding TOPP animals' salinity data to North Pacific physical characteristics will improve ocean dynamic models, and everyone from students to scientists will be able to explore their journeys on an enhanced Web site. About $12.5 million has been committed.

2005-2009. TOPP Phase II will continue intensive deployment of tags on the 19 species already tagged and a few new ones, focused on the California Current boundary. The major challenge in this period is integrating and presenting the vast quantity of data effectively. TOPP data are not at fixed locations, are not gridded in time or location, do not have predictable delivery or location qualities, and require new data management tools. A data management system is being designed to ingest data and facilitate interactive handling. Low bandwidth and intermittent connectivity must be managed and generally hidden from end users. Automated post-processing is fundamental to correct tag data for calibration and coherency. To apply TOPP data to a wide variety of analyses, including integration with models and oceanographic data sets, its server must facilitate these analyses and provide automated notification and transmission of new data. TOPP is working closely with OBIS-SEAMAP and FMAP on these issues.

This data management and server capacity will help TOPP to focus the entire global telemetry community. Many new projects adopting the TOPP model are under development beyond current efforts in the North and South Pacific. These include: (1) Novel Exploration of the Ocean (NEO), a consortium of European biologists, oceanographers, engineers, and businesses focused on bio-logging, (2) the Marine Conservation Corridor Initiative in the tropical Pacific, (3) Japan's Deep Sea Look project, and (4) Southern Ocean TOPP, an idea developed at the International Bio-logging Conference in Tokyo, March 2003. Antarctic programs, already using bio-logging technology, will take advantage of TOPP's data systems to oversee national Antarctic research programs. Such data integration will facilitate management of these vast ocean areas and will be linked to the Census of Antarctic Marine Life (CAML) project.

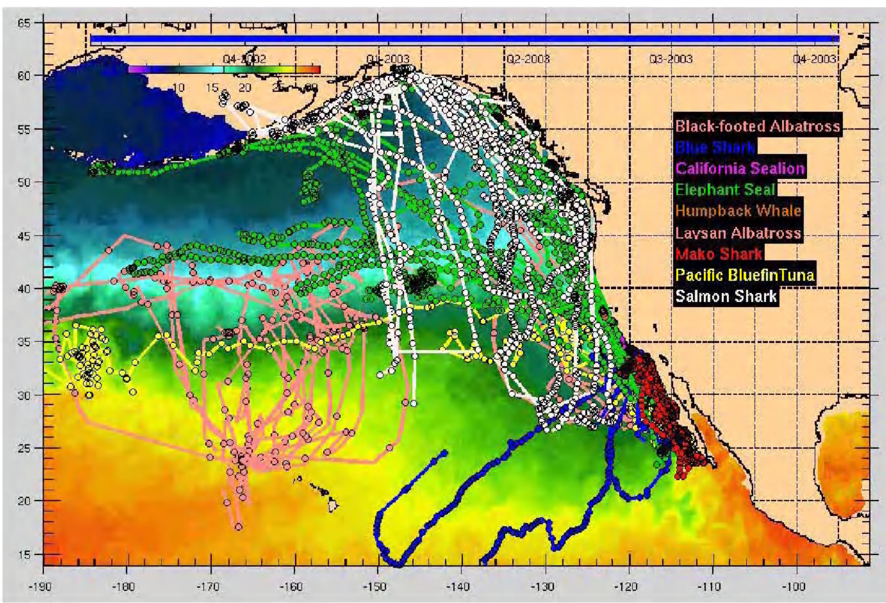


Figure 12. The 2002-2003 tracks of nine of the 22 species tagged by TOPP to define oceanic habitat use. Background is spring sea surface temperature.

2010. TOPP will produce a unique, integrated overview of open ocean biology in the Pacific, and will have aided efforts around the world. TOPP will also be an operational element of GOOS, supplementing data from autonomous underwater vehicles with focused biologically relevant data from collaborating species.

Dark Zone (mid- and bottom-waters)

Mid-Atlantic Ridge Ecosystem (MAR-ECO)

Goal. *Explore and understand the distribution, abundance, and trophic relationships of the organisms inhabiting the middle and deep waters of the mid-oceanic North Atlantic, and identify and model ecological processes that cause variability in these patterns. Focus on pelagic and* *benthic macrofauna, using innovative methods and up-to-date technology to map distributions, analyze community structure, study life histories, and model trophic relationships.*

Baseline. Extending to depths of 4 kilometers or more, the mostly dark deep-sea environment far exceeds the volume of the 200-meter light zone. The major source of energy and material for the organisms living in the deep ocean is ultimately plants produced near the surface, and the biomass declines exponentially with depth. However, many processes ensure that material produced at the surface becomes available to the diverse deep-sea fauna. There is a steady yet sometimes seasonal, snow of wastes, e.g. dead algae and fecal pellets, and also carcasses of small and large animals. Also important is the “Vinogradov’s ladder of migrations,” i.e., the process whereby animals with different but overlapping vertical migration ranges prey on each other and ensure a rapid transfer of material downward from the productive surface layers. A particularly important process along slopes and on seamounts is the seasonal and diurnal impingement of dense layers of mesopelagic fish and crustaceans on the slopes, providing food to a variety of near-bottom predators.

Mid-ocean ridges affect circulation and watermass distributions both near the surface and in the deep, and this in addition to topography affects distribution patterns at many spatial scales. Mid-ocean ridges are of volcanic origin and thus rugged; this and the shear size of the ridge system create major sampling and observation challenges. A suite of most modern technologies needs to be mobilized to study such systems and their wide variety of inhabitants, such as planktonic organisms of many sizes and designs from small crustaceans to huge but fragile gelatinous forms, fish, squids and octopuses, and even mammals and seabirds. Because densities are low, big trawls or gears attracting animals to bait are required to obtain samples, but in many cases remote sensing by echo sounders or visual observations by manned or unmanned submersibles are the only options to gain new knowledge.

By 2005. A multidisciplinary transatlantic team of researchers, led by a steering group with representatives from the United States, Germany, the United Kingdom, Iceland, Portugal, France, and Norway, has initiated the field phase of MAR-ECO and has already carried out investigations between Iceland and the Azores using ships and submersibles. The Institute of Marine Research and the University of Bergen in Norway coordinate the efforts. The focus is the North Atlantic section of the Mid-Atlantic Ridge. Experiences here and the technological solutions found will be useful for biodiversity studies initiated by other teams on other ridges around the world.

In 2003, field sampling and observations were made from several platforms from Iceland, Russia, Germany, and Portugal. The Icelandic vessel RV *Arni Fridriksson* conducted studies and sampling of mesopelagic fish and zooplankton in the northern end of the study area, the Reykjanes Ridge. The Russian vessel RV *Smolensk* and the German vessel RV *Walther Herwig* also conducted some sampling in the northern area. These efforts were extensions of an ICES co-ordinated survey of redfish (*Sebastes* sp.) in the Irminger Sea.

Perhaps the most remarkable effort was made by the Russian RV *Mstislav Keldysh* and its manned submersibles Mir-1 and Mir-2. This Russia-U.S. collaboration included scientists from both countries who made two double dives to depths of 3000-4500 meters in the Charlie-Gibbs Fracture Zone, an area never before visited. Analyses of the observations and samples obtained are ongoing, and detailed results will be presented elsewhere. However, preliminary analyses of the footage from the dives document occurrence of many fish species, cephalopods, and swimming holothurians, as well as a diverse sessile macro- and megafauna dominated by suspension feeders. The density of "marine snow" and phyto-detritus on the bottom appeared higher than expected, and a particularly interesting finding was high densities of juvenile macrourid fish and holothurians.

In mid-2004, the international MAR-ECO team studied and sampled the entire study area for two months aboard the new Norwegian RV *G.O. Sars* (Figure 13). This is the most comprehensive survey of this region to date, which utilized trawls and traditional sampling techniques as well as a variety of novel acoustical and optical approaches. Sampling yielded 45-50 squid species (2 potentially new to science) and 80,000 fish specimens still undergoing identification, although many are estimated to be new to science or new to the North Atlantic. Other interesting findings included jellyfish segregating in depth layers, strange dash-line patterns of bioturbation, and amazing diversity and density of fauna associated with deep coral banks.

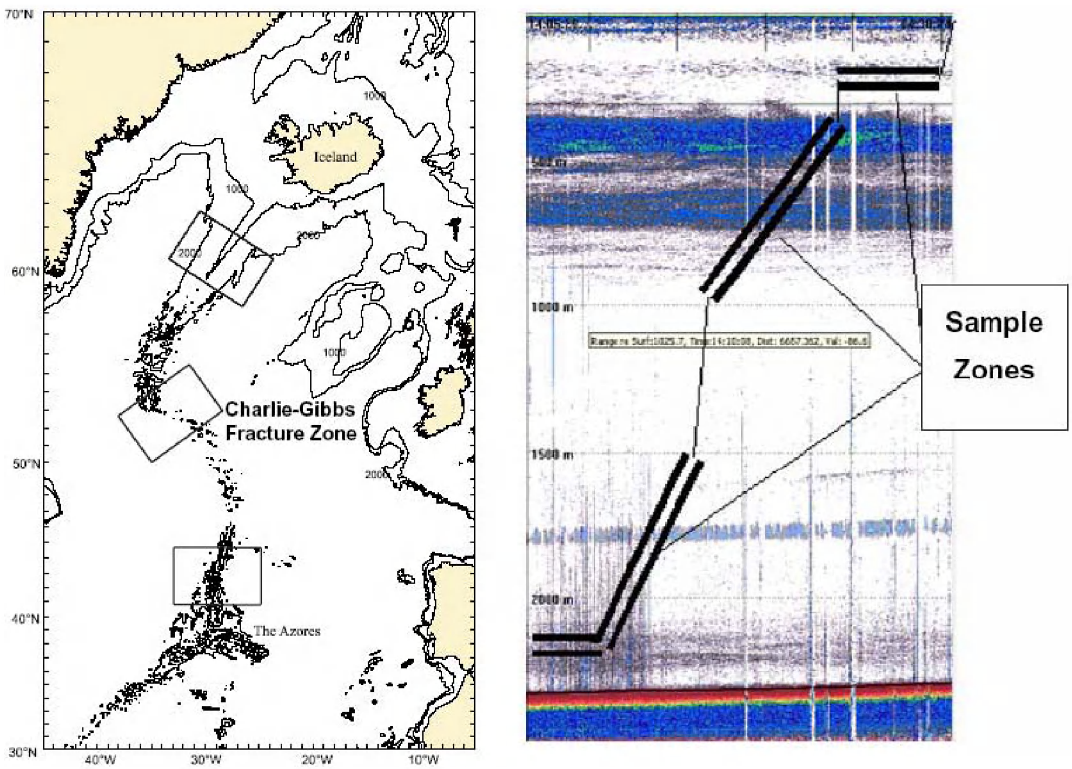


Figure 13. (Left) The focal areas for MAR-ECO along the Mid-Atlantic Ridge. (Right) A typical *G.O. Sars* 3-kilometer-deep acoustic image of the layers of life in the water column as recorded by SIMRAD EK60 18 kHz echo sounder, indicating where physical samples were collected to confirm species and abundance. The vertical noise lines at deep water are typical for this frequency during steaming or bad weather.

In the southern end of the area, MAR-ECO benefits from activities of a German-led, EC-funded project OASIS focusing on seamount ecosystems. Several cruises were made by Portuguese, German, and UK vessels to the Sedlo seamount just south of the southern MAR-ECO sub-area. Of particular interest were efforts to sample and study macrofauna by the Portuguese vessel RV *Archipelago* of the Azores, also in 2004. This vessel operates longlines and provides samples for studies of trophic ecology, fish genetics, hydrography, etc. Commitments to date total nearly $3 million.

2005-2009. The field phase of the Mid-Atlantic Ridge study will continue through 2007, although the analytical phase will overlap. The MAR-ECO researchers will complete the identification of expedition collections, publish the synthesized findings, and contribute data to OBIS through 2008. A wealth of information enhancing our understanding of the species, communities, and ecosystems of the Mid-Atlantic Ridge and associated waters is expected. This study will enhance the knowledge base for advisory bodies, e.g., ICES and NAFO, and management authorities such as OSPAR, NEAFC, and national governments. MAR-ECO addresses many issues listed by OSPAR as biological "uncertainties" (OSPAR, 2000).

2010. MAR-ECO will provide a comprehensive chapter on mid-oceanic species, communities, and ecosystems to the final report, and its new information on known and new species will increase OBIS' third, vertical dimension (i.e., depth). It is not yet possible to predict how much of the biota of the total volume of the world's oceans will be investigated, but demonstrated success should invite imitation to gain a global view. Globalizing MAR-ECO ridge studies is a great challenge to the Census because of the vast volume involved (Figure 2) and costly cutting-edge technology required. Major commitments from governments beyond the present MAR-ECO network would be required, but the research network of the Census could make it happen.

4. Active Geology

As volcanic cones and eruptions plus earthquakes testify on land, seamounts, vents, and seeps testify to active geology under the ocean. Although relatively few seamounts are erupting, we group these ghost volcanoes under active geology arrayed along the areas shown in yellow in Figure 2.

Biogeography of Deep-Water Chemosynthetic Ecosystems (ChEss)

Goal. *Discover new hydrothermal vents and cold seeps, assess the diversity, distribution, and abundance of their fauna in relation to other chemosynthetic ecosystems such as whale falls, sunken wood, or oxygen minimum ecosystems, perhaps remnants of Precambrian oceans, to explain the differences and similarities at the global scale.*

Baseline. Not until 1977 did explorers first discover deep-sea hydrothermal vents and their associated fauna, and not until 1983 did they discover cold seeps. On the vents, temperatures can be high, oxygen is scarce, and chemo- rather than photosynthesis feeds the life. Vents were first discovered along the Galapagos Rift in the eastern Pacific, and chemosynthetic-based fauna at cold seeps were first described from the base of the Florida Escarpment. Vents are now known to occur along all active mid-ocean ridges and back-arc spreading centers. Cold seeps occur along passive and active continental margins.

Only a small fraction of the 60,000 kilometers of ridge system has been investigated for hydrothermal vents. However, whether along fast-spreading ridges such as the East Pacific Rise or ultraslow-spreading ridges such as the Gakkel Ridge in the Arctic, exploration always discovers new vents and seeps. Seeps result from seepage of cold fluids with high concentrations of methane or sulfide from the underlying sediments supporting chemosynthetic life.

Accumulations of sunken wood, whale and kelp falls, as well as areas of low oxygen intersecting with continental margins or seamounts also create highly reduced habitats where chemosynthetic-based communities develop. These more open systems are less studied.

Understanding of chemosynthetic systems is limited to studies of only a few sites around the globe. Explaining the biogeography and diversity of chemosynthetic ecosystems requires their study across a global span.

By 2005. In January 2003 the ChEss scientific steering group convened at the Scripps Institution of Oceanography (SIO) to identify targets that would explain the biogeography of deep-water chemosynthetic ecosystems. The preliminary target areas were subsequently endorsed by the international research community and include three major priority regions and a number of specific locations (Figure 14). In parallel, ChEss developed a database on deep-water chemosynthetic species.

The major aim of the planning phase is to design and initiate the ChEss field phase. To this end, a number of additional research and education proposals are being submitted to various national, and international funding bodies to address the ChEss scope, aims, and protocols. ChEss will establish close collaboration with other ocean science programs that venture for other reasons to vent and seep sites to make future research and exploration affordable. Key among these is the EuroDEEP collaborative research program for the European Science Foundation. The ChEss office is at the Southampton Oceanography Centre (SOC) in the UK. Over $2 million has been committed to ChEss projects to date.

2005-2009 Develop the three main field programs:

1. Equatorial Atlantic Belt. This area extends on a longitudinal gradient, including the following key sites: Costa Rica cold seeps, Gulf of Mexico cold seeps, Cayman Trough, Barbados Accretionary Prism, hydrothermal vents on the Mid-Atlantic Ridge north and south of the Equatorial Fracture Zones, and cold seeps on the continental margin of west Africa. The aim is to understand connectivity and isolation of geographically distant chemosynthetic ecosystems. ChEss offers to act as the umbrella program for a number of cruises funded through national programs that are already under way. Coordinated efforts amongst scientists and laboratories from the different countries involved will join efforts and ensure a maximum return from the ongoing science to benefit the community as a whole. The SOC in the UK and IFREMER in France are coordinating the umbrella project.
2. Southeast Pacific region. This area encloses active vents on the Chile Rise, cold seeps on the Chile margin, a well-established OMZ on the Peru-Chile margin, and high potential for whale falls and sunken wood along the margin, all in close geographical proximity. The aim is to investigate the phylogenetic relationships of species where distance is not a barrier for dispersal and colonization. A Worldwide University Network international Grand Challenge program is being developed, led by SOC, SIO, and the Center for Oceanographic Research in the Eastern South Pacific (COPAS) of the University of Concepción in Chile.
3. New Zealand region. This area also encompasses all chemosynthetic systems of interest to ChEss in close geographical proximity offering a good comparison site for the Southeast Pacific to investigate relationships across ocean basins. There are vents on the Kermadec arc, seeps on the east margins of the north and south island, an important whale migration route and potential for sunken wood on the southern fjords. Woods Hole Oceanographic Institution,

University of Hawaii, and New Zealand's National Institute of Water and Atmospheric Research coordinate this program.

2010. ChEss will have substantially increased the number of known vents and seeps. It will have discovered new species in the chemosynthetic environments and entered assessments of their new and known species diversity, distribution, and abundance into OBIS. Beyond these contributions, ChEss will bequeath its example and methods for effective international assessment and explanation of marine life in a peculiar realm.

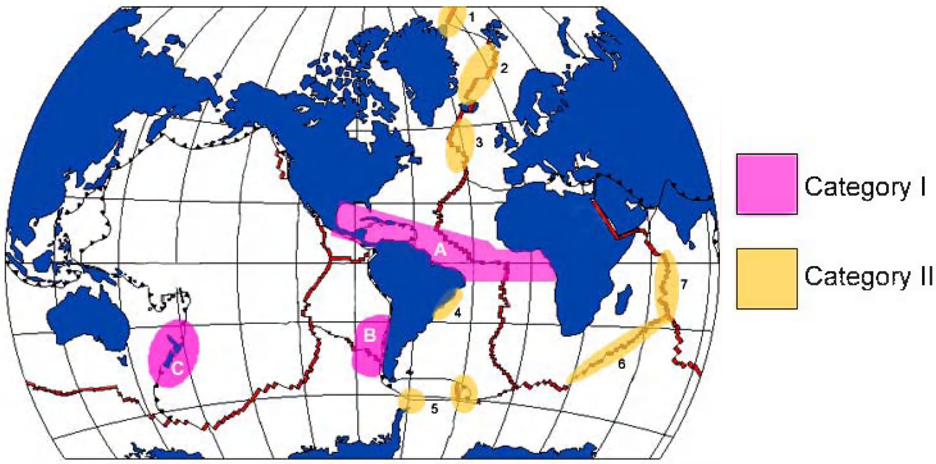


Figure 14. Target areas selected for ChEss where specific scientific questions relevant to biogeographical issues will be answered. Category I, combined areas for seeps, vents, and falls: Area A: Equatorial Atlantic Belt region; Area B: Southeast Pacific region; Area C: New Zealand region. Category II, specific vent areas: 1 – Ice-covered Gakkel Ridge, 2 – Ultra-slow ridges of the Norwegian-Greenland Sea, 3 – Northern MAR between the Iceland and Azores hot spots; 4 – Brazilian continental margin, 5 – East Scotia Ridge and Bransfield Strait, 6 – Southwest Indian Ridge, 7 – Central Indian Ridge.

Global Census of Marine Life on Seamounts (CenSeam)

Goal. *To synthesize existing biodiversity knowledge and direct future field efforts toward a comparative ecology of seamounts, categorizing communities, and developing proxies for generalized models. The capacity to predict properties of unexplored seamounts is an important scientific tool for urgently needed policy decisions.*

Baseline. A detailed exploration of more than 30,000 seamounts is unrealistic, and only about 200 have been sampled (Figure 15). Interaction of seamounts with water currents makes them especially rich in mobile fish and squid that feed on drifters trapped in eddies. Large mammals often dive to feed on them, and now humans are targeting them for trawl fisheries. Some recent explorations found that up to 40 percent of the species collected were new to science and likely to be found nowhere else. The varied topography creates unique biological communities, whose differences should reveal the connection between physical characters and ecosystems and so allow improved understanding and generalizations over the thousands of seamounts. Like islands, they are isolated and a natural laboratory for evolving new species. They are potential oases in the deep, supporting life and spreading species richness. Good science is essential for guiding management and conservation efforts related to increasing human activities. Important decisions regarding seamounts are planned in the next 5-7 years, such as the UN General Assembly considerations of marine protected areas.

By 2005. The SeamountsOnline database provides for data assembly in OBIS, and both commercial and scientific sampling on seamounts globally is rapidly expanding (Figure 15). A global network of seamount researchers defined this project at a KUU workshop in August 2003. Its leaders reported outcomes to the FAO-initiated Deep Sea Conference in New Zealand in December 2003. Key questions identified include:

1. What factors drive seamount community structure, diversity, and endemism, both at the scale of whole seamounts and individual habitats within seamounts?
2. What key processes operate to cause differences between seamounts, and between seamount and non-seamount regions?
3. What are the impacts of fisheries on seamount community structure and function?

A workshop with FMAP in September 2004 began defining the most efficient sampling strategies to answer these questions and targeted additional existing data resources to be brought into SeamountsOnline to guide planning for new research cruises during the field phase. The Seamount secretariat is hosted by the National Institute of Water and Atmospheric Research (NIWA) in New Zealand and data management will continue through the San Diego Supercomputer Center.

In addition to updating as much species information as possible, assembling a set of physical information to provide a biologically meaningful description or categorization scheme for seamounts is important. Factors to consider include physical or geological setting (age, substrate type), geography (latitude, ocean basin, distance from nearest continental margin), size, depth, shape, and physiography, productivity of the overlying water column, and its associated hydrographic characteristics (localized upwelling, presence of Taylor columns, and relationships to mesoscale oceanographic features). The work would involve an iterative process of categorizing communities, relating them to various factors, developing hypotheses about important factors/proxy variables, testing those ideas with existing or newly gathered data, and using the results to refine community categorizations. Improved fishery distribution and intensity information will also be a priority to link with the biological knowledge and provide scientific input to global concerns about the management of fisheries on seamount habitat.

2005-2009. Although bringing together fragmented work on seamount ecology and biogeography is necessary, given how few seamounts have been explored, new field research will be essential. Supporting and coordinating existing efforts and developing new field projects will be priorities during this phase. Partnerships with other COML projects, particularly MAR-ECO and GOMA, and more than 20 other programs visiting seamounts in every ocean will be developed to maximize appropriate biological sampling opportunities. Details await model analysis, but there will be an active field phase because of high global interest.

2010. The roles seamounts play in the biogeography, biodiversity, productivity, and evolution of marine organisms and their effect on the global oceanic ecosystem should be clarified and quantified. The question whether seamount communities differ in ecological structure and function should be answered as well as whether seamounts act as centers of speciation, as refugia for relict populations, and to what extent they serve as stepping-stones for transoceanic dispersal. This will be a key chapter in the Census and a contribution to global efforts to manage marine resources.

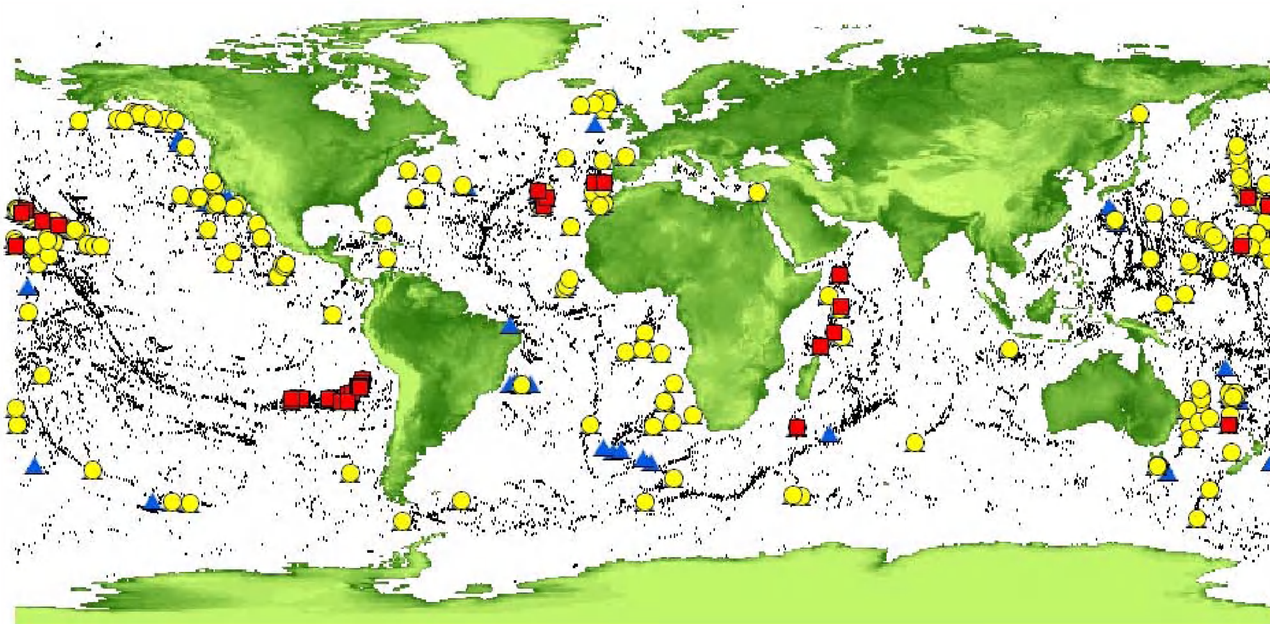


Figure 15. Distribution of seamounts and sampling. Small black points indicate the predicted locations of 14,300 seamounts from Kitchingman and Lai (2004). Squares indicate seamounts with data in SeamountsOnline (http://seamounts.sdsc.edu) that have received taxonomically broad sampling, circles indicate seamounts with some level of data, and triangles indicate seamounts that have been sampled biologically but for which data are not available in SeamountsOnline.

5. Ice Oceans - Arctic and Antarctic

At the ocean surface, seawater solidifies between -1.5 and -2.0°C creating new transient solid habitats at each pole. Climate change appears to be raising temperatures globally and altering the sites and nature of polar life for marine species and humans. Historically such changes seem to occur faster than the movements of continents, so they provide interesting case studies in evolution, and the two poles provide an interesting contrast. Research in these regions requires special techniques and icebreaking vessels, so cruises must be carefully coordinated to sample all habitats and all scales of life.

Arctic Ocean Diversity (ArcOD)

Goal. *Assemble existing knowledge of biodiversity in the least known ocean, direct new international explorations using new technology, and create a framework for understanding and predicting biological correlates with expected climatic changes in this rapidly changing ocean.*

Baseline. In the cold and seemingly inhospitable oceans near the poles, photosynthesis proceeds. Microscopic ice algae absorb light transmitted through the ice and feed a spectrum of life from crustaceans to fish to mammals. Even at the top of the food chain and out of the water on the ice, Arctic bears ultimately depend on these tiny plants at the bottom of the icy food chains. This frozen realm is distinguished both by its shrinking size as climate warms and by obstacles to its exploration. Nearly surrounded by the barrier of continents and Greenland, the Arctic is the smallest and least explored ocean, and its Canada Basin the least-disturbed and least-sampled water on the planet (Figure 16). Bottom, mid-water and sea ice systems are not isolated, so connection between them must be a focus to understand biodiversity in the Arctic Ocean. Decreasing ice means increasing use of Arctic shipping routes for global trade, introduced species and other risks. Without focused research, the chalkboard of ancient biodiversity in the Arctic Ocean may be wiped clean.

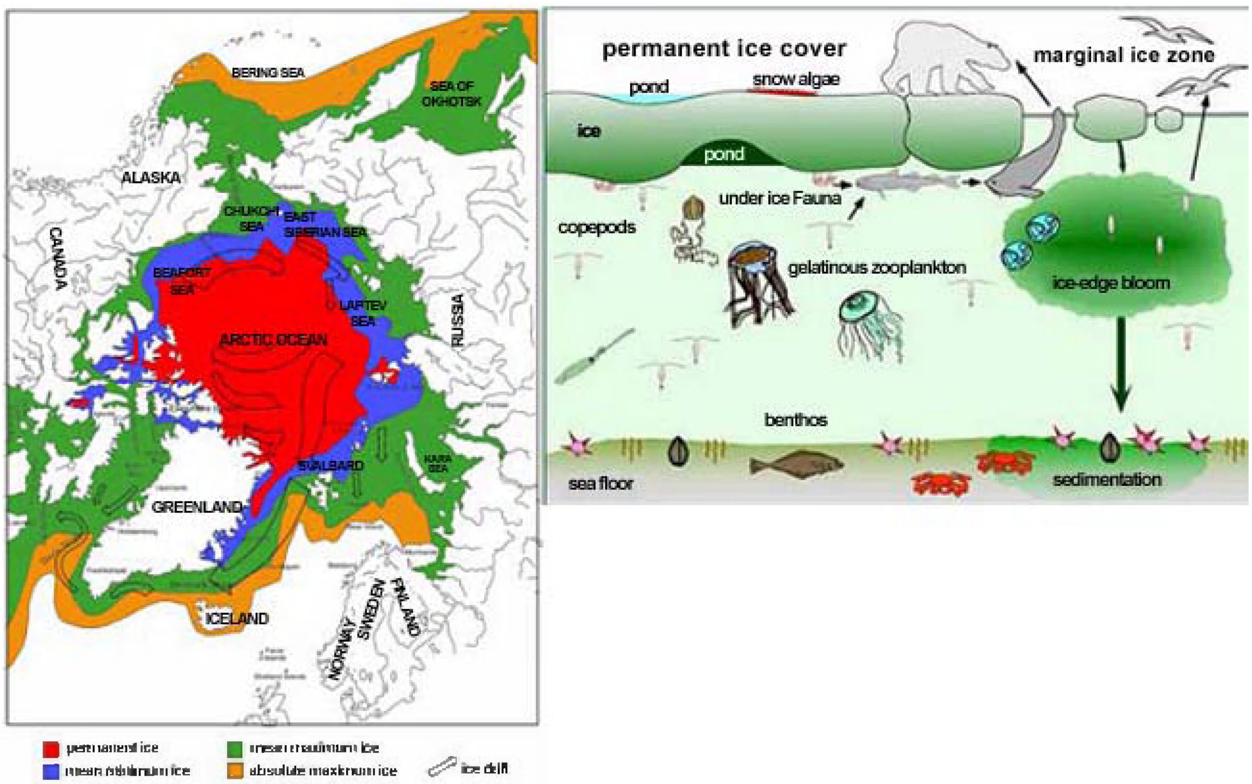


Figure 16. Some current models for climate change predict the complete disappearance of the permanent Arctic ice (red zone, left panel, von Quillfeldt, 1996) by 2030. ArcOD will chart the biodiversity of the currently ice-covered ecosystems, to better understand and predict the consequence of these changes on species and humans living there.

By 2005. The Arctic is the most extreme ocean in seasonality of light and in its year-round ice cover. It is also the ocean where climate change may be most strongly expressed. The tremendous ongoing changes make the effort to identify the diversity of life in the realms of sea ice, water column, and seafloor urgent. An Arctic biodiversity KUU workshop in April 2003 defined the problems and gaps, linking scientists from countries with essential icebreaker capacity. A SCOR symposium in Moscow in September 2003 also focused on potential Russian contributions to an Arctic census and led to a Russian workshop in 2004. Current knowledge indicates that the Arctic seas hold a multitude of unique life forms adapted to the extremes. ArcOD will document the present Arctic biodiversity from an international Pan-Arctic view with an office at the University of Alaska Fairbanks and taxonomic centers in St. Petersburg and Moscow. The SSG will identify available data for entry into OBIS. Because of unique vessel requirements, the SSG is carefully cross-linked to other projects and has a strong focus on identifying cruises and International Polar

Year (IPY) planning. The RUSALCA cruise to the Chukchi Sea in August 2004 explored the unknown Herald Canyon, reviving Russian-U.S. collaboration.

2005-2009. The core phase will compile existing data and make full taxonomic use of collected but unprocessed samples. Geographic, taxonomic, and temporal gaps will be filled through new collections emphasizing active participation in the IPY activities. These will be coordinated with CAML. Russian partners will create a georeferenced list of species of Arctic marine free-living invertebrates, record Russian expeditions and stations taken in the Arctic from 1800, and catalog some 500 Russian publications on marine Arctic fauna.

2010. The synthesis phase will integrate newly accumulated data fully into OBIS to be synthesized, published, and presented at international meetings and used within HMAP and FMAP, as well as providing the Census "chapter" on the biogeography of the Arctic.

Census of Antarctic Marine Life (CAML)

Goal. *To assemble the rich biological data on the Southern Ocean currently distributed widely internationally, to encourage biodiversity sampling on all cruises in the region, particularly during the focal period of the International Polar Year, 2007-2008, and to couple this new understanding of biology to the complex current dynamics there that control gene flow through all the world's oceans.*

Baseline. The Southern Ocean around Antarctica is a giant wind-driven mixing bowl of currents, moving organisms vertically and horizontally among the Atlantic, Pacific, and Indian Oceans. The ocean south of 60 degrees falls under the Antarctic Treaty that created the Convention on the Conservation of Antarctic Living Resources (CCAMLR) in 1982. This convention, together with the Scientific Committee on Antarctic Research (SCAR), has produced a wealth of international research collaborations. Although Antarctic marine biodiversity is particularly valued for its relatively pristine state, its highly adapted character, and its sensitivity to environmental changes, it is still only partially known at the surface and virtually unknown at depth. Existing biodiversity information is widely scattered and not easily accessible. Integration will allow it to be correlated to other geospatial, environmental, climatic, oceanographic, ecotoxicological and genetic data to address environmental or scientific (e.g., evolutionary) questions as well as practical conservation issues. The Antarctic region of the Southern Ocean is currently the unique piece of open ocean with an internationally agreed management framework designed to protect its biodiversity for future generations, so a census here provides special value.

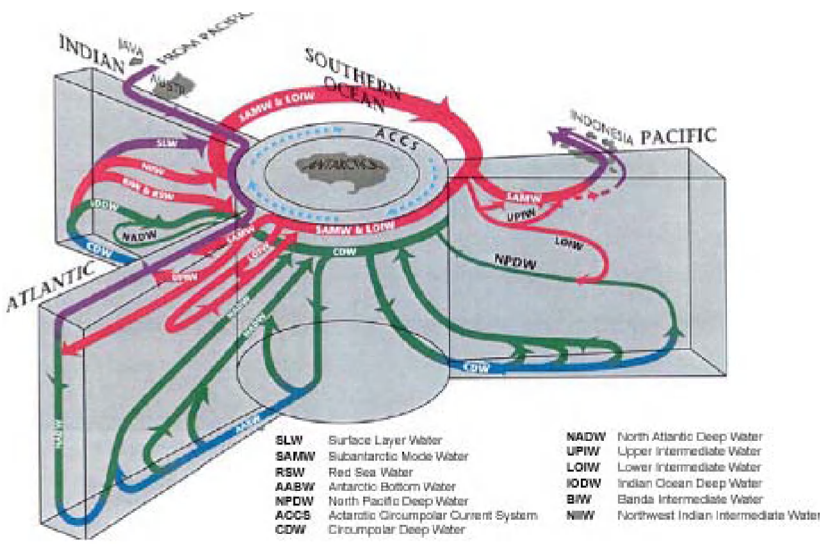
By 2005. CAML, led by the Australian Antarctic Division, with a SCAR-appointed SSG representing seven major nations with research interests in the region, was endorsed by the Life Science Scientific Standing Group of SCAR. SCAR also supports the Marine Biodiversity Information Network (MarBIN) to consolidate data from the region in a database compatible with OBIS and GBIF. Increased commitment of existing data from a workshop in Curitiba, Brazil, in July 2005, linking MarBIN with the South American OBIS node, will encourage South American countries to participate in IPY projects in benthic biology. Fourteen nations have already indicated an interest in providing ship time in Antarctic waters during IPY for biodiversity sampling. SCAR and SCOR are working together to coordinate cruise activity to provide interdisciplinary sampling opportunities as well as maximum coverage during IPY. The region's complex oceanography (Figure 17) gives it a special role in distributing biodiversity.

2005-2009. Information assembly in MarBIN will make it possible to identify key areas for new exploratory sampling as well as areas where biological coverage is good, but some crucial details are lacking. Because the major field activities of CAML will take place during the IPY in 2007-2009, one of the complications of IPY is that key platforms such as icebreaking vessels will be required at both poles. COML will organize meetings between its two polar projects to ensure comparability between data sets and optimized use of people and equipment.

A major SCAR goal in IPY will be high-resolution benthic mapping, a tremendous asset for the benthic biology community and future ocean conservation. Combining these physical maps with comprehensive biological data will support application of benthic surveys developed in GoMA.

2010. Given the scheduling for IPY, it will be difficult to provide a fully developed biodiversity atlas for the Antarctic by 2010, but advanced data management techniques, including integration of MarBIN with OBIS, should make it possible.

Figure 17. This three-dimensional representation of flows among ocean basins shows how central the Antarctic Circumpolar Current System (ACCS) is and has been to movements of marine species around the planet, in contrast to the isolated Arctic (modified from Schmitz, 1995).



6. The Microscopic

International Census of Marine Microbes (ICOMM)

Goal. *To develop a highly resolved biodiversity database for marine microbes and to understand how microbial populations evolve, interact, and redistribute on a global scale. The definitions of biodiversity among microbes will be based largely on the application of molecular techniques.*

Baseline. The distinct technology for exploration of organisms hidden by small size separates the microscopic as a realm encompassing the prokaryotes and protists, minute single-celled microbes. Microbes make up for their size by their numbers; an estimated 10^{30} microbe cells constitute more than 90 percent of the biomass in the oceans. Some of the cells that perform photosynthesis make oceanic food from carbon dioxide, while others break it down. Others turn the nitrogen, sulfur, iron, and manganese cycles. Although molecular analysis may give clues to microbial evolution, the horizontal transfer of genome fragments among microbes will obscure the time when species and physiology branched (Figure 18). Also, uncertainties about global change will frustrate prediction of microbial biodiversity. Analyses of genomes are being accelerated by advances in gene sequencing and by high-throughput machines in studying genes, the proteins they encode, and their pathways. The aiming of these new techniques on the oceans promises the discovery of diversity, much rising to or above the level of differences between species. A microbial soup stirred by wind and tide fills the great bowl of the oceans. New studies of microbial genomes are uncovering the mind-boggling diversity among the myriad microbes that permits the selection of populations to fit the temperatures and chemistry brought by the stirring within the bowl.

By 2005. Early in the year, the SSG for ICOMM will meet in Amsterdam with ICOMM organizers and chairs of working groups to review documents generated by the groups and to develop a plan for a broader community meeting. This plan must include discussion of opportunities to acquire samples and to link the information in a specially designed microbial genetic database (MICROBIS) to other Web portals. MICROBIS will be subject to critical review by working groups, SSG, OBIS, and collaborators. Later in this year a meeting will be hosted for representatives of the marine microbial community to address funding and identify sampling opportunities within and outside the existing COML projects. They will also describe common technology issues and database content, including community input, and will confirm potential pilot projects that could shape future funding initiatives.

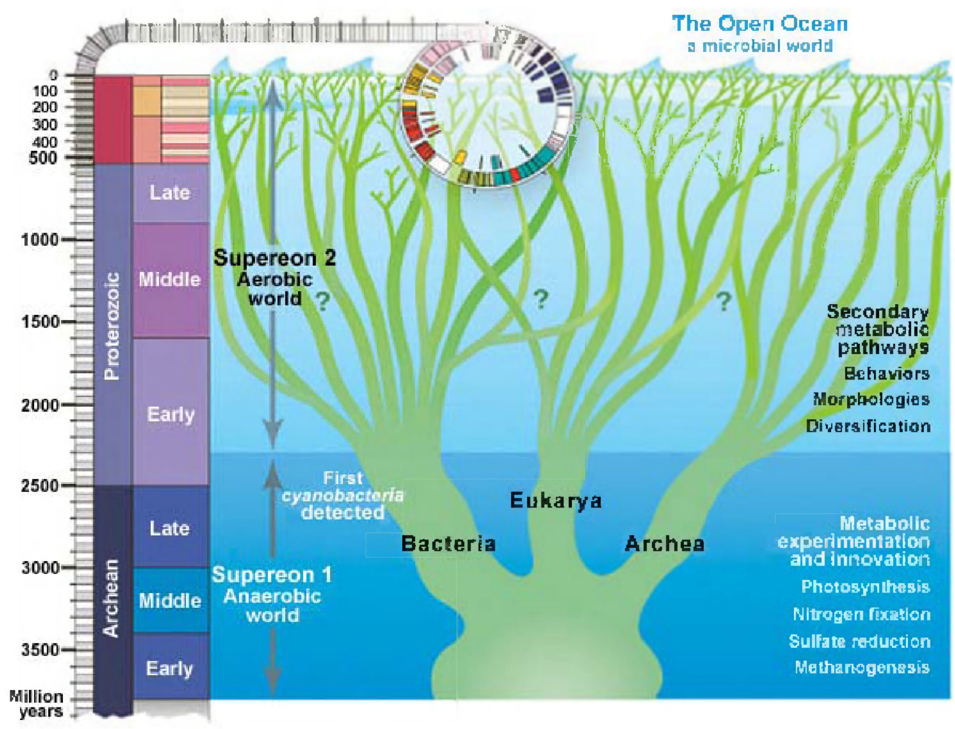


Figure 18. Automated DNA sequencing provides a new way of exploring the record of life all the way back to its origins in the sea 4 billion years ago. Unlike barcoding, which looks at partial sequences from larger genomes in plants and animals, entire microbial genomes can be reconstructed (modified, reprinted with permission from Falkowski and de Vargas, 2004. Copyright 2004 AAAS.).

2005-2009. Education and outreach resources will be developed. Pilot projects will be initiated and completed by 2006. In 2006, the working groups, ICOMM organizers, and SSG will review progress and synthesize a final strategy document addressing funding opportunities, technical issues relating to sampling, sample processing, MICROBIS standards, scientific priorities, and long-term funding opportunities. These will determine the scale of the DNA sequencing approach possible and the number of samples from other COML project collections that can be processed and integrated into analyses.

2010. The "chapter" on the biogeography of marine microbes will potentially redefine our understanding of biodiversity at this level. The project explores both new regions and new concepts. The image-rich MICROBIS will provide a unique resource with cross-compatibility between biogeographic databases like OBIS and GBIF and genetic databases like GenBank.

D. What will live in the oceans? Future of Marine Animal Populations (FMAP)

Goal. *To help design the observational strategies of COML field projects and to develop models using OBIS data to aid in synthesis, including prediction of what animals will live in the oceans of the future, examining both fished and unfished species, in light of changes in climate and other changes that may influence the oceans in coming decades.*

Baseline. Marine life past and present interests people intellectually, but practically future marine life is more interesting. We might think practical interest centers on what lives in the oceans today, but daily evidence shows that marine life is transitory. Thus, predicting the future state holds more practical interest. The urge to model the future is heightened even more by the ease and speed of calculation by modern computers. To realize the practical worth of a census of marine life, scientists must compose models to predict what animals will live in the oceans of the future. Filling the models with the factual content of the census will help predict how fishing, coastal degradation, and climate change will change marine life. Concurrently the models provide concepts that improve the observations. Models striving to predict future oceans must also be tools for analysis of the past and present. They help define the limits of knowledge: what is known and how firmly, what may be unknown but knowable, and what is likely to remain unknowable.

1) Past: models are needed to interpret and design subsampling of historical data. New HMAP information about historical oceans critically link current field censuses and future prediction.
2) Present: modeling and analysis must integrate into research from the beginning so initial field sampling can be done efficiently and design systematically modified as work continues. In conjunction with this, synthetic models help combine and understand the data collected.
3) Future: models effective for synthesis have potential for prediction. An understanding of the possible effects of changes in global climate or the fishing industry will help us to take effective management action.

By 2005. FMAP grew out of a workshop held in Canada in June 2002. Representatives of the all the major COML projects participated in this initial event and continue to contribute as FMAP evolves. FMAP has established centers in Canada (Halifax), Iceland (Reykjavik), and Japan (Yokohama). FMAP focuses on five themes that will be developed into related but separate component projects: (1) statistical design, (2) data exchange and model interface, (3) model development, (4) data synthesis, and (5) prediction.

The Canadian center coordinates the service function of FMAP to the Ocean Realm Field Projects, OBIS and HMAP, providing modeling and statistical advice, and linking to modelers to further the goals of the COML. The FMAP team has met with each of the newly formed projects and is meeting with others as they enter into their second phase. A key strategy is to identify young researchers to interface between the projects and statistical experts. The Japanese center has a close association with NaGISA and expertise in population modeling. The Iceland center links to MAR-ECO and models entire communities of mobile marine organisms useful for POST and TOPP. Joint modeling workshops with TOPP, NaGISA, POST, CMarZ, and CenSeam are complete. FMAP developed from HMAP and OBIS and extends their time and space analyses.

Mining unexploited data sets, FMAP researchers have already provided insight into declines in the population of large marine animals of many species and into diversity of predators in the open ocean (Figure 19). Total commitments to date exceed $3 million.

2005-2009. Accurate predictions are commodities of great value, particularly in a world of change, and models with predictable accuracies are key to producing them. Increasing the information available for models always increases accuracy. Thus, FMAP and OBIS will develop synergistically. As the FMAP team improves the accuracy and value of its predictions from an expanding database, it will directly demonstrate the value of OBIS. An initial FMAP focus on fishery and global climate change predictions is intended to enhance this synergy by encouraging both industry and managers to add their databases to OBIS, thereby improving the quality of the their predictions. This strategy improves both the funding base and the database for COML.

The FMAP team similarly has a vested interest in ensuring that all the Ocean Realm Field Projects collect the best possible data and enter it into OBIS in the most efficient way. High-quality, large-scale, long-term information makes models that have real predictive capacity. The modelers who best understand a database and have demonstrated success using it will be asked to make the next big model. The FMAP project is focused on producing products of demonstrable value during the development of COML to raise awareness and the estimated half-billion dollars the Census will cost.

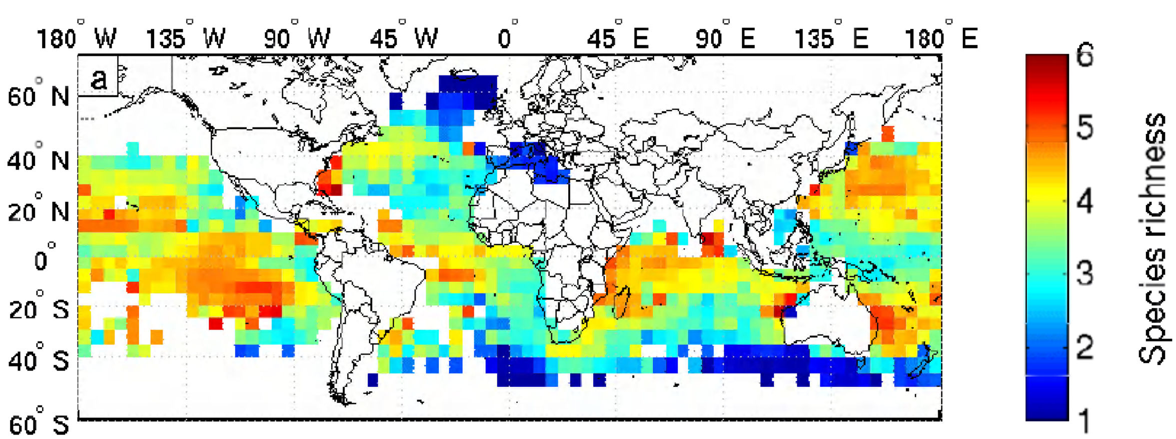


Figure 19. The global pattern of species richness of tuna and billfish from 50 years of Japanese longline fishing. Colors indicate number of species per 50 individuals (Worm et al., submitted).

2010. Models include statistical estimates of accuracy that help define the limits of knowledge. In addition to contributing its accumulated products, FMAP will make major contributions to the culminating report of the COML by identifying its limits.

E. Organization

1. Governance

An International Scientific Steering Committee (SSC) oversees the COML. The SSC has listened to the recommendations of the ocean science community to identify areas of marine science where improved knowledge of biodiversity is both possible and beneficial and to outline the goals of the COML research program. Individual projects form with scientific steering groups (SSGs) supporting principal investigators. The SSC recognized that implementing a successful global census requires global support, input, and cooperation and initiated a series of national and regional implementation committees (N/RICs). These communities work with the SSC toward the goals of the international COML to shape national and regional programs to meet the needs of local interests worldwide and contribute to COML's legacies.

The COML legacies will include greater awareness of the role of the oceans in

- Marine biodiversity and shifts in ecosystem structure from coasts across the sea surface to the depths of the ocean floor.
- Global and regional climate change.
- Coastal zone processes.
- Changes in the Arctic and Antarctic.

The COML will contribute to

- Comprehensive coastal and ocean observing systems that include biodiversity.
- Building capacity for technology and long-term programs.
- Clarifying government agency roles and global interagency coordination.
- Promoting a strong relationship between research and operations.

The COML will provide enduring access to ocean knowledge and data through OBIS. There is still much to be done, but COML is a key example of dramatic progress in ocean science and observations. COML will help integrate ocean science to contribute to earth's essential need for end-to-end decision support systems for sustainability.

International Scientific Steering Committee (SSC) Members

- J. Frederick Grassle (Chair), Rutgers, The State University of New Jersey, USA
- Victor Ariel Gallardo (Vice Chair), COPAS, Universidad de Concepción, Chile
- Vera Alexander, University of Alaska Fairbanks, USA
- D. James Baker, Philadelphia Academy of Natural Sciences, USA
- Patricio Bernal, Intergovernmental Oceanographic Commission, France
- D. Chandramohan, National Institute of Oceanography, India
- David Farmer, University of Rhode Island, USA
- Carlo Heip, Netherlands Institute of Ecology, The Netherlands
- Poul Holm, Southern Denmark University, Denmark

- Ian Poiner, Australian Institute for Marine Science, Australia
- Yoshihisa Shirayama, Kyoto University, Japan
- Michael Sinclair, Bedford Institute of Oceanography, Canada
- Meryl J. Williams, Future Harvest Alliance Office, Malaysia

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PI: Poul Holm (University of Southern Denmark)

Ocean Biogeographic Information System
PI: Mark Costello (University of Auckland, NZ)

Future of Marine Populations
PI: Ransom Myers (Dalhousie University, Canada)

Ocean Realm Field Projects

Natural Geography in Shore Areas - NaGISA (Algae and Sea Grass Communities)
PIs: Yoshihisa Shirayama (Kyoto University, Japan), Brenda Konar (University of Alaska Fairbanks, USA)

Global Census of Coral Reef Ecosystems - GCCRE
PIs: Nancy Knowlton (Scripps Institution of Oceanography, USA), Julian Caley (Australian Institute of Marine Science, Rusty Brainard, NOAA Pacific Islands Fisheries Science Center, USA)

Gulf of Maine Area Program – GOMA (Regional Integrated Ecosystem Studies)
PIs: Evan Richert, Lewis Incze (University of Southern Maine, USA)

Pacific Ocean Shelf Tracking - POST
PI: David Welch (Fisheries and Oceans, Canada)

Continental Margin Ecosystems on a Worldwide Scale - CoMargE
PIs: Myriam Sibuet (Ifremer, France), David Billet (Southampton Oceanography Centre, UK), Robert Carney (Louisiana State University, USA), Lisa Levin (Scripps Institution of Oceanography, USA), Helena Passeri Lavrado (Federal University, Brazil), Gilbert Rowe (Texas A&M University, USA)

Census of Diversity of Abyssal Marine Life - CeDAMar
PIs: Pedro Martinez Arbizu (Senckenberg University, Germany), Craig Smith (University of Hawaii, USA)

Census of Marine Zooplankton - CMarZ
PIs: Ann Bucklin (University of New Hampshire, USA), Shuhei Nishida (Ocean Research Institute, Japan), Sigrid Schiel (Alfred Wegener Institute for Polar and Marine Research, Germany)

Tagging of Pacific Pelagics - TOPP
PIs: Barbara Block (Stanford University, USA), Dan Costa (University of California, Santa Barbara, USA), Randy Kochevar (Monterey Bay Aquarium, USA)

Patterns and Processes of Ecosystems in the Northern Mid-Atlantic - MAR-ECO
PI: Odd Aksel Bergstad (Institute of Marine Research, Norway)

Biogeography of Chemosynthetic Ecosystems - ChEss
PIs: Paul Tyler, Chris German (Southampton Oceanography Centre, UK)

Global Census of Marine Life on Seamounts - CenSeam
PIs: Malcolm Clark, Ashley Rowden (National Institute of Water and Atmospheric Research, New Zealand), Karen Stocks (University of California, San Diego, USA)

Arctic Ocean Diversity - ArcOD
PIs: Russ Hopcroft, Bodil Bluhm, Rolf Gradinger (University of Alaska Fairbanks, USA)

Census of Antarctic Marine Life - CAML
PIs: Colin Summerhayes (Scott Polar Institute, UK), D. Michael Stoddart, Australian Antarctic Division

International Census of Marine Microbes - ICOMM
PIs: Mitch Sogin (Marine Biological Laboratory, USA), Jan de Leeuw (Royal Netherlands Institute for Sea Research)

The most current project and contact information is available through: http://www.coml.org

Implementation Committees

These committees promote the common approach of the COML – implementing and affiliating successful model projects that broaden the scope of the COML, developing regionally specific projects consistent with the goals of the COML, and working to further national and regional collaborations for successful implementation. Such an approach allows for variations consistent with national or regional priorities, while providing consistent information to reveal higher scale information about biological diversity, distribution and abundance patterns.

National Committees are located in countries with major ocean research capacity:

- Australia - Max Kitchell, National Oceans Office (Chair)
- Canada - Paul Snelgrove, Memorial University of Newfoundland (Chair)
- China - SUN Song, Institute of Oceanology (Chair)
- Japan - Yoshihisa Shirayama, Kyoto University, Japan (Chair)
- United States - Daphne Fautin, Kansas University (Chair)

Regional Committees seek to strengthen and support efforts especially where the area of unexplored ocean dramatically exceeds research capacity:

- Caribbean - Patricia Miloslavich, Universidad Simón Bolívar, Venezuela (Chair)
- Europe - Graham Shimmield, Scottish Association for Marine Science, Oban, UK (Chair)
- Indian Ocean - Mohideen Wafar, National Institute of Oceanography, India (Chair)
- South America - Ruben Escribano, COPAS, Universidad de Concepción, Chile (Chair)
- Sub-Saharan Africa - Charles Griffiths, University of Cape Town, South Africa (Chair)

2. Agreement for Affiliation

The COML recognizes that a comprehensive assessment of the oceans must take advantage of the many ongoing initiatives around the world that share the COML's goal of decreasing the unknown about marine biodiversity. Collaboration with other programs and activities is an important aspect of ensuring global coverage. The SSC and N/RICs encourage affiliation with, and help from, existing projects under the following guidelines.

The project agrees to

1. Make all of the data collected by the project available through links to OBIS.
2. Acknowledge the relationship to COML in publications, Web sites and productions, which are appropriate to COML's role as a provider of factual information rather than opinion. Submission for review by COML is available, if there is doubt.
3. Be aware of and actively seek to collaborate with other COML projects (e.g., ship time, technology, equipment).
4. Inform national and regional implementation committees of plans to raise funds.
5. Work to develop a synthesis of the COML at the end of the program.

The COML agrees to

1. Promote the project in COML literature and presentations.
2. Facilitate participation in OBIS.
3. Seek to expand the funding base for all affiliated projects.

4. Seek collaborative opportunities with other COML projects (e.g., ship time, technology, equipment).

Current Affiliated Projects (January 2005)

The Gulf of Mexico – Past, Present, and Future (GOMx)

Goal. *Develop an Internet-accessible all-taxa inventory within the large Gulf of Mexico ecosystem to understand and manage the long-term sustainable use and conservation of the gulf*

Baseline. Shared by Cuba, Mexico, and the United States, the Gulf of Mexico is one the world's most ecologically and economically productive bodies of water. Knowledge and management of this large marine ecosystem has generally and historically occurred independently among the countries. Advanced twenty-first century communication and transportation can enable better cooperation and collaboration for both knowledge and management.

The basin was formed by seafloor spreading before the Cretaceous period, between the Permian and early Jurassic periods (~170-240 million years before present), with a total surface area of 564,200 square kilometers, a maximum east-west dimension of 1,575 kilometers, and a maximum north–south dimension of about 900 kilometers. The continental shelf constitutes about 35 percent of its area. About 25 percent is very deep (3,000 m), the deepest being Sigsbee Deep at 3,850 meters. Estuaries and lagoons are common along shorelines of the gulf with oyster reefs, sea grasses, and coastal wetlands common in the north, and some oyster reefs, local to regional sea grasses, and mangrove forests in the south. Offshore, coral reefs are common in some localities in the southern gulf, along northwest Cuba, along the Florida Keys, and on the Texas Flower Gardens Banks.

Biogeographically, continental shelf biota are primarily warm temperate in the north and tropical in the south. Knowledge of marine biodiversity in the Gulf of Mexico varies by region and taxon. *Gulf of Mexico – Its Origin, Waters, and Marine Life* from 1954 is the only census or inventory of species within the gulf. It listed 3,302 species, but not even all species of all taxa were known then. Since 1954, species counts in the two best-studied taxa, fish and marine mammals, have increased from 51 and 12 to 1,459 and 31, respectively.

By 2005. The Harte Research Institute for Gulf of Mexico Studies (HRI) launched the Gulf of Mexico – Past, Present, and Future initiative in 2003 to achieve trinational knowledge synthesis and expansion, new and exploratory research, outreach and education, as well as management of the Gulf of Mexico (Figure 20). On the joint recommendation of the COML's U.S. Implementation Committee and HRI, and consideration of the SSC, it became a COML affiliate in 2003.

The new initiative includes the following components:

1) GulfBase – a sortable and searchable database Web site listing over 1,500 researchers and 450 institutes working on the Gulf of Mexico. GulfBase will be expanded for other gulf data in the future.
2) Exploratory Expeditions – annual collaborative research expeditions will be carried out to further knowledge.

3) State of Knowledge Workshop – held in October 2003 to initiate the gulf state of knowledge project, through items 4 and 5.
4) Biodiversity of the Gulf of Mexico - a peer-reviewed, all-taxa inventory of the biodiversity of the gulf, to be accomplished by preparing a checklist of all living species. The dynamic digital atlas will include habitat, distribution, and key references for each species. It will be one of the first all-taxa inventories of a large marine ecosystem anywhere in the world, and it will be accessible on the Internet through GulfBase and OBIS.
5) Bulletin 89, 50-Year Update – with collaborators, HRI will produce an update of Bulletin 89, U.S. Fish and Wildlife Service, 1954, expanded from one to at least five volumes (geology, physical and chemical oceanography, biota, human impact, and management).
6) State of the Gulf of Mexico Summit – in November 2005, this summit will publicly address the "state" (condition or health) of all aspects of the Gulf of Mexico (biota, biotic habitats and communities, fisheries, water and sediment quality, coastal development, oil and gas exploration and development, tourism, natural resource management, etc.). This summit will be the first in a series occurring every five years in a different major city around the gulf. Ten criteria (a "report card") will be established to measure change in the state of the gulf.
7) Annual Thematic Working Conferences – HRI will annually sponsor a small working conference with leading scientists concerning important, current issues affecting the Gulf of Mexico (e.g., invasive species, harmful algal blooms, coastal development, dead zones, etc.).
8) Gulf of Mexico Alliance – an alliance of all stakeholders with concern, interest, use, or jurisdiction will be established, including members from private business (fisheries, tourism, oil and gas, etc.), state and federal government agencies, academia, conservation and other nongovernmental groups, and private citizens. The alliance will work cooperatively and collectively for the long-term sustainable use and conservation of the Gulf of Mexico.
9) Public Policy Initiatives – as HRI develops and grows, it will be a leader in encouraging and achieving cooperation with multiple partners in influencing public policy for the long-term sustainable use and conservation of the Gulf of Mexico.

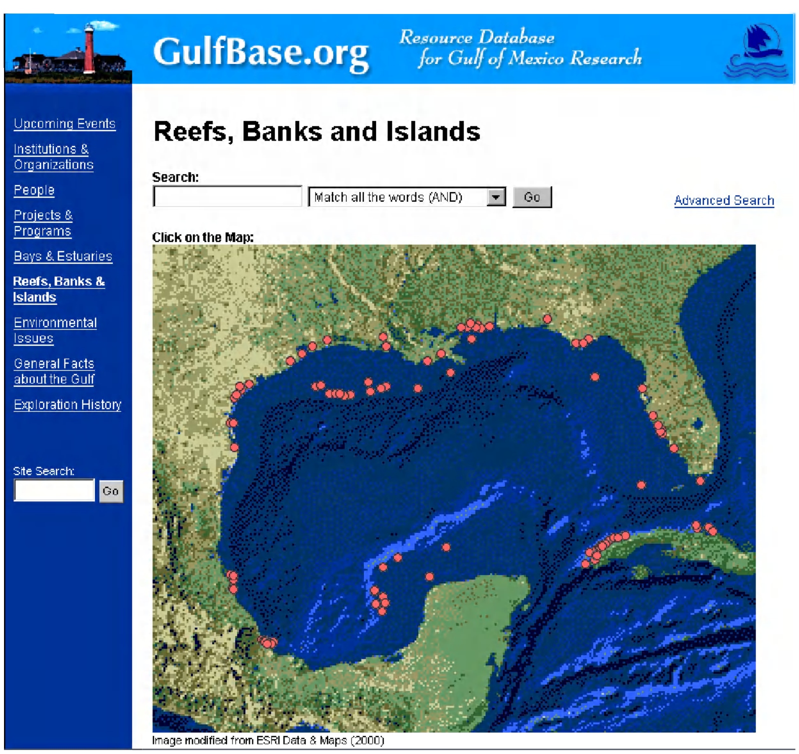

Figure 20. The "American Mediterranean." The Harte Research Institute for Gulf of Mexico Studies and the U.S. Implementation Committee are sponsoring a COML affiliate project in this region focused on ecosystem management issues similar to those in the Gulf of Maine. The GulfBase Web site (http://www.gulfbase.org/) links research in all of the areas indicated by red dots and will put biodiversity information into OBIS.

HRI has developed a comprehensive project entitled The Biodiversity of the Gulf of Mexico as part of a 50-year update of Bulletin 89 to be published in the Gulf Coast Studies book series of Texas A&M University Press. During 2004, over 100 taxonomists from more than 40 institutions in six countries have inventoried all known species with the Gulf of Mexico. This inventory, listing all species in a standardized format, includes geographical distribution, habitat, and key taxonomic and ecologic references. These will be edited to produce a complete, peer-reviewed census list by the end of 2005 to be integrated into OBIS. A quarter of a million dollars has been committed directly to this project so far.

2005-2009. The book version of the Gulf of Mexico biodiversity census will be submitted for publication during 2006. Because older taxonomists are reluctant to prepare lists for electronic databases, text files will be transferred into a database and then in 2006 to GulfBase so that it will be fully OBIS accessible. Then will begin analyses of the ecosystem by taxon, by habitat, by county, etc. Information gaps identified will be used to target expeditions and locations.

2010. GOMx will build a fully operable and maintained all-taxa inventory or census of all species within the Gulf of Mexico. This dynamic, digital database will be provided by HRI so that researchers and managers can work together for long-term sustainable use and conservation of the gulf.

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Acronyms

COML Acronyms

ArcOD	Arctic Ocean Diversity
CAML	Census of Antarctic Marine Life

CeDAMar	Census of Diversity of Abyssal Marine Life
CenSeam	Global Census of Marine Life on Seamounts
ChEss	Biogeography of Deep-Water Chemosynthetic Ecosystems
CMarZ	Global Census of Marine Plankton
CoMargE	Continental Margin Ecosystems on a Worldwide Scale
COML	Census of Marine Life
FMAP	Future of Marine Animal Populations
GCCRE	Global Census of Coral Reef Ecosystems
GMBIS	Gulf of Maine Biogeographic Information System
GOMA	Gulf of Maine Area Program
GOMx	Gulf of Mexico – Past, Present, and Future
GSS	Goals, Scope, and Strategy (COML Program document)
HMAP	History of Marine Animal Populations
ICOMM	International Census of Marine Microbes
KUU	known-unknown-unknowable
MAR-ECO	Mid-Atlantic Ridge Ecosystems project
NaGISA	Natural Geography in Shore Areas
N/RIC	national and regional implementation committee (COML Program)
OBIS	Ocean Biogeographic Information System
POST	Pacific Ocean Shelf Tracking
RON	regional OBIS node
SEAMAP	Spatial Ecological Analysis of Megavertebrate Populations (OBIS)
SSC	International Scientific Steering Committee (COML Program)
SSG	scientific steering group (COML Ocean Realm Field Projects)
TIES	Trophic Interactions in Estuarine Systems
TOPP	Tagging of Pacific Pelagics

Other Acronyms

ANDEEP	Antarctic Benthic Deep-Sea Biodiversity
CBOL	Consortium for the Barcode of Life
CCAMLR	Commission for the Conservation of Antarctic Marine Living Resources
COPAS	Centro de Investigación Oceanográfica en el Pacífico Sur-Oriental (Chile)
CORE	Consortium for Oceanographic Research and Education (COML Secretariat)
DFO	Department of Fisheries and Oceans, Canada
DIVA	Latitudinal Gradients of Deep-Sea Biodiversity in the Atlantic Ocean
DZMB	German Centre for Marine Biodiversity Research (Senckenberg Institute)
EC	European Commission
EEZ	exclusive economic zone
ERMS	European Register of Marine Species
ESF	European Science Foundation
FAO	Food and Agriculture Organisation of the United Nations
GBIF	Global Biodiversity Information Facility
GOMOOS	Gulf of Maine Ocean Observing System
GOOS	Global Ocean Observing System
HERMES	Hotspot Ecosystem Research on the Margins of European Seas
HRI	Harte Research Institute for Gulf of Mexico Studies
IABO	International Association for Biological Oceanography
IBOY	International Biodiversity Observation Year
ICES	International Council for the Exploration of the Seas
IFREMER	Institut Français de Recherche pour l'Exploitation de la Mer

IOC	Intergovernmental Oceanographic Commission of UNESCO
IODE	International Oceanographic Data and Information Exchange
IOOS	Integrated Ocean Observing System
IPY	International Polar Year
ITIS	Integrated Taxonomic Information System
IUBS	International Union of Biological Sciences
MAR	Mid-Atlantic Ridge
MarBIN	Marine Biodiversity Information Network
NAFO	Northwest Atlantic Fisheries Organization
NEAFC	North East Atlantic Fisheries Commission
NEO	Novel Exploration of the Ocean
NGO	non-governmental organization
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
NOAA	National Oceanic and Atmospheric Administration
OASIS	Oceanic Seamounts: An Integrated Study
OMZ	oxygen minimum zone
ORION	Ocean Research Interactive Observatory Networks
OSPAR	Commission for the Protection of the Marine Environment of the North-East Atlantic
PICES	North Pacific Marine Science Organization
POGO	Partnership for Observation of the Global Oceans
RUSALCA	Russian-American Long-term Census of the Arctic
SCAR	Scientific Committee on Antarctic Research
SCOR	Scientific Committee on Ocean Research
SIO	Scripps Institution of Oceanography
SOC	Southampton Oceanography Centre
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCMC	World Conservation Monitoring Centre
WHOI	Woods Hold Oceanographic Institution
WUN	World University Network

Acronyms are typically pronounceable abbreviations, combining letters and syllables from a title. COML acronyms adopt the convention that the first letters of words are capitalized and others lowercase, but they are also recognized in all capital letters.

The Census of Marine Life (CoML) is a global network of researchers in more than 70 nations engaged in a 10-year initiative to assess and explain the diversity, distribution, and abundance of life in the oceans—past, present, and future. It is governed by a number of international, national, and regional steering committees coordinated by an international Secretariat based at the Consortium for Oceanographic Research and Education.

Research Plan of the Census of Marine Life

CENSUS OF MARINE LIFE

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