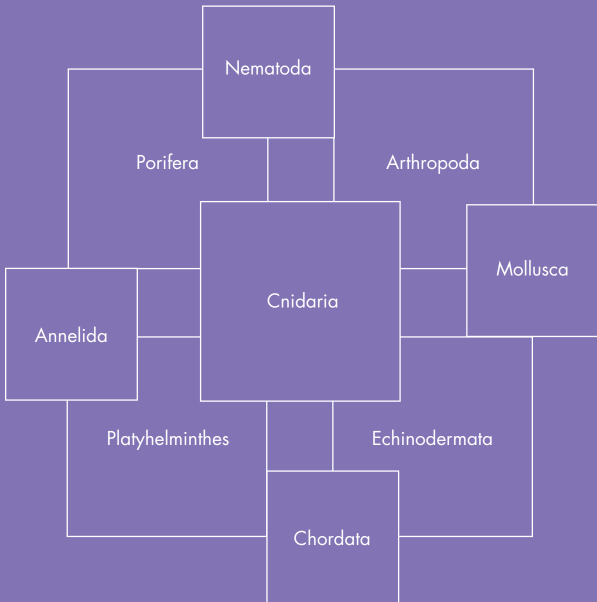
The Unknown Ocean

CENSUS OF MARINE LIFE

Research Plan of the Census of Marine Life

Draft: October 2003



Cover Images

Annelida: Marine polychaet, *Polychaete* (Serpulidae). Photo: Sea Studios Foundation, Monterey, CA.
Arthropoda: Armed hermit crab, *Pagarus 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
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Porifera: Stove-pipe sponge, *Aplysina archeri.* Photo: Shirley Pomponi

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Preface

Our priority in this Draft Plan is to convey the whole of the Census of Marine Life (CoML), its overall strategy, and how components contribute to the large goal of CoML: to assess and explain the diversity, distribution, and abundance of marine life. It should be read in conjunction with CoML's Baseline Report, which, for example, establishes the realms and zones of the ocean for the purposes of the Census. Scientific staff members and associates of CoML's International Secretariat have prepared the draft plan specifically for discussion at the All-Program Meeting of researchers involved in the Census 24 October 2004 in Washington DC. Where possible, this draft plan abstracts from the detailed plans and proposals of CoML's component projects. In cases where projects are in early stages, the draft seeks to anticipate likely major goals and directions. To keep the document digestible, each description is brief. Readers should refer to the project websites and principal investigators for greater detail. In the age of the Web, a plan such as this is a living document. We look forward to frequent updating of sections of the plan, as achievements accumulate and strategies to address challenges become more definite.

This document focuses on the major cooperative international efforts of CoML. Along with these large international efforts, we anticipate important contributions made by single nations, often within their own territorial waters. The surveys and research thus conducted will ultimately flow into the global database and help form the global picture. The Census also relies on the continuing work of government agencies, for example, in mapping types of habitat on the seafloor, that are not strictly part of the Census. We gratefully acknowledge these efforts, as well as the many research efforts in allied domains of ocean science that crucially help the Census aspire to and achieve its goals.

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International Secretariat, Census of Marine Life

I. CoML Summary

The Census of Marine Life (CoML) is a search for life on a new planet - right here. Earth's oceans occupy 70% its surface and 95% of its biosphere above the rock - they are largely unexplored and the life in them largely undescribed. The CoML is a research program that seeks to assess the diversity, distribution, and abundance of ocean life and to understand and explain how it changes over time. Its Ocean Biogeographic Information System (OBIS) is a working, internet accessible, repository for species level, geo-referenced information and analysis. Its History of Marine Animal Populations project (HMAP) assembles comparative historical views of ocean life, providing time-series for projections from a current global census to the Future of Marine Animal Populations (FMAP). The FMAP project integrates new biological knowledge with rapidly improving knowledge of continuous ocean movements. As a way to launch and frame inquiry, CoML has initiated a series of conferences on the theme of what is Known, Unknown, and Unknowable (KUU) about marine populations and ecosystems. These conferences identify and assemble existing information for entry into OBIS, consider what is unknowable with existing technology, and allow international scientists to form teams to tackle the unknown.

Field projects demonstrate new technologies and procedures to sample life-forms quantitatively in a wide range of specific ocean habitats. This new information is assembled in OBIS to build a coherent global picture of biodiversity and geography. An International Scientific Steering Committee has established a global alliance of Implementation Committees to facilitate local adoption of efficient sampling techniques on a global scale, to spur creative approaches, and to strengthen partnerships involving government agencies, industries, marine laboratories, natural history museums, and other organizations to capture biological information from existing sources and integrate it with data from new explorations. In addition to surprising us with new life, CoML will help us to imagine better how climate and human activity will change our lives and the living ocean on a planetary scale. CoML seeks to share its discoveries and information widely, to satisfy curiosity about our planet and to improve management of resources.

This document outlines the relationships among five elements of the Census of Marine Life that assemble and create new knowledge:

1) KUU workshops explore the structure of marine ecosystems: what we know, what we do not know, and why we do not know. Workshops are assessing the KUU of past, present, and future marine biodiversity and the challenges to specific field projects.

2) OBIS, the marine component of the Global Biodiversity Information Facility, links marine databases around the world to provide an Internet accessible, dynamic interface for comparing species level, geo-referenced biodiversity data in relation to ocean habitats. All CoML field project data will be managed in and accessible through OBIS.

3) HMAP is a unique new synthesis of historical and biological research that will document marine biodiversity, globally, up to 500 years ago, before significant human impact, and store it in formats compatible with modern data in OBIS.

4) Ocean Realm Field Projects develop and calibrate quantitative biological technologies encouraged by a Working Group of the Scientific Committee on Ocean Research in selected regions to facilitate and accelerate global biodiversity research. As calibrated technologies and protocols are adopted in many regions, qualitative and quantitative biodiversity discoveries accumulate in OBIS to provide a census of current marine life, and understanding deepens.

5) FMAP uses OBIS data for modeling and predicting changes in global biodiversity in response to fishing, pollution, and climate change challenges. Biological time-series linked to physical ocean observations assist in documenting the impacts of conservation efforts on sustainability.

II. The Census of Marine Life

http://www.coml.org

1. Introduction

By the latter half of the 1990's warnings made clear that intense fishing, pollution, and altered climate were changing the oceans. Because scientists have sampled less than 0.1% of the volume of the oceans, however, a reliable appraisal of the change awaits a global census. So, two hundred scientists in workshops recommended a comprehensive international research program called the Census of Marine Life (CoML) (See Appendix History). CoML has begun to assess and explain the diversity, distribution and abundance of marine life throughout the world's oceans. It is organized around the questions: What did live in the oceans? What does live in the oceans? What will live in the oceans?

Despite the vastness of the 95% of the volume of the global biosphere in the oceans, the two hundred scientists in the workshops agreed that new technologies available at the turn of the millennium plus international collaboration make answering the three questions plausible. To focus research where effort will effectively lead to discovery, other workshops considered what is known, unknown, and unknowable.

CoML will benefit from related programs such as the Global Ocean Observing System (GOOS), which will supply continuous streams of observations to challenge existing capabilities for data access, analysis, and presentation. While new research is costly, especially on a global scale, much sampling is underway. In addition to present international and governmental monitoring, industries such as transportation, fishing, oil exploration, and mining are sampling the oceans in a variety of ways on a continuous basis. The real key to conducting an assessment of life in the oceans is cooperation and collaboration among scientists and stakeholders, combined with the use of computer and internet technology to bring global data and expertise together.
Although the precision of the Census cannot be predetermined and costs are estimated to be in the billion-dollar range, major advances are possible by 2010. The plan described here promises to assemble what is known, assess what is knowable, and avoid pursuit of the unknowable as outlined in *The Unknown Ocean: Baseline Report for the Census of Marine Life.*

2. Mission & Strategy

Assessing and *explaining* the changing *diversity, distribution, and abundance* of marine *species* on a global scale is the reason for being of the Census of Marine Life (CoML). CoML focuses on species because it is species that define diversity. It is species that reproduce, and reproduction allows adaptation to change. The global span of the Census imparts advantage for understanding what increases and decreases marine life in the communities of local ecosystems, including the flows of migration. The grand challenge thrown down by this mission makes priorities and a strategy essential for success.

CoML strategy begins with classifying knowledge into known, unknown, and unknowable (KUU), and already components of CoML are working to transform unknown to known. The Ocean Biogeographic Information System (OBIS) is assembling the known globally and making it accessible so that questions about species interactions with each other and the environment can be made promptly anywhere from data online. The History of Marine Life (HMAP) is mining the archives of known history and biology as long as 500 years into the past to make the records compatible with the modern OBIS and get a head start on perceiving trends through the present into the future. After an appraisal, the unknowable is set aside.

CoML's initial Field Projects are demonstrating the feasibility and dividends of global planning and collaboration. To ensure encompassing *all* marine life, CoML has begun or designed Projects in *realms* from nearshore to abyssal plain that are distinguished by the technology and difficulty of their exploration (see the realms in Baseline Figure 4). At the same time that the Projects encompass all realms, they also span geography (Figure 2). Three-hundred scientists from 53 nations are already at work on these projects to assess and explain. CoML recruits commercial interests like shipping and oil as allies. Large-scale programs like GLOBEC that sample a limited number of species extensively are invited to contribute to OBIS. Regional and national implementation committees are working to broaden CoML's coverage by encouraging and promoting common approaches globally to ensure compatible results enter OBIS and can test global hypotheses.

CoML's program entitled Future of Marine Animal Populations (FMAP) plays a strategic role in *explaining* the three parameters of diversity, distribution, and abundance. For CoML diversity is the multiplicity of species, distribution is their presence from place to place, and abundance is their population and biomass. Explanation as well as assessment of the three is the mission of CoML. FMAP will check that the data entering OBIS will enable the testing of hypotheses about explanation, answering what causes the three parameters to vary. To test its criteria for data in OBIS and to anticipate the effectiveness of conservation measures for sustainability, FMAP will hindcast and forecast with models linked to physical ocean observations like those in OBIS.

Although humanity worries about its impact on diversity, distribution, and abundance of marine life, its means and resources for assessing and explaining its impact will always be weighed against other demands. Hence the merit of CoML's strategy for sorting the known, unknown, and unknowable: 1) the merit of its getting a head start on knowing trends by analyzing history, 2) the merit of its initial Projects encompassing and finding global patterns of species in all oceanic realms, and 3) the merit of testing by using the assembly of data in the global OBIS.

Believing that deadlines have a healthy effect on the organization and conduct of research, CoML is committed to learning as much as possible by 2010 and to sharing with the world at that time the most complete picture ever offered of marine life. CoML will share both knowledge and the limits of knowledge. It will describe what we know, and it will also explain what we do not know, why we do not know it, and whether we are ever likely to know some of what we would like to know about ocean life.

3. Education & Outreach

For the Census of Marine Life to succeed, its discoveries and information must be widely shared and accessible. Each component and field project commits to develop, and secure funding for, a range of education and outreach initiatives related to the specific thrusts of their own research projects. Outreach Liaisons associated with individual projects facilitate coordinated E&O efforts through development and/or production of:

- Features, news stories, or interviews about new discoveries and new technologies
- Educational web sites
- Books, field guides, and other printed materials
- Documentary videos
- Live television or Internet broadcasts (shipboard- or shore-based)
- Museum or aquarium displays and exhibits
- Marine art exhibitions
- Research experiences for journalists
- Research experiences for teachers and/or students (secondary school/undergraduate)
- Interpretative programs for local schools and civic groups
- Curriculum materials

Several projects are already underway or in development, for example, a film about the mid-Atlantic Ridge (MAR-ECO) project, an aquarium exhibition project for the coastal salmon tracking (POST), and an interactive website for the top Pacific predators (TOPP).

While each project focuses effort on communicating its own research interests, targeting audiences (i.e. other scientists, teachers, students, journalists, policy makers, government officials, funding agencies, or general public, etc.), the projects also work together. Generally, one or two individuals associated with each project have E&O responsibility. These Outreach Liaisons in turn form a global E&O Liaison Network of individuals committed to communicating the work of CoML, whatever the particular audience or venue might be. They generate ideas, share information, and receive feedback on ideas and proposals. A team at the University of Rhode Island (USA) facilitates and supports the E&O Liaison Network, individually and as a group. This creates a cohesive E&O strategy for the Census as a whole, and make it easier for Liaisons to expand and garner support for their efforts. The E&O network has responsibility for the CoML Portal. CoML expects about 10% of all CoML expenditures to be dedicated to education and outreach over the life of the program.

III. Ocean Biogeographic Information System (OBIS)

http://www.iobis.org

Goal: A dynamic, global digital atlas for explanation of relations in the oceans with accurate identification of species and their location and abundance, all integrated with environmental data, maps, and model outputs on the Internet.

Baseline: The Ocean Biogeographic Information System (OBIS) begins with authoritative information contributed by experts concerned with particular taxonomic groups about the presence or absence of the relevant species in locations on a map of the oceans. OBIS further incorporates other geo-referenced species-level data sets, for example, the catches from continuous plankton recorders, sampling along millions of kilometers and reports of the world's fisheries reported to the Food and Agriculture Organization. OBIS is integrating samples collected by oil companies near Britain and Brazil and by mining prospectors in the Pacific abyssal plains. 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.
In October 2003 the Ocean Biogeographic Information System (OBIS) at the center of CoML and the marine component of the Global Biodiversity Information Facility already locates fully 1.1 million species entries for everyone with a connection to the web, north or south, east or west.

By 2003: A visit to http://www.iobis.org/Portal.html shows the promise of OBIS, which will grow during 2003/2010. At the portal enter, for example, the common name *squid*. OBIS promptly shows you fully 131 species of squid, beginning as follows:

Name	Genus	Species	Citation
Eye-flash squid	Abralia	veranyi	Ruppell, 1844
Antarctic neosquid	Alluroteuthis	antarctica	Odhner, 1923
Sharpear enope squid	Ancistrocheirus	lesueurii	(Orbigny, 1842)
…			
Atlantic giant squid	Architeuthis	dux	Steenstrup, 1857
Giant squid	Architeuthis	dux	Steenstrup, 1857
Giant squid	Architeuthis	martensi	(Hilgendorf, 1880)
Giant squid	Architeuthis	sanctipauli	(Velain, 1877)
…			

The computer screen for squid—and all inquiries--also shows another column, which is labeled Distribution and not printed above. Clicking on *Distribution* in the row for *Architeuthis dux* takes the browser to a global map showing that Atlantic giant squid specimens have been recorded twice, once off Newfoundland and once off Carolina. Along with mapping capabilities OBIS offers a growing suites of tools for analysis and projection, for example, of habitats that might be suitable for a particular species.

Entering *cod* links to 424 species and synonyms. Choosing Lingcod *Ophiodon elongatus* (Girard 1854) reveals 188 reports, and the linked map locates the 188 from the coast of southern California through Canada to the Aleutian islands with an outlier near New Zealand.

The Members of the OBIS Federation include groups organized by taxon, taxon and habitat, habitat, region, data type, and national or institutional database holdings, for example:
• FishNet
• Census of Marine Fishes (CMF), including Catalog of Fishes and FishBase
• CephBase
• Corals, Sea Anemones, and their Allies (Hexacorallia)
• Marine Mammals, Birds, Turtles
• Biotic Database of Indo-Pacific Marine Mollusks
• Zooplankton and Micronekton Species Composition in the Subtropical Atlantic (Diel, Seasonal, and Interannual Patterns)
• SeamountsOnline
• Gulf of Maine Biogeographic Information System
• ZooGene (genetic information on copepods and euphausiids)
• Estuarine Invasion Database• The History of Marine Animal Populations (HMAP)
• Southampton Oceanography Centre Atlantic Bathypelagic Biota

Each of the Census of Marine Life Field Projects (http://coml.org) becomes a Member of the OBIS Federation as its field programs begin. Rutgers University (New Jersey, USA) hosts the OBIS Portal. The Huntsman Marine Science Centre (New Brunswick, Canada) hosts the OBIS Executive Office.

At a technical level, CoML has adopted a DNA protocol to encourage the standard inclusion in OBIS of a minimal gene sequence that helps rapid, cheap, reliable species identification. Such a "DNA barcode" using, for example, parts of the mitochondrial CO1 gene, also helps match larval and adult forms of animals, addressing a vexing challenge for ocean life that often takes several distinct forms in a life cycle.

During 2003-9: OBIS will grow with new species and new locations. DNA barcodes will be added for many species. OBIS will integrate with databases containing information on the sounds animals make. It will develop 5-10 regional nodes to assure and sustain global coverage.

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. Accumulation of DNA barcodes will foster insights into evolutionary trees of marine life. 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.

Based on scheduled addition of datasets, OBIS will put at least 10 million records of species and their location on line. The schedule is 2002, 800 thousand; 2003, 2 million; 2004, 3.5 million; 2005, 6 million; 2006, 10 million and 2007, 10 million.
OBIS Members, the International Committee, and CoML have formed affiliations. Major ones include the Global Biodiversity Information Facility (GBIF), Intergovernmental Oceanographic Commission (IOC), 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). In 2003-4, the United Nations Environmental Program (UNEP), World Conservation Monitoring Centre (WCMC), , and Global Ocean Observing System (GOOS) are expected to become OBIS partners.

Key partnerships are GBIF and GOOS. OBIS is an Associate Member of GBIF and GBIF's primary marine component. Plans are:

2003 Establish an OBIS GBIF Node, participate in Electronic Catalogue of Names of Known Organisms, Digitization of Natural History Collection Data, data access and infrastructure building
2004 OBIS ecological and fishery information system becomes a GBIF prototype
2005 OBIS genetic information service, linking to GenBank, becomes a GBIF prototype
2006 OBIS environmental data service adopted by GBIF
2007 OBIS geospatial data integration and mining tools adopted by GBIF

GBIF is at an early stage of development. Current development reflects GBIF's 5-year focus on the Catalog of Names and digitization of biological specimen data, capitalizing on momentum in a few communities, such as Species 2000, Taxonomy Database Working Group (TDWG), and the natural history museum data linked by The Species Analyst (TSA). OBIS will optimize mutual growth with GBIF. For example, OBIS is adopting existing products developed or endorsed by GBIF to ensure GBIF support for OBIS.

OBIS will be a key partner providing a framework for the assimilation of biological information for GOOS. Specifically, OBIS aims to:

2003-5 Collaborate with major national initiatives on distributed ocean data and virtual ocean data systems on data integration and on data discovery standards and data archiving
2006 Lead GOOS' biological geospatial data modeling/integration development
2007 Lead GOOS' biological data mining initiative

OBIS seeks to bridge GBIF and GOOS, two prominent "Mega Science" initiatives, one aiming to produce an encyclopedia of life and the other useful information for marine operations. As in GBIF, there are no major players yet in the area of geospatial marine biological data integration and mining in the GOOS community and little has been done in the research community either.

In 2010. The atlas must be three-dimensional to recognize the depth of the ocean and to be dynamic, must add the fourth dimension of time. The final report of the Census of Marine Life will be a dynamic global atlas of ocean biology, either OBIS or a child of OBIS, accessible online and analyzable to test hypotheses and make predictions about diversity, distribution, and abundance of marine life. Although the research program called the Census of Marine Life expects to culminate in 2010, OBIS should live on, a major legacy of CoML, the next generation informatics infrastructure for managing, researching, and educating about living marine resources.

IV. What lived in the ocean?

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.

History of Marine Animal Populations (HMAP)

http://www.hmapcoml.org/

Goal. This project will 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.

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 2003. HMAP was the first CoML project approved by the SSC in 1999. It has well established centers at the universities of New Hampshire, Southern Denmark and Hull (UK), engaging over 50 historians and scientists from 18 different countries in seven case study research teams with four more coming (Figure 1). The centers build the field of marine environmental history and its infrastructure. A sophisticated data management system links to OBIS. Fifty-eight research students have participated in two HMAP summer schools and a range of graduate programs. These research efforts have yielded exciting findings. The innovative multidisciplinary approach delivers fresh, enlightening perspectives on the process of long-term change in the diversity, distribution, and abundance of life in the oceans. Tangible outputs include 12 conference papers, three journal articles, three web publications, eight datasets available via the HMAP Portal, and a volume of proceedings from HMAP Workshop 1 published as Holm, Smith & Starkey (eds.), *The Exploited Seas: Essays in Marine Environmental History*. Results of the 11 case studies will be ultimately disseminated in 2-3 refereed journal papers each.

During 2003-9. 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. HMAP will collaborate closely with OBIS to encourage development of FMAP. The developing components of HMAP include:

Centers:

(a) *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 over 18 countries and a range of disciplines.

(b) *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.

(c) *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.

Case studies:

(1) *North West Atlantic.* The North West Atlantic case study has four sub-projects. A post-doctoral ecologist is analyzing the substantial time series that have been compiled, melding the four together.

(2) *South West Pacific.* Two sub-projects 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.

(3) *White & Barents Seas.* A Russian team from St Petersburg, Archangelsk, and Moscow have White & Barents Seas projects on historical reconstructions of Atlantic walrus, salmon, and herring. Abundant records and initial modeling exercises promise collaborative work with Norwegian partners to elucidate the full Barents Sea ecosystem.

(4) *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 challenge of political barriers and linguistic diversity are successfully overcome through identified partners in all Baltic countries.

(5) *South West African Shelf.* Benguela Current physical forcing may have caused dramatic changes in productivity over the last century, but historical data from government-generated sources are now compiled in a volume of analytical papers to develop models to test these hypotheses.

(6) *World Whaling.* Focuses include: (1) organizing and making twentieth-century whaling data available on line, (2) defining and describing whale fisheries world wide and (3) estimating pre-1900th 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.

(7) *Caribbean.* Ecological analysis of historical data progresses well at the Scripps Institute of Oceanography, but a welter of archival source material has been discovered in various repositories of European colonial powers that will greatly extend its scope and value.

(8) *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.

(9) *Mediterranean.* A workshop in 2004 will link Eastern Mediterranean researchers with a funded Black Sea project.

(10) *Northeast Pacific.* A 200 year NE Pacific rim fishery ramped up to industrial scale in the last 50 years. The missing link in this extensively studied system is the historical archives and records of human interactions with these marine ecosystems over the past 500 years from California to Alaska.

(11) *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.

The years 2008-2009 will focus on integration and a sustained modeling exercise in close collaboration with FMAP.

In 2010. HMAP will focus on synthesis of the worldwide picture of the oceans before fishing became important and publication 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. Unlike field projects, the heart of this project is institution and discipline building, which will be sustained.

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

To assess present marine life and prepare for explaining its changing diversity, distribution, and abundance on a global scale, CoML divides the oceans into realms with similar challenges requiring similar technologies. The six realms and subsidiaries called zones encompass all world oceans and are tabulated in the outline of this section of the Plan. In each realm, one or more Projects will develop 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 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.

1. <u>Human Edges</u>

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 realm are linked, spawning in adjacent or even remote bays influences recruitment in other bays. Testing hypotheses about nearshore ecology requires similarly linked researchers across latitude, climate, and ecosystems, the essential character of CoML.

Natural Geography In Shore Areas (NaGISA)
http://210.227.161.22/nagisa.htm

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

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 km of the coast, and waste from people and their activities 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 2003. 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. The web site http://210.227.161.22/nagisa.htm describes NaGISA's work and part in CoML. NaGISA will produce an extensive, consistent database on nearshore biodiversity to supplement and enhance intensive, idiosyncratic ones focused on local problems.

NaGISA established an administrative center in Japan, organizing the longitudinal transect, and a center in Alaska, responsible for the latitudinal transect. Building on site selection criteria and sampling protocols developed during the International Biodiversity Observation Year (IBOY), the project aims to achieve wide coverage with standardized techniques for future comparisons. Figure 2 shows the span of the initial project fully from pole to pole and around the equator. NaGISA stretches 160 degrees around the equator from the east coast of Africa to the Palmyra Atoll in the Pacific. From north to south, it stretches 160 degrees from the Arctic Ocean above Alaska to McMurdo Sound near Antarctica.

NaGISA means ‘beautiful coast’ in Japanese, and a center at Kyoto University coordinates the Project. NaGISA initially focused on biodiversity gradients along the western Pacific coastline. It completed some twenty transects from Alaska to Thailand, with scientists and funding committed to complete initial transects at 300 km intervals. Training for field sampling and sorting are underway in Phuket, Thailand, and experts for explorations are identified.

The South American committee of NaGISA, administered from the Catholic University of Chile, completed the Pacific circle and also introduced NaGISA into the South 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.

During 2003-9. NaGISA will complete Pacific Rim sampling for east-west pattern comparisons by 2006. A website provides the essential communication link and will contribute to OBIS as samples are processed. Comparisons between basins should possible be by 2010.

As NaGISA proves feasibility and refines techniques, other transects will be added. The methods will require no sophisticated or expensive ships or equipment, allowing scientists in developing countries or even supervised volunteers to run them. They can be easily incorporated into existing protocols, adding capacity for large-scale comparisons to any nearshore experiment. Initial protocols were for macrophyte and eel grass habitats present intermittently over the 15,000 km stretch of coastlines from Arctic to Antarctic to provide a baseline for testing hypotheses about latitudinal variation in marine biodiversity. Additional protocols are being developed for coral reefs and rocky and sandy shores. In developed regions NaGISA transects can be incorporated into monitoring and so benefit from the international taxonomic expertise.

In 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 east-to-west and between basins. Although NiGISA 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. Some of the core sites in Japan are already funded to repeat transects 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.

Coral Reefs (tentative)

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 complex and ancient coral reef systems may contain 600,000 species, most unknown. A 3 cubic-meter sample carved out of hundreds of kilometers of coral reef off New Caledonia in the South Pacific contained 130,000 molluscs alone belonging to 3,000 species, many not described. Globally, mollusc species are being described at 300 per year. If all the taxonomists in the world describing molluscs 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. Groups such as the Global Coral Reef Monitoring Network produce periodic status reports on coral reefs of the world. Such efforts need to be expanded to cover many more taxonomic groups and the deeper reaches of reefs.

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/rare?, and (c) their functional ecological roles? The task of acquiring multi-scale quantitative biogeographic data on species abundances and functional characteristics is formidable, but essential.

By 2003. Several national and regional committees have identified biodiversity of coral reefs as well as deep-sea corals as a priority for a field project. By the end of 2003 agreement should be reached on the time and place in 2004 for the first CoML KUU coral workshop. The following topics will be addressed:

- What do we know now? What remains to be discovered?
- At what taxonomic levels can a coral census be conducted?
- How many sites and where? Tropical hotspots of diversity and depauperate regions?
- What approaches are feasible?

During 2003-9. The International Coral Reef Symposium in Okinawa in the summer of 2004 will convene many of the world's experts and offers the chance for the CoML program to gel. The expected strategy is to complement existing initiatives to achieve a more global and comprehensive picture. Because reefs are so dense in species, how OBIS assimilates and visualizes reef data must be addressed.

In 2010. Reef biodiversity will be summarized. OBIS offers an ongoing framework for frequent reporting on these rapidly changing zones.

Coastal

Because 90% of the ocean harvest comes from the coastal shelves between the nearshore and the continental margins, studies have concentrated on it. 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 trans-boundary 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 non-commercial species—could accelerate and increase knowledge for management of commercial species at the same time CoML 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 Ecosystem Census (GoMe)
http://www.usm.maine.edu/gulfofmaine-census/

Goal. On a coastal shelf where interests, scientists, and resources congregate but naturally focus on commercial fish, test the feasibility and profit of assessing and explaining all diversity and processes from microbes to the top predators and even birds in the system.

Baseline. With a steep latitudinal gradient in the atmosphere and the ocean, the Gulf 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 (Figure 7A). 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. Sea lanes among Halifax, Portland, and Boston plus connections to New York and Europe transverse the area.

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

Canada and the USA amicably divided the area, both nations have long histories of surveys and management, and both now focus advanced technologies on it. A concentration of marine scientists with instruments and sensors of physical and biological characteristics outfits the Gulf of Maine for a census. 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, 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. Intense local interest suggests areas like the Gulf of Maine can be modeled in 4-dimensions, using databases of the known plus new exploration and censuses of the knowable. Models assembling 'state-of-the-ecosystems' censuses from new, knowable knowledge plus the present knowledge of such connections as from bacteria and krill to whales are now a recognized requirement for sustainable fisheries.

By 2003. In 1999 early in its life, CoML initiated the Project GoMe 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.

A senior planner and policy expert and a chief scientist, both at the University of Southern Maine, lead GoMe under the guidance of a Policy Advisory Board and a Scientific Steering Committee composed of Canadian and U.S. stakeholders and scientists from the region. This bi-national model may be most appropriate for coastal regions, less dependent on large scale collaborations than projects in the open ocean.

Both the Canadian Department of Fisheries and Oceans (DFO) and the US National Marine Fishery Service (NMFS) supported GoMe, including sharing costs and data to create the Gulf of Maine Biogeographic Information System online as the first regional component of OBIS, and interoperable with historical data from HMAP. Both nations have begun extensive sea bottom mapping programs with resolutions that will allow relating habitat types to the marine life in them Figure 7B. Fishers are contributing fish-finder records. Crucially, the GoMe project and the Gulf of Maine Ocean Observation System (GoMOOS), are providing continuous information about ocean physics that allows relation of biological samples not only to a geographic location, but also to simultaneous observations of water temperature, salinity, currents, etc. The relation to water conditions thus made possible is critical because most ocean life is associated with a mass of water and not a place. All GoMe sampling is being evaluated in the context of GoMOOS to ensure that the techniques standardized by the Census can contribute to OBIS' role as a key biological data framework for the Global Ocean Observation System (GOOS) that the U.N. Intergovernmental Oceanographic Commission is developing.

Although much of the sampling required in the Gulf can be done in association with routine fisheries surveys conducted by the two cooperating national agencies, extending the study to the New England Seamount Chain has added a specifically GoMe exploration. Two NOAA Ocean Exploration cruises have conducted biological sampling for GoMe, 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.

During 2003-9. GoMe will extract knowledge from a wealth of existing data to produce an electronic Dynamic Atlas. Using GIS and internet, this exemplary Atlas from a component of CoML will improve access to existing time series and so facilitate and broaden their use. GoMe will develop both historical reconstruction and predictive tools through two funded projects: the History of Marine Animals Populations (HMAP) and the Future of Marine Animal Populations (FMAP) in the Gulf of Maine.

GoMe is rapidly extending beyond the Atlas, HMAP, and FMAP to become a component of a real-time monitoring system linking biology and ocean dynamics. This extension links to programs like GLOBEC that focus on processes and opens a two-way avenue for sharing data. (CoML links are also building with GLOBEC and other IGBP programs globally.) The U.S. National Committee for the Census has made development of integrated GoMe-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.The largest effort will generate new knowledge through field studies. This component of the program will convene scientists, managers, and users from the U.S. and Canada to sort the known, unknown, and unknowable.

In 2010. GoMe will deliver its Dynamic Atlas plus the results of its HMAP and FMAP work. It will leave the legacy of the tested model of GoMe for a gulf. The practical consequence of this model should be the first comprehensive (sediments to seabirds) ecosystem management plan and a cleaner more productive Gulf.

Pacific Ocean Shelf Tracking (POST)
http://postcoml.bayleaf.com/

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

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 are 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%-- while other stocks of the same species have had survival as low as 0.5%; a 40-fold difference in the numbers returning from each spawning parent. At the same time, record returns in recent years to some of these weak stocks speaks 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 do 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 river's 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 8 years of study remained over the continental shelf north to the end of the Alaskan Peninsula (Figure 6) 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 2003. Scientists from DFO and NOAA initiated POST and in 2001 the SSC of CoML 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 US governments, as well as foundations, fisheries commissions, and NGOs. POST's Scientific Steering Committee is drawn from both North American salmon experts as well as others from Australia and the North Atlantic.

The high survival observed during field studies in 2002-3 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 6. Because the West Coast shelf is often narrower than 20 km, a string of 20-30 acoustic receivers across the shelf should detect all tagged animals crossing each line. These acoustic curtains would track and identify any smolts, immature or maturing shelf-resident salmon stocks, or even eels, whales, or other animals implanted with acoustic tags.

During 2003-9. A permanent seabed node to host multiple instruments will be developed and tested so that the existing deployment strategy for the acoustic receivers can become less costly, more reliable, and less laborious. POST will collaborate 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 2004-5 a skeleton continental-scale acoustic array will be deployed from California to Alaska to demonstrate that large-scale movements can be tracked. A focused array will also be built in the large enclosed "Salish Sea" (Georgia Strait, Puget Sound, Juan de Fuca Strait, Johnstone Strait, and Queen Charlotte Strait). The Salish Sea tracking will demonstrate 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 will test POST's earlier findings that after leaving freshwater salmon survival is initially high. Confirming this is important because it will encourage development of the extensive array envisioned in Figure 6.

During 2005-6 in co-operation with the VENUS 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.

With further collaborators, POST will deploy an array in south Puget Sound in 2004 and soon after in the Hood Canal region and along the coastal shelf north of the Columbia River. Still other collaborators plan arrays in Monterey Bay, California. Data on the migrations of a wide variety of species will eventually be compiled and made available in OBIS.

POST and allied programs have submitted requests totalling more than $6 million to assist with the purchase of acoustic tags, deployment of the array, and to help administer its work during 2003-5.

In 2010. POST will have tested and demonstrated continental-scale acoustic tracking by a consortium of salmon researchers, and perhaps also apply 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 curtain of listening devices stretching from the shore to the edge of the coastal shelf and stretching along a continent, and 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 have 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 push 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 totally alter local habitats and powerful currents mix water layers and scrub the bottom. These energy rich areas likely have high biodiversity, but are poorly sample until recently.

Margins, Canyons, and Trenches (tentative)

Goal. To capture new evidence of biodiversity resulting from commercial exploitation of vast areas of margins to understand their 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, they support many of the same species and 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 2003. A KUU workshop in August 2003 developed basic information and concepts, and a steering group is forming.

During 2003-9. To be determined.

In 2010. (To be expanded) Provide the "chapter" of the Census on the biogeography of margins, canyons, and trenches.

Abyssal plain

Census of Diversity of Abyssal Marine Life (CeDAMar)
http://pc004446.biologie.uni-oldenburg.de/cms/

Goal. What factors vary the multiplicity of species, or biodiversity, from place to place in the sediment of the abyssal plain?

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 the plain a happy hunting ground for new species. The hunting should be especially good for molluscs and the roundworms called nematodes. Every technological improvement in diving 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 mined few of the samples for new species. The richness of the silt in the abyssal plain beckons the explorer.

By 2003. Coordinated from the German Centre for Marine Biodiversity Research of the Senckenberg Research Institute, CeDAMar has become a dynamic part of CoML contributing impressively to Workshops and program development. Initially focused on German and French cruises, during a CoML Sediments Workshop CeDAMar agreed to develop and integrate similar efforts in all oceans. The web site describes CeDAMar’s work and part in CoML.

CeDAMar's established specimen sorting center has already added hundreds of new species to its archives and will soon add them to OBIS. CeDAMar completed three Abyssal Plain sampling cruises using benthic grabs and sleds, DIVA in the South Atlantic and ANDEEP I and II in the Southern Ocean. Results from the cruises were integrated at two workshops. CeDAMar has planned three more cruises, including the French led Biozaire (Figure 8).

During 2003-9. The CeDAMar network must focus 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 will first perform the challenging task of sampling the abyssal plain at several localities. The local samples will be adequate to reveal the distribution of widespread species. The consequent knowledge of global patterns of abyssal diversity will be related to conditions in the overlying zones of water.

The CeDAMar organizers will create a global steering committee to coordinate abyssal projects in all ocean basins. They have taxonomists for the most common abyssal fauna and two oceans and will make alliances for other taxa and other oceans. This network will support and benefit from projects like NaGISA, ChEss, Arctic Transect, and Seamounts that sample organisms in sediments.

Because crustaceans are numerous in both the abyss and in the light zone, there can be synergy between the genetically-oriented Global Plankton project 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 in the water column. Genetic comparisons between light zone and abyssal crustaceans could reveal interesting evolutionary patterns. CeDAMar will furnish samples for the Global Marine Microbes project.

Deep-sea sampling is costly. Billions of liters of surface water have been sampled for plankton for not much more than the cost of netting and the good will of a ship of convenience. 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. There are many funding sources for deep-sea sampling, ranging from efforts to measure carbon fluxes into sediments, to geological drill studies to nodule mining.

In 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 workers with the habit of exploiting costly abyssal samples.

3. Central Waters

Light Zone (drifters and swimmers)

At least 40% of the world's primary production 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 generally considered 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 a global molecular approach to compare populations in the ocean basins.

In contrast, there is now no question about the basin-wide and 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 the same individuals! New technologies are now making it possible to provide realistic estimates of the global distribution and abundance in this realm, and the animals themselves are identifying the 'ocean oases' where they concentrate to feed on smaller species of taking advantage of production hotspots.

Global Plankton (tentative)
http://www.zoogene.org/

Goal. A global-scale analysis of all marine planktonic 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. Although not exceptional in terms of species diversity, the metazoan and protozoan plankton are exceptional in the degree to which new species still 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, and/or systematic complexity of many taxa (Figure 13). Many planktonic groups remain poorly known and problematical 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 preserved appropriately for molecular and biochemical analysis. Widely-distributed, cosmopolitan, and circumglobal species need molecular systematic assessment across their geographic range, particularly systematically complex and/or morphologically conserved groups. Tropical oligotrophic waters have higher species diversity, yet are poorly explored or characterized even by traditional techniques. Effort is needed throughout the water column in these ecosystems, which may be centers of speciation (e.g. Banda Sea) and in novel and productive environments in remote regions.

By 2003. A KUU workshop is planned for early 2004 bringing together an international partnership using ships of opportunity and a coordinated international network of technicians, taxonomic experts, and biological oceanographers.

During 2003-9. The workshop will launch a global-scale effort to complete analysis of at least the ~6,800 described species of marine metazoan and protozoan plankton by 2010.

In 2010. (To be expanded) Provide the "chapter" of the Census on the biogeography of plankton.

Tagging of Pacific Pelagics (TOPP)
http://www.toppcensus.org/index.cgi?flash=1

Goal. Use bio-logging for an “organism-eye” view of pelagic habitats in the North Pacific by integrating biological and physical data collected by twenty-two species, including tunas, sharks, seals, cetaceans, seabirds, and turtles coupled with earth-observing satellites and in-situ data collection. An interdisciplinary approach provides temporal and spatial data at high resolution on animal use of a complex of very large interactive oceanic regimes and indicates where prey species accumulate. Knowing the behavior of the top predators thus allows inference about the distribution and abundance of much else that lives in the ocean.

Baseline. At their cruising speed of 20 km/h whale 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, but improved telemetry by satellites has made them full allies.

2003. Headquartered in California's Monterey Bay (Hopkins Marine Station, Monterey Bay Aquarium, and the U. of California) and guided by an international scientific steering group, TOPP scientists have tagged a total of 16 species ranging from albatross, to albacore, to elephant seals (Figure 9). More than 30 investigators are conducting projects in 8 countries. As of May 2003, 514 tags had been deployed, including archival tags, pop-up satellite tags, conventional tags, satellite and dummy tags. Humboldt squid, a previously untagged species, have been tagged successfully, developing methods to capture, handle, and attach a number of different tag types.

While performance of electronic tags is critical, success also depends upon field methods: tag attachment, retention, and recovery. Leatherback sea turtle studies in Costa Rica developed attachment methods for new tags to insure long-term retention, expanding the tagging options and enabling collection of environmental data. Another key objective is tagging sufficient numbers of animals to allow complex statistical analysis and modeling of movement data. Net pen and bait boat releases deployed 131 tagged Pacific bluefin in only four days in early 2003. Four archival tags already 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 in salmon sharks, compared different geolocation methods: day length to estimate latitude and longitude, GPS archival tags, and Argos satellite transmitters. A new generation of ocean sensor tags for animals, adding salinity to light, temperature and depth is under development. Including salinity among the physical characteristics of the North Pacific supplied by TOPP organisms can dramatically improve ocean dynamic models.

2003-9. TOPP will continue intensive deployment of tags on these species and a few new ones, but 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 faciliate 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.

This data management and server capacity will allow TOPP to focus the entire global telemetry community and 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 biologging, and 2) Southern Ocean TOPP, an idea developed at International Bio-logging Conference in Tokyo, Japan, March 2003. SOTOPP would allow international programs like the Scientific Committee of Antarctic Research and the Committee on the Convention of Antarctic Marine Living Resources to take advantage of TOPP data systems and oversee research in national Antarctic research programs, already using biologging technology. Such data integration will facilitate management of these vast ocean areas.

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

Dark Zone (mid-water and bottom-water)

Mid-Atlantic Ridge Ecosystem (MAR-ECO)
http://www.efan.no/midatlcensus/

Goal. MAR-ECO aims to describe and understand the patterns of distribution, abundance, and trophic relationships of the organisms in the deep mid-oceanic North Atlantic, and identify and model associated ecological processes, focusing on pelagic and benthic macrofauna (Figure 10). Utilizing innovative methods and up-to-date technology, it will map distributions, analyze community structure, study life histories, and model trophic relationships.

Baseline. Extending down more than 4 km into pitch-blackness, the dark zone's volume exceeds the volume of the 200 m light zone manyfold. Even in the dark most animals must feed ultimately on plants from nearer the surface, which deliver a marine snow into the dark zone. The snow of wastes, carcasses of large animals, and swimmers venturing below their normal light zone feed the animals in the dark beneath. The mass of organisms declines with depth, modified by mid-ocean ridges that affect circulation just as mountains affect weather. At best the technology to explore these dark, deep waters is brand-new, and at worst it is still inadequate. The challenge of exploration includes midwaters with crustaceans, fish and strange floating jellyfish and mollusks, as well as bottom waters with an even broader spectrum of species. The falling snow collects at the bottom, so food is plentiful, and creatures here can rest on the bottom without the strange and specialized floatation and swimming structures required above.

By 2003. The wide distribution and extensive area of mid-ocean ridges with few previous investigations have drawn together a multidisciplinary and international steering group with representatives from USA, Germany, the United Kingdom, Iceland, Portugal, France, and Norway, led from the Institute of Marine Research and the University of Bergen, to the study of the animal communities inhabiting these characteristic areas of the world ocean. Beginning with the Mid-Atlantic Ridge from Iceland to the Azores they have plans to learn if ridges have characteristic faunas and the extent of their influence on intercontinental migrations and the dispersion of slope and shelf biota. Joint gear-testing cruises with GoMe to Bear Seamount and dives to the Charlie-Gibbs Fracture Zone with the Russian Mir submersibles have given the project a strong start, and a planned series of cruises totaling four month on the special new acoustically sophisticated *G.O. Sars* research vessel will provide breakthroughs in the large-scale quantitative sample technologies need for open-ocean water column research.

During 2003-9. The field phase on the Mid-Atlantic Ridge will be complete by 2005, but analysis will continue through 2008 with data assembly in OBIS. Active linkages to other CoML projects and regional and international research program should spread the techniques broadly to develop comparable descriptions of other open ocean ecosystems. Clear opportunities for 'piggy-backing' the MAR-ECO approach on Census cruises headed deep-sea vents, seamounts, and even abyssal plains can extend the concepts and understanding to other oceans.

The full challenge for MAR-ECO was laid out by the Oslo-Paris Commission (OSPAR, 2000), in a comprehensive review of information on the ecosystems of the oceanic North Atlantic, including this list of biological "uncertainties":
- Basic systematic information about benthic taxa, especially the smaller organisms;
- Importance of inadequately sampled gelatinous organisms in pelagic ecosystems;
- Role of microorganisms in food webs related to biogeochemical cycling;
- Zoogeographical patterns and distributions of keystone species and communities;
- Life cycles of many keystone species;
- Structure and dynamics of most deep-water food webs;
- Biological pathways for contaminants in deep ocean ecosystems;
- Natural variability for comparison to contemporary changes in biological systems;
- Long-term physical cycle affects on midwater and seabed communities and processes;
- Links between biodiversity, productivity and other ecological processes;
- Impact of removing top predators, such as fish, from the oceanic ecosystems; and
- How to distinguish between natural variation and anthropogenically-generated change.

In 2010. MAR-ECO will provide the most comprehensive chapter on a mid-water oceanic ecosystem ever to the final report, and its rare specimens will tremendously increase OBIS' third, vertical dimension. It is not yet possible to predict how much of total volume of the world's oceans can be resolved to this degree, but demonstrated success should invite imitation to gain a global view. Globalizing MAR-ECO is a great challenge the Census faces because of the vast volume involved (Figure 3) and cutting edge technology required. Major commitments from many governments would be required, but the collective research network of the Census could make it happen. Efficient sampling in this realm could even make it manageable, if international law also reaches into this great unknown.

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 very few seamounts are erupting, we group these ghost volcanoes under active geology.

Biogeography of Chemosynthetic Ecosystems (ChEss)
http://www.soc.soton.ac.uk/chess/

Goal. Discover seeps and vents, assess the diversity, distribution, and abundance of the peculiar fauna in their chemosynthetic ecosystems, and explain the differences and similarities from place to place, globally.

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. Near vents, temperatures can be high, oxygen is scarce and chemo- rather than photo-synthesis feeds the life. Vents were first discovered along the Galapagos Rift in the eastern Pacific, and chemosynthetic-based fauna at cold seeps first along the base of the Florida Escarpment. Vents are now known along all active mid ocean ridges and back-arc spreading centers. Cold seeps occur along continental margins. Only a small fraction of the 60 thousand km 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.

Cold seeps occur at both passive and active continental margins, where seepage of cold fluids with high concentrations of methane or sulphide from the underlying sediments support chemosynthetic life. Accumulations of sunken wood and organic matter as well as areas of low oxygen intersecting with continental margins or seamounts also create highly reduced habitats where chemosynthetic-based communities develop.

Our 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 2003. In January 2003, the ChEss steering committee of scientists from five European, one Asian, one South American, and two North American nations convened at the Scripps Institution of Oceanography (USA). They phrased the scientific questions whose answer would explain the biogeography of deep-water chemosynthetic ecosystems. A key outcome was a hierarchy of targets. A first priority was the Equatorial Atlantic Belt and the SE Pacific region. Subsequently

(June 2003), a region around New Zealand was chosen as a third area. A still further suite of targets was identified where important national or international interests exist. Figure 11 locates the ChEss targets. ChEss has established close cooperation with other ocean science programs that will cruise to sites of vents and seeps and thus makes research and exploration affordable. The ChEss office is at the Southampton Oceanography Center (UK).

During 2003-9. To explore the targets, cruises in the Equatorial Atlantic Belt will be:

•Costa Rica – Germany – ROV
•Gulf of Mexico – US (Alvin, Johnson Sea-Link) 2003; GEOMAR 2005
•Mid-Cayman Rise – UK – ROV, 2004
•Barbados Prism/Dominica – Germany - 2005
•Amazon Fan – Brazil (Petrobras); ODP Leg 155
•Mid-Atlantic Ridge, 0-15°N – Germany – ROV – 2004/05
•Mid-Atlantic Ridge, 5-15°S – UK/US – TOBI/BRIDGET/ABE - 2005
•Gulf of Guinea – France - Nautile, 2004/05; Germany - ROV, 2005

Planned cruises to other targets are: SE Pacific, New Zealand, Gakkel Ridge, Norwegian-Greenland Sea Ridges: Mid Atlantic Ridge, Azores-Iceland, Continental margin off central Brazil, Bransfield Straight/East Scotia Ridge, SW and Central Indian Indian Ridges.
During its life, ChEss will discover new vents and seeps. It will optimize methods for location, mapping and sampling of vent and seep ecosystems. Standard protocols for sampling, preserving and archiving biological samples will permit morphological, biochemical and molecular analyses for assessing marine life in the oxygen-poor habitats of vents and seeps. ChEss will build a central, web-based database for vent and seep species accessible through OBIS.

ChEss will advance explanation by modeling the distribution, diversity and abundance of vent and seep species and testing them across the global span of chemosynthetic ecosystems its explorations will reach.

In 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 and known species diversity, distribution, and abundance into the accessible OBIS. Beyond these contributions, ChESS will bequeath its example and methods for effective international assessment and explanation of marine life in a peculiar realm.

Global Seamounts (tentative)
http://seamounts.sdsc.edu/

Goal. To synthesize existing biodiversity knowledge and direct future field efforts towards a comparative ecology of seamounts, categorizing communities and/or 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 12). 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 recently they have attracted a new mammal that is targeting them for fisheries. Recent explorations of seamounts 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 generalizations over the thousands of seamounts. Like islands, they are isolated and a natural laboratory for evolving new species that may spread or remain isolated. 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 2003. The Seamounts Online database provides for data assembly in OBIS, and both commercial and scientific sampling on seamounts globally is rapidly expanding. A global network of seamount researchers defined this project at a KUU workshop in August 2003.

During 2003-9. The leaders of the KUU workshop will report on its outcome at the FAO initiated deep sea Conference in New Zealand in December 2003 and take next steps toward institutionalization, including forming the international leadership team. An early step is to assemble a minimal set of physical information (e.g. gravity anomalies and location) to provide a biologically meaningful description/categorization scheme for seamounts. Factors to consider include physical/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 (with existing or newly gathered data), and using the results to refine community categorizations. Although bringing together fragmented work on seamount ecology and biogeography is necessary, given how few seamounts have been explored, new field research will critically determine better understanding. Therefore, supporting and coordinating existing efforts and developing new fieldprojects will be high priorities for the program. Partnerships need to develop with Mar-Eco and non-CoML programs visiting seamounts.

In 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/or to what extent they serve as stepping-stones for trans-oceanic dispersal.

5. Ice Oceans-Arctic and Antarctic

Arctic Transect (tentative)

Goal. To assemble existing knowledge of biodiversity in the least know ocean, to direct new international explorations using new technology, and to create a framework for understanding and predicting biological changes associated with expected climatic changes in this rapidly disappearing habitat.

Baseline. In the cold and inhospitable oceans near the poles, photosynthesis proceeds. Microscopic algal diatoms 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 14). 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 routes for global trade of introduced species. Without focused research the chalkboard of ancient biodiversity in the Artic Ocean may be wiped clean.

By 2003. An Arctic Biodiversity KUU workshop in April 2003 defined the problems and linked 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 planned Russian workshop in 2004. An international leadership team has formed and is actively working to build the organizational structure and funding base to harness increasing research activity from the many nations that enclose the smallest ocean.

During 2003-9. A tentative plan revolves around an Arctic biological transect emphasizing the Canada Basin.

In 2010. (To be expanded) Provide the "chapter" of the Census on the biogeography of the Arctic.

6. The Microscopic

Global Marine Microbes (tentative)

Goal. Answer key questions about the biodiversity of marine microorganisms: 1)What microorganisms (bacteria, archaea, protists, viruses) are present in a given community, what are they doing and how do they interact? 2) What is the spatial and temporal heterogeneity within communities and niches? 3) How do prokaryotes affect, through symbiosis, higher marine life forms?

Baseline. The distinct technology for exploration of organisms hidden by small size separates the microscopic as a realm encompassing the prokaryotes and protists, minute microbes without complex cells. Microbes make up for their size by their numbers. 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 ready switching of genome fragments among microbes will obscure the time when species and physiology branched. 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 in studying genes, the proteins they encode, and their pathways. Aiming these new techniques at ocean 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 2003. Forty scientists from around the world will meet in a November 2003 KUU workshop to develop a plan for a global Census of Marine Microorganisms. Under the auspices of the Institute for Biological Energy Alternatives, microbial sampling cruises took place this year in the Sargasso Sea and the Gulf of Maine.

During 2003-9. On the one hand, other CoML field projects will be visiting many environments, so one element of strategy may be to sample the microbial environment in many places that CoML or other expeditions go anyway. On the other hand, some environments that might not otherwise be visited may be uniquely interesting for microbes. In this regard, discussions are advanced for expeditions in South American waters in 2004, both in the East Pacific and toward Antarctica.

In 2010. (To be expanded) Provide the "chapter" of the Census on the biogeography of marine microbes.

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

http://fmap.dal.ca/index.php

Goal. A network of scientists to develop models using OBIS data to predict what animals will live in the oceans of the future, examining both fished and unfished species, and climate change, which will both alter marine ecosystems.

Baseline. Marine life past and present interests people intellectually, but practically future marine life is more interesting. We might think practical interest was 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 heighten 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 sub-sampling 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 can systematically modified as work continues. In conjunction with this, synthetic models are needed to 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 2003. FMAP grew out of a workshop held in Canada, June 2002. Representatives of the all major elements of the Census of Marine Life participated in this initial event and continue to contribute as the vision as FMAP evolves into a working program. FMAP has established centers in Iceland (Reykjavik), Japan (Tokyo), and Canada (Halifax) as well as a network of cooperating researchers. FMAP focuses on five themes that will be developed into related but separate component projects. These include 1) Statistical Design, 2) Data Exchange and Model Interface, 3) Model Development, 4) Data Synthesis, and 5) Prediction.

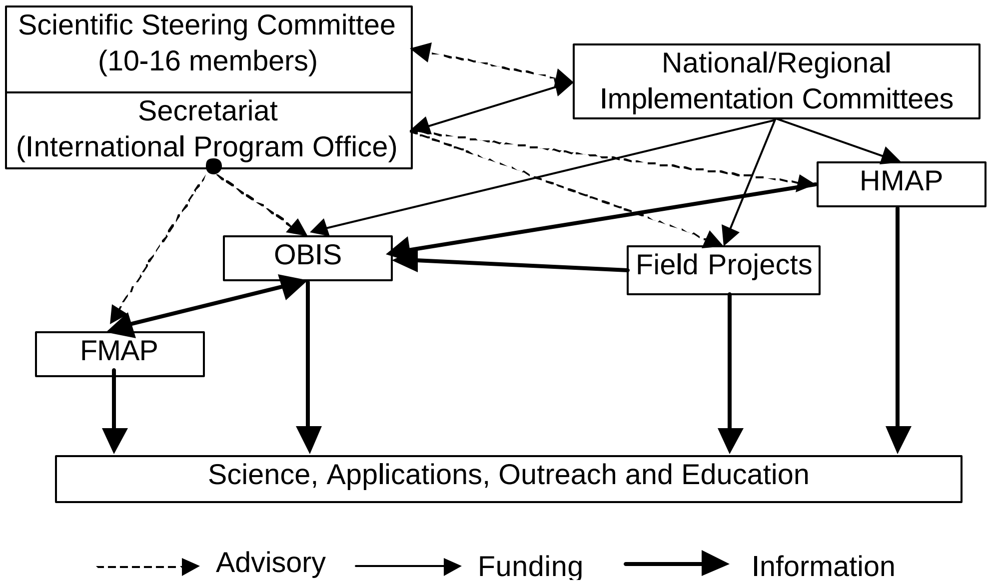
Mining unexploited datasets, FMAP researchers have already provided insight into declines in the population of large marine animals of many species and into diversity of predators in the open ocean.

During 2003-9. 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 it predictions from an expanding database, it will directly demonstrate the commodity value of OBIS. An initial focus FMAP 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 predictions they get. This strategy improves both the funding base and the data base for the Census.

The FMAP team similarly has a vested interest in ensuring that all the 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 focuses on producing products of demonstrable value during the early development of the Census to raise awareness and the estimated billion dollars the Census will cost.

In 2010. Models include statistical estimates of accuracy that help define the limits of knowledge: what is known and how firmly, what is still unknown but knowable, and what is likely to remain unknowable. In addition to contributing its accumulated products, FMAP will make major contributions to the culminating report of the CoML by identifying its limits.

VII. Governance



1. Scientific Steering Committee (SSC)

The CoML developed rapidly guided by its international SSC, which meets thrice yearly in regions where it anticipates important advances. It identifies areas of marine science where improved knowledge of biodiversity is both possible and beneficial. This pragmatic approach has driven its goal of applying the latest tools and techniques to create a quantitative record of biodiversity within a decade on a global scale - a Census. HMAP, OBIS, FMAP and the initial field projects all have independent steering groups, coordinated by Principal Investigators, to decide scientific directions, develop funding and report to the SSC. An Education and Outreach Network stimulates all components of CoML to communicate broadly and aggressively. Current Investigator and Committee leadership is outlined in Appendix 2. The SSC recognized a global Census was possible only if the models for initial projects were adopted by regional interests and initiated a series of National and Regional Implementation Committees. These committees promote the CoML models, both HMAP and field projects, and work to develop collaborations and funding to extend the area covered with standardized approaches. They work integrally with the SSC. National Committees are located in countries with major ocean research capacity. Regional Committees seek to strengthen and support efforts especially where the area of unexplored ocean dramatically exceeds research capacity - most of the Southern Hemisphere. By their nature, OBIS and FMAP are both global in scope. One of the considerations for becoming a CoML project is an agreement to provide and maintain data for OBIS, which will strengthen the links between the SSC, the Secretariat and OBIS. Eventually, OBIS and FMAP will become powerful tools for regional management applications and this functionality should ensure that the legacies from the CoML are maintained.

2. Implementation Committees

CoML National Committees exist in Australia, Canada, Europe, Japan and the USA with a development workshop planned for Russia. Europe has a Regional Committee, as does South America. Processes are underway to develop regional commitees in the Caribbean & Gulf of Mexico, Indian Ocean, Southeast Asia and Sub-Saharan Africa.

VIII. Appendices

1. History

After two years of feasibility workshops involving more than 300 scientists, a group of senior marine scientists from around the world met in June 1999 to form a Scientific Steering Committee (SSC) for the Census of Marine Life. Following a meeting under the aegis of the Intergovernmental Oceanographic Commission in Paris in early 2000, this group agreed that environmental change and increasing human access to the oceans made a baseline or census of present marine life, especially its biodiversity, critical as a baseline to measure future changes. They outlined three essentials to create the first Census as a new approach to marine biological research: 1) assemble existing data in an internet-accessible information system, 2) exploit the most current technologies in field studies for discovery new complementary to species-level, geo-referenced information and 3) develop analytical tools to allow the information system to be queried to generate and test hypotheses.

The SSC first initiated a project called the History of Marine Animal Populations (HMAP) to assemble data on marine organisms before the era of modern fisheries management. Historians, anthropologists, and biologists formed an international consortium to ‘rescue’ historical records of distribution and abundance. This rescued history is creating a new baseline of ocean life as it existed before major human impacts and providing a historical context for new information. At the same time, the SSC established the Ocean Biogeographic Information System (OBIS) to host a massive global network of interoperable databases. This internet-based, distributed system is able to access species-level maps of the distribution and abundance of living organisms and superimpose them on the chemical and physical characteristics of their ocean environments.

The SSC next encouraged a series of field projects to demonstrate new quantitative approaches for sampling a full spectrum of life in major ocean habitats. Typically these began with workshops to explore what was know, unknown, and unknowable with current technology in an ocean realm. Realms were defined in terms of the technology required to explore them rather than geographically, ecologically or biologically. At these workshops the known was cataloged for entry into OBIS, leaders in their disciplines agreed that certain aspects were beyond knowing in a timely manner with present technology, and they recommended efficient approaches to the knowable. Seven field projects are now underway, demonstrating global and have achieving levels of globalization. Four additional Known, Unknown, Unknowable (KUU) workshops have met and established teams of scientists to tackle additional realms or zones.

The observations from these projects are being assembled in, and made available through, OBIS. Historical information, fisheries surveys and new, biologically comprehensive observations assembled in OBIS are being used to test new analytical tools able to integrate long time-series with broad spatial coverage to improve projections of species and ecosystem responses to change. The project developing these tools is called the Future of Marine Animal Populations (FMAP).

2. CoML Project Criteria Guidelines

Below is a list of general characteristics, which the Scientific Steering Committee has agreed would contribute to their recommending a new project for inclusion in the CoML. They are in no particular order. No project is likely to meet all criteria, but appropriate projects will meet many of them.

1. Potential to change present perspectives
2. Known, unknown, unknowable context
3. At least regional in scope
4. Novel technologies or applications
5. Opportunities for discovery of new taxa
6. Focus on species distributions
7. Education and capacity building
8. Complements existing projects
9. Contribute to 2010 report
10. Data available through OBIS

Examples of systems in need of study:

1. Unique or extreme habitats such as gas hydrates, canyons, anchyhaline caves
2. Deep ocean systems, especially in the Indo-Pacific
3. Open ocean water column
4. High-velocity currents and upwelling
5. Sea floor sedimentary structures
6. Coral reefs on a regional-scale and at depth
7. Large-scale microbial distribution patterns

3. Agreement for Affiliation

As an alternative to developing new projects, the SSC will affiliate with and help to expand existing projects to a global scale under the following rules, first applied to the CeDAMar project described below.

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, websites 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. shiptime, technology and 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. shiptime, technology and equipment).

4. Project and Committee Leaders

International Scientific Steering Committee

J. Frederick Grassle (Chair), Rutgers University, USA
Vera Alexander, University of Alaska Fairbanks, USA
D. James Baker, Academy of Natural Sciences, USA
Patricio Bernal, Intergovernmental Oceanographic Commission, France/Chile
Donald Boesch, University of Maryland, USA
David Farmer, Institute for Ocean Sciences, Canada, & University of Rhode Island, USA
Victor Ariel Gallardo, University of Concepcion, Chile
Carlo Heip, Netherlands Institute of Ecology, Netherlands
Poul Holm, Southern Denmark University, Denmark
Olav Rune Godoe, Institute of Marine Research, Norway
Ian Poiner, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
Yoshihisa Shirayama, Seto Marine Biological Laboratory, Japan
Meryl Williams, WorldFish Center, Malaysia

Implementation Committees

Australia, Max Kitchell (Chair), National Oceans Office, Australia
Canada, Kees Zwanenburg (Chair), Bedford Institute of Oceanography, Canada
Caribbean (forming), Eduardo Klein, Universidad Simon Bolivar, Venezuela
Europe, Ulf Lie (Chair), University of Bergen, Norway
Japan, Yoshihisa Shirayama (Chair), Seto Marine Biological Laboratory, Japan
Indian Ocean (forming), Mohideen Wafar, National Institute of Oceanography, India
Russia (forming), Andrey Gebruk, P.P. Shirshov Institute of Oceanology, Russia
South America, Ruben Escribano (Chair), Universidad de Concepcion, Chile
Sub-Saharan African (forming), Charles Griffiths, University of Cape Town, South Africa
USA, Daphne Fautin, Kansas University Natural History Museum, USA

Ocean Biogeographic Information System (OBIS)
Mark Costello, Huntsman Marine Science Centre, Canada

History of Marine Animal Populations (HMAP)
Poul Holm, Southern Denmark University, Denmark (Chair)
David Starkey, University of Hull, England
Andrew Rosenberg, University of New Hampshire

Future of Marine Animal Populations (FMAP)
Ransom (RAM) Myers, Dalhousie University, Canada (Chair)
Hiroyuki Matsuda, University of Tokyo
Gunnar Steffansson, Marine Research Institute of Iceland

Education and Outreach Network
Sara Hickox, U. Rhode Island, USA

Ocean Realm Field Projects (chairs or conveners)

Natural Geography In Shore Areas (NaGISA)

Yoshihisa Shirayama, Seto Marine Biological Laboratory, Japan
Brenda Konar, University of Alaska, Fairbanks, USA

Coral Reefs

Terry Hughes, James Cook University, Australia (convener)

Gulf of Maine Ecosystem (GoMe)

Evan Richert and Lewis Incze, University of Southern Maine, USA

Pacific Ocean Shelf Tracking (POST)

David Welch, Department of Fisheries and Oceans, Canada

Margins, Canyons and Trenches

Dave Billett, Southampton Oceanography Centre, UK (co-convener)
Miriam Sibuet, IFREMER, Brest, France (co-convener)

Census of Diversity of Abyssal Marine Life (CeDAMar)

Pedro Martinez Arbizu, German Center for Marine Biodiversity Research, Germany

Global Plankton

Ann Bucklin, University of New Hampshire, USA (convener)

Tagging of Pacific Pelagics (TOPP)

Barbara Block, Stanford University Hopkins Marine Station, USA
Dan Costa, University of California, Santa Cruz, USA

Mid-Atlantic Ridge Ecosystem (MAR-ECO)

Odd Aksel Bergstad, Institute of Marine Research, Norway

Biogeography of Chemosynthetic Ecosystems (ChEss)

Paul Tyler, Chris German, Eva Ramirez-Llodra, Southampton Oceanography Centre, UK

Global Seamounts

Karen Stocks, San Diego Supercomputer Center, USA (convener)

Arctic Transect

Russell Hopcroft, University of Alaska, Fairbanks, USA (convener)

Global Microbes

Mitch Sogin, Marine Biological Laboratory, USA (convener)

Figure 1. History of Marine Animal Populations. Current Projects: Caribbean Sea, East Australian Shelf , North West Atlantic, White and Barents Sea, North Sea and Baltic, South West Africa, World Whaling. New 2003 Projects: Mediterranean, New Zealand, South East Asia, North Pacific, Black Sea.

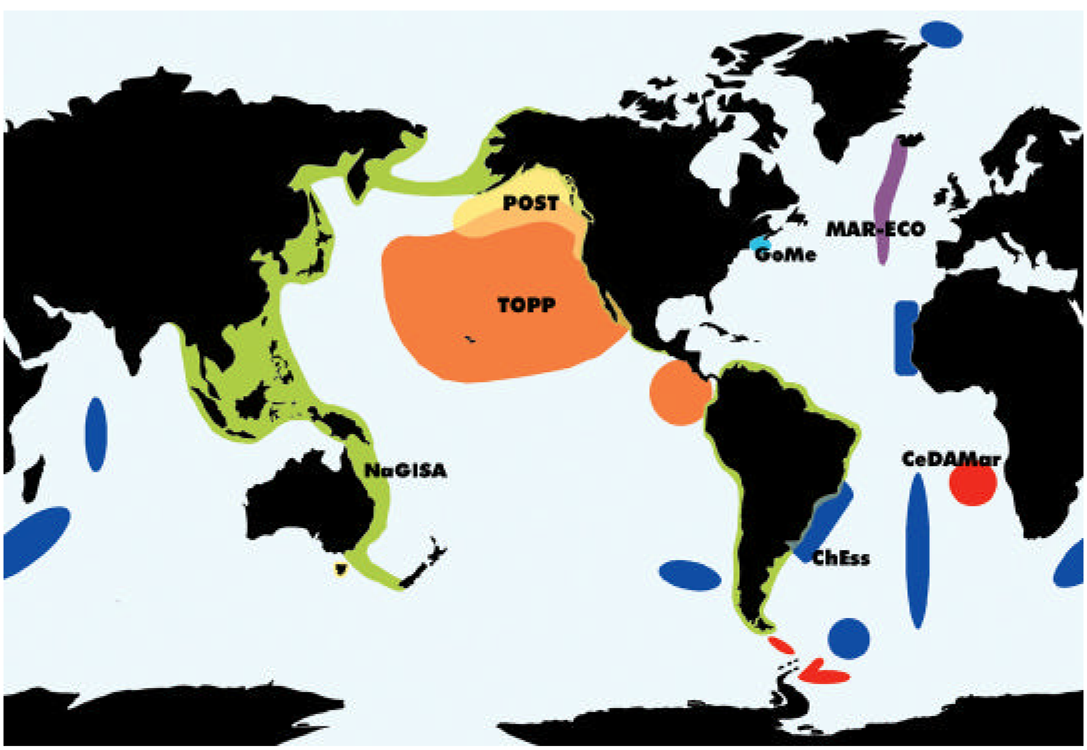


Figure 2. Global reach of the seven CoML initial field projects in 2003.

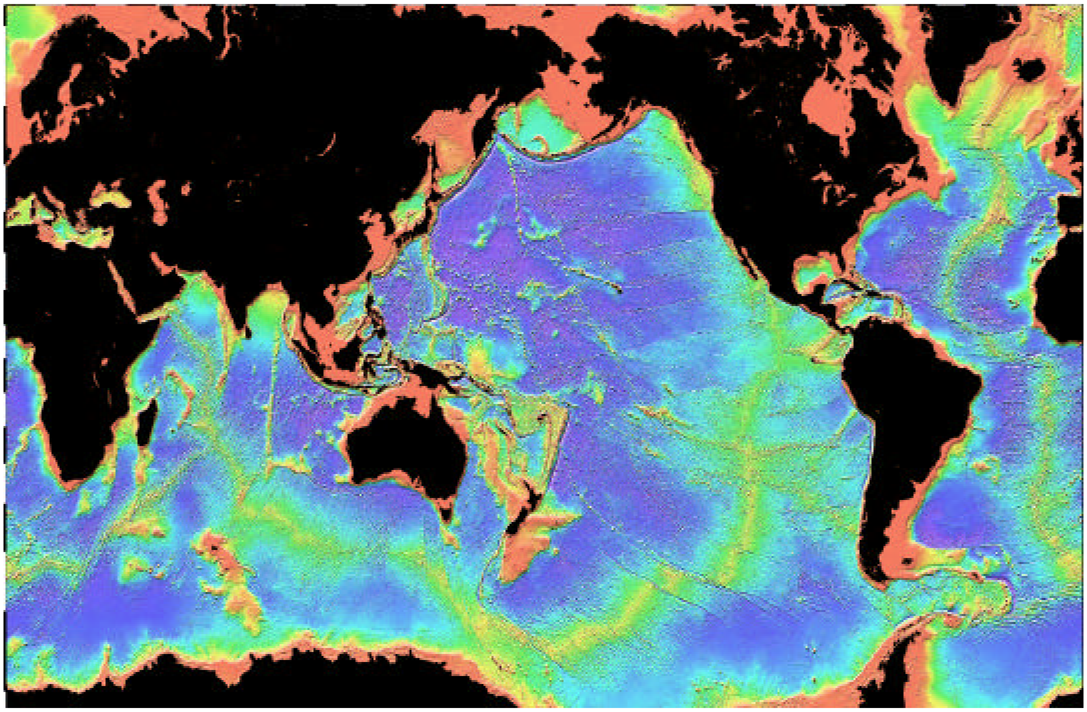


Figure 3. The ocean is not flat and simple as figure above suggests. Below the surface, waters reach 300m on the pink continental shelves, then dive down continental margins to11,000 m in trenches below the blue abyssal plains. Ranges of underwater mountains in yellow ring the globe rising thousands of meters above the average 4,000 m plain. CoML projects are organized around the realms created by this complex geography and the currents flowing over it as shown in Figure 3.

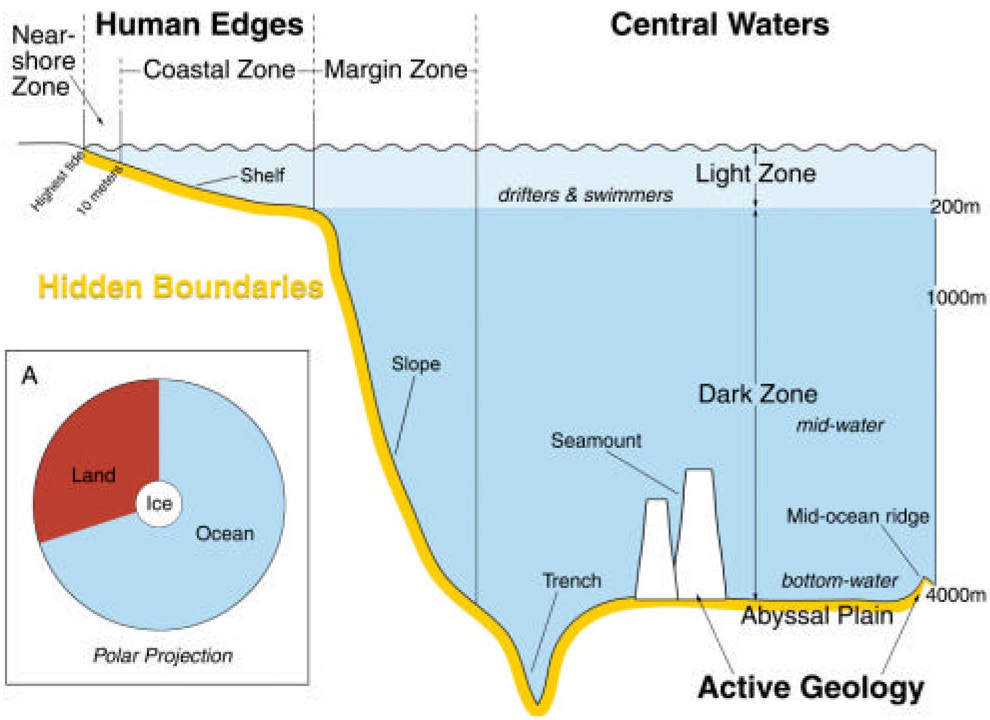


Figure 4. Vertical section of the ocean defining 'realms' and 'zones' distinguished by the difficulty and technology of their exploration. Field projects are grouped to show similarities in approach and challenge.

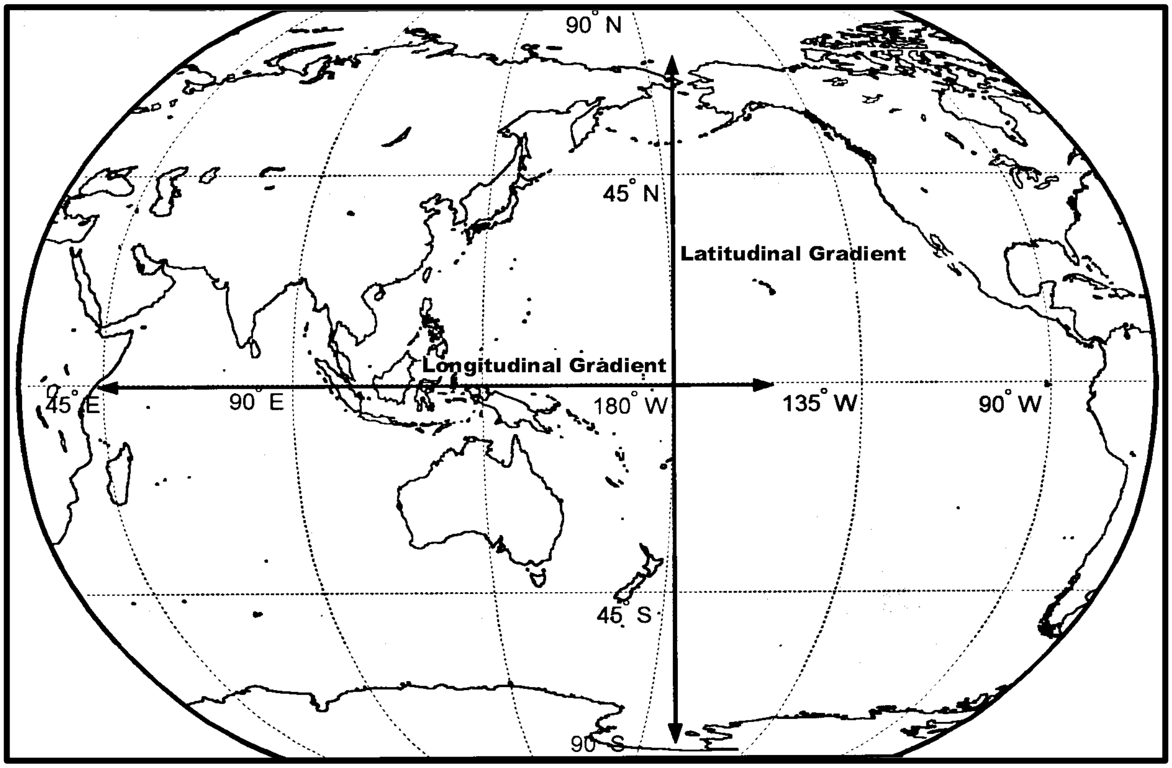


Figure 5. NaGISA will compare biodiversity on identical transects every 300 km along 15,000 km latitudinal and longitudinal gradients in the Pacific and Indian Oceans. A Figure 1 shows the concept is also being adopted in the Atlantic.

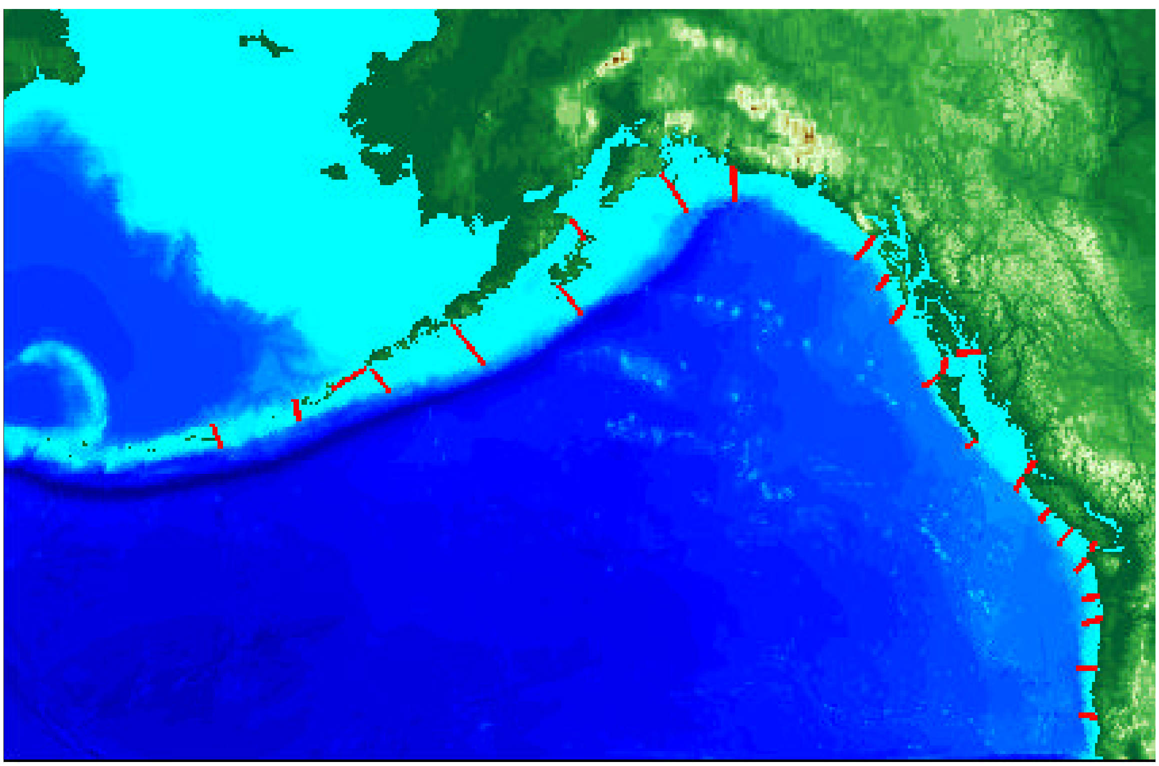
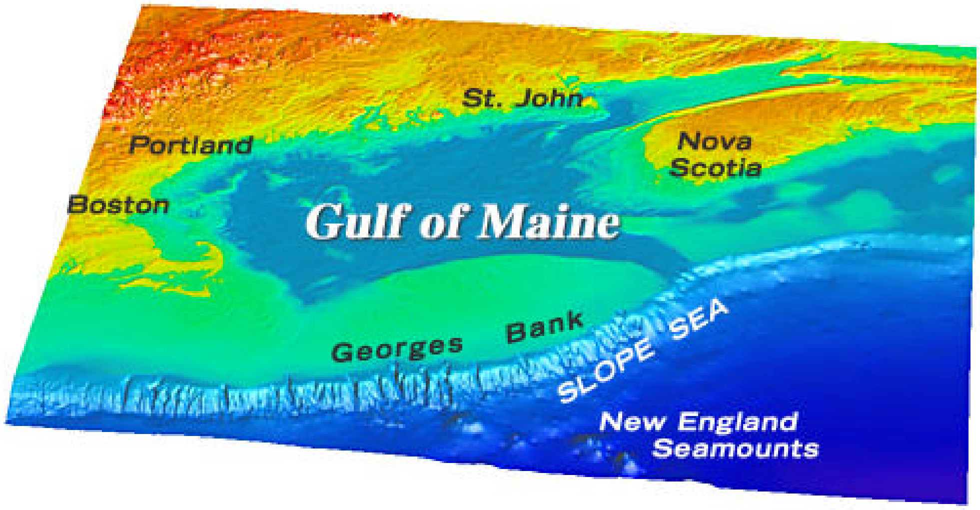


Figure 6. The Pacific Ocean Shelf Tracking project will test a tracking array concept that could reveal migration patterns on narrow shelves globally (Figure 2). Wide shelves are harder, but still possible.



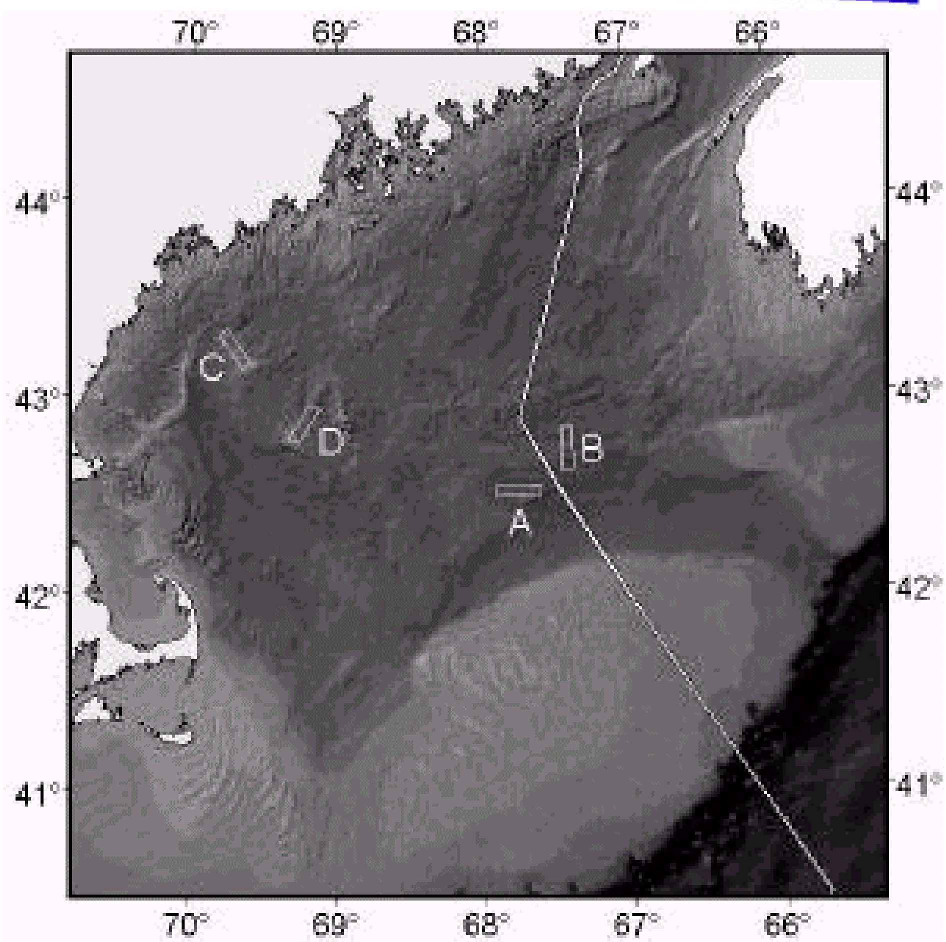


Figure 7. A. The Gulf of Maine project (GoMe) integrates all aspects of biodiversity from the world's highest tides in the Bay of Fundy to the Gulf Stream breaking around the New England Seamounts. B. A program to create high resolution benthic maps of the area will allow areal extrapolation of detailed sampling sites.

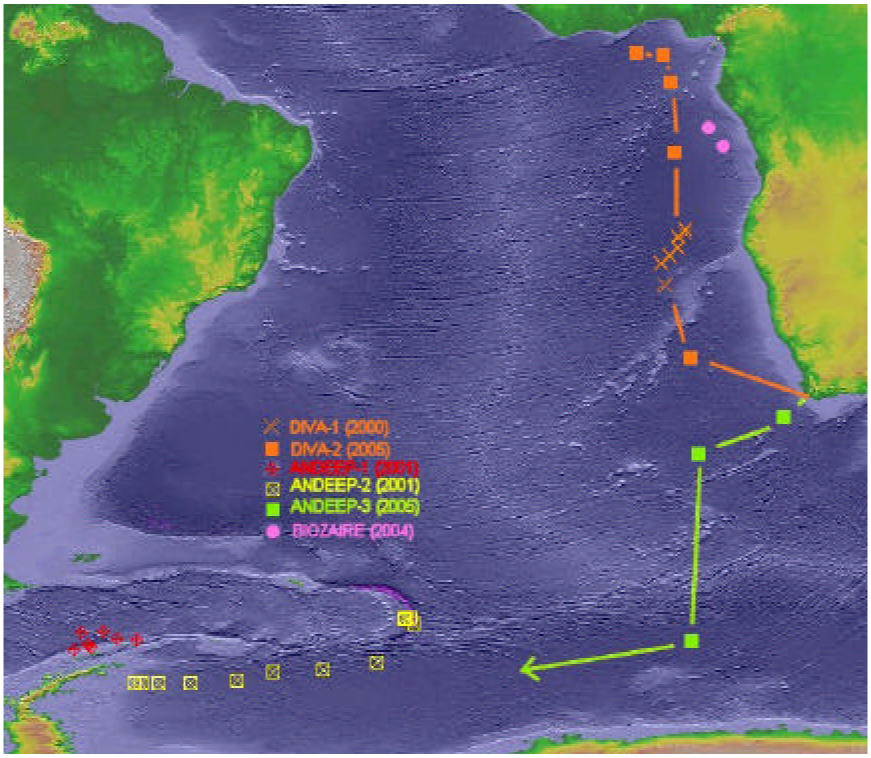


Figure 8. CeDAMar will develop latitudinal biodiversity gradients for the abyssal plains comparable to the nearshore gradients from NaGISA.

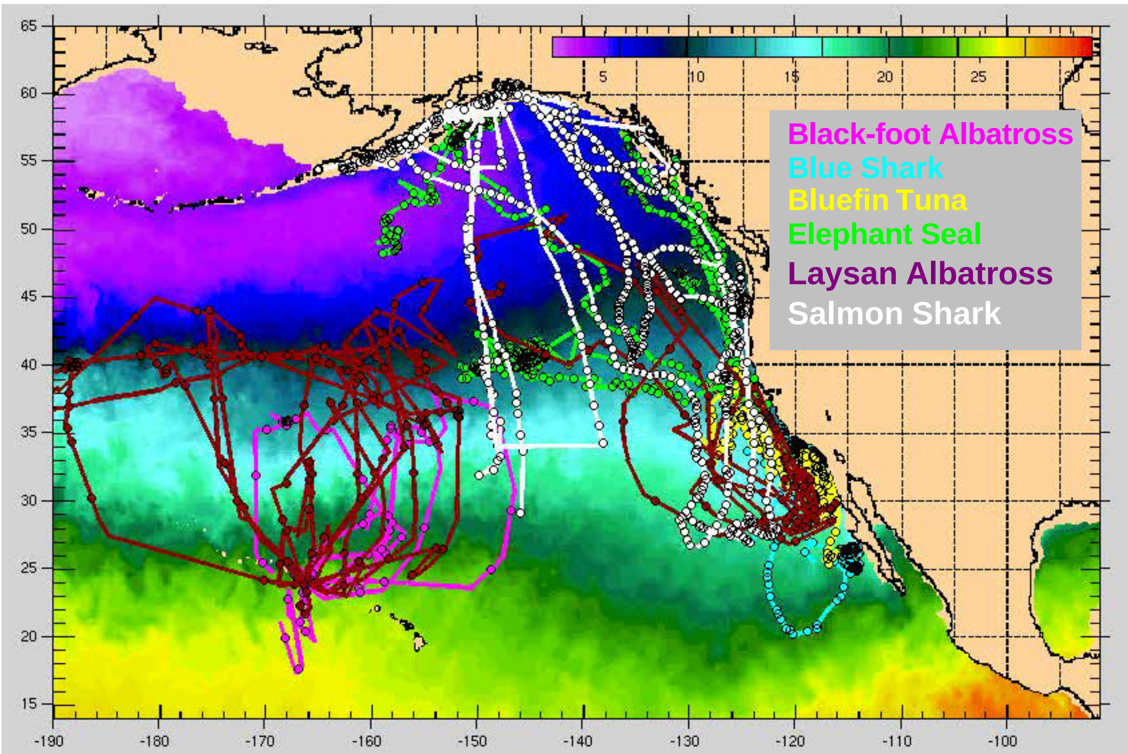


Figure 9. Six species are already reporting their travels and the ocean conditions over vast areas of the North Pacific as it changes over the seasons.

Figure 10. MAR-ECO samples the entire water column from plankton on the surface to the epi-benthos just above bottom, but expects its greatest discoveries in the vast poorly explored mid-water layers. It tests its technologies on the mid-Atlantic Ridge where underwater mountain ranges interrupt current flows creating a food rich environment 3 to 4 km below the surface, but the same technologies could be applied to any of the ridge systems outlined in Figures 1 and 9 as well. In fact, they would work anywhere in the deep ocean.

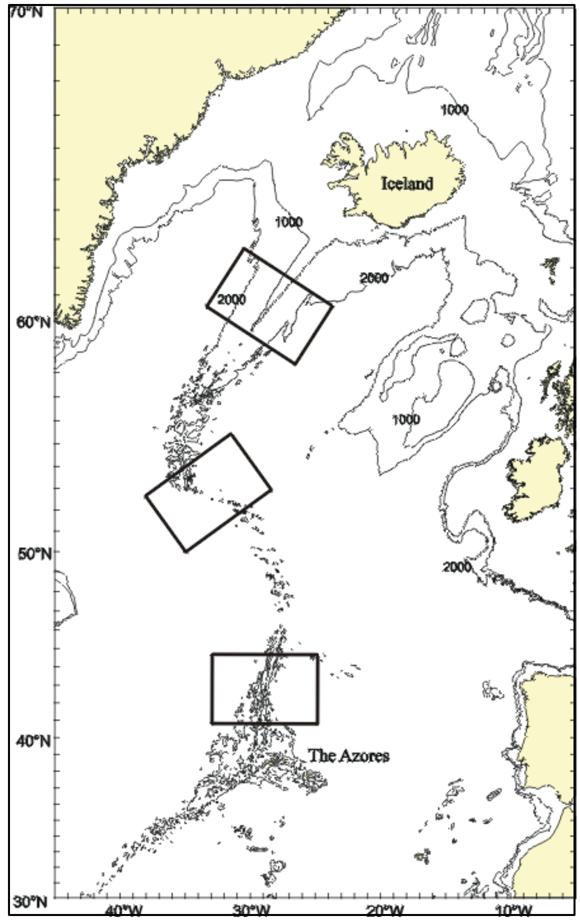
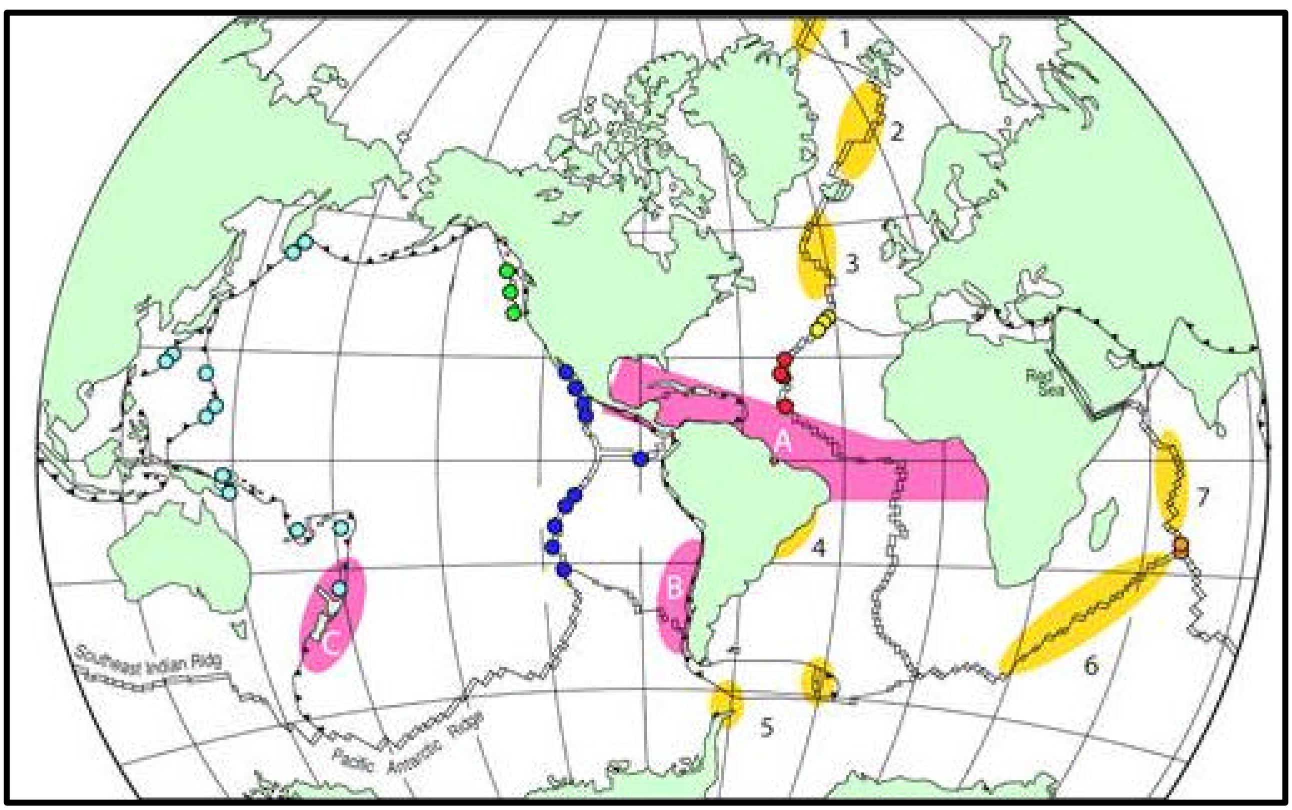


Figure 11. The deep-sea vents studied by ChEss create unique ecosystems fed by chemicals dissolving from spreading zones at the center of the ocean ridges marked below. Similar ecosystems also exist in shallower areas around continental margins where ground water and methane seep out it supply food for bacteria at the bottom of these food chains. The question of how species develop at and spread between these isolated habitat require a strong genetic component. Only 43 out of more than 5,000 have been sampled biologically.



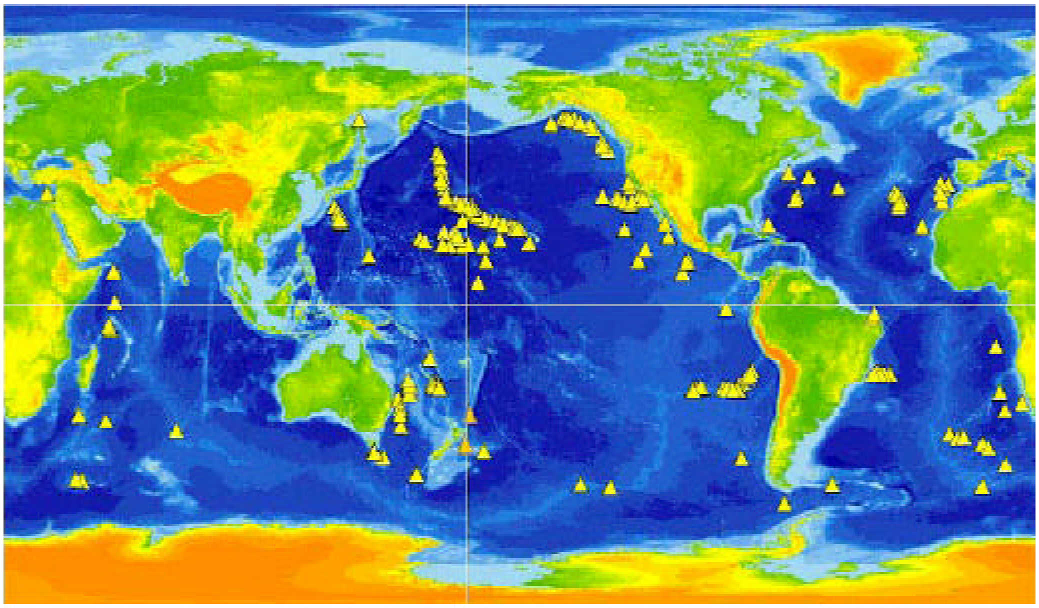


Figure 12. Seamounts are ghost volcanoes and like ridges and vents are isolated products of active geology with much richer ecosystems than surrounding water. Only 220 (yellow triangles) out of more than 30,000 have been sampled scientifically.

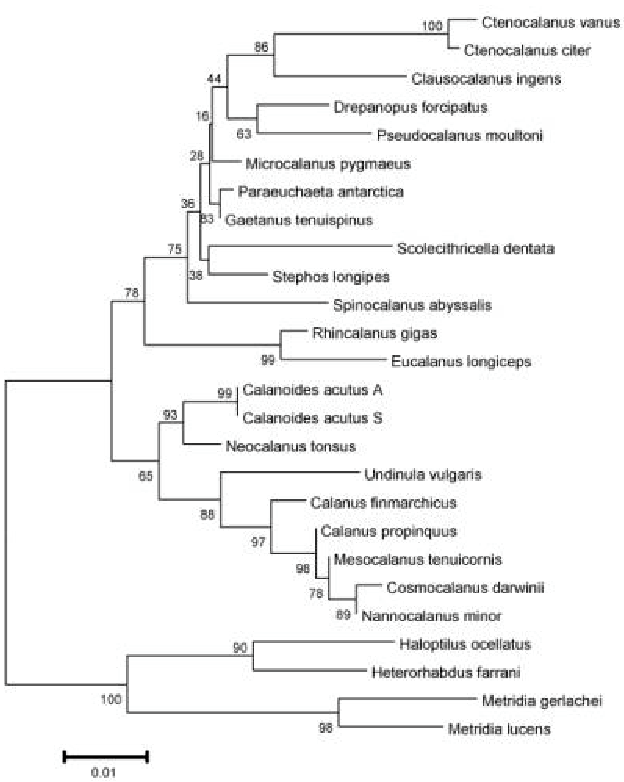


Figure 13. Plankton like these calanoid copepods, perhaps the genus with the highest biomass on earth, are everywhere, but only genetic maps can tell us how different or closely related they really are

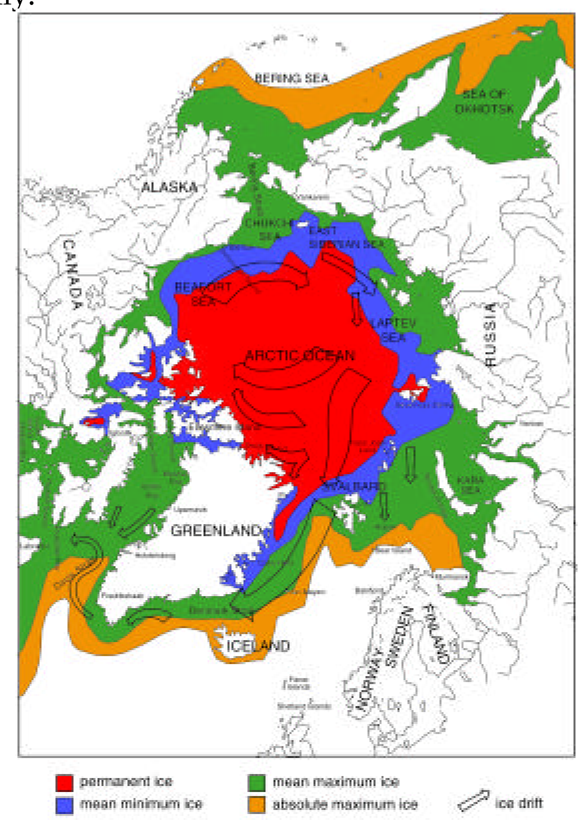


Figure 14. The Arctic is the smallest, least known ocean with all the living systems of the others, plus a solid 'lid' of ice on top with its own ecosystem. Special technologies are required for every study in this realm.

The Census of Marine Life (CoML) is a global network of researchers in more than 50 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.

The Unknown Ocean: Research Plan of the Census of Marine Life

2003

CENSUS OF MARINE LIFE

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