The Future of Marine Animal Populations (FMAP)

Data synthesis and prediction of future marine populations and communities for the Census of Marine Life

On Behalf of the FMAP Network: Ransom A. Myers, Killam Chair of Ocean Studies
Department of Biology, Dalhousie University
Halifax, Nova Scotia, Canada B3H 4J1

Summary

The Future of Marine Animal Populations (FMAP) is the new modeling component of the Census of Marine Life. It is a network of statisticians and mathematical modelers that will ultimately address the third question of CoML, "What will live in the oceans?" However, the network will contribute to CoML in several key ways besides prediction, including exploration of the limits of knowledge in the past, present, and future.

During the past two years, FMAP has added to existing CoML expertise by creating a network of top ecological modelers, balanced internationally and in terms of schools of thought. This network consists of three FMAP Centers, in Iceland, Tokyo, and Nova Scotia. The Nova Scotia Center has overall managerial responsibility for FMAP. During 2003-2004, FMAP provided feedback on the design of present Census field projects to help refine and coordinate them. This was done by attending project meetings for the TOPP, CenSEAM, CMarZ, and SEAMAP groups and advising them on how best to design field plans and management for efficient and effective analysis. FMAP has also aligned itself with the OBIS project and has provided expertise on database design and data input for CoML.

In the upcoming three years, members of the FMAP network will begin to use existing and new datasets arising from the Census, publishing methods and maps that will be made available through OBIS. This will be done by partnering members of each node with a particular CoML project to produce maps and models of global diversity that will be completed by 2007. Between 2007 and 2010, these maps of diversity will be overlaid and analyzed to produce a multi-trophic understanding of worldwide biodiversity and abundance, as well as the factors that drive it. This compilation will include projections, under a multiple possible climatic and fisheries scenarios, for the future of marine life.

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Contents

1. Introduction: Modeling as an Integral Part of CoML

The Census of Marine Life (CoML) initiative is an international research program aimed at assessing and explaining the diversity, distribution and abundance of marine organisms throughout the world's oceans. This ambitious overall goal is to be reached by stimulating well-coordinated, dedicated, regional research efforts based on initial projects that demonstrate efficient methods to census ocean habitats. Together these will provide significant new information on patterns and processes of marine life on a global scale. Modeling is crucial for the cost effective collection of data, formulation of testable hypotheses, synthesis of data, and prediction of the future. It is important that modeling and analysis be integrated into research from the beginning so that the initial sampling is done in an optimal manner and so that design can be modified as field work continues, based upon modeling that is simultaneous with data collection. Modeling cannot wait until fieldwork is finished.

Three questions encapsulate the CoML: What did live in the oceans? What does live in the oceans? What will live in the oceans? The Future of Marine Animal Populations (FMAP) adds to the critical modeling and analysis components of all three aspects of CoML - past, present, and future. Models are needed to interpret and design sub-sampling of historical data. Statistical design provides for optimal and cost effective data collection and interpretation. Synthetic, meta-analytic models are needed to combine and understand the data collected. Finally, models effective for synthesis have potential for prediction. The best test of a model's ability to predict the future is its ability to predict the past. Thus, early and extensive efforts to develop collaborations with the existing CoML elements are essential to FMAP's success. New HMAP information about historical oceans is a critical link between current field censuses and future prediction. Moreover, modeling can 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. Thus, FMAP will make major contributions to the culminating report of the CoML in 2010.

FMAP grew out of a workshop held in Halifax, Nova Scotia (Canada) in June 2002. Representatives of all the major elements of the Census - its program on the History of Marine Animal Populations (HMAP), its initial field projects, and its data assimilation framework (the Ocean Biogeographic Information System, OBIS) participated there and subsequently. Already, the FMAP project has produced research that has contributed substantially to our understanding of global pelagic diversity, and the results of this assessment have been published in high impact journals such as *Science*, *Nature*, and *Ecology*.

2. Themes

FMAP focuses on 5 themes: Design, Data Exchange and Model Interface, Model Development, Data Synthesis, and Prediction.

a) Statistical Design for the CoML.

b) Data Exchange and Model Interface.

c) Model Development and Sharing.

d) Data Synthesis.

e) Prediction.

Theme Projects and Approaches

A. Statistical Design for CoML

The Census of Marine Life (CoML) seeks to document the past, present and future of marine life. The development and refinement of statistical tools for data calibration, spatial analysis and scenario development involved in FMAP will be useful to and will benefit from exchange with the CoML's *History of Marine Animal Populations* (HMAP), TOPP, CenSEAM, SEAMarZ etc etc.

As part of this effort, FMAP will host a workshop in the winter of 2006 to help other CoML projects develop and utilize statistical modeling methods to deal with the challenges of analysis for marine census data. A common theme amongst a variety of fisheries data sets and other incidentally-gathered information is a lack of confidence in zeros reported in datasets. The FMAP team has and continues to develop original means of dealing with this problem and proposes to host a workshop devoted to sharing these techniques with the rest of the CoML team.

B. Data Exchange and Model Interface

The FMAP project will draw upon a multitude of data sources to develop its global analysis. By establishing links with several CoML projects over the past two years we have provided advice regarding sampling programs to enhance the statistical rigour of their data analysis, advised them on how to link their data to the OBIS database, and assist in statistical modeling techniques.

FMAP will continue to liaise with the following CoML projects:

Gulf of Maine

FMAP is working with Dr. Andy Cooper and Andy Rosenberg (Univ. of New Hampshire) to examine the existing invertebrate and fish survey data, collected over varying temporal and spatial scales, contained in the National Marine Fisheries Service Northeast Fisheries Science Center (NMFS-NEFSC) / Department of Fisheries and Oceans, Canada (DFO) combined database for the Gulf of Maine. This project was initiated in the spring of 2004. The final product will be a quantitative description of the data and a discussion of how it may be applied to assessing changes in biodiversity and community structure for the Gulf of Maine ecosystem.

CenSeam

CenSeam aims to conduct a representative sampling of the world's seamounts as well as a comprehensive synthesis of seamount data. Given the large number of seamounts in the oceans, comprehensive sampling is not possible. Thus FMAP is assisting CenSeam by developing a statistically rigorous sampling procedure that will fill critical knowledge gaps and target understudied regions and types of seamounts. Derek Tittensor is performing this work as part of his Ph.D. thesis.

Many countries and institutions have active or planned seamount research programs. FMAP can assist efforts to expand and coordinate these activities through research on methods of data compatibility and exchange. Much of the existing information on seamounts is functionally inaccessible, being distributed in many print sources and institutional holdings, yet it represents decades of research and millions of dollars of work. FMAP will develop methods that access this data and analyze it for emergent patterns. These goals were initiated during a meeting in Woods Hole in September 2004. FMAP will ….**Derek??/**

Tagging of Pacific Pelagics

The Tagging of Pacific Pelagics (TOPP) research program applies new technologies to obtain an understanding of the environmental basis for the movements and behaviors of large pelagic animals in the North Pacific. Movement is an important component of most animals' life history; it defines the scales at which animals interact with their environment and can have strong influence on other demographic rates. FMAP is working to provide methods and models for working with this type of data. Our work provides a more powerful and coherent statistical framework for analysis of animal trajectory data than was previously available to ecologists. The framework allows behavior to be inferred directly from multiple animal trajectories, while accounting for both process and estimation uncertainty. This method has great potential for understanding how different marine animals interact with their environments. This knowledge is crucial for the design of effect conservation and management plans for marine species.

This aspect of FMAP has proved to be extremely successful and produced innovative results, including an upcoming paper to be published in the journal *Ecology* (see Figure 2) on NNN.

The following people are involved with this project:

> Greg Breed (PhD. Candidate) will probably work directly with TOPP, i.e. Costa.
> Mike James (Post-Doctoral Fellow) who is tracking and modeling the movement of endangered leatherback turtles.
> Mike Stokesbury (PhD. Candidate) is working with Barbara Block on TOPP related data.
> Drs. Joanna Mills Flemming (Switzerland), Ian Jonsen (Department of Biology, Dalhousie University), and Chris Field (Department of Mathematics and Statistics, Dalhousie University) are developing models.

FMAP members will be participating in the TOPP meeting in California in the fall of 2005. We will also be using data gathered on the movement of seals, Greenland sharks, and leatherback turtles to develop statistical techniques that will be applicable to modeling the movement of a variety of pelagic organisms.

HMAP

In the upcoming three years, Boris Worm and Heike Lotze will strengthen links between the HMAP and FMAP projects by NNNN. They will build on their work with HMAP and incorporate their experience as members of the National Center for Ecological Analysis and Synthesis (NCEAS) to apply successful modeling techniques used for open ocean environments to include finer-scale models for coastal regions. FMAP will also complete writing a statistical guide for methods reconstruction. It is hoped that this will improve the ability of HMAP to produce quantitative estimates of population history.

SEAMAP

FMAP, in collaboration with SEAMAP, has developed data standard for abundance data (with standard errors and confidence limits). Spatial models have been developed to test hypotheses for the decline of the sea turtle and sealion data. PhD student Dan Kehler, Ransom Myers, and Terry Quinn of the University of Alaska have completed this analysis and will publish the results of their analysis in 2005-2006. SEAMAP will also input the results of this work in into OBIS database.

Some of the sources of data we are currently using or plan to tap into include:

- *The Pew Global Shark Assessment:* This ongoing program will provide us with many of the input datasets for sharks.
- *Larry Madin's Database of Zooplankton Data.* PhD candidate Andrea Ottensmeyer, Honours student Beth Sampson, and Ransom Myers have begun to utilize the unique dataset provided by Larry Madin and his colleagues to produce the first global maps of zooplankton. FMAP will use this data to develop mathematical models of the distribution of zooplankton species (resolved to the level of Phyla and season). Developed in collaboration with the CoML's CMarZ project, these techniques will be an essential component for furthering our understanding of the factors that drive zooplankton distribution and abundance and to predict future trends under various climatic and ecological scenarios.
- *The REEF Fish Survey Project* – Ph.D. candidate Christine Ward-Paige and Ransom Myers have begun to work with the Reef Environmental Education Foundation's (*REEF)* excellent fish survey data to determine changes in abundance and distribution of reef fishes.
- *Conservation International/IUCN Global Marine Species Assessment*: Still in preliminary stages, this joint Conservation International-IUCN program hopes to assess the status of a number of marine fish and coral species. Calibrated data and spatial analyses generated by FMAP will inform and complement these efforts.
- *The Sea Around Us Project, University of British Columbia (UBC):* Outputs from this UBC-based initiative, such as a global map of fishing effort, will be useful to our spatial analyses. In turn, we can assist the Sea Around Us Project by providing it the carefully calibrated abundance data we will be compiling for our own purposes. Solid time series of abundance data are needed if EcoSim models-a crucial component of the Sea Around Us Project-are to provide reliable results (Daniel Pauly, personal communication).
- *The Wildlife Conservation Society's Human Footprint:* In a program run by Caterina D'Agrosa and Eric Sanderson, WCS is extending its "human footprint" analysis from terrestrial environments to the oceans. The project is scheduled for completion in April 2005. Its outputs are expected to be useful, but will present only a coarse picture of the state of the oceans. Key products, such as spatial estimates of coastal human population density, could be incorporated into our spatial models. In turn, FMAP will yield analyses that may improve future updates of WCS' human footprint program.
- *The Nature Conservancy's Global Marine Initiative:* This program, led by Lynne Hale, tackles four goals: (1) setting priorities for marine conservation via the delineation of ecoregions; (2) ensuring resilience of coral reef conservation programs in the face of both local stresses and global warming; (3) conserving estuarine and other coastal habitats by acquisition of submerged lands and habitat restoration; and (4) policy development. Analyses of the past, current and possible future ranges of marine organisms produced by FMAP should benefit both ecoregion delineations and the development of strategies to safeguard the long-term viability of protected coral reefs and other marine reserves.

- *World Resources Institute Reefs at Risk Program:* The World Resources Institute is creating maps of the potential threats to coral reefs. We will have access to their data, and our analyses should feed into the Reefs at Risk Program.
- *The National Center for Ecological Analysis (NCEAS):* Ben Halpern, Fiorenza Micheli and Hunter Lenihan recently initiated an NCEAS working group aimed at Putting Ocean Wilderness on the Map. The project seeks to define, identify, and create an interactive GIS atlas of pristine ocean environments. This atlas will be useful to the spatial analyses we propose, but may also benefit from findings we produce. Ransom Myers, Boris Worm, and Heike Lotze are members of the working group, facilitating efficient collaboration.

C. Develop Modeling Frameworks for CoML

Essentially, the FMAP team will use state of the art modeling techniques to utilize marine survey data, fisheries data, movement data collected from satellite tags, information recorded by divers, and historical records to model marine biodiversity and abundance on a global scale. Understanding where marine organism go and why will help inform conservation efforts and enable us to predict how marine communities will change in the future. Statistical methods we have used to perform these analyses include meta-analysis, Monte Carlo blah blah blah **RAM!!!!**

In collaboration with CenSeaM, FMAP is also working on a theoretical model structure to relate patterns of endemism, species ranges, and the relationship between diversity and area. Such a model will be used to visualize patterns of endemism across multiple ecosystems such as seamounts, reefs, and the open ocean, and be used to assess and predict relative vulnerability. FMAP is also developing robust methods for modeling species-area relationships when sampling is incomplete, an important issue in the marine environment as complete censuses are often impossible, but one which is generally ignored - though it may be an important factor in generating observed patterns.

Models for mapping distribution and abundance.

FMAP will produce analyses and maps that will change the perception of life in the ocean, from large pelagic organisms to zooplankton. FMAP continue to focus on rigorous, quantitative analysis, combining a diversity of datasets through the use of highly specialized data calibration techniques.

Fig. 1. Boris' Science Paper?

Tools to Predict Where CoML Should Sample.

Has this been done and how? RAM?

CenSEam??? Derek

Inferring animal movement and distribution from state-of-the-art tracking devices.

The FMAP team has been extremely successful utilizing state space models to deduce animal location and behavior (Figure 2). The results of this work have resulted in several high impact papers. In the next three years, FMAP will share its expertise with other CoML projects, starting with the TOPP meeting scheduled for next fall in California. We will also be applying our techniques to data produced from satellite tags placed on leather back sea turtles and Greenland sharks in the North Atlantic.

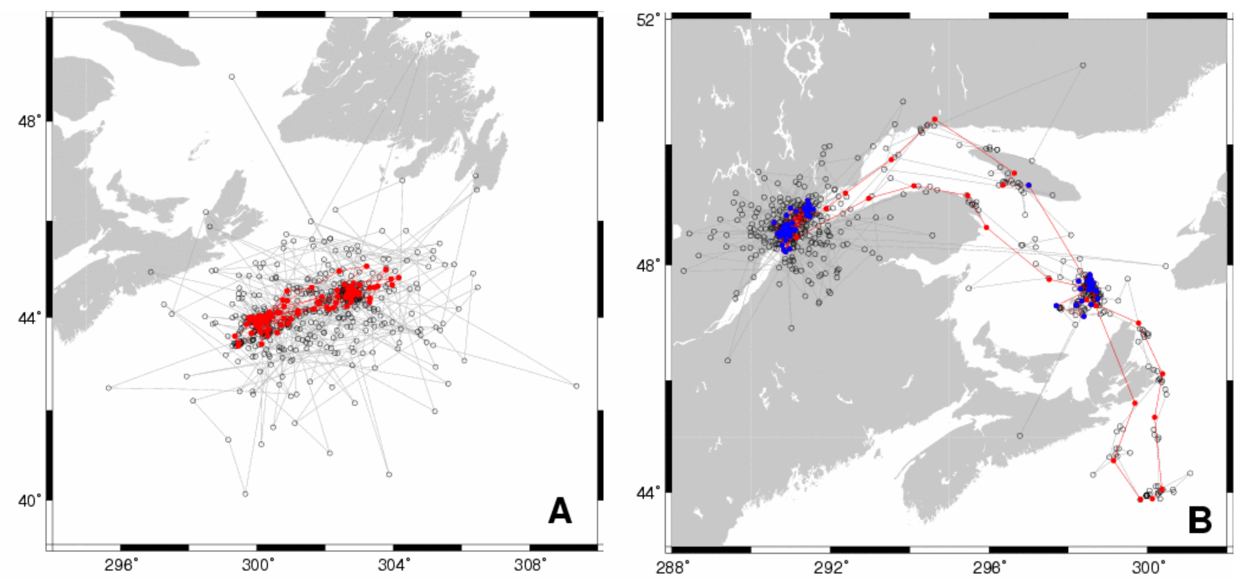

Fig. 2. Demonstration of use of state-space models to determine the location and behavior of grey seals on the East Coast of Canada. The open circles indicate location of the animal estimated from ARGOS tags. A. Model estimates of animal location (red). B. Model estimates of migration (red) and foraging (blue) behavior.

D. Data Synthesis

We are currently investigating the Ocean Biogeography Information System (OBIS) standard as a candidate data format to interface with various FMAP modeling systems. OBIS is part of the larger GBIF initiative (Global Biodiversity Information Facility) and has received considerable interest from the biodiversity research community. The OBIS standard is used to store, retrieve, and share a variety of data of interest to GBIF and we are experimenting with expanding its use for fisheries data. In particular, we are expanding the OBIS standard to better suit statistical time-series where an estimate of the uncertainty is important and to better handle values of zero in the data. The extended OBIS standard (unofficially called OBIS+) will be used both for data storage/retrieval/sharing through OBIS and for model inputs and outputs in FMAP.

Dan R.?

FMAP will also synthesize data from multiple large-scale oceanic longlining surveys to derive species-area relationships for upper-ocean predatory fish at large (basin) scales. Such systems have hitherto been unexamined in terms of the scaling of diversity with area, and this work will facilitate the comparison of diversity-area patterns with regions of comparable size on land (continents, for example), and provide a new tool for assessing the impact of fishing upon these vast environments. In a similar manner, the impacts of coral reef marine protected areas upon fish biodiversity-area relationships are being studied in a field program and meta-analysis. Examining these patterns across multiple marine environments will further extend our knowledge of the impact of exploitation upon marine macro-ecological processes, and extend our predictive capabilities.

E. Develop Predictive Methods for Changes in Biodiversity: Some novel approaches

By documenting changes in species' range sizes and abundance, FMAP will proceed to develop models to predict changes in diversity and abundance as a consequence of fishing and climate change. Prediction of future changes will be based on quantified relationships between past changes and both environmental factors and anthropogenic pressures. It will allow for the exploration of alternative management and policy scenarios, and prognosis of future species extinctions.

Ecological consequences of global fishing.

The FMAP team has documented drastic declines (75-99%) in large predatory fish caused by fishing pressure (Baum et al 2003; Baum and Myers, 2004; Myers and Worm, 2005). In the next two months we will publish a peer in the journal *Science* demonstrating that over the past forty years, diversity of open ocean pelagic species has declined by at least 10% per decade as a result of overexploitation (Worm et al, Submitted to *Science*).

This loss in diversity in the open ocean is expected to have dramatic and lasting ecologic consequences for oceanic communities, and FMAP is beginning to describe these impacts. For instance, it is well known from terrestrial systems, for example, that human-induced loss of top predators can lead to considerable increases in the abundance of smaller predatory species (mesopredators; Ward and Myers, 2005). Similar dynamics can be expected in the oceans, and are important to document, since the proliferation of mesopredators can ultimately drive their prey species to extinctions or extirpations. This concern is particularly acute where mesopredators are unpalatable and therefore not of interest to commercial fisheries.

FMAP will be producing several high-impact papers in the next three years demonstrating how declines in predators impacts a variety of trophic levels. We have in preparation a startling paper that revealed that the loss of hammerhead sharks on the East Coast of the United States has resulted in declines in clams abundance through the releasing the club-nosed skate, a species of skate that consumes large amounts of clams , from predation. Thus through careful analysis, we have been able to show that loss of sharks may contribute to eutrophication in coastal estuaries. These links between tertiary consumers and primary production are extremely difficult to decipher due to messy data and multiple factors that influence community structure. We anticipate that, by working closely with other coml. Teams, this type mult-species assessment will be possible for most of the open ocean communities and several estuaries over the next three years.

Climate change and marine biodiversity.

Recent global analysis of diversity performed as part of FMAP (Worm et al, Submitted to *Science*) has demonstrated that sea surface temperature was the most powerful predictor of predator diversity, with richness and density increasing between 5-25°C. At temperatures above 25°C, diversity was observed to decline, probably due to shallow thermocline created in warm waters resulting in reduced habitat for foraminifera and, possibly, increased metabolic costs at high temperatures for large pelagic fish such as tuna. Oceanic fronts and eddies were also found to be important diversity hotspots, and such areas have long been recognized as places where seabirds, tuna, turtles, billfish and whales aggregate in large numbers.

On an annual basis, warming events caused by the El Niño Southern Oscillation were found to be linked to annual variations in diversity in the Pacific. On a year-to-year basis, warming trends were positively correlated to species richness in the temperate central Pacific whilst species richness declined in tropical areas. Interestingly, the analysis suggests that several migratory species, such as the Indo-Pacific blue marlin (*Makaira mazara*), may migrate from the tropical areas to sub-tropical areas during El Niño years, a hypothesis that workers studying the movement of large predatory on the Pacific, such as members of the CoML's TOPP team, will hopefully be able to test. This link between diversity and ocean-wide climatic oscillations was not observed in the Indian Ocean, and was weakly present in the Atlantic.

In the next three years FMAP will use this global synthesis to created predictions for future abundance and distribution of marine animals in the open ocean in response to climate change scenarios, including increase temperature and modifications in basin-wide atmospheric oscillations such as El Nino and the North Atlantic

Possible marine extinctions.

We propose to quantify the nature and extent of past marine extinctions and future risks. We will rely on scientifically collected data and other datasets carefully calibrated against scientific surveys. These data will be used to quantify and map changes in the abundance of a selection of marine species, over time and space, to (1) document empirically past extirpations and their link to human impacts; and (2) explore the future of marine life under a number of alternative management scenarios.

3. Organization and Collaboration: the Management Strategy

Communication with Field Projects, OBIS, and HMAP.

In the winter of 2006, FMAP will host a workshop on the utilization of oceanic data collection for modeling and prediction. Ransom Myers and Joanna Flemming will provide statistical expertise for dealing with the unique problems presented through the use of fisheries and other incidentally-collected data (divers' logs, natural history records).

By developing broad stroke global models of zooplankton distribution, methods developed by FMAP be integrated into finer-scale biodiversity data gathered by CMarZ, as well and help tailor their sampling methods to optimize efficiency and ecological modeling applications of their data.

Reporting Process.

Principle investigators for the FMAP project will be Heike Lotze, Ransom Myers, and Boris Worm. The administrative base for the project will be Dalhousie University, Halifax, Nova Scotia. Research nodes in Japan, Iceland, New Zealand will report to the project leaders on a semi-annual basis through the production of an annual report summarizing publications and other outputs, including data gathered new modeling techniques and outputs.

4. Outreach to the Public and Research Community

Outreach to the general public by FMAP team will be primarily be mediated via our website and publicity generated by high-impact publications. The FMAP team has been extremely successful in attracting sustained media attention over the years, and the productivity of our group gives us reason to believe this success will continue into the future. Ransom Myers, Boris Worm, and Heike Lotze will continue to liaise with other CoML teams by attending project meetings and hosting workshops for the CoML on the subject of improved statistical analysis of difficult data.

5. Synergy with OBIS

The FMAP project is integrally linked to the goals of OBIS by virtue of the large amounts of data required for our analyses and our strength in complete modeling and database management. We are currently helping OBIS experiment with database management systems and mapping utilities, and are aprticpating in the development of extended OBIS standards more suitable for inclduig the results of our analyses.. PhD student Dan Ricard is a member of the technical boards for OBIS Canada and Canada's Centre for Marine Biodiversity, and has been involved in planning the OBIS meeting scheduled for 2007 in Germany. In the long term, we hope to develop methods to merge the current OBIS data format with information on the population trendns, uncertainty, and data quality estimates for fisheries data. This database development will enable FMAP and other CoML projects (such as HMAP) to make the results of our analyses available and greatly enhance the information available via the OBIS portal.

6. Plans for Integration with Field Projects

FMAP has initiated links with the following field projects within the CoML:

Census of Marine Zooplankton (CMarZ)

Census of Marine Life in the Gulf of Maine (GoM)

Patterns and Processes of Ecosystems in the Northern Mid Atlantic (MAR-ECO)

Pacific Ocean Salmon Tracking (POST)

Tagging of Pacific Pelagics (TOPP)

Biogeography of Chemosynthetic Ecosystems (ChEss)

Natural Geography in Shore Areas (NaGISA)

Census of Diversity of Abyssal Marine Life (CeDAMar)

In the upcoming three years, FMAP plans to continue to assist CoML projects in gathering data efficiently, modeling and prediction. This will be done by hosting a workshop for all projects to assist them in dealing with problems in marine survey data. In addition, members of the FMAP team will attend the meeting of the TOPP group in California in the fall of 2006.

Proposed Budget and Matching Funds

	Sloan	Matching	PI
Statistical Design and Consulting			
Statistical Advisory Team			Centers
Standard Programs for Extrapolation			Rosenberg
Data Exchange - Model Interface			
Standard Data Exchange Formats			Centers
Fisheries Data into OBIS			Centers
Archiving of Non-Fisheries Data			Worm
Model Development			
CoML Standard Mapping Modeling			Center and Open Competition
Movement Models			Jonsen, Flemming, Myers
Pelagic Fish Biodiversity			Worm
Spatial Multispecies Models			Stefansson
Data Synthesis			
Meta-Analysis of interactions			Myers-Collie
Prediction			
Global predictions of fishing			Cox
Models for dynamics of biodiversity			Worm, Lotze, Myers
Extinction models and analysis			McPherson
Organization			
Center and Organizational			Myers, Stefansson
			Matsuda
Total			

8. Deliverables

Outcomes

First Year	Second Year	Third Year
Statistical Design and Consulting **(1)** Workshop on use of challenging data hosted by FMAP **(2)** Attend meeting with TOPP project **(3)** Statistical advisors established for each field project	**(1)** Project-specific extrapolation methods developed, implemented, and tested **(2)** Extrapolation methods incorporated in OBIS	**(1)** Statistical advisor an integral part of field projects **(2)** Modeling and data available vie OBIS database
Data Exchange -Model Interface **(1)** Standards implemented into OBIS	**(1)** Testing of OBIS database (2) Inclusion of fisheries data and divers' log data into OBIS	**(1)** Ongoing development of standards **(2)** Fisheries data entry into OBIS semi-automatic
Model Development **(1)** Implement initial spatial multi-species models **(2)** Expansion of meta-analytic state-space movement models to Greenland sharks and leatherback turtles	**(1)** Mapping models implemented in OBIS	**(1)** Analytic tools continually improved for OBIS
Synthesis **(1)** Meta-analytic methods identified implemented in OBIS	**(1)**	**(1)** Models used to synthesize CoML results
Prediction **(1)** Models for predictions of fishing, habitat dependent biodiversity, and extinction developed	**(1)** Implemented in OBIS	**(1)** CoML results predicted in short and medium time frame

9. Justification, Scientific and Societal Benefits

Besides intellectual interest, FMAP, the modeling component of the CoML, is key to improved conservation of the natural resources of the ocean. The results from mapping the present diversity, distribution, and abundance in the ocean will improve conservation and sustainable use of ocean life. The meta-analysis of communities will improve our understanding of species interactions and help to predict how the diversity of marine life will change with natural and anthropogenic impacts. The extinction models will enable protection of endangered life. FMAP will surprise us with how much we can know and it will shock us with how much we might never know. In short, FMAP brings to the CoML the statistical and analytical tools needed for its success, for maximum impact for the conservation and understanding of life in the ocean.

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Appedix 1. CV's of Representative Project Researchers

The CV's of several of the key network members and leaders follow.