Progress Report
Future of Marine Animal Populations
Census of Marine Life

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Overview: Within the last year, FMAP has produced 4 stories that have received international media attention (papers in Science, Nature, PNAS, and Ecology Letters). FMAP has also established and obtained independent funding for a model program to "Census" one very important taxonomic group globally, the sharks. This project will serve as a test for global modeling of abundance of trends for other taxonomic groups within the CoML. It is also hoped that this project will arouse widespread interest around the world, and through a proposed web-based interface for information for divers, participation in the Census from non-scientists as well.

Significant progress has been made in other components of FMAP (reviewed below). The major task for the coming year is to develop a network of centers globally.

1) Global Shark Assessment

FMAP has initiated a project to assess, i.e. "Census", and conserve sharks and their ecosystems. Sharks (and other elasmobranches) are particularly vulnerable to fishing pressure due to several factors. They are long-lived, slow to reproduce, and produce few offspring compared with most other fish species. Hence, directed fishing can much more quickly decimate a shark population than other fish species. In addition, sharks are often taken as bycatch in multispecies fisheries, in which the target species are much quicker to replenish themselves than the sharks. This occurs in pelagic longline fisheries that target highly productive tuna species, but catch great numbers of sharks, and also in the directed bottom longline fishery for sharks on the southeastern U.S. coast, which catches many different shark species with varying vulnerabilities to overfishing. In these fisheries, sharks may be fished to extinction while the more productive fishes continue to drive the industry. Just a few examples of the rapid declines already identified in shark populations outline the gravity and the global nature of the situation:

- Fourteen species of elasmobranches (sharks and rays) disappeared from the Gulf of Lions (NW Mediterranean) in trawl surveys between 1957 and 1995 (Aldebert 1997)
- Nine species of elasmobranches have disappeared from the Bay of Biscay since 1727 (Quero 1998)
- Harrissons and Southern dogsharks, formerly the two most common species on the New South Wales shelf (18.5 % of total biomass), declined by a factor of 300 between 1956 and 1996 (Graham et al. 2001).

The potential benefits of shark conservation are great. In protecting a host of large, charismatic, but particularly vulnerable species, shark conservation offers the opportunity to protect not just sharks, but the myriad other species and ecosystems with which and in which sharks interact. Hence, at stake are not merely sharks, but our still vastly misunderstood marine realm.

Currently, there exist both substantial amounts of unanalyzed data on sharks and a large number of dedicated shark biologists. However, these two key resources have not, as yet, been utilized to their full potential. FMAP will put the data and biological experts together with a team of modeling and statistical experts to produce a global assessment, with an emphasis on producing results in a form that is accessible to decision makers. Specifically, FMAP will:

- locate data and develop analysis techniques that demonstrate the magnitude of the declines in shark populations on a global scale
- effectively communicate the results
- force conservation action

Progress

While FMAP funds were used to initiate this project, full funding for three years is now in place from the PEW Charitable Trusts; this will free up funds from the Sloan Foundation to operate an international network for FMAP.

Analysis has begun for the following regions:

Argentina, South Atlantic	Dr. Luis Lucifora (INEDEP Argentian, now an FMAP post doc).
Asia	Scott Sherrill-Mix (PhD candidate)
Tropical Pacific	Peter Ward (PhD candidate)
Northwest Atlantic, Gulf of Mexico	Julia Baum (PhD candidate)
Mediterranean	Francesco Ferretti (PhD candidate) (Collaboration is underway with several scientists from the region for this project. Additional funds will be sought from the EU. Univ. of Ancona has received FMAP funds for coordination.)
Northwest Atlantic	Dr. Jon Egil Skjaeraasen (Bergen, Norway)
S.E. Asia/Australia	Discussions have been initiated with WorldFish (Ilona Stobutski) on collaboration using trawlbase.
Reef Sharks	A spatial meta-analysis of data has been proposed jointly with several groups.

Model development – by Dr. Andy Edwards (Post Doctoral Fellow) and Dan Kehler (PhD candidate).

2) Relationship to other projects

The CoML Initial Field Projects (IFPs) need to develop statistical rigor in their sampling programs, to place their data in convenient and compatible database formats and to maximize the utility of the data for a variety of analyses and modeling processes. The FMAP network will explore various means of analyzing and modeling and will provide feedback to projects on possible improvements. Currently, FMAP is liaising with the following field 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 will be initiated in the spring of 2004. The final product for the first year 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 will assist CenSeam by developing a statistically rigorous sampling procedure that will fill critical knowledge gaps and target understudied regions and types of seamounts. Secondly, 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. Third, 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.

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. FMAP is working to provide methods and models for working with this type of data.

The following people are involved with this project:

Greg Breed (PhD. Candidate) will probably work directly with TOPP, i.e. Costa.
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.

Meta-analysis and animal movement:

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. Our study 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.

Jonsen, I.D., R.A. Myers, and J. Mills Flemming. 2003. Meta-analysis of animal movement using state-space models. Ecology 84: 3055-3063.

The study of animal movement and behavior is being revolutionized by technology, such as satellite tags and harmonic radar, that allows us to track the movements of individual animals. However, our ability to analyze and model such data has lagged behind the sophisticated collection methods. We review problems with current methods and suggest a more powerful and flexible approach, state-space modeling, and we illustrate how these models can be posed in a meta-analytic framework so that information from individual trajectories may be combined optimally. State-space models enable us to deal with the complexity of modeling animals interacting with their environment but, unlike other methods, they allow simultaneous estimation of measurement error and process noise that are inherent in animal-trajectory data. A Bayesian framework allows us to incorporate important prior information when available and also allows meta-analytic techniques to be incorporated in a straightforward fashion. Meta-analysis enables both individual and broader-level inference from observations of multiple individual pathways. Our approach is powerful because it allows researchers to test hypotheses regarding animal movement, to connect theoretical models to data, and to use modern likelihood-based estimation techniques, all under a single statistical framework.

HMAP

FMAP is 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 is collaborating with SEAMAP to develop a data standard for abundance data (with standard errors and confidence limits). Spatial models are being developed to test hypotheses for the decline of the sea turtle and sealion data that SEAMAP will be put in into OBIS (with Terry Quinn, Univ. of Alaska, and Ph.D. student Dan Kehler).

3) Development of XML-based data standards for international data storage/retrieval/sharing of fisheries data

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.

4) Baseline population estimates of large predatory fish

FMAP has recently produced a number of papers that estimate the population sizes of large predatory fish from pre-exploitation to the present. This baseline information is crucial so that we are not drawn into complacency by a false perception of recent, post-exploitation population levels as the norm. An important component of these projects is the development of statistical methods for historical data that can be used for future projects. The titles and abstracts of these papers follow:

Ward, P., and R. A. Myers (submitted) Major shifts in pelagic fish communities of the open-ocean coinciding with the commencement of fishing. Ecology.

Large predators may exert a powerful influence over ecosystems, but their initial removal when humans first venture into new environments is rarely quantified. We identify changes in the pelagic fish community of the tropical Pacific Ocean by comparing recent data collected by observers on longline fishing vessels with data from a 1950s scientific survey when industrial fishing commenced. A major shift in the species abundance, biomass, and size composition of the community accompanied the start of fishing. The largest and most abundant predators, such as large tunas and sharks, suffered the greatest declines in abundance, and they also showed striking reductions in mean body-size. By contrast, several small and formerly rare species increased in both abundance and body-

size. However, the increases in small species did not balance the reductions in large predators. The decline in total biomass indicates that the top trophic level of the open-ocean ecosystem has not compensated for current levels of fishing.

Ward, P., R. A. Myers, and W. Blanchard. 2004. Fish lost at sea: the effect of soak time and timing on pelagic longline catches. Fishery Bulletin 102: In Press.

Our analyses of observer records reveal that abundance estimates are strongly influenced by the timing of longline operations in relation to dawn and dusk and soak time – the amount of time that baited hooks are available in the water. Catch data will underestimate the total mortality of several species because hooked animals are "lost at sea". They fall off, are removed or escape from the hook before the longline is retrieved. For example, longline segments with soak times of 20 hours were retrieved with fewer skipjack tuna and seabirds than segments with soak times of 5 hours. The mortality of some seabird species is up to 45% higher than previously estimated.

Baum, J.K. and R.A. Myers. 2004. Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. Ecology Letters 7(1): 135-145.

Historical abundances of many large marine vertebrates were tremendously greater than today. However, while pelagic sharks are known to have declined rapidly in the Northwest Atlantic in recent years, there, as elsewhere, little is known about the former natural abundances of these species. Here, we compare initial (1950s) and recent (late-1990s) standardized catch rates of pelagic sharks in the Gulf of Mexico, the area where methods of exploitation between these two periods were most comparable. We estimate that oceanic whitetip and silky sharks, formerly the most commonly caught shark species, have declined by over 99% and 90% respectively. That the former prevalence of oceanic whitetip sharks in this ecosystem is unrecognized today is clear evidence of shifting baselines. Our analysis provides the missing baseline for pelagic sharks in the Gulf of Mexico that is needed for the rational management and restoration of these species.

Myers, R.A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423: 280-283.

Serious concerns have been raised about the ecological effects of industrialized fishing, spurring a United Nations resolution on restoring fisheries and marine ecosystems to healthy levels. However, a prerequisite for restoration is a general understanding of the composition and abundance of unexploited fish communities, relative to contemporary ones. We constructed trajectories of community biomass and composition of large predatory fishes in four continental shelf and nine oceanic systems, using all available data from the beginning of exploitation. Industrialized fisheries typically reduced community biomass by 80% within 15 years of exploitation. Compensatory increases in

fast-growing species were observed, but often reversed within a decade. Using a meta-analytic approach, we estimate that large predatory fish biomass today is only about 10% of pre-industrial levels. We conclude that declines of large predators in coastal regions5 have extended throughout the global ocean, with potentially serious consequences for ecosystems. Our analysis suggests that management based on recent data alone may be misleading, and provides minimum estimates for unexploited communities, which could serve as the 'missing baseline' needed for future restoration efforts.

Baum, J.K., R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, and P.A. Doherty. 2003. Collapse and conservation of shark populations in the northwest Atlantic. Science 299: 389-392.

Overexploitation threatens the future of many large vertebrates. In the ocean, tunas and sea turtles are current conservation concerns because of this intense pressure. The status of most shark species, in contrast, remains uncertain. Using the largest data set in the Northwest Atlantic, we show rapid large declines in large coastal and oceanic shark populations. Scalloped hammerhead, white, and thresher sharks are each estimated to have declined by over 75% in the past 15 years. Closed-area models highlight priority areas for shark conservation, and the need to consider effort reallocation and site selection if marine reserves are to benefit multiple threatened species.

5) Incorporation of information from divers into OBIS and the Global Shark Assessment

The marine life in many areas of the world's oceans is almost impossible to sample. However, a wealth of previously untapped information exists in the journals of divers from around the world. Because the first generation of divers is dying, it is very important to capture this information before it is too late.

FMAP will develop the tools to allow this type of data to be (1) incorporated into OBIS, and (2) analyzed for trends in the distribution of key species. We will develop the software initially for sharks, because they are easily identified by divers with moderate training. We will take advantage of similar, well-established programs for terrestrial species, along with methods to obscure the location of sensitive species. Also, we will establish a protocol to distinguish reliable from unreliable sources in a similar manner to ebay.

The results will be key tools to keep track of marine life in otherwise unknown areas of the world's oceans. This project will also bring wide public interest and participation into CoML—a critical component of its success.

6) Models of Global Biodiveristy

Boris Worm (Univ. of Kiel) has received FMAP funds to develop statistical and process models for global marine biodiveristy, including the identification of hotspots. The first part of this work was published in PNAS, and received global press coverage. These methods will be extended to other taxa, and tools will be produced that can be widely used. Collaboration with physical oceanographers is underway.

Worm, B., H. Lotze, and R.A. Myers. 2003. Predator diversity hotspots in the blue ocean. Proceedings of the National Academy of Science USA 100: 9884-9888.

Concentrations of biodiversity, or hotspots, represent conservation priorities in terrestrial ecosystems but remain largely unexplored in marine habitats. In the open ocean, many large predators such as tunas, sharks, billfishes, and sea turtles are of current conservation concern because of their vulnerability to overfishing and ecosystem role. Here we use scientific-observer records from pelagic longline fisheries in the Atlantic and Pacific Oceans to show that oceanic predators concentrate in distinct diversity hotspots. Predator diversity consistently peaks at intermediate latitudes (20–30° N and S), where tropical and temperate species ranges overlap. Individual hotspots are found close to prominent habitat features such as reefs, shelf breaks, or seamounts and often coincide with zooplankton and coral reef hotspots. Closed-area models in the northwest Atlantic predict that protection of hotspots outperforms other area closures in safeguarding threatened pelagic predators from ecological extinction. We conclude that the seemingly monotonous landscape of the open ocean shows rich structure in species diversity and that these features should be used to focus future conservation efforts.

7) Prediction

Initial estimates of extinction rates in the marine environment have been started (see abstract below). An NCEAS workshop is being proposed that would bring researchers together worldwide to study this issue. A graduate student within FMAP (with external funding) is modeling the joint role of climate change and effects of aquaculture on the survival of wild salmonids in the oceanic stages. This analysis will be targeted for the journal Science in 2005.

Ransom A. Myers and Boris Worm. 2004. Extinction, survival, or recovery of large predatory fishes. Proceedings of the Royal Society, B.: In press.

Large predatory fishes have long played an important role in marine ecosystems and fisheries alike. Overexploitation, however, is gradually diminishing this role. Recent estimates indicate that exploitation has depleted large predatory fish communities worldwide by at least 90% over the last 50-100 years. Here, we demonstrate that these declines are general, independent of methodology, and even higher for sensitive species such as sharks. Then we attempt to predict the future prospects of large predatory fishes. (1) An analysis of maximum reproductive rates predicts the collapse and extinction of sensitive species under current levels of fishing mortality. Sensitive species occur in

marine habitats worldwide and have to be considered in most management situations. (2) We show that to ensure the survival of sensitive species in the Northwest Atlantic fishing mortality has to be reduced by 40-80%. (3) We show that rapid recovery of community biomass and diversity usually occurs when fishing mortality is reduced. However, recovery is more variable for single species, often due to the influence of species interactions. We conclude that management of multi-species fisheries needs to be tailored to the most sensitive, rather than the more robust species. This requires reductions in fishing effort, reduction in bycatch mortality, and protection of key areas to initiate recovery of severely depleted communities.

8) Synthesis

Meta-analytic methods have been developed to greatly improve our ability to estimate species interactions in the ocean (see below). These methods are being extended to include meta-analytic state-space that will be usual from OBIS datasets.

Worm, Boris and Ransom A. Myers. 2003. Meta-analysis of cod–shrimp interactions reveals top-down control in oceanic food webs. Ecology 84(1):162–173.

Abstract. Here we present a meta-analytic approach to analyzing population interactions across the North Atlantic Ocean. We assembled all available biomass time series for a well-documented predator–prey couple, Atlantic cod (*Gadus morhua*) and northern shrimp (*Pandalus borealis*), to test whether the temporal dynamics of these populations are consistent with the ''top-down'' or the ''bottom-up'' hypothesis. Eight out of nine regions showed inverse correlations of cod and shrimp biomass supporting the ''top-down'' view. Exceptions occurred only close to the southern range limits of both species. Random-effects meta-analysis showed that shrimp biomass was strongly negatively related to cod biomass, but not to ocean temperature in the North Atlantic Ocean. In contrast, cod biomass was positively related to ocean temperature. The strength of the cod–shrimp relationship, however, declined with increasing mean temperature. These results show that changes in predator populations can have strong effects on prey populations in oceanic food webs, and that the strength of these interactions may be sensitive to changes in mean ocean temperature. This means that the effects of overfishing in the ocean cascade down to lower trophic levels, as has been shown previously for lakes and coastal seas. In order to further investigate these processes, we establish a methodological framework to analyze species interactions from time series data.

9) Meetings

FMAP presentations were made at 12 scientific meetings.

Ocean Life: The Known, Unknown and Unknowable. October 24, 2003, Census of Marine Life, Washington D.C.

Marine Biodiversity: Using the Past to Inform the Future. November 14-17, 2003. Scripps Institution of Oceanography, La Jolla, California.

Literature Cited

Aldebert, Y. 1997. Demersal resources of the Gulf of Lions (NW Mediterranean). Impact of exploitation on fish diversity. Vie et Milieu **47**: 275-284.

Graham, K.J., N.L. Andrew, and K.E. Hodgson. 1997. Changes in relative abundance of sharks and rays on Australian Southeast Fishery trawl grounds after twenty years of fishing. Marine and Freshwater Research **52**: 549-561.

Quero, J. 1998. Changes in the Euro-Atlantic fish species composition resulting from fishing and ocean warming. Italian Journal of Zoology **65**: 493-499.

Thomas C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus, M. Ferreira de Siqueira, A. Grainger, L. Hannah, L. Hughes, B. Huntley, A.S. Van Jaarsveld, G.F. Midgley, L. Miles, M.A. Ortega-Huerta, A. Townsend Peterson, O.L. Phillips, and S. E. Williams. 2004. Extinction risk from climate change. Nature **427**: 145-148.

Schedule of upcoming events

New FMAP Centers: In 2004, 2 new FMAP centers will be established in Japan and Iceland. The establishment of the Japan center had waited until Hiro Matsuda changed universities.

Scientific Papers

- Empirical meta-analysis combined with a theoretical analysis showing that present fishing practices will result in the widespread loss of sharks. To be published in the Proceedings of the Royal Society, 2004.

- Meta-analysis of the conservation status of mammals, sharks, and bony fish showing that sharks are the most vulnerable to extinction. Target journal: Science.

- Major shifts in the pelagic fish communities of the open-ocean coinciding with the commencement of fishing. Target journal: Ecology.

- Models and statistics for reconstructing marine populations (for HMAP). To be published: 2004.

- Eight regional shark assessments will be published over the next 2.5 years.

- Global shark assessment (in 2006) will be published in book from, on the WEB, and as an article in Science or Nature.

- Two papers on meta-analytic synthesis to be published each year.

Meetings

- Future of Marine Animal Populations annual meeting. November 2004, La Jolla, California. This will be held after, and in conjunction with, the Center for Marine Biodiversity Meeting at Scripps.

- Predicting Global Marine Extinctions, Workshop Winter 2005 – Fall 2005.

  Loss of species in the ocean has been difficult to quantify given the spatial and temporal scales involved, the vastly understudied biodiversity of the marine world, and the shortage of long term datasets. However, recent predictions of the number of extinction of various terrestrial species due to habitat loss caused by climate change (Thomas et al. 2004) provide a model of how such predictions might be made in the ocean. We propose to host an NCEAS (National Center for Ecological Analysis and Synthesis) workshop that will first estimate the loss and degradation of marine habitats, and then use species-area relationships to predict current and future extinctions of marine species. This workshop will be attended by marine scientists and modelers from around the world.

Outreach

- Media campaigns to accompany the publication of major papers.

- Incorporation of information from divers into OBIS and the Global Shark Assessment

  FMAP will use the information in the journals kept by divers to shed light on difficult to sample areas of the world's oceans. This project will be of great public interest—especially because the first generation of divers is dying—and will increase public participation in the Census of Marine Life.

- Addition of an educational page or section to the FMAP website. Winter 2004

- Production of a module "Overfishing and Extinction in the Sea" to be used by highschool, college, and university teachers. Winter 2004

FMAP Open Grant Competitions for Modeling for the CoML

Beginning in the March 2004, FMAP will have an open competition for grants to provide modeling and statistical input for the CoML.