NEREUS

PREDICTING THE FUTURE OCEAN

THE NIPPON FOUNDATION AND THE UNIVERSITY OF BRITISH COLUMBIA NEREUS ANNUAL REPORT

2012/13

THE NIPPON FOUNDATION

UBC

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PARTNERS

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FOREWORD

The University of British Columbia is delighted to report on the completion of another successful year of the Nippon Foundation-UBC Nereus Program. As The Nippon Foundation continues its essential role in the collaborative efforts of the Nereus Program, the university is inspired by the foundation's commitment to the same values and principles that guide UBC's strategic initiatives.

A primary aim of Nereus is to ensure that future generations can enjoy the bounty of the sea, and it is with great pride that the University of British Columbia can also take a leadership role in this noble effort. But it is collaboration and partnership with other organizations and universities that allows Nereus to proactively address some of the world's most pressing problems.

This program would not be possible without the tireless efforts of the numerous partners, researchers, fellows, and principle investigators (PIs) from throughout the world. Their dedication is leading the way to possible research breakthroughs that will support a sustainable future for the world's oceans. The expertise, intellect, and innovation displayed by all working in the program is an inspiration and provides hope for the future of our oceans, and the university is pleased to see the program's ambitious goals are now developing into well-executed research strategies.

The following report reviews the program's progress over the past year. UBC is honoured to continue this strong partnership as the Nippon Foundation–UBC Nereus Program positively impacts the world's oceans and encourages a sustainable future for everyone.

Professor Stephen J. Toope
President and Vice-Chancellor, the University of British Columbia

EXECUTIVE SUMMARY

BY DR. SIMON PEACOCK
DEAN OF UBC'S FACULTY OF SCIENCE

With the completion of another successful year of The Nippon Foundation–UBC Nereus Program, I am thrilled to see this vital international marine initiative continue to accelerate scientific research surrounding the state of the world's oceans. As the program advances, UBC's Faculty of Science is impressed by the great work done by researchers and fellows, who are collaborating to increase public understanding of the current state of our marine resources.

For its second year, the NP-UBC Nereus Program continued its full-fledged activities based on the following three pillars:

1. Scientific research: Predictions of the state of the ocean in 2050;
2. Capacity building/human resource development: Cultivation of marine scientists with a comprehensive outlook; and
3. Public outreach: Helping politicians and the general public understand the state of marine resources.

Currently, researchers from the University of British Columbia, Duke University, Princeton University, Stockholm University, Cambridge University, and the World Conservation Monitoring Centre, as well as young researchers appointed as Nippon Foundation Nereus Fellows, are collaborating on research projects for this truly global endeavour that works to predict and sustain the future of the world's oceans.

There are now ten Nereus Fellows working around the world and collaborating with each other across continents. They, along with talented PIs from each contributing member organization, have published dozens of papers in some of the most influential journals in global fisheries research, including *Science* and *Fish and Fisheries.* In addition, Nereus Fellows have presented workshops, guest lectures, and presentations at universities and conferences around the globe. The program has now graduated two alumni, who are taking the perspective and collaborative approach of the Nereus Program to other influential positions where they will continue their integrated work in marine conservation research (see Page 31).

The cooperative system established in year one with each participating organization has been successful, and now the program is looking to re-design its program office at UBC in order to meet new strategic goals for year three of the program: to organize further enhancement of scientific and outreach capacity. This includes the addition of two new members (see Page 32): Dr. William Cheung as Science Advisor and Dr. Ryan Vachon, who will be in charge of public relations and communication.

The program is moving forward in exploring the use of multi-media to communicate results. The program is also advancing the concerted development and uses of multiple modeling approaches to link climate models through ecosystem and human dimensions. Research in these areas is flourishing, and the program is focusing on how to convert ambitious goals into thoughtful and well-executed research strategies.

An exciting area of focus this year was building capacity within the Nereus Program, most notably through an influential trip to Tohoku, Japan, an area devastated by the 2011 earthquake and tsunami. On this trip, Nereus Fellows spoke to students and at Japanese fisheries about the state of the oceans; many were deeply impacted by the trip and have shared insights from their experiences in this report (see Page 38).

The Nereus Program was also the focus of a session at the American Association for the Advancement of Science (AAAS) meeting for the second consecutive year. Additionally, a successful and well-attended annual meeting convened in February 2013, where the group discussed the challenges and opportunities within the Nereus Program, and how to optimize the fellows and the diverse mix of PIs to meet the program's goals.

Overall, strategic development of research and capacity building activities has been observed. As the Nereus Program progresses, it is fulfilling its previous mandate to increase outreach while supporting collaborative research that makes an impact on the world's oceans. Thanks to the tremendous support of The Nippon Foundation, the program shows great promise for continued success.

A NOTE FROM DR. DANIEL PAULY, CHAIR OF THE STEERING COMMITTEE

The Nereus Program addresses one of the most urgent concerns of the ocean and the future of global sustainable fisheries. The progress to date is noteworthy and I would like to thank Dr. Christensen for his work as its Founding Director. Dr. Christensen is now the Nippon Foundation Professor of Marine Ecosystem Modeling and Management, and I would like to express my high hopes for his research. I'm also pleased to welcome Dr. William Cheung into the Nereus Program, as he has accepted the role of Nereus' Science Advisor.

What distinguishes the Nereus Program is that it is a global endeavour. There are few projects that are truly global—not merely an institution with a few international fellows, but one that provides data at a global scale and at the same density everywhere. Essentially, we should try to develop insights, techniques, and models that have these features, and which can therefore be applied globally.

Many social, economic, and biological processes that we are interested in are inherently global. We must study the whole world because anything that happens in one location will affect another. This is what I see as a chance and an opportunity for those involved in the Nereus Program.

INSTITUTIONAL PARTNERS

Established in 1962, **The Nippon Foundation** is a non-profit philanthropic organization active both in Japan and abroad. Since its inception, its efforts to bolster the domestic development of Japan have focused largely on the maritime and shipping fields. Over the years, The Nippon Foundation has expanded its activities to include education, social welfare, and public health, both within Japan and in more than one hundred countries to date. The foundation's fundamental aim is the realization of a peaceful and prosperous global society, in which no one has to struggle to secure basic human rights. The Nippon Foundation feels a strong sense of responsibility and mission as it works together with the people of the world in developing its activities. For the sake of humankind and the planet in general, the foundation is bringing together the world's wisdom and using it to transform society.

The Fisheries Centre at **the University of British Columbia** promotes multidisciplinary study of aquatic ecosystems and broad-based collaboration with maritime communities, government, NGOs and other partners. UBC believes that social and intellectual capital developed through collaboration and increased knowledge can lead to the re-investment in natural capital is necessary to conserve and restore aquatic systems. The NF-UBC Nereus Program has been created to address the global issue of over-exploitation of the world's fish resources and the widespread concern that the world oceans will be unable to supply fish products for future generations. The UBC Fisheries Centre serves as scientific and logistic hub for the Nereus Program.

The Marine Geospatial Ecology Laboratory (MGEL) at **Duke University** was established to cross the multidisciplinary boundaries of ecological analysis, eco-informatics and analytical tool development. Current activities include marine ecosystem-based management tool development; biogeography, marine animal behaviour and telemetry; marine habitat modeling; fisheries bycatch reduction; and climate change impact. Given the focus of the lab on spatio-temporal analyses, marine conservation, and bioinformatics, MGEL will work on synthesizing and translating data and information between different Nereus project teams, as well as developing research concerning spatio-temporal patterns of both fish and fisheries.

The Atmospheric and Oceanic Sciences (AOS) Program is a unique collaboration between a renowned academic institution, **Princeton University**, and a world-class climate research laboratory, the Geophysical Fluid Dynamics Laboratory (GFDL) of the National Oceanic and Atmospheric Administration (NOAA). Since its inception in 1964, the AOS program has been at the forefront of atmospheric and oceanic study and research. The program is internationally recognized for its development of models of atmospheric and oceanic circulation and climate, and world-renowned for its development of earth system models and its training of graduate students and post-docs. The focus of the Princeton's efforts for the Nereus Program, in collaboration with Nereus partners and leveraging research at NOAA's Geophysical Fluid Dynamics Laboratory, will meet the challenges of making reliable projections of the response of fisheries to future climate.

The Stockholm Resilience Centre is a joint initiative between Stockholm University, the Stockholm Environment Institute, and the Beijer International Institute of Ecological Economics at The Royal Swedish Academy of Sciences. It has international focus in its activities, and advances interdisciplinary research for governance of social-ecological systems with special emphasis on resilience. For the Nereus Program, the centre will specifically help to develop new governance strategies for future oceans. This will involve several of the centre's experts, including Dr. Henrik Österblom, on issues like governance structures, networks, and technological development.

The **UNEP World Conservation Monitoring Centre** (UNEP-WCMC) is a joint venture between the United Nations Environment Programme and WCMC (UK), a UK-based charity. UNEP-WCMC is UNEP's specialist biodiversity assessment arm, and the centre for UNEP's collaboration with WCMC. The activities of UNEP-WCMC include biodiversity assessment, support of international conventions such as the Convention on Biological Diversity and the Convention on International Trade in Endangered Species of Wild Fauna and Flora, capacity building, and management of databases on species and habitats of conservation concern. The doctoral fellows of the Nereus Program will be positioned jointly at UNEP-WCMC and the Geography Department at **the University of Cambridge**. The theme of the work proposed by UNEP-WCMC within the Nereus Program is to improve the robustness of spatially explicit predictions of marine biodiversity and ecosystem services. In particular, work focuses in two areas. The first aims to understand the drivers of (and predict the effects of) cumulative impacts on productivity of critical marine and coastal ecosystems. The second aims to improve species range map methodologies for marine biodiversity.

INSTITUTIONAL REPORTS

THE UNIVERSITY OF BRITISH COLUMBIA

The Nereus Program is an interdisciplinary, collaborative initiative working on the advancement of international sustainable fisheries and ocean governance. As the operational hub of the program, and with the exceptional partnership of The Nippon Foundation, the University of British Columbia is enthusiastic about the two successful years of research and outreach. With a re-organized and enhanced program office, UBC looks forward to increased capacity building and a renewed focus on strategic objectives in year three.

In order to fulfill its three core objectives of research, capacity building, and outreach, it is necessary for Nereus to have strong leadership. As such, the program office at UBC has been devoted to coordinating and developing the overall program strategy. Dr. Daniel Pauly and Dr. Villy Christensen are supervising the scientific direction of the program and have contributed greatly to the successful advancement of the research. Dr. Yoshitaka Ota has taken on much of the program's coordination and design by promoting collaborative work between the fellows. The outcome of these collaborations has become one of the program's core projects: creating the Nereus diagram, which explains the relationship between different components of both natural and social drivers that contribute to global fisheries dynamics.

Dr. Christensen has been advancing his research on the Nereus Global Model, which will integrate different components of global fisheries dynamics. In February 2013, he became a Nippon Foundation Professor of Ecosystem Modeling and Management, allowing him to devote the majority of his time to this research. Subsequently, the program office has established new leadership with Dr. Ota, Dr. Pauly, and Dr. William Cheung, the recently-appointed Science Advisor. Much of Dr. Cheung's work on studying vulnerability and responses of marine ecosystems and fisheries to climate change has already been in collaboration with Nereus partners, including Princeton University, Duke University, and the Stockholm Resilience Centre. In his role of science advisor, Dr. Cheung will advance the integrating mechanism of the program.

In addition to this new leadership, Dr. Ryan Vachon has come on board as Education and Communication Coordinator. Dr. Vachon will work on building internal and external communication network for the program, redesigning the web page, increasing social networking, and composing an educational short video. This new position will lead to enhanced program outreach in coming years (See "New Members of the Program" on Page 32).

Senior Fellow Dr. Wilf Swatz has made significant progress in his research on the "real price of fish." Dr. Swartz also participated in various workshops, expanding his network through new socio-economic and governance approach in fisheries. He was also instrumental in organizing the Nereus trip to Tohoku and continues to support the communities in north Japan (see Page 38).

Below is a research summary and year highlights from UBC's current Nereus Fellows.

DR. WILF SWARTZ, UBC SENIOR RESEARCH FELLOW

Research Summary

In the past year, my primary focus has been developing research questions and exploring methodologies for evaluating and quantifying the plethora of externalities and non-market benefits associated with fishing and seafood consumption. The main goal of this research is to provide a theoretical "real" price of fish when all the costs of production are taken into account. This research is a continuation of some of the work I did for my PhD thesis, which among other things, evaluated the ex-vessel price of fish worldwide (Swartz *et al*., 2012).

In addition, my other research focuses on the trade-offs associated with fisheries management, particularly with regard to policies involving multi-user groups. I am currently involved in a research project that examines various successes in marine spatial planning (MSP). The anticipated outcome of this project is an integration of the concept of corporate social responsibility (CSR) into the MSP framework for applied use in local (British Columbia) MSP initiatives. Concurrently, I am involved in a project led by Drs. Quentin Hanich and Yoshitaka Ota, which explores various policy options for alleviating inequalities and bias in current conservation management models. Ideally, this will redistribute the conservation burden in a more equitable manner (i.e., shared by both coastal countries and distant water fleets). In this project, I will again be incorporating the idea of CSR.

Meetings, Workshops, and Presentations

- "The Great East Japan Earthquake and the revival of fisheries in Tohoku." Fisheries Centre Seminar Series, University of British Columbia, Vancouver, BC, Canada (Jan. 2013)
- "Global marine fisheries: balancing the two aspects of sustainability." Guest lecture, ECOSUS Program, Hokkaido University Hakodate, Japan (Nov. 2012)
- "Fisheries subsidies." Guest lecture, FISH508 Issues in Fisheries Research: Fisheries Economics, University of British Columbia, Vancouver, BC, Canada (Oct. 2012).

AUDREY VALLS, UBC RESEARCH FELLOW

Research Summary

My PhD project focuses on three main questions: (1) Can we predict marine species trophic interactions? (2) Why are marine species trophic interactions critical to ecosystem functioning? (3) How are marine species trophic interactions impacted by human activities? For the past year, my research has been mainly focused on two chapters: (1) predicting diet composition for fish species, and (2) refining the keystone species concept for the marine food web.

For my first chapter, I am using diet composition data for fish species worldwide from the FishBase global biodiversity database and applying a Rank Proportion Algorithm (RPA) model previously published. I am building a new version of the RPA model—which I intend to be automated and flexible—in order to allow predicting fish diet composition for any species and any ecosystem in the world. I have already built a flow

chart of predator types for fish species, based on a literature review on fish feeding behaviour (Fig. 1). I have also identified a suite of 45 species traits known to be correlated to fish feeding behaviour, which I have translated into a suite of 119 ecological and biological parameters potentially available in FishBase (Fig. 2). I have then extracted all these parameters and assessed their availability in order to select the most available ones. On this work, I am collaborating with Dr. Deng Palomares (UBC), who is one of the leaders of the FishBase and SeaLifeBase projects. Predicting diet composition will address the issue of limited stomach contents data and thus allow for a better representation of trophic interactions between marine species in food web models.

For my second chapter, I am using a database of Ecopath with Ecosim (EwE) models, which I am currently building with another PhD Candidate, Mathieu Colleter (UBC, Sea Around Us Project). From this database, I will select a pool of suitable models to which I will apply a methodology for keystone species identification that I have already defined and tested on a sample of models. First, I have formulated a clear, precise and exclusive definition for the keystone species concept. To do so, I reviewed the abundant literature on the concept and focused on the historical definitions proposed by R.T. Paine to extricate the original definition of all the overlapping concepts. Second, I developed a methodology based on specific and consistent criteria and testable quantitative thresholds. This tool includes a new index measuring the "keystoneness" of species, based on previously published indexes (Libralato et al. 2006) and validated with statistical tests (Fig. 3a). It also includes a graphical method for a-priori identifying keystone and other critical species in marine food webs (Fig. 3b). On this work, I am also collaborating with Dr. Marta Coll (Formally with CSIC-ICM), who is an expert in meta-analysis of food-web models. I notably did a study abroad program at CSIC-ICM from June to July 2012, funded by a Graduate Student International Research Mobility Award from UBC. By refining the keystone species concept for marine food webs, I intend to propose a methodology making the keystone species concept truly operational directly applicable to biodiversity conservation purposes, especially in marine ecosystems. We intend to publish our database of EwE models and make them available to other scientists who are interested in conducting meta-analyses on food web models.

Next Steps

For my first chapter, the next step is to conduct a statistical analysis based on available and reliable diet composition data extracted from FishBase in order to identify the parameters that are significantly correlated to diet composition. I will then use them as key parameters for implementing a predictive framework I have already defined. I am planning to submit an article about this work by the end of August 2013, so that it will be presented during the next FishBase Symposium, in September 2013.

For my second chapter, the next step is to submit what I have written to the Fisheries Centre Research Reports, as well as to submit two articles that are currently in preparation. The FCRR and the first article are about the database and a preliminary review of the EwE models we gathered, and the second article is about my work on the keystone species concept. Also, I am going to present this work during the next French Fisheries Science conference ("Forum halieumétrique") in Bordeaux (France) in June 2013.

Publications (2012 to Present)

Coll M., P. Cury, E. Azzurro, M. Bariche, G. Bayadas, J. M. Bellido, C. Chaboud, J. Claudet, A-F. El-Sayed, D. Gascuel, L. Knittweis, C. Pipitone, Y. Samuel-Rhoads, S. Taleb, S. Tudela, **A. Valls** and Participants. 2013. The scientific strategy needed to promote a regional ecosystem-based approach to fisheries in the Mediterranean and Black Seas. *Reviews in Fish Biology and Fisheries*. pp. 1-20.

Presentations

- **Valls A.,** W. Cheung, and V. Christensen. Index of overall vulnerability to fishing for marine species. 2nd ICES/PICES Conference for Early Career Scientists, Majorca, Spain, April 24-27 2012. Poster presentation.
- **Valls A.**, D. Palomares, J. Link, and V. Christensen. Predicting species diet composition in marine food web models. 6th World Fisheries Congress, Edinburgh, Scotland (UK), May 7-11 2012. Oral presentation.
- **Valls A.** and V. Christensen. The Nereus—Predicting the Future Ocean Program: regional case study of the Mediterranean Sea. CREAM Project, 1st WP6 Workshop "Scientific Strategy for a Global Approach to Promote Regional Ecosystem-based Approach to Fisheries (EAF) in the Mediterranean and Black Seas", Sète, France, July 3-4 2012. Oral presentation.

Key Slides

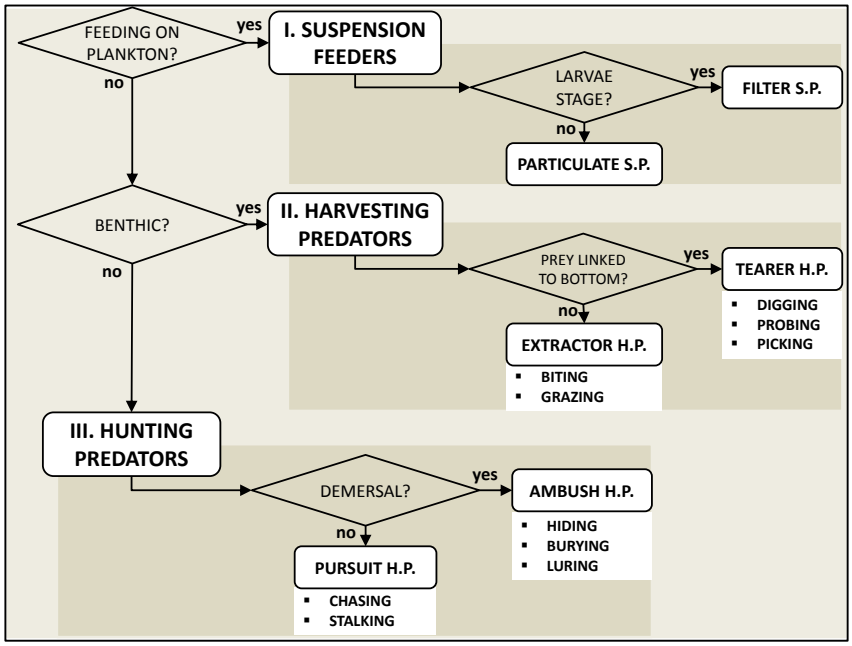


Fig. 1: Flow chart of fish predator types

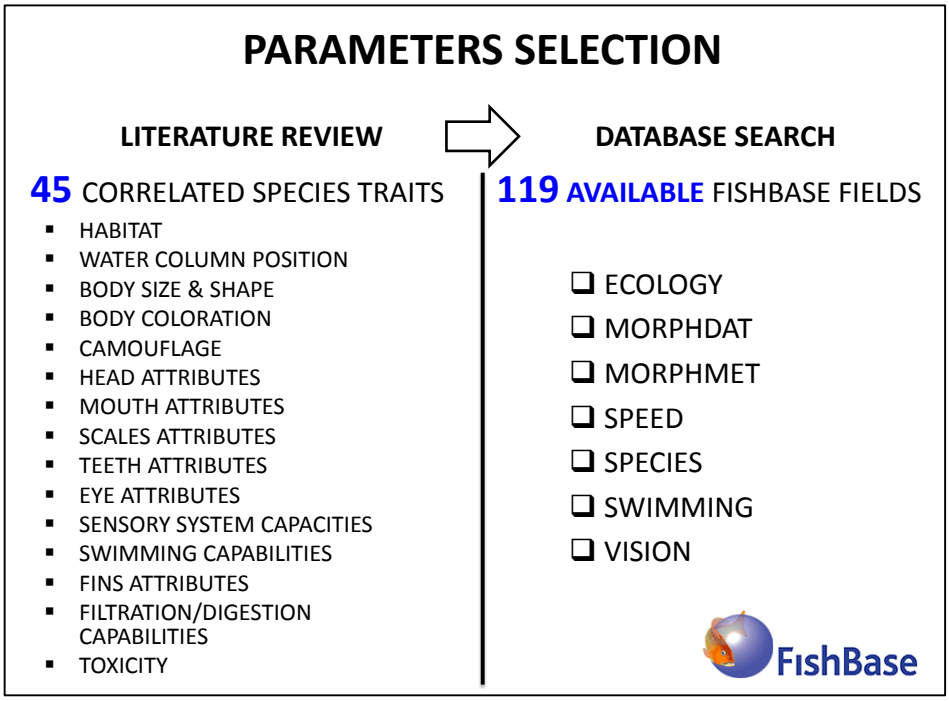


Fig. 2: Summarized list of fish species traits and corresponding ecological and biological parameters available in FishBase, which have been identified as correlated to fish feeding behaviour.

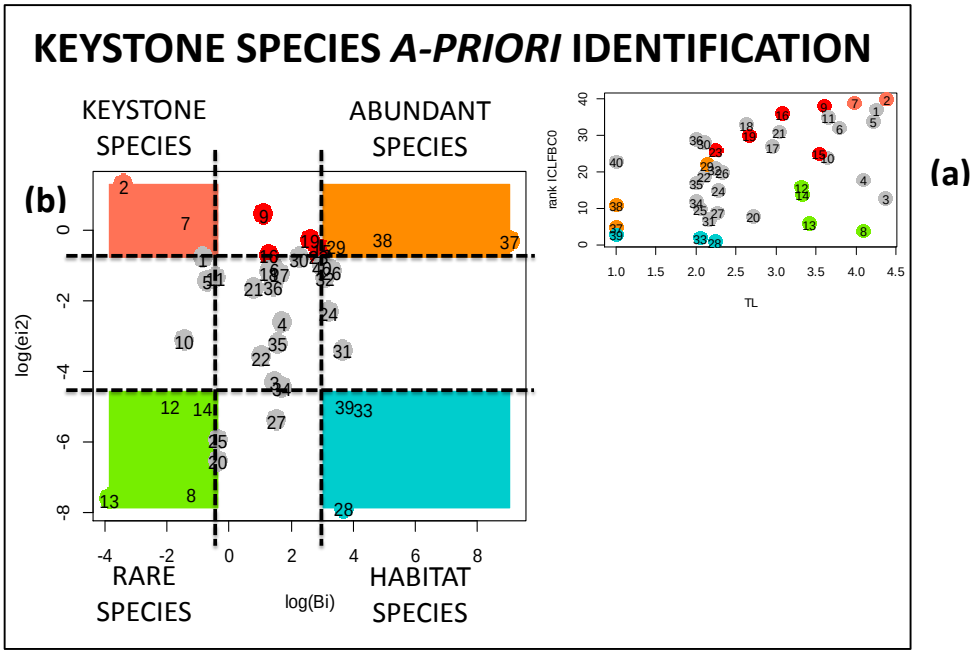


Fig. 3: Example of application of the keystone species identification methodology: each dot on the plots represents a species or a group of species from a particular EwE model, identified by its number (a) “rank ICLFBC0” is the new index of keystoneness and “TL” is trophic level (b) the graphical method for a-priori identifying keystone (pink box) and other critical species (orange, green, turquoise).

MARINE GEOSPATIAL ECOLOGY LAB, DUKE UNIVERSITY

Nereus collaborators at the Marine Geospatial Ecology Lab include Dr. Patrick Halpin (PI), Mr. Daniel Dunn (Nereus Fellow), and Dr. Andre Boustany (Senior Nereus Fellow).

Dr. Patrick Halpin
Director, Marine Geospatial Ecology Lab

Although Mr. Dunn has yet to complete his preliminary examination, he has already published a book chapter and has two additional articles that have either been submitted or are in revision, as well as two to three others to be submitted shortly. Mr. Dunn and Dr. Boustany have been involved in an ongoing collaboration with the Stockholm Resilience Centre, and are currently developing a paper through their collective efforts.

Dr. Halpin and Mr. Dunn have attended several international meetings for the Global Ocean Biodiversity Initiative (GOBI) and the Convention of Biological Diversity (CBD), which Duke will incorporate into new directions for the Nereus Program. The expertise in biodiversity provided by Dr. Halpin and Dr. Boustany will help with this integration. Mr. Dunn also operates as the lead for the Pelagic Working Group under GOBI.

Overall, the lab has been both pleased and enthusiastic about the program. It has been an incredible experience, offering the opportunity to collaborate and share ideas with exceptional colleagues—especially with those who offer expertise other than its own.

Below is a research summary and year highlights from Duke's current Nereus Fellows.

DR. ANDRE BOUSTANY, DUKE SENIOR RESEARCH FELLOW

Research Summary

For the past year, I have been developing methods to identify fisheries ecotypes and determine how environmental conditions (sea surface temperature, productivity, bathymetry, etc.) affect the catch composition in global fisheries. As capture fisheries extract seafood directly from a dynamic ecosystem, they are likely to see significant shifts in distribution and yield due to climate change. For US pelagic longline fisheries in the North Atlantic, it was found that static variables such as bathymetry were greater determinants in predicting catch composition than dynamic variables such as sea surface temperature. This means that for large regions of the ocean, fish and the fisheries that target them will be exposed to changing oceanographic conditions *in situ* rather than see large shifts in distribution. In addition, I have been continuing collaborative work examining the environmental correlates of distributions of a number of fish and bycatch species. Modeling outputs from these studies will aid in management of commercially exploited fishes and protected species. To further these management aims, I also continued to serve on the Highly

Migratory Species Advisory Panel and the US ICCAT Advisory Committee, which advises on domestic and international fisheries, respectively.

Next Steps

The immediate next steps in my research will be to complete several of the ongoing studies initiated under the Nereus Program. The next major product will be an examination of the effects of the resolution of environmental variables on our ability to predict species distribution shifts under a changing climate. The highest resolution climate models are still rather coarse in their resolution (~ 1 degree), while marine animal habitat models are generally built using satellite and bathymetric data at a much higher resolution (~4 km, 30 arc second). What effect this difference in resolution has on our ability to define animal habitat will have important impacts on the confidence we have in predicting animal distributions under a changing climate. For this work, I will be working with Nereus researches at GFDL, Princeton, and Cambridge to examine simulated marine animal distributions as environmental data are progressively made coarser.

Publications (2012 to Present)

Farrell, E. R., **A. M. Boustany**, P. N. Halpin, and D. Hammond. (submitted) The influence of biophysical ocean conditions on dolphinfish (*Coryphaena hippurus*) commercial and recreational catch in the U.S. Atlantic fishery. *Canadian Journal of Fisheries and Aquatic Sciences.*

Epstein, G., M. Nenadovic, M. Cox, and **A. M. Boustany.** (submitted) Governing a complex resource in oceanic commons: International governance of Atlantic Bluefin Tuna.

Hsu, A. C., **A. M. Boustany**, J. Roberts, and P. N. Halpin. (In Review) The effects of mesoscale eddies on tuna and swordfish catch in the U.S. northwest Atlantic longline fishery. *Fisheries Ocenography*.

Dunn, D. C., **A. M. Boustany**, J. J. Roberts, E. Brazer, M. Sanderson, B. Gardner, P. N. Halpin. (2013). Empirical move-on rules to inform fishing strategies: a New England case study. *Fish and Fisheries*; DOI: 10.1111/faf.12019.

O'Dor, R., **A.M. Boustany,** C. M. Chittenden, M. J. Costello, H. Moustahfid, J. Payne, D. Steinke, M. J. W. Stokesbury, and E. Vanden Berghe. 2012. A Census of Fishes and Everything They Eat: How the Census of Marine Life Advanced Fisheries Science. *Fisheries* 37(9): 398-409

Meetings, Workshops, and Presentations

- US Advisory Committee to ICCAT, April 3-5, 2013. Silver Spring, MD.
- "Habitat and Fisheries Interactions: Spatial Patterns Under Climate Change." AAAS Meeting. Feb. 17th, 2013. Boston, MA.
- Japan Fisheries Agency, November 20, 2012
- Hokkaido University, November 18, 2012
- Highly Migratory Species Advisory Panel, Sept 19-21, 2012. Silver Spring, MD.
- Workshop on "Trends of Humana Use in Areas Beyond National Jurisdiction." Sept 10-14, 2012. Stockholm, Sweden.
- "Spatial Management of Pelagic Ecosystems Workshop: Visions for the Future." March 26-30, 2012. Sete, France.
- US Advisory Committee to ICCAT, April 30-May 2, 2012. Silver Spring, MD.
- Highly Migratory Species Advisory Panel, March 13-15, 2012. Silver Spring, MD.

DANIEL DUNN, DUKE RESEARCH FELLOW

Research Summary

Over the last year I have mainly focused on fulfilling the coursework required by my PhD program and on the first chapter of my dissertation. The focus of my research was on understanding how autocorrelation in fishing events can inform rules on how to avoid them. Many fisheries have employed such "move-on" rules, but they are never informed by an analysis of the correlation of the events over time and space (i.e., autocorrelation). In a publication in *Fish & Fisheries* that came out in early 2013, I show how such rules can be generated from observer data, and how they could have reduced finfish bycatch (juveniles and non-target species) and depredation events (catch eaten by another species before it gets decked) by between 27% and 54%. This has vast implications for decreasing waste and increasing landings in global fisheries.

Next Steps

The next step in my PhD program is my preliminary exam that will take place on May 23rd. This is one of the largest hurdles in US PhD programs as it involves both a dissertation proposal defense and an exhaustive exam. After the preliminary exam, I will focus on producing the next chapters of my dissertation. Chapter 2 will focus on use of species response curves to develop area-based closures to avoid the same type of economically undesirable catch events as I examined in chapter 1. Specifically, I will attempt to identify optimum temperatures to differentiate multiple catch events. Depending on how quickly this study goes, I will also look at how the voluntary closures identified in chapters 1 and 2 might compare to static closures meant to accomplish the same objectives. I will also continue to work with Nereus-affiliated researchers at the Stockholm Resilience Centre on a manuscript describing trends in use of the high seas.

Publications (2012 to Present)

2012 (Pre-Nereus work)

Curtice, C., **D. C. Dunn**, J. J. Roberts, P. N. Halpin. (2012) Ecosystem-Based Management May Fail Without Changes to Tool Development Financing. *Bioscience* 62(5):508-515.

Garcia, S. M., J. Kolding, J. Rice, M-J. Rochet, S. Zhou, T. Arimoto, J. E. Beyer, L. Borges, A. Bundy, **D. C. Dunn**, N. Graham, M. Hall, M. Heino, R. Law, M. Makino, A. D. Rijnsdorp, F. Simard, and A. D. M. Smith (2012) Balanced harvesting: reconsidering the consequences of selective fisheries. *Science* 335:1045-1047.

Van Dover C. L., C. Smith, J. Ardron, **D. C. Dunn**, K. Gjerde, L. Levin *et al.* (2012) Designating networks of chemosynthetic ecosystem reserves in the deep sea. *Marine Policy* 36: 378–381

2013 (NF-UBC Nereus Program acknowledgement)

Ban, N. C., N. J. Bax, K. M. Gjerde, R. Devillers, **D. C. Dunn**, P. K. Dunstan, A. J. Hobday, S. M. Maxwell, D. Kaplan, R. L. Pressey, J. A. Ardron, E. T. Game, P. N. Halpin. (2013) Systematic Conservation Planning: A new recipe for managing the High Seas. *Conservation Letters*. Available online early.

Dunn, D. C., A. M. Boustany, J. J. Roberts, P. N. Halpin (2013) Empirical move-on rules to inform fishing strategies: a New England case study. *Fish & Fisheries*. Available online early.

Meetings, Workshops, and Presentations

Workshops:

- Eastern Tropical and Temperate Pacific Regional Workshop to Facilitate the Description of Ecologically or Biologically Significant Marine Areas. Galapagos, Ecuador.
- Conservation Planning in the Open Ocean Workshop. Stradbroke Island, Australia.
- Spatial Management of Pelagic Ecosystems Workshop: Visions for the Future. Sete, France.

Upcoming:

- Biogeography of the Deep Pelagic Workshop. Glasgow, Scotland.

Presentations:

- "Identification of Pelagic EBSAs: Examples & Guidelines." World Conference on Marine Biodiversity. Aberdeen, Scotland.
- "Spatiotemporal methods to reduce bycatch in the New England groundfish fishery." World Conference on Marine Biodiversity. Aberdeen, Scotland.
- "Examples of the description of areas meeting the EBSA criteria." Convention on Biological Diversity's Eastern Tropical and Temperate Pacific Regional Workshop. Galapagos, Ecuador.
- "The alphabet in the pelagic soup." Society for Conservation Biology, North American meeting. Oakland, California, USA
- "Spatiotemporal methods to reduce bycatch in the New England groundfish fishery." Spatial Management of Pelagic Ecosystems Workshop: Visions for the Future. Sete, France.

Upcoming:

- Stanford Symposium on Dynamic Ocean Conservation. Stanford, California, USA.
- "Managing Our Nation's Fisheries." Washington, DC, USA

PRINCETON UNIVERSITY

Dr. Jorge L. Sarmiento
Director, Atmospheric and Oceanic Sciences Program

Princeton University's recruitment of Nereus Fellows began last year with Dr. Kelly Kearney as its junior fellow and Dr. James Watson as its senior fellow. Because Dr. Kearney already had received funding, the university was able to hire an additional senior fellow, Dr. Ryan Rykaczewski. The Princeton team is pleased to note that it now has two alumni from the program: Dr. Kearney recently successfully defended her PhD thesis, and has accepted a position at the University of Miami; Dr. Rykaczewski has accepted a position as assistant professor at the University of South Carolina. Dr. Thomas Frölicher is a new postdoctoral researcher from Switzerland who has been contributing significantly to the department, and has joined Princeton as a Nereus Fellow. Dr. Watson is continuing to work with the lab, and Princeton is currently advertising for new candidates for the position of the junior fellow, and has made an offer to an oceanography expert at Scripps Institute of Oceanography.

With respect to publications, Dr. Kearney has published a paper on ecological modeling through an end-to-end Ecopath-based Nemero model for lower trophic levels in the northeast Pacific. Dr. Rykaczewski has interfaced extensively between researchers looking at climate responses and earth systems and has written several papers on this, with Dr. Charles Stock contributing as an important intellectual lead. Dr. Watson has two interesting projects: one developing a size-based ecosystem model used to look at the effect of movement on the distribution of fish in the ocean, as well as a model for baleen whales. Drs. Frölicher, Pauly, Cheung, and Jorge Sarmiento have written several papers, with Dr. Frölicher providing much of the data for these studies.

This year, representatives from another foundation were considering developing environmental fellowships and asked the university for advice regarding potential models for their initiative. Princeton is confident that the Nereus Program represents the ideal model. Princeton sincerely admires the effort of the program offices at UBC, Dr. Ota in particular, to organize this program, and believes the initiative can operate as a model for future interdisciplinary efforts.

Below is a research summary and year highlights from Princeton's current Nereus Fellows.

DR. THOMAS FRÖLICHER, DUKE RESEARCH FELLOW

Research Summary

My overall goals are (1) to assess the response of fisheries relevant quantities (i.e. primary production, oxygen, acidity) to global warming, and (2) to examine the degree of reversibility on human timescales. For tools, I am using and running comprehensive fully coupled Earth System Models such as the ESM2M model developed at the NOAA Geophysical Fluid Dynamics Laboratory (GFDL). Earth System Models combine physical climate models with ocean biogeochemistry and ecology.

In the last year I have performed a series of model simulations with the GFDL ESM2M to investigate the response of the marine ecosystem to an instantaneous removal of all anthropogenic radiative forcing agents from the atmosphere at different times during the 21st century. Preliminary results indicate that changes in global mean surface pH and primary production are largely reversible on decadal-to-centennial timescales. In contrast, past and future carbon emissions cause irreversible ocean warming, deoxygenation, and deep ocean acidification. See Figure 1 for an illustration of the preliminary results. The results will be submitted to a peer-reviewed journal in the next few months. In addition, the physical and biogeochemical variables from the simulations are used to run the dynamic bioclimate envelope model developed by Dr. William Cheung of the University of British Columbia. The goal is to explore how long it will take for the marine ecosystem to reestablish the status quo (i.e. how long it will take for fish to move back towards the equator), and how many species of marine fishes will be lost in the warming interval.

In collaboration with researchers at the University of British Columbia and Princeton University, I have employed a model to examine the integrated biological responses of over 600 species of marine fishes due to changes in distribution, abundance and body size. The model has an explicit representation of ecophysiology, dispersal, distribution, and population dynamics. The model results show that assemblage-averaged maximum body weight is expected to shrink by 14–24% globally from 2000 to 2050 in a warmer less oxygenated ocean under a high-emission scenario. About half of this shrinkage is due to change in distribution and abundance, the remainder to changes in physiology. The tropical and intermediate latitudinal areas will be heavily impacted, with an average reduction of more than 20%. This study provides a new dimension to understand the integrated impacts of climate change on marine ecosystems. The results were published in *Nature Climate Change* last year.

In collaboration with European climate modelers, I have investigated decadal-to-century scale trends in oxygen and indicators of stress for marine life in global warming projections of seven Earth System Models. We show that a decrease of 2% to 4% in the total ocean inventory of dissolved oxygen by year 2100 is projected by the range of models. Projected changes in the total volume of hypoxic and suboxic waters, however, remain relatively small.

Next Steps

I recently accepted an AMBIZIONE grant from the Swiss National Science Foundation that allows me to work as a researcher at ETH Zürich in Switzerland in the Environmental Physics group led by Professor Nicolas Gruber. I will visit Drs. Cheung and Ota from Nereus in May 2013. The purpose of the meeting is to discuss

my work on irreversible and reversible changes, and to examine preliminary results from Dr. Cheung's simulations with the dynamic bioclimate envelope model.

Publications (2012 to Present)

Raupach, M. R., M. Gloor, J. L. Sarmiento, J. G. Canadell, **T. L. Frölicher**, T. Gasser, R. A. Houghton, C. L. LeQuéré, C. M. Trudinger, 2012, Diagnosis and attribution of observed changes in the global carbon cycle over the last 50 years, submitted.

Fernandes, J., W. W. Cheung, S. Jennings, M. Butenschoen, L. de Mora, **T. L. Frölicher**, M. Barange, A. Grant, Modeling the effects of climate change on the distribution and production of marine fishes: accounting for trophic interactions in a dynamic bioclimate envelope model. *Global Change Biology,* accepted.

Frölicher, T. L., F. Joos, C. C. Raible, J. L. Sarmiento, 2013, Atmospheric CO2 response to volcanic eruptions: The role of ENSO, season, and variability. *Global Biogeochem. Cycl*es, 27, 1-13.

Cocco, V., F. Joos, M. Steinacher, **T. L. Frölicher**, L. Bopp, J. Dunne, M. Gehlen, C. Heinze, J. Orr, A. Oschlies, B. Schneider, J. Segschneider, J. Tjiputra., 2013, Oxygen and indicators of stress for marine life in multi-model global warming projections. *Biogeosciences*, 10, 1849-1868.

Joos, F., R. Roth, J. S. Fuglestvedt, G. P. Peters, I. G. Enting, W. von Bloh, V. Brovkin, E. J. Burke, M. Eby, N. R. Edwards, T. Friedrich, **T. L. Frölicher**, P. R. Halloran, P. B. Holden, C. Jones, T. Kleinen, F. Mackenzie, K. Matsumoto, M. Meinshausen, G.-K. Plattner, A. Reisinger, J. Segschneider, G. Shaffer, M. Steinacher, K. Strassmann, K. Tanaka, A. Timmermann, A. J. Weaver, 2013, Carbon dioxide and climate impulse response functions for the computation of greenhouse gas metrics: A multi-model analysis. *Atmos. Chem. Phys.*, 13, 2793-2825.

Jones, M. C., S. R. Dye, J. A. Fernandes, **T. L. Frölicher**, J. K. Pinnegar, R. Warren, W. W. L. Cheung, 2013, Predicting the impact of climate change on threatened species in UK waters. *PLoS ONE*, 8(1).

Cheung, W. W. L., J. L. Sarmiento, J. Dunne, **T. L. Frölicher**, V. Lam, M. L. Deng Palomares, R. Watson, D. Pauly, 2013, Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems. *Nature Climate Change*, 3, 254-258

Winton, M, S. M. Griffies, B. Samuels, J. L. Sarmiento, **T. L. Frölicher**, 2013, Connecting changing ocean circulation with changing climate. *J. of Climate*, 26, 2268-2278

Keller, K. M., F. Joos, C. C. Raible, V. Cocco, **T. L. Frölicher,** J. P. Dunne, M. Gehlen, T. Roy, L. Bopp, J. C. Orr, J. Tjiputra, C. Heinze, J. Segschneider, N. Metzl. 2012, Variability of the Ocean Carbon Cycle in Response to the North Atlantic Oscillation. *Tellus B*, 64, 18738.

Gruber, N., C. Hauri, Z. Lachkar, D. Loher, **T. L. Frölicher,** G.-K. Plattner, 2012, Rapid progression of ocean acidification in the California Current System. *Science*, 337(6091), 220-223.

Meetings, Workshops, and Presentations

- AOS Program Seminar, Princeton University, USA (12/12), talk
- All hands meeting, C-SOBOM NSF Site visit, Princeton University, USA (10/12), invited talk
- SOBOM student/postdoc symposium, Princeton University, USA, talk
- SCAR Open Science Conference, Portland, USA (7/12), poster
- AMBIZIONE phase 2, Swiss NSF, Bern, Switzerland, (5/12), invited talk
- AOS Program Seminar, Princeton University, USA (5/12), talk

- CMI annual meeting, Princeton University, USA (4/12), poster
- Seminar, Lamont-Doherty Earth Observatory, Columbia University, New York, USA (4/12), invited talk
- CMIP5 Analysis workshop, Honolulu, USA (3/12), talk and poster
- Ocean Sciences Meeting, ASLO, Salt Lake City, USA, (2/12) talk
- Environmental Geology and Geochemistry Seminar, Princeton University, USA (1/12) invited talk
- Seminar, Goddard Institute for Space Studies, NASA, New York, USA (1/12) invited talk

Key slide

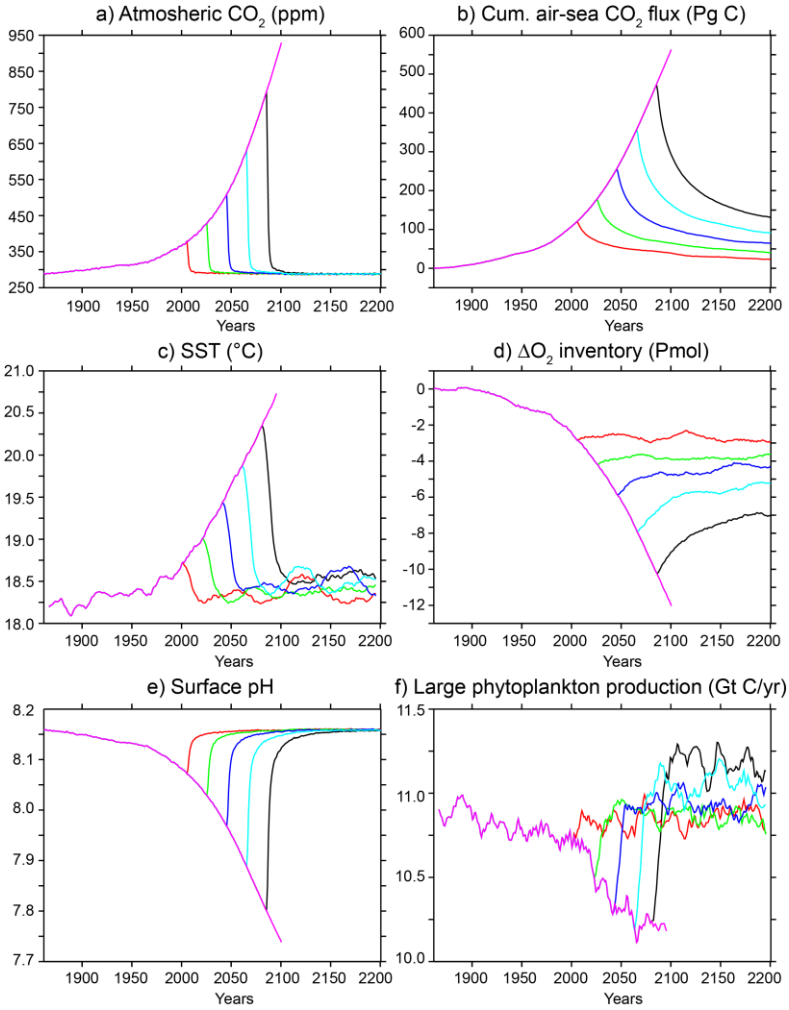


Fig. 1: Reversible and irreversible changes in response to an instantaneous removal of all anthropogenic radiative forcing agents simulated by the GFDL ESM2M model. (a) Prescribed atmospheric CO2 concentrations. Time series of simulated global annual mean (b) cumulative air-sea CO2 fluxes, (c) sea surface temperature, (d) oxygen inventory, (e) surface pH and (f) large phytoplankton production.

DR. JAMES WATSON, PRINCETON SENIOR RESEARCH FELLOW

Research Summary

In the last year, I have developed a global size-based ecosystem model that simulates the dynamics of upper trophic marine species. This model integrates size-based theory, developed by the likes of Simon Jennings and Julia Blanchard, with output from Charles Stock's (Nereus affiliate) Carbon Ocean Biogeochemistry and Lower Trophics model (COBALT) run at the Geophysical Fluid Dynamics Laboratory. My main results are (1) estimates of the spatial distribution of fish (from sardine to large top predators) globally; (2) an understanding of how these distributions change with time, for example with El Niño; and (3) the location of "Ecoregions," or areas of the ocean with distinct size spectra. Most importantly, I have shown that these results are highly sensitive to the implementation of movement, lending insight into its ecological importance. (See Figures 1 and 2 for an illustration of my main results.)

My other research drive has been to investigate the migration of baleen whales. I have developed an agent-based model of whale migration that uses zooplankton (i.e. whale food) and temperature (i.e. whale calving habitat) fields from COBALT to infer migration routes globally. Presently, I am validating my model results with empirical maps of baleen whale migration.

Next Steps

This year I have obtained an National Science Foundation (NSF) grant to investigate the role human behavior plays in determining the success of fisheries. I am leading this project with Dr. Simon Levin (a professor in the Ecology and Evolutionary Biology department at Princeton University) and with Dr. Yoshi Ota from Nereus as a collaborator. I have also accepted a researcher position at the Stockholm Resilience Centre (a partner institute in the Nereus Program) and I will be using my NSF grant to bridge common interests between Princeton University and Stockholm. My work on size-based ecosystem modeling will also be focal research while at Stockholm. I am currently developing models of fishing and international markets that will be integrated into the existing global modeling framework. This work will necessitate collaborations between ecologists and oceanographers at Princeton and economists at Stockholm and the Beijer Institute. My long-term goal with the development of these models is to make projections (under different climate scenarios) of the abundance of upper trophic marine species, and concomitant changes in the ecosystems services provided by the oceans (i.e., food and jobs).

Publications (2012 to Present)

J. R. Watson, C. Stock, and J. Sarmiento. The role of movement in determining the global distribution of marine biomass. In review at the Proceedings of the National Academy of Sciences (PNAS).

J. R. Watson, B. E. Kendall, D. A. Siegel, and S. Mitarai. Changing landscapes, stochastic connectivity and metapopulation dynamics. *The American Naturalist*. *180 (1) 90-112*. Identified as important by the Faculty 1000: http://f1000.com/717948573

Meetings, Workshops, and Presentations

- "Flow, Fish and Fishing: analyzing the links between physics, ecology and human behavior in marine systems." Massachusetts Institute of Technology (MIT), invited speaker: Department of Earth, Atmospheric and Planetary Sciences.
- "Flow, Fish and Fishing: analyzing the links between physics, ecology and human behavior in marine systems." Rutgers University, invited speaker: Institute of Marine and Coastal Sciences.
- "Earth System Modeling and Global Marine Food-security," American Fisheries Society annual meeting (session organizer), St. Paul, Minnesota.
- "Changing Seascapes, Stochastic Connectivity and Marine Metapopulation Dynamics," Ecological Society of America annual meeting, Portland, Oregon.
- "Quantifying the distribution and dynamics of forage fish using a size-based ecosystem model," PICES annual meeting, Yeosu, Korea.
- "Modeling the Spatial Dynamics of Baleen Whales and Forage Fish." American Association for the Advancement of Science (AAAS) annual meeting (Poster), Vancouver, Canada.

Key Slide

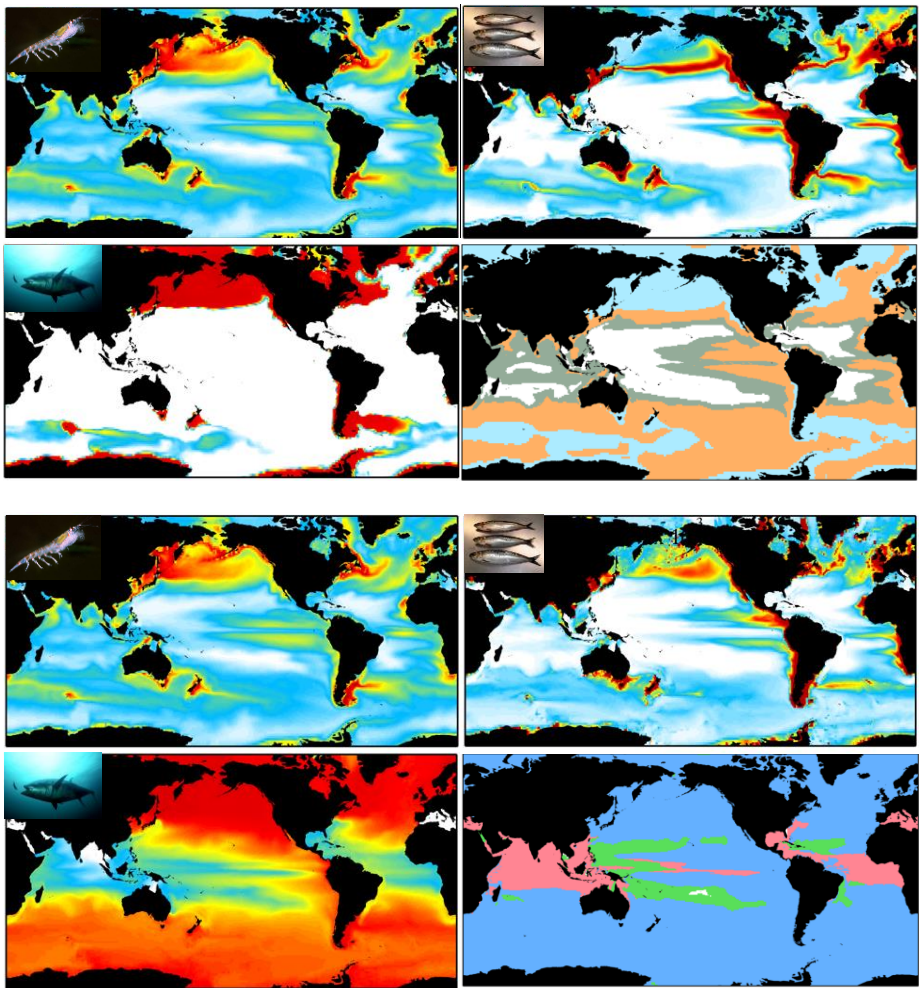


Fig. 1: Distribution of marine biomass with movement. Top left: distribution of krill produced from COBALT. Top-right and bottom-left: distribution of forage fish and top-predators respectively. Colors denote relative abundance (reds more, whites less). Bottom-right: distribution of marine ecoregions, defined by the shape of size-spectra.

STOCKHOLM RESILIENCE CENTRE, UNIVERSITY OF STOCKHOLM

The marine research team at the Stockholm Resilience Centre sets its research scope on multi-level (local, national, and international) governance, promoting Nereus' engagement with higher levels of governance, which has brought excellent collaboration opportunities to the center through Nereus.

Last year, the centre has had internal and external discussions regarding various ways to incorporate the Nereus Program into wider governance studies conducted in the centre. As a result, more than 20 people from the centre have participated in the Nereus workshops (one organized collaboratively with UBC and another with Duke).

Dr. Carl Folke
Professor,
Science Director and
Theme Leader

Dr. Henrik Österblom
Docent, Deputy Science
Director and Theme Leader

The SRC's two Nereus Fellows have been participating for one year, and have progressed well during this time. Dr. Marc Metian, Senior Nereus Fellow, has been directing his efforts toward understanding how aquaculture fits into the picture of food security as well as the associated trade-offs with capture fisheries. Through collaboration with colleagues, Dr. Metian has produced three papers that have been submitted or accepted on these issues. Mr. Andrew Merrie, the Nereus Fellow of the centre, has been working on marine resource global governance, and his work has been progressing well. He has also organized a workshop with Duke fellows to address the issues on the increased use of high sea and the need for a new management regime.

The SRC has expanded its efforts toward collaborating with Dr. Jorge Sarmiento of Princeton University and others in order to understand the level of analysis or detail it can focus on when conducting global analyses on marine socio-ecological scenarios, considering the framework to integrate different aspects of scientific analysis within the Nereus Program. The paper developed for this purposes is in review, and functioned as a useful exercise to determine a common approach towards understanding socio-ecological systems.

Below is a research summary and year highlights from Princeton's current Nereus Fellows.

DR. MARC METIAN, SRC SENIOR RESEARCH FELLOW

Research Summary

During the last 12 months, I have worked intensively within the Nereus Program on various aspects of global aquaculture development. The major part of this first year of my fellowship was to elaborate my own project ideas and, in parallel, develop and formalize collaborations and discussions with other colleagues. The main objective was to investigate the future expansion of aquaculture within the specific context of limited resources of fish from global fisheries and an increasing demand. The main focus of my fellowship stays the same: to investigate links between sustainable aquaculture, food security, and governance, particularly in

light of projected substantial increased demand for seafood due to both population growth and global per capita consumption.

In order to understand global dynamics of aquaculture development, I am using data from FAO, SUA, and questionnaires. These allow me to estimate how aquaculture is affecting consumption, ecosystems and people due to social-ecological trade-offs. Trade-offs exist, for example, between aquatic and terrestrial ingredients used for feeds in aquaculture and direct human consumption.

At the Stockholm Resilience Centre (SRC), I have the opportunity to be involved in interdisciplinary projects (ranging from political science, economics, and social science). I am also involved with groups outside the SRC working on global issues related to human wellbeing and where aquaculture is included in the overall food portfolio.

This year, research outputs involved publications on nutritional aspects (aquaculture and human nutrition) and interdisciplinary work addressing governance of social ecological systems. Aquaculture's role for global food security been addressed in two publications (submitted in 2012).

Next Steps

The work plan for my second and last year of the fellowship will mainly be to finalize ongoing work, especially the papers I have started to write. These papers are dealing with global diversity of aquaculture, trophic levels in aquaculture, supply and consumption of fish and also sustainable development of aquaculture. Of course, collaborative work will still be very important and be maintained in parallel to my own work, including the new Fellows' Working Group on Fisheries and food security (with some Nereus colleagues) and the continuation of developing an aquaculture model (with PBL and the UBC Fisheries Centre).

Publications (2012 to Present)

Published or in the process of being published:

Tacon A. G. J. and **M. Metian.** (2013) Fish Matters: Importance of aquatic foods in human nutrition and global food supply. *Reviews in Fisheries Science* 21 (1): 22–38.

Beveridge M., S. Thilsted, M. Phillips, **M. Metian**, M. Troell, and S. Hall. (revised) Meeting the Food and Nutrition Needs of the Poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculture. *Journal of Fish Biology.*

Österblom H., M. Merrie, **M**. **Metian**, W. J. Boonstra, T. Blenckner, J. Watson, R. Rykaczewski, Y. Ota, J. L. Sarmiento, V. Christensen, S. Birnbaum, B. G. Gustavsson, C. Humborg, C.-M. Mörth, B. Müeller-Karulis, M. Schlüter, M. T. Tomczak, M. Troell, and C. Folke. (in revision) Social-ecological scenarios for marine systems. *BioScience*.

Other publications (not directly related to the Nereus Program):

Metian, M., M. Warnau, T. Chouvelon, F. Pedraza, A. Rodriguez y Baena, and P. Bustamante. (accepted) Trace element bioaccumulation in reef fish from New Caledonia: influence of trophic groups and risk assessment for consumers. *Marine Environmental Research.*

Norström, A. V., A. Dannenberg, G. McCarney, M. Milkoreit, F. Diekert, G. Engström, R. Fishman, J. Gars, E.

Kyriakopolou, V. Manoussi, K. Meng, **M. Metian**, M. Sanctuary, M. Schlüter, M. Schoon, L. Schultz, and M. Sjöstedt. (submitted) Three necessary conditions for establishing effective Sustainable Development Goals in the Anthropocence. Science.

Meetings, Workshops, and Presentations

Presentations:

- **Metian**, M., T. Troell, H. Österblom, A. Merrie, and C. Folke. "Bridging demand and supply of seafood: Sustainable aquaculture in a changing world." AAAS annual meeting 2013 - "Beauty and benefit of science, February 14-18, Boston, USA.
- Tacon, A. G. J. and **M. Metian**. "Role of fish and aquaculture products in human nutrition and global food security." VI AQUASUR conference: "Soñando y construyendo la acuicultura del mañana", Octobre 11-12, 2012, Puerto Varas, Chili.
- Tacon, A. G. J. and **M. Metian**. "Contribution of fish to global of Fish to Global food supply: Role of aquatic produce in Human nutrition and food security of the poor." AQUA 2012 - "Global Aquaculture - Securing Our Future", September 2-5, 2012, Prague, Czech Republic.
- Tacon, A. G. J. and **M. Metian**, and T. Troell. "Aquaculture development – implications from environmental pollution and contaminant." AQUA 2012 - "Global Aquaculture - Securing Our Future", September 2-5, 2012, Prague, Czech Republic.
- Beveridge, M., S. Thilsted, M. Phillips. **M. Metian,** T. Troell, and S. Hall. "Meeting the Food and Nutrition Needs of the Poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculture." 6th World Fisheries Congress. May 7-11, 2012, Edinburgh, Scotland.

Invitations:

- **2nd Workshop of the Beijer Young Scholar (2013)**, by the Beijer Institute of Ecological Economics. Topic: Cross-scale dynamics of food production and consumption? May 13rd -16th 2013 (Stockholm, Sweden - Scholar).
- **Lecture on Sustainable Aquaculture** at ECOSUS –Aqua 2012 (Education Course of Sustainability) / Master training course at the Center for Sustainability Science (CENSUS) of Hokkaido University, Japan (HU Usujiri Fisheries Station - Lecturer) - November 17th 2012.
- **1st Workshop of the Beijer Young Scholar (2012)**, by the Beijer Institute of Ecological Economics. Topic: How can we stimulate social innovation and steer technological progress to promote desirable and resilient futures for humanity? 20-25 May 2012 (Stockholm, Sweden - Scholar).
- **Workshop on development of aquaculture in China**, invited by the Center on Food Security and the Environment (Rosamond Naylor; Stanford University. June 27-29 2012 (Palo alto, CA - Scholar).

Key Slide

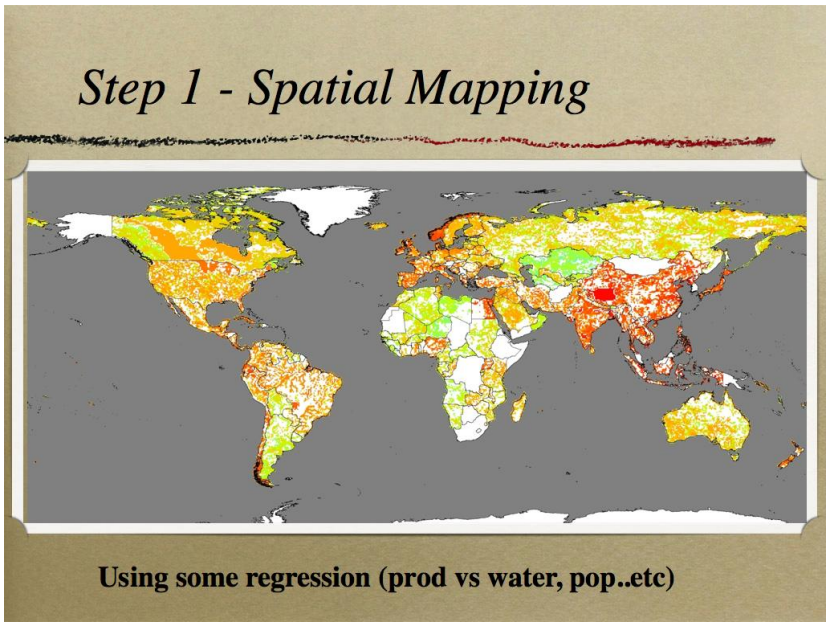


Fig. 1: Slide from the Annual meeting: Illustration of collaborative work started in 2012 with UBC and PBL on an aquaculture model (the first step – mapping the activity and a better resolution)

ANDREW MERRIE, SRC RESEARCH FELLOW

Research Summary

Global Governance of Marine Resources – Actors, Networks and Organizations

Over the year I have been working on four individual projects that are each specific contributions to better understanding emerging global governance of living marine resources. The first project builds on work I did during my master's and is focused on the emergence and spread of Marine Spatial Planning as a tool for ecosystem based management of the oceans. Secondly, I have been leading a Nereus Contribution paper about trends in the high seas. This paper is the output of a fellows workshop held towards the end of 2012 in Stockholm with Duke University. Thirdly, I have been working on a paper about governing the high seas under climate change which connects prospects of Regional Fisheries Management Organizations to effectively govern a changing ocean. Finally, I with the SRC Senior Fellow have been working on a project that looks at the evolution of marine science and its ability to deal with complex social-ecological challenges facing the oceans. I have also been co-supervising a master's student at the SRC whose work is focused on formal and informal governance mechanisms within international tuna fisheries management organizations.

Next Steps

In addition to wrapping up publication of the projects described above, Andrew is working on a media analysis of the global industrial fishing industry which would consider evolution in technologies and industry responses to governance initiatives as a strategy for developing plausible future governance scenarios of the ocean that contributes to the social-ecological modeling roadmap submitted as a Nereus contribution to

Bioscience. Andrew very much looks forward to ongoing collaborations as part of the Nereus Program and being inspired by the excellent work that is in progress as part of the program.

Publications (2012 to Present)

Österblom, H., **A. Merrie**, M. Metian et. al. (2013) Social-Ecological Scenarios in Marine Systems, Bioscience (In Press).

Meetings, Workshops, and Presentations

Design and Facilitation of two day Marine Spatial Planning Workshop held at SRC in April 2013.

"Marine Social-Ecological Innovations" – A presentation to the Singularity University 2013 Graduate Studies Program, June 2013, San Francisco, USA.

UNEP-WCMC: UNIVERSITY OF CAMBRIDGE

In Cambridge, there are two fellows: Dr. Chris McOwen, who began in September 2011, and Mr. Laurens Geffert, who recently joined the university in October 2012. Despite the absence of Dr. Louisa Wood, the head of the Marine Assessment and Decision Support program at UNEP-WCMC, both fellows have assisted in providing strategic direction in research and collaboration.

Dr. Mike Bithell
Assistant Director of Research in Computing, Cambridge University

Dr. Louisa Wood
Head of Program, Marine Assessment and Decision Support, UNEP-WCMC

Dr. McOwen is working on the temporal variance of fish yield, addressing how space and time, as well as human factors, interfere with or distort the view of biomass through yield. He is also working on the spatial variance of catch in the high seas and coasts, which has yielded two papers that he is currently writing. Mr. Geffert, the Nereus Fellow, is looking at species range maps and how these relate to the environment and can be developed using different techniques, which his supervisor, Dr. Tom Spencer has been focusing on matters relating to this field.

The University of Cambridge is especially intrigued by the inherently interdisciplinary component of this program. In particular, it is interested in the interactions and influences between people and climate, since the Department of Geography at the University of Cambridge deals directly with this confrontation and focuses on developing the study in different geographical scales. Institutionally, the contact with Nereus began through the Cambridge Conservation Initiative, which also had a strong seminal focus and the university is hoping that there will be future opportunities for collaborating with this program through Nereus.

Below is a research summary and year highlights from Princeton's current Nereus Fellows.

DR. CHRIS MCOWEN, CAMBRIDGE/WCMC SENIOR RESEARCH FELLOW

Research Summary

In the last year, I have investigated the primary drivers of temporal variance in commercial fisheries yield—the first study to do so on a global scale using a mixture of environmental and anthropogenic factors. My main result is that the primary correlate(s) of yield varies between regions, i.e., within some fisheries, changes in sea surface temperature are "key" while in others fishing effort is of greater importance. Most importantly, I have shown the latitude of a system acts as a proxy for the key correlate(s), with low-latitude fisheries primarily influenced by fishing pressure; mid-latitude systems influenced by ChlA, and high latitude systems influenced by sea surface temperature.

My other research has been to look at catch within high seas and ask: do the same factors driving variation in the coastal zone apply to the high seas? It is so far clear that they don't. Spatial variation in catch within the coastal zone is primarily related to changes in environmental or oceanographic factors, while—largely due to differences in target species and the greater industrialization of high seas fisheries—catch within the high seas is economically driven. This finding has relevance to how high seas fisheries should be managed and also gives an insight into the role non-ecological or environmental factors play in shaping fisheries catch.

Next Steps

This year I am planning to extend my models of catch to include two additional factors. First, I am keen to investigate the role habitats have in determining the catch within a region. Within the Gulf of California it has been demonstrated that fisheries yield increases with the surrounding density of mangrove; however, I wish to extend this, incorporating more sites (e.g., Africa, Australia) and more habitats (e.g., coral, seagrass). Additionally, I want to develop our understanding of the relationship: currently no account for non-linearity in the relationship has been made (i.e. thresholds) and the spatial area in which yield changes is unknown. This will be a timely study as governments, NGOs, and conservation agencies are keen to quantify the economical benefit provided by marine habitats when conducted ecosystem service assessments. Secondly, I want to incorporate the influence land-based nutrients (e.g., nitrogen) have on coastal fish catch.

Publications (2012 to Present)

Draft papers of both of the topics discussed above have been circulated to the fellows and PI's I have collaborated with. The target journals are *PNAS*/*Ecology Letters* for the study investigating temporal variability in catch and *Fish and Fisheries* for the coastal/high seas work.

Meetings, Workshops, and Presentations

- "Linking terrestrial processes, coastal landscapes, and marine ecosystems." AAAS Annual Meeting, Boston. February 2013.
- "Linking terrestrial processes, coastal landscapes, and marine ecosystems." NHM London.
- "Variation in fisheries – why and where?" CEFAS.
- Accepted speaker: "Variation in fisheries – why and where?" European Marine Biology Symposium, Galway, Ireland.

LAURENS GEFFERT, CAMBRIDGE/WCMC RESEARCH FELLOW

Research Summary

Species range maps are a central prerequisite for the management, conservation, and sustainable use of natural resources (Elith et al., 2006). However, our knowledge on the distribution of many species is still poor, especially in the marine realm (Webb et al., 2010). A common approach to overcome data limitations is to predict species ranges through species distribution modelling (SDM).

The central assumption in SDM is that a species' geographic distribution is determined by environmental factors. Each species requires specific environmental conditions in order to survive and successfully reproduce. These requirements make up the ecological niche of a species and also shape its geographic

distribution, as observed by Grinnell (1917). In statistical SDM, species records are used together with environmental variables of particular relevance for the given species to estimate its ecological niche, i.e. the multidimensional volume of suitable environmental conditions. The niche is then projected back into geographic space to infer the actual range (Pearson, 2007).

Next Steps

Range maps generated from SDMs are frequently used to assess the environmental impact of resource management and exploitation. Distribution maps of rare species are also important to estimate extinction risks and prioritize conservation effort. In the framework of the Nereus Program, range maps can be used to inform food web models and other Nereus model components about presence and absence of species at a given location, as well to project future distributions under changing climatic conditions.

NEREUS ALUMNI

DR. KELLY KEARNEY, PRINCETON NEREUS FELLOW

Dr. Kelly Kearney has successfully completed her PhD in Geosciences. Her research title was "An analysis of marine ecosystem dynamics through development of a coupled physical-biogeochemical-fisheries food web model." She has been recruited to a NOAA project based at the University of Miami and NOAA Atlantic Oceanographic and Meterological Laboratory in Miami, FL, working on modeling the effects water management policies and climate change on the Florida Bay ecosystem. Dr. Kearney participated in 2013 Annual meeting and gave a presentation on her current work. Kelly comments on her experience being involved in the program interesting and beneficial to her research because it gave her an opportunity to see the perspectives of those working closely with fisheries science. It gave her a broader perspective of what was being done, offering a greater understanding of other fields. In particular, participating workshops also showed some of the approaches to doing large-scale ecosystem modeling, which reaffirmed her methods as well as giving her alternative ideas.

DR. RYAN RYKACZEWSKI, FORMER PRINCETON SENIOR NEREUS FELLOW

Dr. Ryan Rykaczewski has been successfully finished his term in Nereus and started his new position as Assistant Professor, Department of Biological Sciences, Marine Science Program, at the University of South Carolina. His research as the Nereus Fellow in the context of the research matrix above will primarily be focused on this question: How will the ocean capacity support fisheries change in the future? Currently Dr. Rykaczewski is exploring, in collaboration with Dr. William Cheung (UBC), how long it will take for the marine ecosystem to reestablish the status quo (i.e. how long it will take for the fishes to move back towards the equator), and how many species of marine fishes will be lost in the warming interval. Learn more about Dr. Rykaczewski at http://ww2.biol.sc.edu/~ryk/index.html.

NEREUS EXPANSION STRATEGY

THIRD YEAR, PHASE 1 | FEBRUARY 2013–AUGUST 2014

In order to fulfill Nereus Program objectives, it is necessary for the program office at UBC to organize further enhancement of the scientific and outreach capacity. As such, the program has decided to add more expertise support to its current operational framework. Proposed changes will involve the establishment of new strategy and re-design of the program office.

In respect to this new strategic direction, Dr. William Cheung has joined the Nereus Program as a Nereus' Science Advisor, leading the program with Dr. Yoshi Ota and Dr. Daniel Pauly.

Dr. Christensen will function as The Nippon Foundation Professor of Marine Ecosystem Modeling and Management, and will continue his work towards establishing Nereus' global model.

Also, Dr. Ryan Vachon has joined the program as Education and Communication Coordinator, and will be in charge of all public relations and communication.

NEW MEMBERS OF THE PROGRAM

DR. WILLIAM W. L. CHEUNG

Dr. William Cheung has been an assistant professor at UBC's Fisheries Centre since 2011 and is the Principal Investigator of the Changing Ocean Research Unit. His main research area is assessing the biophysical and socio-economic vulnerabilities and impacts of marine climate change and other human stressors, and identifying mitigation and adaptation options. William obtained his BSc in Biology and MPhil from the University of Hong Kong. He worked for WWF Hong Kong for two years, after which he completed his PhD in Resource Management and Environmental Studies at UBC. From 2009 to 2011, he was a lecturer in Marine Ecosystem Services in the School of Environmental Sciences at the University of East Anglia in the UK. Currently, he works on various interdisciplinary research projects with global collaboration networks including the UK, Australia, Kenya, China, and the USA. He has been the lead author in various high level international assessments, such as the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) and Global Biodiversity Outlook. He also serves as scientific advisor for a number of international and local organizations including the International Union for Conservation of Nature (IUCN) and WWF Canada.

DR. RYAN VACHON

Climate scientist and videographer Dr. Ryan Vachon focuses on science communication through film, public speaking, and multimedia presentations.

Dr. Vachon received his PhD in stable isotope geochemistry from the University of Colorado in 2005. His expertise is in climate dynamics, glacial geology, and chemistry. During his PhD, Dr. Vachon started to produce educational films that showed in international film festivals. These have since been widely viewed and well-received, as climate change has become one of the biggest challenges facing the globe.

Dr. Vachon's filming expeditions have taken him to remote regions of the world. He has produced work for the BBC, CNN, *National Geographic*, the Discovery Channel, and Rocky Mountain PBS. He weaves his explorations together with his deep understanding of water resources and climate to create engaging experiences for students in grades 6 through 12. Under the name "Doc Ryan," Dr. Vachon is the main presenter in the Institute of Arctic and Alpine Research's "120 Seconds of Science" series, where he creatively explains a basic scientific concept in two minutes.

NEREUS JOINT OUTPUT

NEREUS PUBLICATIONS LIST 2011 – 2012 (INCLUDING EARLY 2013)

Dunn, D. and A. Boustany. et al. 2013. Empirical move-on rules to inform fishing strategies: a New England case study. *Fish and Fisheries.* DOI; 10.111/faf.12019

Hanich, Q and **Y. Ota.** 2012. Moving Beyond Rights-Based Management: A Transparent Approach to Distributing the Conservation Burden and Benefit in Tuna Fisheries. *The International Journal of Marine and Coastal Law.* VOl. 28.1; 135-170

Hazen, E. L., E. Jorgensen, **R. R. Rykaczwski,** S. J. Bograd, D.G. Foley, I. D. Jonsen, S.A. Shaffer, J.P. Dunne, D. P. Costa, L. B. Crowder, and B. A. Block. 2012. Predicted habitat shifts of Pacific top predators in a changing climate. *Nature Climate Change*. doi:10.1038/nclimate1686.

Jones, M. C., S. R. Dye, J. A. Fernandes, **T. L. Frölicher**, J. K. Pinnegar, R. Warren, **W. L. Cheung**, 2013, Predicting the impact of climate change on threatened species in UK waters. *PLoS ONE*, 8(1)

Kearney, K. A., C. Stock, K. Aydin, and J. L. Sarmiento. (2012). Coupling planktonic ecosystem and fisheries food web models for a pelagic ecosystem: Description and validation for the subarctic Pacific. *Ecological Modelling*, 237-238, 43-62.

Ban, N. C., N. J. Bax, K. M. Gjerde, R. Devillers, **D. C. Dunn,** P. K. Dunstan, A. J. Hobday, S. M. Maxwell, D. M. Kaplan, R. L. Pressey, J. A. Ardron, E. T. Game, and P. N. Halpin. Systematic conservation planning: A better recipe for managing the high seas for biodiversity conservation and sustainable use. *Conservation letters.*

Villasante S., T. Morato, D. Rodriguez-Gonzalez, M. Antelo, **H. Österblom,** L. Watling, C. Nouvian, M. Gianni, and G. Macho. (2012) Sustainability of deep-sea fish species under the European Union Common Fisheries Policy. *Ocean & Coastal Management* 70: 31-37 http://dx.doi.org/10.1016/j.ocecoaman.2012.07.033

WEAVING THE FUTURE OCEAN WEB THROUGH COLLABORATION: AAAS ANNUAL MEETING

BOSTON, MA | FEBRUARY 14-18, 2013

On February 17th, the Nereus Program was the focus of a session on Global Fisheries and Food Supply at the 2013 annual meeting of the American Association for the Advancement of Science (AAAS). The program focused on the following:

> Life in the global ocean is a complex web of interactions, spun by nature, described by science, and often reshaped by human activities. To understand these often-conflicting mechanisms and their interactions, researchers rely on scientific disciplines that do not have tradition for interacting. Yet interdisciplinary cooperation is vital to secure a sustainable future ocean. The Nippon Foundation-University of British Columbia Nereus Program develops and supports ocean management policies that enhance resilience to climate change and can help ensure seafood and healthy oceans for future generations. Nereus works across disciplines, using global datasets in a modeling complex framework, to project conditions of and evaluate management options for the future ocean. In doing so, Nereus participants strive to overcome the inherent differences between scientific disciplines and

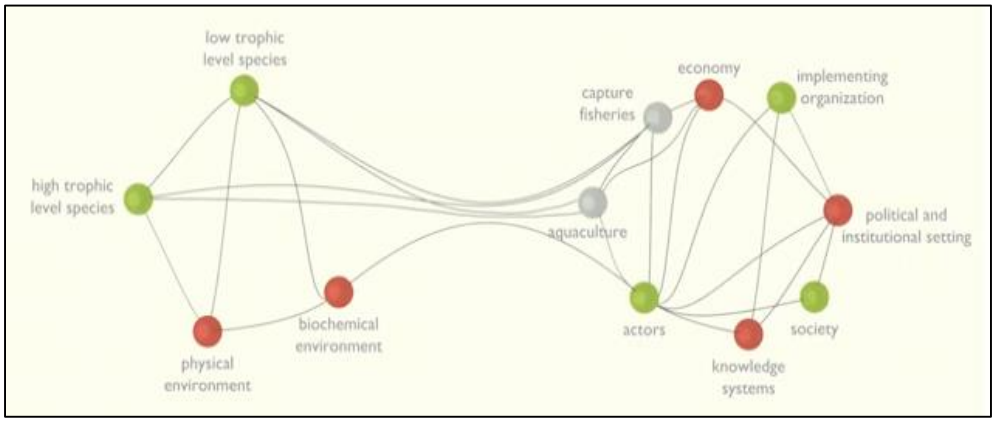
develop a framework for interdisciplinary collaboration. The session is based on the development of an Earth-system diagram that links our disciplinary work (biogeochemical, ecological, social, and economic), and focused on the interdisciplinary linkages through which information is exchanged. This is crucial for the comprehensive modeling and for providing feedback to the individual components of the overall framework. By understanding the interactions, drivers, and impact, we build capacity for how we collectively can shape the future ocean.

A number of speakers from the Nereus Program elaborated on this theme; their abstracts follow.

WEAVING THE FUTURE OCEAN FOOD WEB: THE NEREUS DIAGRAM

Dr. Henrik Österblom | Stockholm University

Abstract: Dr. Österblom is team leader for Governance and Ecosystem Management at the Stockholm Resilience Centre. He described the development of the Nereus diagram, presenting an overview of the process that led to the conceptualization of the diagram with a focus on how it can contribute to interdisciplinary communication and cooperation. The process involved finding common elements between disciplinary research fields, evaluating how the linkages between the fields can best be evaluated, and how qualitative and quantitative data can be combined.



The NF-UBC Nereus Model Diagram, as presented during the AAAS Annual Meeting in Boston, MA on February 17th, 2013. (Dalai Felinto/UBC)

LINKAGES BETWEEN THE CARBON CYCLE AND BIOTA IN THE GLOBAL OCEAN

Dr. Ryan Rykaczewski | Princeton University

Abstract: Ocean biogeochemistry and physics are fundamental in shaping the composition and productivity of marine fisheries. Integrating the effects of various physical and chemical processes that influence the production and structure of the planktonic community is challenging, especially when considering changes resulting from anthropogenic emissions of greenhouse gases. Utilization of global "earth system" models allows comprehensive assessment of the atmospheric, hydrographic, and biogeochemical processes affecting productivity in the context of global change. Such models allow us to examine qualitative hypotheses concerning future change in a more quantitative fashion. Here, Dr. Rykaczewski explores the results of earth system models and describes biogeochemical changes that are expected to influence future fisheries

production by altering the base of the marine food web, changing the intensity of oxygen minimum zones, and reducing the ocean's pH. One key finding of this work is recognition that the statistical relationships based on historical observations of the marine environment may be inadequate to predict changes that will occur as a result of global climate change. These differences between historical and future physical-biological relationships are particularly evident in eastern boundary current upwelling systems—regions which are invaluable to the world's fisheries. Understanding the mechanisms through which climate change will alter the production and flux of organic matter to higher trophic levels is a central step in projecting the future of marine fisheries.

BRIDGING DEMAND AND SUPPLY OF SEAFOOD: SUSTAINABLE AQUACULTURE IN A CHANGING WORLD

Dr. Marc Metian | Stockholm Resilience Centre

Abstract: In a world where nearly a third of humanity is suffering from malnutrition and over 70% of our planet is covered with water, fish and aquatic products represent an essential component of the global food basket, improving peoples nutritional status, health, and wellbeing. Capture fisheries are in decline, or at best kept at status quo, and aquaculture is the only solution for significantly increasing production of fish and other aquatic organisms. The rapid aquaculture expansion taking place within the last two decades has in some places been poorly regulated and resulting in negative environmental and social consequences. However, many aquaculture systems can offer more efficient ways to produce food compared to many terrestrial animal food systems. Responsible aquaculture development will not only involve efficiency and good environmental performance, but also enabling production of food being accessible and affordable for poor people.

The present paper discussed resilience of present and emerging aquaculture systems. Special focus is on the sustainability of feed usages, implications for global fisheries and overall food production. In complement the paper also explores how the supremacy of China will influence global fish resources via its aquaculture industry.

LINKING TERRESTRIAL PROCESSES, COASTAL LANDSCAPES, AND MARINE ECOSYSTEMS

Dr. Chris McOwen | UNEP, World Conservation Monitoring Centre

Abstract: Driven by the necessity to predict future fishery yields, the environmental mechanisms that determine the magnitude of ecosystem-level production have received a great deal of attention, particularly within the coastal zone, where an estimated 70% of commercial fish are captured. However, given the decrease of coastal catch and commercial fisheries expanding into the high seas, our relatively scarce knowledge of oceanic stocks and the issue of oceanic resources management are increasingly coming to international attention.

Here, Dr. McOwen extends the use of statistical models to the high seas to test if the patterns observed in the coastal realm hold fast. Furthermore, as fisheries are driven by more than environmental factors, the role

of the “human dimension” was investigated, through the integration of human-derived nutrient run-off, fishing effort, and market value. A key finding is a shift in the significance of environmental versus anthropogenic variables between the coastal zone and the high seas, indicating the need for differential management strategies. Moreover, Dr. McOwen found that within the coastal region the observed yield of Large Marine Ecosystems (LMEs) is driven by different environmental and anthropogenic variables according to the target fishery and ecosystem characteristics of the LME, suggesting statistical models aggregated to a global scale mask spatial variability in the drivers of fisheries yield.

This work reinforces the evidence that there is perfect solution in the management of fisheries, and that management needs to take into account both the intrinsic variability of the underlying ecosystem and economic drivers (e.g. market price, development of fishing gears, new technologies, etc.) when predicting and managing fish stocks.

HABITAT AND FISHERIES INTERACTIONS: SPATIAL PATTERNS UNDER CLIMATE CHANGE

Dr. Andre Boustany | Duke University

Abstract: Marine capture fisheries constitute the largest component of global seafood production. As these industries are reliant on extracting seafood directly from a dynamic ecosystem, they are likely to see significant shifts in distribution and yield due to climate change. Understanding the influence physical and biological oceanographic variables have on the current distribution of fish and fisheries is essential in being able to form predictions on what fisheries will look like in a future ocean. Some fish species distributions are driven more by static variables (bathymetry, distance from shore, distance from fishing port, etc.) while others are more influenced by dynamic variables (water temperature, ocean productivity, etc.). Determining which factors are the major determinants for fish distribution will provide insight into what changes to fisheries are expected under a changing climate. Fisheries targeting species whose distributions are “sticky” (likely to remain static) will see change in climate manifesting mainly through changes in fish stock productivity, while those targeting fish stocks more heavily influenced by dynamic oceanographic variables will see shifts in the distribution of target species. These shifts in distribution can have secondary effects on fisheries yield if future distributions make fish more or less susceptible to exploitation. Ultimately, making useful predictions about the future of global capture fisheries will involve not only determining the predicted shifts in distribution of fishes but in understanding the economic, social, and ecological interactions inherent in all fisheries.

NEREUS CAPACITY BUILDING

TOHOKU

From left to right (above): Dr. Yoshitaka Ota, Co-Director of Nereus; Dr. Ryan Rykaczewski, Senior Nereus Fellow; Audrey Valls, Nereus Fellow; Dr. Marc Metian, Senior Nereus Fellow; and Daniel Dunn, Nereus Fellow. (Kei Kodera/The Nippon Foundation)

In February 2012, the Nereus Program invited its fellows to visit Tohoku, the area in Japan that was severely impacted by the Great East Japan Earthquake and Tsunami of 2011. While there, the fellows gave presentations to students at Miyako Fisheries High School, Miyako High School, and Onagawa Junior High School and spoke with some of the fishers who had been impacted by the catastrophe.

Here are a few of the comments from our fellows following their experience in Tohoku:

Dr. Wilf Swartz, the University of British Columbia:

> "The three days that we spent in the communities affected by the Tohoku earthquake and tsunami of 2011 are among the most emotional and inspiring days of my life. Prior to our trip, I naively believed that 20 months were more than sufficient for post-disaster recovery efforts to take shape and that the revival was well under way. The reality is that the devastation is so catastrophic in its magnitude that real recovery can only be measured on a scale of decades, rather than months or years.
>
> One stark example of this occurred when it took more than a day for me to truly comprehend that the empty fields I saw scattered across the regions were not abandoned farmland or rice paddies, but rather land where hundreds of houses—either washed out to sea or reduced to splinters—once stood. These were houses just like the one I used to live in when my family lived in Tokyo.
>
> Despite all I saw, and the statistics I heard, what I found most overwhelming and ultimately inspiring were the people. Every single person that I met during the three days we spent there, from the fishermen of the Miyako Fisheries Cooperatives to the students at the Miyako Fisheries High School and Onagawa Junior High School, was warm, welcoming and optimistic about the future. This, in spite of the countless tragedies each one of them had endured over the past 20 months. The smiles of the children and the laughter that echoed around the classrooms during our visit to Miyako and Onagawa will remain with me forever and will serve as my inspiration both for my research and, no matter what may happen to me in the future, for my life.

I am eternally grateful to The Nippon Foundation and the people that I met in Tohoku for all they shared."

Daniel Dunn, Duke University:

"Each experience in Tohoku seem to make me more humble and more emotionally frayed, but the bus ride through the valleys around Onagawa middle school with their enormous piles of debris ridden with the clothes and personal items of the families that once lived there, and then meeting the school kids who were trying to move on and just be kids was devastating. It is something I will never forget, and hope to never see again. Even now I find it difficult to force myself to refocus on the heart-wrenching scenes we witnessed there. The destruction in Onagawa was unlike anything I have ever seen. Coming from North Carolina, I am very familiar with the destructive force of the ocean as we are regularly hit by hurricanes. However, Tohoku was on a completely different scale than anything I had previously seen. I was, and am, completely shocked by it. I am sure everyone else has said the same thing, and I am sure we all follow such statements by saying that the only thing more incredible than the wreckage was the resilience of the children and the tenacity, ingenuity and selflessness of people like Mr. Ishimori. The presentations we gave in Tohoku disguised the true nature of our visit: yes we were trying to give the kids knowledge and something to reach for, but they were the ones teaching us. Regardless of what you're doing, the experience of talking to those kids makes you want to try harder; to be better. For that I am eternally grateful to the school kids and to The Nippon Foundation for organizing and supporting the trip."

Audrey Valls, the University of British Columbia:

"I was very impressed and inspired by MASKAR, the Onagawa fisheries processing centre. I thought it was a very good symbol of recovery and hope for the community. However, it was not a mere symbol, but also the material expression of the exceptional resilience of the local community struck down by the tsunami. Every single part of the building has been thought and built based on the traumatizing experiences of tsunamis in the past, aiming at providing better protection and resistance to the community in the future. Finally, our visit in Rikuzentakata was a very important, yet difficult, moment in our trip to Tohoku. I felt very touched, but also closer to all the local people we met, and I wished I could do more for them than one rather short visit. I hope we will find ways to keep in touch with them—especially with the students."

Dr. Marc Metian, Stockholm Resilience Centre:

"The most memorable moment from the trip was the view of smiles on the faces of the children at Onagawa Junior High School and, more generally, the courage of the inhabitants of Tohoku. Although they have been deeply affected, either directly or indirectly, I realized that

all are looking towards the future and that this is their recipe for happiness. Those young school kids are so courageous, trying to put aside their sorrows, looking for the future, and embracing life. They were so happy to talk with us—to laugh with us—and we hope our visit will provide them with some general inspiration. Who knows: there might be some future marine scientists in those classes. I will never forget the three days I have spent in Tohoku."

Dr. Ryan Rykaczweski, Princeton University:

"It has been nearly a month since I visited Tohoku with the other Nereus Fellows, and I have thought about the communities of the region every day. The impact of the tsunami is difficult to fathom, but what leaves a greater impression on my daily thoughts is the personalities of the fishermen, processors, school children, our tour guide, and our hosts. Given the destruction that they have seen and the loved ones that they have lost, I am astonished by the spirit and endurance and hospitality expressed by these individuals. When faced with a similar situation, I cannot imagine what my response would be, but these communities are quietly struggling to persevere.

A shift has occurred in my thoughts about fisheries, oceanography, and society as I have been reflecting on Tohoku. My expertise is in ocean biogeochemistry, plankton, and climate; studying fisheries is a means through which I can combine my interests in science and the ocean ecosystem. But now I have also begun to recognize that the ocean and its resources cannot be approached from a strictly scientific perspective. Rather, the ocean and coast is something that shapes people's lives and acts as a nucleus for the formation of communities. Fisheries are more than wet carbon and trophic transfer; these resources are the reason why people live and are inspired to carry on even in the face of tragedy. This issue is one of the defining factors making marine resources so difficult to manage. It's not just the mathematics of physics and biology that need to be considered, but also the communities and lives that will be transformed as a result of the changing oceans. This close relationship between the ocean resources and the social aspects of communities is not something that I have previously had a strong appreciation for, but this is an issue that needs to be included in any plan to preserve fisheries for future generations.

Our trip to Tohoku has influenced my scientific thoughts as well as my personal conceptions about life and disaster."

NEREUS ANNUAL MEETING

PRINCETON UNIVERSITY | FEBRUARY 11-14, 2013

PARTICIPANTS

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Nereus Guests	Fred Soons	Netherlands Institute for the Law of the Sea (NILOS), Utrecht University	Professor	
	Alex Oude Elferink	Netherlands Institute for the Law of the Sea (NILOS), Utrecht University	Assistant Professor	
Nereus Alumni	Kelly Kearney	NOAA's Atlantic Oceanographic and Meteorological Laboratory	Researcher, The Ocean Chemistry Division (OCD)	Kelly.Kearney@noaa.gov

MEETING PROGRAM

TUESDAY, FEBRUARY 12, 2013	
9:00 – 9:30	OPENING
9:30 – 10:00	MEET AND GREET / REFRESHMENT BREAK
10:00 – 12:00	PROGRESS SUMMARY FROM NEREUS PROGRAM OFFICE AND DISCUSSION
12:00 – 13:00	LUNCH
*13:00 – 18:00	PRESENTATIONS FROM NEREUS FELLOWS, PART 1
WEDNESDAY FEBRUARY 13, 2013	
9:00 – 12:00	PRESENTATIONS FROM NEREUS FELLOWS, PART 2
12:00 -12:30	LUNCH
*12:30 – 14:00	NEREUS SPECIAL LECTURE (NETHERLANDS INSTITUTE FOR THE LAW OF THE SEA)
14:00 – 18:00	NEREUS STRATEGIC WORKSHOP (COLLABORATIVE RESEARCH THEMES)
THURSDAY FEBRUARY 14, 2013	
9:00 – 12:00	NEREUS TECHNICAL WORKSHOP ADVISORY PANEL MEETING
12:00 – 13:00	LUNCH
*13:00 – 16:00	NEREUS WORKSHOP ON AAAS (ONLY FELLOWS) ADVISORY PANEL FEEDBACK (ONLY AP AND PIS 13:00-14:00) STEERING COMMITTEE MEETING (ONLY PIS 14:00-16:00)
16:00 – 16:30	PI (INCLUDING DANIEL PAULY AND NF) ENDING REMARKS
16:30 – 18:30	GENERAL CLOSING

NEREUS PROGRAM REVIEW | FEBRUARY 14, 2013

By Philippe Cury, Daniel Pauly, and Jeffrey Polovina

The Nereus Program has made good progress over the course of the last year. The program has a full complement of very talented fellows who interact well and have worked towards achieving the program's goal of building capacity. The program has shown to be moving forward in exploring the use of computer visualizations of model output to communicate results. The program is also advancing ecosystem modeling to link climate models through ecosystem and human dimensions. Lastly, the program has been the focus of sessions at the AAAS annual meeting for two successive years—a strong acknowledgement of the program's appeal and vision. The program faces a number of challenges that are discussed below:

1. The program offers an excellent diversity of projects that reflect the interests and expertise of the individual PIs and fellows. Since we feel that the global focus of Nereus is one of its strengths and unique aspects, we recommend that Nereus concentrate on global issues only or cases studies that include global applications.
2. A key strength of Nereus is its evident mix of talented PIs; however, it is unclear how the group identifies projects within the program and how future projects will be consistent with the three phases of the Nereus Program. For this reason, it might be beneficial for both internal and external communication if the PIs identified a short list of deliverables for *each* of the three program phases. These deliverables will help new fellows understand the program's history and direction.
3. The Nereus modeling framework consisting of many proposed linked models covering climate, ecosystems, fisheries, aquaculture, the human dimensions, and policy is a unique aspect of Nereus but also extremely ambitious and clearly not all the modules or boxes in the Nereus framework flow chart will be modeled. It is timely to update this flow chart listing the specific models that is expected to be constructed and linked to clarify the scope and direction of the program.
4. Nereus has as key objective to build scenarios. However it is not clear which scenarios are going to be built at the global level, and the level of expertise that is required. The link between physical, ecological, socio-economical or anthropological aspects needs to be formalized in a better and more integrated manner and should promote inspiring science.
5. A vital element of the Nereus Program is coordinated access to data resources for members of the program. As such, Nereus requires explicit rules regarding data exchange with other projects.

CLOSING REMARKS FROM THE FELLOWS

By Dr. Andre Boustany, Senior Nereus Fellow

On behalf of the fellows, I would first like to thank The Nippon Foundation for helping us to make this possible. I believe that I can speak on behalf of everyone when I say that, of all the projects I have worked on, not one has come close to offering the linkages between institutions that the Nereus Program provides. It is very telling in terms of structure, and can be observed in the active effort to create these linkages, flows of information, and collaborations. We would collectively like to thank The Nippon Foundation, and especially Mr. Unno and Yoshi Ota, for the success of this program.

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