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Ecopath 25 Years Conference Proceedings: Extended Abstracts

Fisheries Centre, University of British Columbia, Canada

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ECOPATH 25 YEARS CONFERENCE PROCEEDINGS: EXTENDED ABSTRACTS

edited by

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FOREWORD

I wish to congratulate the organizers of this conference, as it celebrates a momentous event in the history of fisheries science: the emergence of a simple way of representing a marine ecosystem. Many approaches had been developed at the time Ecopath emerged to represent and simulate the interrelationships of prey, predators and fisheries in marine ecosystems, and many have been published since. But none had the simplicity of the approach that Jeffrey Polovina proposed and none of them used data that fisheries and marine scientists readily had available on their desks the way Ecopath does.

The first of the abstracts in this report, by Jeff outlines how Ecopath came to be in Hawaii. The second, by Daniel Pauly, outlines how the 'franchise' for this approach and software then went from Hawaii to Manila, where he and Villy Christensen further developed the software and assisted in its dissemination. Interestingly, it was in developing countries where, at first, it was most readily picked-up.

When Daniel and Villy moved to the Fisheries Centre, in the mid 1990s, the 'franchise' moved with them and Carl Walters, by developing Ecosim in Ecopath, put the finishing touch on the Ecopath approach, which was then eagerly adopted by researchers in the Fisheries Centre, and gradually, by a wider circle of colleagues in North America, Europe and elsewhere, even reaching the borders of my discipline, Economics.

Ecopath, now 25 years old, really has come of age, to the extent that it was named recently by NOAA as one of the 10 major scientific breakthroughs in the organization's 200-year history. It is fitting that the Fisheries Centre should host this meeting, both because of its members' role in the development of Ecopath and because it continues to serve as a hub for its further development.

RASHID SUMAILA
DIRECTOR,
FISHERIES CENTRE

WELCOME NOTE

In 1984, Dr. Jeffrey Polovina and his colleagues at the National Marine Fisheries Service, Honolulu Laboratory, developed an innovative marine ecosystem model known as Ecopath. With a name conveying its focus on ecological pathways, Ecopath was the first model to apply a type of statistics called 'path analysis' to the field of marine ecology. The model's simplicity and its ability to accurately identify ecological relationships have revolutionized scientists' ability worldwide to understand complex marine ecosystems. Now, 25 years later, the Ecopath suite of software is recognized as one of NOAA's top ten scientific breakthroughs in the last 200 years. The current approach Ecopath and Ecosim (EwE), developed and promoted by Villy Christensen, Carl Walters and Daniel Pauly is used in over 150 countries for a multitude of purposes.

EwE has contributed substantially and in tangible ways towards an ecosystem-based management approach of marine resources worldwide. EwE is the first ecosystem-level simulation model to be widely and freely accessible. As of October 2008, there were 5 649 registered users in 164 different countries (www.ecopath.org, 27th October 2008) and well over 200 publications; making EwE an important modelling approach to explore ecosystem related questions in marine science. Further technical and application details on EwE can be found at www.ecopath.org.

The *Ecopath 25 Years Conference* aims to provide an overview of 25 years of progress using this approach in different fields: fisheries management, ecosystem comparisons, spatial analyses, climate impacts, and ecosystem-based management as well as to introduce exciting new features. It is intended to be an international scientific reunion on ecosystem modelling using the software Ecopath and Ecosim (EwE). Futhermore, this event will allow users from the scientific community, education bodies, members of governmental organizations and NGOs to be given an overview on what has been achieved since Ecopath's inceptions. Key topics of the conference include: expansion of features to the analysis of fishing policies; establishment of marine protected areas (MPAs); study of socioeconomic factors of marine exploitation; and incorporation of climatic drivers in the analysis of marine ecosystems.

We wish all participants a fruitful stay in Vancouver and a very exciting week at the *Ecopath 25 Years Conference and Workshops*!

THE ORGANIZING COMMITTEE
ECOPATH 25 YEARS CONFERENCE AND WORKSHOPS

THE ORGANIZING COMMITTEE

ADVISOR:

Villy Christensen

Villy Christensen has led the development of the Ecopath approach and software since 1990, when he joined Daniel Pauly at ICLARM in the Philippines on secondment from the Danish International Development Agency. Since the mid-1990s he has worked closely with Carl Walters on what became Ecopath with Ecosim. He is now a faculty at the UBC Fisheries Centre.

CHAIR:

Chiara Piroddi

Chiara Piroddi is a researcher with the *Sea Around Us* Project at the Fisheries Center, University of British Columbia. Her Master's thesis used Ecopath with Ecosim to study ecosystem-based approach for two dolphin populations around the island of Kalamos, Ionian Sea, Greece. She is currently working on a global database for mesopelagic fish distributions and Ecopath with Ecosim models for world's Large Marine Ecosystems. She is also involved in collating basic input parameters from 100 Ecopath models into broad functional groups to reduce parameter specification error for Ecopath models.

Though unwillingly at first, Chiara became the natural leader of the organizing committee of the Ecopath 25 Years Conference and Workshops because of her familiarity with the events and the developments related to EwE. Her leadership and unwavering adherence to quality, notably to the food participants will enjoy in the 2 weeks of this event (she is Italian afterall), is what makes this conference a 'well-oiled' machine.

MEMBERS:

Marta Coll

Dr Marta Coll Monton is a post-doctoral fellow at Dalhousie University (Halifax, Canada) and Institute of Marine Science (Barcelona, Spain). She is currently working on her Marie Curie project "ECOFUN: Analysis of biodiversity changes on structural and functional properties of marine ecosystems under cumulative human stressors" International Outgoing Fellowships (IOF) Call: FP7-PEOPLE-2007-4-1-IOF. Her interest focuses on understanding how documented changes on marine biodiversity have been translated into changes on ecosystem structure and functioning, and services to humans, and how these changes may impact ecosystems in the future. Thus, her work implies hindcasting changes on coastal ecosystem functioning due to effects of human impacts, and forecasting how these effects could develop in the future. To do so, she mainly applies various ecological modelling tools using historical and fisheries data and combines it with laboratory experiments and field work data analysis. Her PhD work had been mainly based on studying marine ecosystems in the Mediterranean Sea, where she studied the ecosystem impacts of fishing by means of food web modelling and trophodynamic indicators using Ecopath with Ecosim.

Carie Hoover

Carie Hoover is currently a PhD student at the Fisheries Center, University of British Columbia. She is looking at the effects of climate change on polar ecosystems, with her research focusing on identifying threats to top predators in the Antarctic Peninsula and Hudson Bay ecosystems. She is currently working in association with DFO assessing the status of marine mammals in the Hudson Bay as part of the Global Warming and Arctic Marine Mammals (GWAMM) Project under International Polar Year (IPY) funding. Carie completed her Bachelor of Science degree majoring in Ecology, Evolution, and Marine Biology (EEMB) at the University of California Santa Barbara. After leaving California, Carie moved to Scotland to attend the University of St Andrews where she completed her Masters degree in a biology-mathematics conversion program, with her thesis focusing on predator prey interactions of grey seals, and prey selectivity.

Sherman Lai

Sherman Lai is the Project Coordinator of the Lenfest Ocean Futures Project which plans to bring Ecopath to a whole new level of decision support tools. He is involved in the development of interfaces and in charge of implementing state-of-the-art technologies on collaborative environments, as well as in designing human-computer interaction schemes. Internally he is responsible for project performance, including tracking and meeting development deadlines.

Lyne Morissette

Dr. Lyne Morissette is a postdoctoral fellow from the "Fonds Québécois de la Recherche sur les Sciences et Technologies" (FQRNT) with Dr Kevin McCann at the University of Guelph. Her current work is focused on the diversity and resilience of ecosystems and the trophic role of predators. Her main interest is to see if genetic diversity is affecting the way prey populations are impacted by predators, and how genetic features of the prey can help maintaining population and community structure through time. Over the years, she gained an expertise on the trophic role of marine mammals in ecosystem, and used Ecopath with Ecosim and other modeling approaches to construct models characterizing ecosystem structure and functions. She is an active member of different research groups with the Department of Fisheries and Oceans of Canada (DFO), the Norwegian College of Fisheries Sciences at University of Tromsø, and the North Atlantic Marine Mammal Commission (NAMMCO). She earned her PhD in Zoology from the University of British Columbia in 2007, and contributed to the *Sea Around Us* Project completing a database for all Ecopath models available from around the world. She is now on the editorial board of the open-access journal "Diversity", guest-editing a special issue on "Biodiversity, Conservation and Wildlife Management".

M.L. Deng Palomares

Dr. M.L. Deng Palomares is a Senior Research Associate with the *Sea Around Us* Project at the Fisheries Center, University of British Columbia. She coordinates integration of fish-related data generated by the *Sea Around Us* Project into FishBase (www.fishbase.org), a very successful information system on fish. This ensures that the fish-related project's results become immediately available to the public, as well as enabling comprehensive analyses by other project members. Since 2005, she is also Project Coordinator of SeaLifeBase (www.sealifebase.org), a FishBase-like information system on all marine organisms, which links to FishBase and other online biodiversity information systems, e.g., Catalogue of Life and the World Register of Marine Species. Both SeaLifeBase and FishBase are structured to 'communicate' with Ecopath with Ecosim for its various data requirements, e.g., trophic levels, diet compositions and growth parameters.

Jeroen Steenbeek

Jeroen Steenbeek is a corporate trained computer scientist from the Netherlands, and has been a technical consultant with Lenfest Ocean Futures Project since the beginning of the Ecopath with Ecosim 6 (EwE6) project. He is one of the key architects of the structure of EwE6. He is responsible for all-over design and quality assurance of EwE6, and handles database implementation, user interface design and implementation, spatial modeling aspects and model interoperability for EwE6. This fall, Jeroen is going to start his MSc thesis on providing Ecospace with a true spatial data interface. Jeroen built the Ecopath 25 Years website.

Divya Varkey

Divya Varkey is a PhD student at the Fisheries Center, University of British Columbia. Her research focuses on challenges for ecosystem-based management in Raja Ampat, Indonesia and New Zealand. She has built an ecosystem model for coral reefs in Raja Ampat using the Ecopath and Ecosim modeling approach. She is currently using Ecospace to model ecological changes inside marine protected areas especially looking at how size of the MPA influences the ecology inside the MPA. She is also involved in collating basic input parameters from 100 Ecopath models into broad functional groups to reduce parameter specification error for Ecopath models and the function of 'mediation' component in Ecosim to capture third party influences on food web interactions.

Colette Wabnitz

Colette Wabnitz is currently a PhD student at the Fisheries Center, University of British Columbia. Colette's main interests lie in marine conservation planning. Specifically, her research aims to: improve methods for gathering spatially explicit information on coastal habitats (e.g., coral reefs and seagrass), which includes the use of remote sensing; understand ecological processes that occur within coastal ecosystems using models (e.g. Ecopath with Ecosim); develop appropriate tools for the monitoring and planning of MPAs at multiple scales; and inform marine conservation policy development and assessment. Her PhD project seeks to derive an estimate of seagrass coverage at the scale of the wider Caribbean region and to understand the role of green sea turtles within these ecosystems. She received her BSc in Biology and Environmental Sciences from McGill University, Montreal. For her MSc in Tropical Coastal Management at the University of Newcastle upon Tyne, UK, she looked at the benthic composition and territory size of 5 species of parrotfishes in Belize under the supervision of Dr Peter Mumby.

ACKNOWLEDGEMENTS

ON BEING GREEN

The Ecopath 25 Years Conference Organizing Committee made an attemp to be 'ecological' and to employ 'sustainable' resources by: (i) providing a website where documents relevant to the Conference, including electronic posters, can be viewed and/or downloaded, thus supporting a 'paperless' option; (ii) providing a 'Notes' section in these Conference Proceedings instead of separate paper blocks and/or notebooks; (iii) providing coffee mugs instead of paper cups; (iv) using silver and china instead of plastic forks, plastic glasses and paper plates; and (v) providing cheese-cloth bags to carry all Conference materials and other goodies in.

Participants are thus requested to use the cloth bags and coffee mugs during the conference and the workshops. Please remember to bring your coffee mugs at coffee breaks or, if necessary, when buying coffee at the nearby cafés. The organizers will not provide paper or plastic coffee cups during these breaks.

Participants are also urged to use the Notes section at the end of this Conference Proceedings instead of asking for separate block notes. The organizers will also refrain from providing extra paper during the conference and workshops.

Food catering is brought to the Conference through the UBC Alma Mater Society Catering, which practices a strong commitment to sustainability. All coffees are certified organic, shade grown and Fair Trade. Dry goods are from local companies wherever possible and produce is purchased locally when in season. There are options on the AMS menu to include wild salmon and organic meats and produce in meal selections. They try to purchase local seasonal produce. They also work with an organic food broker to ensure best price possible for fruits and vegetables. On a smaller scale, they also support UBC's own organic farm. Their plastic and metal containers and any paper materials used in menu planning are recycled and all of the food waste from their menu preparation is composted, as is a large percentage of their post-consumer food waste. The AMS use non-disposable dishes, glassware and cutlery whenever feasible and their cleaning supplies are environmentally friendly.

PROGRAM: ORAL PRESENTATIONS

VENUE

All events are hosted at the Aquatic Ecosystems Research Laboratory (AERL) of the University of British Columbia located at 2202 Main Mall, between the newly built Beatty Biodiversity Centre and the Biological Sciences buildings.

The registration desk will be located in the AERL Atrium (lobby).

All conference sessions will be held in room 120 (east end) of the AERL. Oral presentors are requested to submit their PowerPoint presentations to their respective session Chairs within half a day before their sessions.

Poster sessions will be concurrent with coffee and lunch breaks, which will be held in the Atrium. Authors with posters are requested to mount their posters on Monday, 31 August, 0830-1000 following the appropriate sessions which will be displayed on the panels. Please also remain near your posters during coffee and lunch breaks. Note that electronic posters will be printed on letter-sized paper and displayed together in one poster panel. They are also available at http://conference.ecopath.org/electronic-posters. Participants are encouraged to view these electronic posters and discuss with their authors via email.

Three desktop computers will be made available to conference participants in AERL room 107/108 (west end). Note that wifi Internet access can be obtained through FatPort. Please inquire at the registration desk for details.

SUNDAY, 30-08

1730-2030	**Conference Registration**

MONDAY, 31-08

0830-1000	**Conference Registration**
0900-0915	**Welcome Address, Chair: Villy Christensen**

DON BROOKS, Associate Vice President Research, University of British Columbia, Professor of Pathology and Laboratory Medicine and Chemistry

USSIF RASHID SUMAILA, Director of the Fisheries Centre, Associate Professor, and Director of the Fisheries Economics Research Unit

0915-1015	**Opening Session Keynotes**, Chair: VILLY CHRISTENSEN
0915-0945	JEFFREY POLOVINA: The origins of Ecopath
0945-1015	DANIEL PAULY: Ecopath: from the French Frigate Shoals to the Philippines and to UBC
1015-1030	**Coffee Break and Poster Sessions**
1030-1230	**Session I: Fisheries Applications**, Chair: HOWARD TOWNSEND
1030-1100	**Fisheries Applications Keynote**
	CARL WALTERS: Foraging arena theory
1100-1115	DIDIER GASCUEL: EcoTroph: a new tool in the EwE family.
1115-1130	JIANG HONG: Exploring fisheries strategies for ecosystem-based management in the East China Sea.
1130-1145	SHINGO WATARI: Ecological effect of extermination of moonjelly, *Aurelia aurita*, in the sea of Suo-Nada, Seto Inland Sea, Japan.

1145-1200	ROLAN GERONIMO: Capturing significant coral reef ecosystem and fishery changes in Bolinao, Philippines (1997-2008) using Ecopath with Ecosim.
1200-1215	ANDRES CISNEROS-MONTEMAYOR: Fisheries in Baja California Sur: a trophic-based analysis of management scenarios.
1215-1230	SYLVIE GUÉNETTE: Impact of fishing and climate on the Celtic Sea and the Bay of Biscay.
1230-1330	**Lunch and Poster Session**
1330-1530	**Session II. Spatial Analysis**, Chair: ROB AHRENS
1330-1400	**Spatial Analysis Keynote**
	STEVE MACKINSON: Ecospace: has its time come?
1400-1415	GEORGI DASKALOV: Evaluation of the usefulness of Marine Protected Areas (MPAs) for management of recovery of fish stocks and ecosystems in the North Sea.
1415-1430	HECTOR M. LOZANO-MONTES: Modelling spatial closures and fishing effort restrictions in Jurien Bay, Western Australia: a case study of the western rock lobster (*Panulirus cygnus*) fishery.
1430-1445	CAMILLE ALBOUY: Effectiveness of the natural reserve of the Bonifacio Straits (Corsica, France) on the artisanal and recreative fleets.
1445-1500	TYLER D. EDDY: Trophic modeling of a temperate marine ecosystem throughout marine reserve protection in New Zealand.
1500-1515	FRANK PARRISH: Estimating the carrying capacity of monk seals using the French Frigate Shoals Ecopath.
1515-1530	DIVYA VARKEY: Exploration of ecological and economic benefits from implementation of marine protected areas in Raja Ampat, Indonesia.
1530-1600	**Coffee Break and Poster Session**
1600-1800	**Session III. Ecosystem Comp./Network Analysis**, Chair: MARTA COLL
1600-1630	**Ecosystem Comparisons/Network Analysis Keynote**
	JOHANNA J. HEYMANS: Comparing indicators of ecosystem change using ecological Network Analysis.
1630-1645	LYNE MORISSETTE: Marine mammals – fisheries interactions: how to use Ecopath with Ecosim to capture ecological complexity.
1645-1700	JASON LINK: A simple approach for enhancing ecological networks and energy budgets (namely Ecopath): Please, let's do some PREBAL before we start balancing.
1700-1715	VÍCTOR HUGO GALVÁN PIÑA: Comparison of trophic structures and key players for two periods in the continental shelf ecosystem of the central pacific of Mexico.
1715-1730	LUALHATI LACHICA-ALIÑO: Trophic flow structure of four overfished coastal ecosystems around the Philippines.
1730-1745	J. ERNESTO ARIAS-GONZÁLEZ: Relationship between biodiversity and ecosystem functioning in Mexican aquatic systems.
1900	**Reception**

TUESDAY, 01-09

0900-1130	**Session IV. Climate Impact Evaluation**, Chair: CATHERINE BULMAN
0900-0930	**Climate Impact Evaluation Keynote**
	ELIZABETH A. FULTON. Ecoworld: EwE one link in global systems model.
0930-0945	SIMONE LIBRALATO: Experiences in integrating physical-biogeochemical processes into food web dynamics with EwE.
0945-1000	CHRISTOPHER BROWN: Ecological interactions within marine ecosystems determine winners and losers under climate change.
1000-1015	**Coffee Break and Poster Session**
1015-1030	SHANE GRIFFITHS: Ecological effects of fishing and climate change on the pelagic ecosystem off eastern Australia.
1030-1045	CARIE HOOVER: Ecosystem effects of climate change in the Antarctic Peninsula.
1045-1100	DAVID PREIKSHOT: On the use of both unconventional and traditional time series data in constructing dynamic models of a marine ecosystem.
1100-1115	GLEN SUTTON: Development of an ecosystem model for Galveston Bay: Evaluating the influence of freshwater inflows, nutrient inputs and fisheries.
1115-1130	TORSTEIN PEDERSEN: Structure of two high latitude Norwegian fjord ecosystems analysed using Ecopath.
1130-1230	**Lunch and Poster Session**
1230-1445	**Session V. Implementing EBM**, Chair: JASON LINK
1230-1300	**Implementing Ecosystem-based Management Keynote**
	LYNNE SHANNON: How can EwE assist us in implementing ecosystem-based fisheries management? Drawing from the South African experience.
1300-1315	SERGIO NEIRA: Ecosystem approach to the mutispecies fishery in the south austral zone of Chile.
1315-1330	WILLIAM CHEUNG: Trade-offs between conservation and socio-economic objectives in managing a tropical marine ecosystem.
1330-1345	MARIA ESPINOSA: Supporting ecosystem based management on the West coast of Vancouver Island.
1345-1400	THOMAS A. OKEY: Progress in ranking species importance in whole biological communities using food web models.
14:00-14:15	JAMEAL SAMHOURI: Using ecological thresholds to inform targets for marine ecosystem-based management.
1415-1430	MARIA C. VILLANUEVA: Preservation: the case of the Meru National Park, Kenya.
1430-1445	DAWIT TESFAMICHAEL: Using Ecopath with Ecosim and local ecological knowledge to examine conflict between artisanal and industrial fisheries in the Red Sea.
1445-1500	**Coffee Break and Poster Session**

1500-1715	**Session VI. Ecopath with Ecosim and Beyond**, Chair: JEFFREY POLOVINA
1500-1530	**Ecopath with Ecosim and Beyond Keynote**
	FRANCISCO ARREGUÍN-SÁNCHEZ. Use of EwE outputs to investigate attributes of trophic networks of aquatic ecosystems relevant to fisheries management.
1530-1545	SHERMAN LAI: EwE6: interoperability usage, capabilities, technology, structure and beyond.
1545-1600	LAURA TREMBLAY-BOYER: A global map of the relative impact of fishing on the biomass of marine ecosystems from 1950 to 2004.
1600-1615	JONATHAN BEECHAM: Dynamic linking of Ecosim and the GOTM biogeochemical model using plugins.
16:15-16:30	HOWARD TOWNSEND: Chesapeake Bay Fisheries Ecosystem Model: Computer-generated graphics for creating a gaming experience with ecosystem data and management.
1630-1645	JULIA EKSTROM: MINOE: open source tool to navigate ocean governance in the context of a user-defined ecosystem.
1645-1700	MANUEL ZETINA REJÓN: Revealing changes in fish community at ecosystem level: using of trophic modelling and topological analysis.
1700-1715	KIM DE MUTSERT: Using Ecopath with Ecosim to explore nekton community responses to freshwater input from a Mississippi River diversion in Breton Sound, Louisiana.
1715-1815	**Closing Session**
1715-1745	**Final Keynote**
	VILLY CHRISTENSEN: The future of Ecopath.
1745-1815	Discussion and election of venue for the next EwE conference.

LIST OF POSTER PRESENTATIONS

SESSION I. FISHERIES APPLICATIONS

VARGIU, G., COLL, M., PALOMERA, I., TUDELA, S. Recovery scenarios of a highly exploited species, *Merluccius merluccius*, in the NW Mediterranean Sea using an ecosystem approach.

CHENG HE QIN, JIANG HONG. Thinking on the transfer payment of the fishery fuel subsidies in China.

ARREGUÍN-SÁNCHEZ, F., SALCIDO-GUEVARA, L.A. Vulnerability to fishing off the Central Gulf of California ecosystem.

PIRODDI, C., BEARZI, G., CHRISTENSEN, V. Effects of local fisheries and ocean productivity on the Northeastern Ionian Sea ecosystem.

BULMAN, C., CONDIE, S., KLAER, N., FURLANI, D., CAHILL, M., GOLDSWORTHY, S., KNUCKEY, I. Trophodynamic modeling of the Eastern Shelf and Slope of the South East Fishery.

CHIN, C.P., SUN, C.L., LIU, K.M. The impacts of longline fishery on the pelagic ecosystem in the eastern Taiwan waters.

POONSAWAT, R., SUPONGPAN, M., CHRISTENSEN, V. Introducing ecosystem-based management in the Gulf of Thailand.

FETAHI, T., MENGISTOU, S. Trophic analysis of Lake Awassa (Ethiopia) using mass-balance Ecopath model.

SESSION II. SPATIAL APPLICATIONS

PARK, C.R., KIM, E., KANG, C.W., LEE, S.B. Habitat suitability model for the bush warbler (*Cettia diphone*) at Jeju Experimental Forests of Korea.

SESSION III. ECOSYSTEM COMPARISONS

SALCIDO-GUEVARA, L., ARREGUÍN-SÁNCHEZ, F. Metabolism of aquatic ecosystems.

KHAN, A. A fish chain analysis of Northern Gulf Cod recovery options using EwE modeling approach.

TSAGARAKIS, K., COLL, M., GIANNOULAKI, M., KALLIANIOTIS, A., PAPAKONSTANTINOU, C., MACHIAS, A. Ecosystem structure and functional traits of the N. Aegean Sea (E. Mediterranean, Greece).

SESSION IV. CLIMATE IMPACT EVALUATION

NEIRA, S., MOLONEY, C., CURY, P., MULLON C., CHRISTENSEN V. Mechanisms affecting recovery in an upwelling food web: the case of the southern Humboldt.

LEGAGNEUX, P., GAUTHIER, G., KREBS, C.J. Spatial and temporal trophic dynamics of terrestrial arctic ecosystems

SESSION V. IMPLEMENTING ECOSYSTEM-BASED MANAGEMENT

WABNITZ, C., BJORNDAL, K.A., BOLTEN, A.B., CHRISTENSEN, V., PAULY, D. Restoration of *Chelonia mydas* population in the Caribbean: Ecosystem impacts resulting from reduction of seagrass habitat complexity.

COLL, M., LIBRALATO, S. Modelling marine food webs in the Mediterranean Sea.

TOWNSEND, H., BAUER, M., BROWN, L. A preliminary model of the San Francisco estuary ecosystem.

SESSION VI. ECOPATH WITH ECOSIM AND BEYOND

STEENBEEK, J., CHRISTENSEN, V. Using true GIS data with Ecospace.

PIRODDI, C., VARKEY, D., MORISSETTE, L., CHRISTENSEN, V. Production and consumption in Ecopath models: A global overview.

COLL, M., PIRODDI, C., PALOMERA, I., ARNERI, E., CHRISTENSEN, V. Main drivers of marine resources and food-web changes in the Mediterranean Sea.

VILLASANTE, S., GARCÍA-NEGRO, M.C., RODRÍGUEZ RODRÍGUEZ, G., VILLANUEVA, M.C., CHRISTENSEN, V., SUMAILA, U.R. A preliminary trophic model of coastal fisheries resources of the Patagonian marine ecosystem

LINK, J.S., PRANOVI, F., COLL, M., LIBRALATO, S., CHRISTENSEN, V., LEGAULT, C. Exploring novel metrics of ecosystem overfishing using energy budget model outputs.

KREBS, C.J., KENNEY, A.J., GAUTHIER, G. Why not Ecopath for terrestrial ecosystems?

PALOMARES, M.L.D., BAILLY, N., PAULY, D. FishBase, SeaLifeBase and database-driven ecosystem modelling.

ELECTRONIC POSTERS

DUARTE, L.O. Exploring the effects of MPA's in a tropical marine ecosystem. A multi-species and multi-gear fishing case.

MOTTA CARDOSO, A., DE ALMEIDA TUBINO, R., MONTEIRO-NETO, C. Preliminary Ecopath model of Itaipu Lagoon, Niteroi, Rio de Janeiro, Brazil.

DE ALMEIDA TUBINO, R., MONTEIRO-NETO, C., EDUARDO MORAES, L., TAVARES PAES, E. Trophic model for an artisanal fishery system in southeastern Brazil.

WATERMEYER, K.E., SHANNON, L.J., ROUX, J.P., GRIFFITHS, C.L. Changes in the trophicstructure of the northern Benguela before and after the onset of industrial fishing.

WATERMEYER, K.E., SHANNON, L.J., GRIFFITHS, C.L. Changes in the trophicstructure of the southern Benguela before and after the onset of industrial fishing.

ADDENDUM

Hossain, M.M., Matsuishi, T., Arhonditsis, G. Elucidation of ecosystem attributes using Ecopath with Ecosim (EwE): application to an oligotrophic lake in Hokkaido, Japan.

KEYNOTE SPEAKERS

JEFFREY POLOVINA

DrJeffrey Polovina is the Acting Director at the Pacific Islands Fisheries Science Center. His work includes research in biological oceanography in the Central and Western Pacific with focus on population dynamics of high trophic animals. Currently he is involved in developing indicators from satellite remotely sensed oceanographic data to monitor the state of the Pacific Ocean and in describing migration and "oceanic hot spots" used by large pelagic animals including turtles, tunas, opah, and whale sharks by sending out fleets of pelagic animals with electronic tags. In the early 1980s, Dr. Polovina and his colleagues at the National Marine Fisheries Service, Honolulu Laboratory, developed the innovative marine ecosystem model known as Ecopath. Named to convey its focus on ecological pathways, it was the first model to apply a type of statistics called "path analysis" to the field of marine ecology. At the conference Dr. Polovina will describe research context that led to the origin of Ecopath.

DANIEL PAULY

After many years at the International Center for Living Aquatic Resources Management (ICLARM), in Manila, Philippines, Daniel Pauly became in 1994 Professor at the Fisheries Centre of the University of British Columbia, Vancouver, Canada, of which he was the Director for 5 years (Nov. '03-Oct. '08). Since 1999, he is also Principal Investigator of the *Sea Around Us* Project (see www.seaaroundus.org), funded by the Pew Charitable Trusts, Philadelphia, and devoted to studying, documenting and promoting policies to mitigate the impact of fisheries on the world's marine ecosystems. The concepts, methods and software which Daniel Pauly (co-)developed, documented in over 500 scientific and general-interest publications, are used throughout the world, not least as a result of his teaching a multitude of courses, and supervising students in four languages on five continents. This applies especially to the Ecopath modeling approach and software (www.ecopath.org) and FishBase, the online encyclopedia of fishes (www.fishbase.org).

CARL J. WALTERS

Dr Walters is a Professor at the Fisheries Centre whose areas of research include the development of rapid techniques for teaching systems analysis and mathematical modeling to biologists and resource managers. A member of several of NSERC's grant committees since 1970, he has done extensive fisheries advisory work for public agencies and industrial groups. He has also conducted over two dozen three to ten day workshops in the past decade, for the International Canadian Fisheries Service, US Fish and Wildlife Service and the International Institute for Applied Systems Analysis.He is the editor of The Open Fish Journal and has been on the editorial boards of the Journal of Applied Mathematics and Computation, the Northwest Environmental Journal, the Canadian Journal of Fisheries and Aquatic Sciences, and Marine and Coastal Fisheries. Dr. Walters is a Fellow of The Royal Society of Canada.

STEVE MACKINSON

Dr Steve Mackinson is a scientist at the Centre for Environment, Fisheries and Aquaculture Science. At CEFAS, he has been involved in Ecopath with Ecosim modeling and study of trophic transfer efficiencies in food-webs of North Sea. He has also worked on issues of model complexity and effects of model structure for the Ecopath and Ecosim modeling approach. Dr Mackinson's research efforts also extend beyond the strict ecosystem modeling specialty into socio-economic drivers of fisheries management. He has worked on perceptions of the fishing industry and has elucidated measures to bridge gaps between science and stakeholders.

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Dr Elizabeth Fulton leads a marine ecosystem modelling team based at CSIRO Marine and Atmospheric Research in Hobart, Tasmania, Australia. She is the developer of the marine ecosystem model 'Atlantis' which is used to provide strategic advice to the Australian Fisheries Management Authority concerning the Southern and Eastern Scalefish and Shark Fishery. It has also been applied to 15 marine ecosystems in Australian and United States waters. As well as developing Atlantis, Dr Fulton is a co-developer of the InVitro modelling framework, which allows simultaneous consideration of multiple uses of the marine environment including: oil and gas, transport, tourism, commercial and recreational fishing. InVitro is being used to evaluate regional marine plans as part of Australia's Oceans Policy. For her leadership in mathematics and ecosystem modelling, she received the 2007 Science Minister's Prize for Life Scientist of the Year.

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Dr Lynne Shannon is a Senior Researcher at the Marine Research Institute, University of Cape Town. She has worked on modeling the Southern Benguela ecosystem and has published several papers on the response of fish populations in the Southern Benguela ecosystem to fisheries and environmental change. In addition, she has published on a wide range of topics that include implications of chlorophyll distribution on pelagic fisheries, regime shifts in the ocean, trophodynamic indicators, viability theory for ecosystem approach and the functioning of marine ecosystems. Her current research involves measures to evaluate the ecological status of world's fished marine ecosystems.

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Dr Villy Christensen is a scientist at the Fisheries Center, University of British Columbia. He works with ecosystem modeling and has a background in fisheries research. His research has since 1990 been centered on understanding impacts of human exploitation on marine ecosystems. He has been central to the development and dissemination of the Ecopath approach and software, a tool for ecosystem modeling. Ecopath modeling has become the de-facto standard for ecosystem approaches to fisheries management, and is being applied throughout the world. There are more than 350 derived models and publications, and more than 6000 registered users in 150 countries. Through cooperation with scientists worldwide, he has focused on trophic dynamics of aquatic resources. He has led a large number of training courses and workshops throughout the world, centered on developing ecosystem approaches to fisheries management. His current focus is on communication of science and improving its contribution to the decision-making process. This involves use of advanced gaming technology and visualizations combined with research on the decision-making process.

OPENING SESSION

THE ORIGINS OF ECOPATH[1]

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It is truly an honor to present an opening keynote talk at Ecopath 25 Years. It is fantastic to see the tremendous growth in the Ecopath community over the past quarter century and I think some of the newer members might enjoy learning some historical background on the development of Ecopath.

In 1975 a decade-long research program was initiated and directed by a consortium of agencies initially composed of the State of Hawaii, National Marine Fisheries Service (NMFS), and US Fish and Wildlife and joined several years later by the University of Hawaii. The objective of the program was to assess the marine resources and ecology of the Northwestern Hawaiian Islands for purposes of protecting unique wildlife and managing potential fishery resources. While much of the research effort was distributed across the 1000 km chain of atolls, banks, and seamounts, the program leaders had the vision to identify one atoll, French Frigate Shoals (FFS), as a site to simultaneously study all the major components of the food web. As the ecosystem study of FFS progressed it was recognized that there was a need to have some quantitative framework to build an ecosystem synthesis.

In 1979, I was hired at NMFS and one of my duties was to build an ecosystem model for FFS. I soon learned about the ecosystem modeling work of Dr. Taivo Laevastu at the Alaska Fisheries Science Center, NMFS and initially thought I might use his model for FFS. However I quickly recognized that the complexity of his model required a quantitative understanding of the coral reef ecosystem that we were far from achieving and a simpler model was needed. At FFS, there were over a dozen researchers studying components of the ecosystem ranging from the apex predators such as tiger sharks and monk seals to benthic productivity at the base of the food web and having this team of experts to consult and provide parameter estimates was a key factor in the development of the FFS Ecopath model.

In the early 1980s, as I was developing the model, Dr. Daniel Pauly would occasionally visit the Honolulu Laboratory. Once he learned about the model, he recognized its potential in applications to many ecosystems and his enthusiasm for the model provided additional momentum for me to complete the work. In 1984 colleagues and I published a series of 3 papers in Coral Reefs: the first described the Ecopath model and its application to FFS; the second compared the model's estimate of benthic primary productivity to an independent field estimate as a test of the model; and the third discussed the ecology and management of coral reef ecosystems based on the FFS Ecopath model.

Thus in summary, the initial development of Ecopath was a community effort and it is very satisfying to see, a quarter of a century later, that community has grown and is thriving. I'm confident that the outcomes from this gathering will set the stage for Ecopath 50 years!

ECOPATH: FROM THE FRENCH FRIGATE SHOALS TO THE PHILIPPINES AND TO UBC[1]

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In the early 1980s, the emphasis of most researchers on tropical fisheries, both local and foreign experts, was on applying to exploited fish stocks, and further developing the methods then becoming available for data-sparse situations, length-based stock assessment methods (see, e.g., contributions in Pauly & Morgan, 1987; Roedel & Saila, 1980). It was already becoming clear, however, that single-species approaches were not adequate in the tropics, because the target species, if there even was one, represented an even smaller fraction of the total catch (e.g., of trawlers) than in temperate waters (Pauly, 1979). Hence, applying the then standard yield per recruit (Y/R) models yielded essentially useless solutions (see e.g., Pauly & Martosubroto, 1980).

The extension of single-species Y/R to a number of stocks, which for a while became known as 'multi-species modeling', while straightforward in principle, and successfully applied to a few fisheries turned out to be too unwieldy to be used routinely (Munro, 1980), despite several attempts at revivals. Also, this approach did not make use of the fact that a large number of fisheries biologists in the tropics, as in temperate areas, were collecting huge amounts of stomach content data with at least the tacit expectation that such data might be useful for some sort of understanding of the role of exploited species within ecosystems (see, e.g., bibliography in Pauly, 1982).

I was then based in Manila, the Philippines, and worked at the International Center for Living Aquatic Resources Management, or ICLARM (which despite its unwieldy name was at the time a powerhouse of new ideas), deeply engaged in these research initiatives, including teaching the methodologies they generated (see Venema *et al.*, 1988). This included attempting to organize ecosystem biomass flow estimates into functional groups linked by feeding arrows, a technique I had used earlier (Pauly, 1979, 1982) and taught to others (see, e.g., Yap, 1983).

Thus, my mind was ready for Ecopath (Polovina, 1984a, 1984b), whose gradual development I was following through frequent visits to Jeff Polovina in Hawaii. Indeed, I encouraged him to make the code of Ecopath available, so others could follow up on it. He took the advice (Polovina & Ow, 1983; see Polovina, 1993), and I began to apply, use and teach it to other people, notably to visitors and colleagues who came to ICLARM, like Ms. Yap Siaw-Yang earlier, to learn fish stock assessments and, more pertinently, what had turned from multispecies into ecosystem modeling.

This led to some additions to Polovina's Ecopath software, most, however, dealing with the inputs to Ecopath and the interpretation of its outputs. In particular, I realized that Ecopath would be a straightforward way of parameterizing the network approach then launched by Ulanowicz (1986). The first application of this insight was to the Peruvian upwelling system (Pauly, 1987).

This work lead to the reprogramming of Ecopath by Ms. Mina Soriano, and the development of 'Ecopath II', providing more outputs than the original version. Ecopath II was presented at a workshop in Kuwait, in December 1987. However, the first version of the paper documenting this was destroyed, along with much of the assets of Kuwait Institute of Scientific Research during the subsequent invasion of Kuwait by Iraqi forces; it was included in a book published in the early 1990s (Pauly *et al.*, 1993).

The work documented above having established the potential of Ecopath in assembling and harmonizing previously underutilized data, I convinced the then Director-General of ICLARM, Ian Smith, to reserve the

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position then offered by the Danish international development agency (DANIDA) for a modeler who could take over our Ecopath work. I met young Villy Christensen during a trip to Kiel in 1989, and he was hired. Villy quickly reprogrammed Ecopath II, and released it in the summer of 1990. We could then jointly prepare the extremely successful poster session at ICES in 1990, in which tropical countries were for the first time dominant at an ICES event, and which we documented in a book (Christensen & Pauly, 1993). As well, Villy documented our software, which led to a detailed manual (Christensen & Pauly, 1991), of which numerous updates and translations (in French and Spanish) were subsequently published. Also, he was the lead author of a paper (Christensen & Pauly, 1992), which anchored Ecopath II in the peer-reviewed literature, and which today stands as the third-most cited paper published in the key journal Ecological Modelling.

The mid-1990s were a period of consolidation and expansion, where we simultaneously defended the logic of Ecopath – then still much contested – in various fora, and applied it to numerous ecosystem types, often in the context of training courses in many countries on all continents. This is also the time where colleagues in Mexico (F. Arreguin-Sanchez), France (J. Moreau with M.L. Deng Palomares) and others elsewhere began to support the use of the approach and software independently. Also, the trophic levels that were being estimated, and other insights gained through various Ecopath applications, were used in a high profile publication (Pauly & Christensen, 1995).

But what contributed most to Ecopath 'breaking through' was the development of Ecosim by C.J. Walters, a result of his participating at the Ecopath workshop, documented in Christensen & Pauly (1996), i.e., in the first of many Fisheries Centre Research Reports devoted to Ecopath and related issues. This workshop, held in November 1995, was a result of my transition (September 1994) to the University of British Columbia, and the first in which models were built by a team, whose members were responsible for different functional groups, thus allowing more expertise to be incorporated into the resulting model. Walters (1996), however, saw Ecopath not as an end product, but as the starting point for dynamic simulation, which first included Ecosim (Walters *et al.*, 1997), then later Ecospace (Walters *et al.*, 1998). What happened then is best told by Villy.

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FISHERIES APPLICATIONS: ORAL PRESENTATIONS

FORAGING ARENA THEORY[1]

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Foraging arena theory argues that trophic interactions in aquatic ecosystems occur largely in spatially and temporally restricted arenas, such that interaction rates can be severely limited by exchange rates of prey into and out of these arenas. Foraging arenas are created by a wide range of mechanisms, ranging from restrictions of predator distributions in response to predation risk caused by their own predators, to risk-sensitive foraging behaviour by their prey. Foraging arenas partition the prey in each predator-prey interaction in a food web into vulnerable and invulnerable states, with exchange between these states potentially limiting overall trophic flow. Whenever any one species exhibits spatially restricted foraging, two foraging arena structures and vulnerability exchange processes are created: between the species and its predators, and between the species and its prey (since the species no longer occupies the full habitat that its prey may use).

Inclusion of vulnerability exchange processes in models for recruitment processes and food web responses to disturbances like harvesting leads to very different predictions about dynamic stability, trophic cascades, and maintenance of ecological diversity than do models based on large-scale mass action (random mixing) interactions between prey and predators. Incorporation of foraging arena vulnerability exchange calculations into Ecosim models has been the main reason for success of Ecosim at representation of dynamic behaviour for many aquatic ecosystems, as judged by ability of Ecosim models to fit historical time series data.

Three main challenges for future development of Ecosim are: (1) development of software and protocols for using it to recover estimates of historical, unfished ecosystem states by using a stock reduction analysis approach with historical catch and relative abundance data; (2) representation of changes in trophic interactions due to meso-scale spatial changes in species distribution patterns associated with thermal and hydrodynamic regime shifts caused by climate change; and (3) representation of the highly nonlinear dynamics associated with ecosystem regime shifts and multiple stable states, which can be created by cultivation-depensation effects and other size-dependent interaction patterns.

ECOTROPH: A NEW TOOL IN THE EWE FAMILY[1]

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EcoTroph is proposed as a plug-in module of EwE version 6, providing a simplified picture of ecosystem functioning. It allows users to represent the distribution of the ecosystem biomass as a function of trophic levels, and to analyse or simulate fishing impact in a very synthetic way (Gascuel *et al.*, 2009).

In the EcoTroph approach, the biomass per trophic group and the catch per fishery is represented as a distribution over trophic levels, assuming that the distribution of the biomass (or production, or catch) of a trophic group around its mean trophic level follows a lognormal curve. The Biomass (or production, or catch) Trophic Spectrum is the curve obtained by summing all biomasses across trophic groups. This representation provides a very synthetic overview of an ecosystem and may help users to think at that scale. Thus, trophic ecosystem functioning can be modelled as a continuous flow of biomass surging up the food web, from lower to higher trophic levels, because of predation and ontogenetic processes (Figure 1).
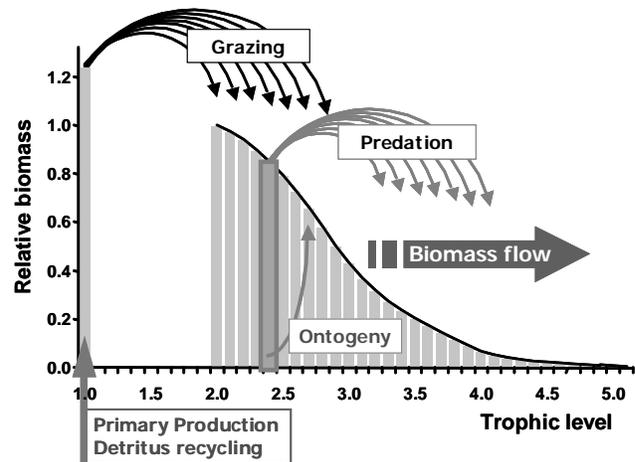
Figure 1. Diagram of the trophic functioning of an ecosystem, in EcoTroph: theoretical distribution of the biomass by trophic level and trophic transfer processes (from Gascuel *et al.*, 2009).

We illustrate the usefulness of such an approach, based on three distinct case studies.

The first case study, Guinean ecosystem, is used to illustrate how EcoTroph provides diagnostic tools for assessing the impact of fishing. Based on a previously built Ecopath model, we estimated the biomass and the catch trophic spectrum related to the current state of the ecosystem (i.e., for the year 2004), and we simulated changes in fishing pressure by using multipliers of the fishing mortality values of 0-5 and applied to the whole ecosystem (Gascuel *et al.*, 2008). We show that the current fishing effort led to a 3-fold decrease in biomass of higher trophic levels, compared to the unexploited ecosystem (multiplier of 0; Figure 2, left panel).

The decrease in abundance of these high trophic level groups is a consequence of their over-exploitation (Figure 2, right panel) and a significant decrease in the mean trophic level of both the total biomass and the catches. These results confirm and generalize previous single species assessments. Forecasting suggests that higher yields might be obtained by exploiting lower trophic levels, but this would result in a higher impact on the ecosystem and a qualitative degradation of the ecosystem's health.

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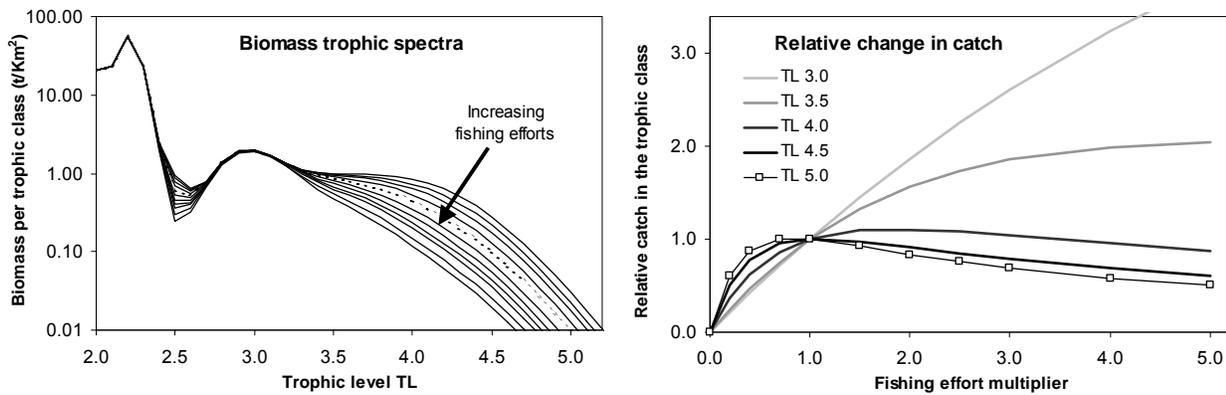
Figure 2. Simulation of the impact of increasing fishing effort in the Guinean ecosystem. Left panel: simulated catches (relative values) expressed as a function of the multiplier of the current fishing mortality. Right panel: impact on the biomass trophic spectrum (dashed lines represent the 'current' situation).

The second case study, the Port-Cros French National park in the Mediterranean Sea, illustrates how EcoTroph may highlight, in a simple way, differences in the ecosystem functioning resulting from the presence of a Marine Protected Area (MPA). In this case study, an Ecopath model was first built using all available information. EcoTroph is used as a tool for the graphical representation of the Ecopath model and to simulate various scenarios, i.e., from a total ban of fishing to the release of all protection currently in force in the MPA. We show that protection leads to a change not only in the biomass trophic spectrum characterizing this ecosystem, but also in the production trophic spectrum and in the functional biodiversity as well.

Finally, we used EcoTroph as a tool for comparison of various ecosystems and to conduct a meta-analysis on a global scale. We considered 57 Ecopath models, recently published and referring to contrasting case studies in terms of ecosystem size, latitude, mean depth, productivity, etc. For each model, biomass, production and catch trophic spectra were built. Then, ecosystems were classified in various types of ecosystem functioning according to their spectra characteristics. Various patterns of the exploitation of ecosystems were also defined and their impact on biomass and production trophic spectra was analysed.

We conclude that, within the EwE family of models, EcoTroph may be regarded as constituting the ultimate stage in the use of the trophic level metric. In this type of model, calculations are based on each trophic level instead of on species or functional group as used in EwE. The representation, thus provided, constitutes a simplified and useful caricature of the functioning of real ecosystems.

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Exploring fisheries strategies for ecosystem-based management in the East China Sea[1]

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The East China Sea (ECS) is a semi-enclosed marginal sea with a wide continental shelf. Large quantities of land-based nutrients and pollutants along with large fresh water inputs mainly from the Changjiang (Yangtze) river system coupled with the ocean current system contribute to a rich fish fauna, with about 700 fish species, and rick offshore fishing grounds exploiting about 20 highly valued species. The wide continental shelf waters of the ECS supported various commercial and recreational fisheries for China, Japan and South Korea. However, heavy fishing pressure exerted on commercial stocks over the last few decades resulted in a significant change in fishery resources, i.e., high value and low volume traditional species are now overfished and marine catches are composed of smaller, younger, lower trophic level and immature fish (Zhang *et al.*, 2007;Chao *et al.*, 2005).

There is wide-spread agreement that fisheries need to be managed with consideration of overarching goals, e.g., restoring and maintaining healthy ecosystems and fisheries (FAO 1995, Garcia & Staples 2000), i.e., Ecosystem Based Fishery Management (EBFM) or Ecosystem Approach to Fisheries. This is currently being implemented in many countries' legislation. EBFM aims to minimize: (i) direct impact on the environment such as caused by destructive gears; and (ii) impact on species composition, abundances, and size (age) structures of populations. Ecosystem models play an important role in the ecosystem approach to fisheries (Araújo *et al.*, 2008), notably *In:* (i) identifying potential changes in complex systems that cannot be identified with single-species models; (ii) revealing otherwise unknown system properties; (iii) improving knowledge about specific parts of the ecosystem; (iv) "testing" the compatibility of data sets; and (v) serving as a basis for the elaboration and/or exploration of scientific hypothesis about system dynamics and functioning (Araújo *et al.*, 2006; Fulton & Smith, 2004; Walters & Martell, 2004; Christensen & Pauly, 1998; Vasconcellos *et al.*, 1997). The Ecopath with Ecosim (EwE) software (Christensen *et al.*, 2005) is currently the most used and tested ecosystem modelling tool for addressing these issues and in finding a balance between economic and social benefits within the framework of ecosystem conservation in regional fisheries management (Arreguín-Sánchez *et al.*, 2004).

The aim of this work is to explore fishery management strategies to optimize current exploitation of fishery resources in the ECS on economic, social and ecological objectives by using a fishing policy optimization routine in a EwE model. The simulations presented here span a period of 11 years based on fleet control, viz.: (i) profits from the fisheries denote the economic achievement; (ii) number of jobs provided by the fisheries that measured with the job/catch value index represents social goals; (iii) the inverse of the P/B ratio by group was used as an ecological criterion of group-species longevity. Both single objectives and combined criteria were tested in the study (Table 1).

Optimizing for a single objective led to the specialization of fishing fleets. Maximizing for economic achievement decreases the effort of all fishing fleets except that for drift gill net which increased by 33.2 %. The increase in fishing effort of drift gill net and stow net fleets satisfied the requirements for social benefits, i.e., increase in jobs. Optimizing for ecological structure led to a drastic decrease in effort of all fishing fleets except that of drift gill net which had a slight increase of 7.5 % (Table 1). Optimizing for economic and social criteria led to small changes in the ecosystem structure. However, optimizing for ecosystem structure led great decreases in fisheries profits and number of jobs. Combinations of economic-social, economic-ecological, and social-ecological criteria appear as realistic possibilities to improve benefits for fishing activity and ecosystem structure. For all scenarios in general, effort of trawl and shrimp trawl fleets are suggested to decrease, drift gill net to increase, and other fleets decrease in most scenarios presented in Table 1. Finally, an 'ideal' mixed policy configuration was found when a compromise was made between economic, social and ecological criteria.

Table 1. Optimization of management policies using Ecosim model through open loop simulation for fisheries of the East China Sea for the period of 1990 to 2000.

Weighting factors for criteria			Outputs after optimization			Fleets					
Econ.	Social	Ecol.	Econ.	Social	Ecol.	Trawl	Stow net	Drift gill net	Purse seine	Shrimp trawl	Other fleet
1	0	0	1.55	1.04	1.21	0.448	0.683	1.33	0.879	0.269	1.02
0	1	0	1.09	1.47	1.016	0.042	1.97	26.8	0.194	0.398	4.86
0	0	1	0.08	0.06	2.41	0.004	0.008	1.07	0.074	0.002	0.017
1	1	0	1.48	1.31	1.06	0.480	0.982	23.4	0.190	0.241	3.02
1	0	1	1.39	0.87	1.46	0.196	0.878	1.38	0.761	0.057	0.694
0	1	1	1.36	1.25	1.09	0.148	1.70	1.69	1.23	0.319	2.17
1	1	1	1.54	1.16	1.29	0.044	0.900	2.72	0.545	0.271	1.62

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ECOLOGICAL EFFECT OF MOONJELLY, *AURELIA AURITA*, REMOVAL IN THE SEA OF SUO-NADA, SETO INLAND SEA, JAPAN[1]

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The Seto Inland Sea, west of Japan, is a highly productive semi-enclosed boy of water. The Sea of Suo-Nada is located in the western part of the Seto Inland Sea, with a total area of about 3,100 km² and an average depth of 23.7 m. Fisheries in this area are important to the local economy, with the annual landings of various fleets (trawl, gill net, set net, and boat seine fisheries) amounting to 12 750 t in 2005. Meanwhile, moonjelly (*Aurelia aurita*) blooms frequently occur, and have become a problem due to interference with fisheries operations in recent years. A device to cut up moonjelly into pieces was developed to address this problem (Yuichi Fukuda, Oita Prefectural Agriculture, Forestry and Fisheries Research Center, pers. comm.). However, the ecological effect of removing moonjelly from this ecosystem has not been assessed. Thus, we attempted to simulate the effect of this moonjelly removal on the biomass of other trophic groups using Ecopath with Ecosim.

The trophic mass-balance model of the sea of Suo-Nada constructed for the period 2001 to 2008 is presented in Figure 1. Species and organic matter of this ecosystem were classified into 23 functional groups, viz.: Spanish mackerel (*Scomberomorus niphonius*), seaperch (*Lateolabrax japonicus*), black porgy (*Acanthopagrus schlegelii*), mullet (*Mugil cephalus*), anchovy (*Engraulis japonicus*), mantis shrimp (*Oratosquilla oratoria*), Japanese tiger prawn (*Marsupenaeus japonicus*), Japanese blue crab (*Portunus trituberculatus*), moonjelly, flatfishes, croakers, piscivorous fishes, planktivorous fishes, benthivorous fishes, cephalopods, shrimps, other crustaceans, large-sized benthos (>1.0 g), small-sized benthos (<1.0 g), zooplankton, phytoplankton, seaweeds, and detritus. Groups were created based on the most abundant species, on economic importance, and classification of fisheries statistics. Parameter values, i.e., biomass, production per biomass, consumption per biomass and diet composition, came from published information (e.g., reports of the Fisheries Agency and Fisheries Research Agency of Japan, 2008; Imoto *et al.*, 2007), monthly trawl surveys with species composition and stomach contents (e.g., Kimura *et al.*, 2003), and estimations using empirical relationships available through Ecoempire. We simulated the changes of biomass and catch over a 15-year period by using Ecosim. In this simulation, we evaluated the impact of the removal of moonjelly in the first 5 years with a removal rate (= catch per biomass) of 0.25.

Biomass of moonjelly decreased during the removal period, and reached half of its current level at the end of this period (Figure 2). Subsequently, the biomass of monjelly recovered to its level before the removal of moonjelly. An increase of the biomass of anchovy was seen as the biomass of moonjelly decreased. In addition, biomass of Spanish mackerel increased over the same period when the biomass of anchovy increased. Total catch in the 5th year was 9.5 % larger than the current catch level, due to an increased catch of anchovy of the boat seine fishery. However, total catch decreased by 4.0 % in the 10th year and by 3.6 % in the 15th year, respectively. Biomass changes of demersal trophic groups were small, accounting for the constant behaviour of trawl and gill net fisheries, which exploit these groups, and thus, of the limited effect of moonjelly removal on these groups.
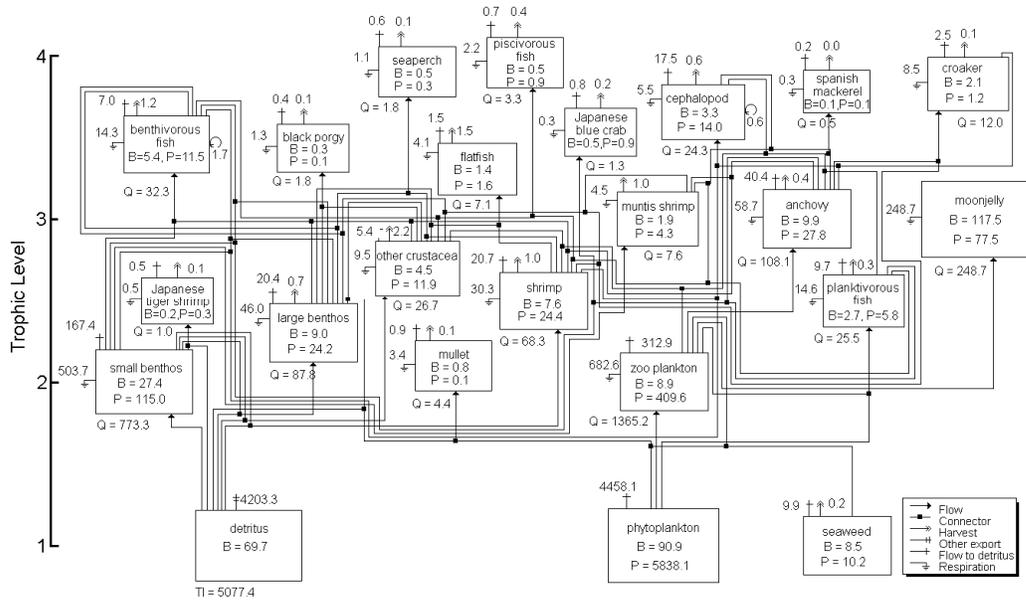
Figure 1. Flow chart of trophic interactions in the Sea of Suo-Nada, Seto Inland Sea, western Japan.
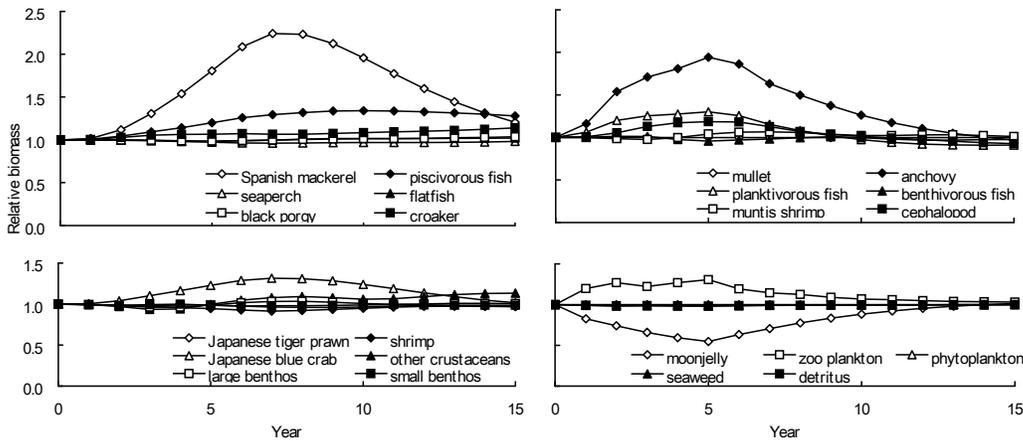
Figure 2. Dynamic changes in the biomass of trophic groups in the Sea of Suo-Nada, Seto Inland Sea, western Japan.

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Capturing significant coral reef ecosystem and fishery changes in Bolinao, Philippines (1997-2008) using Ecopath with Ecosim[1]

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The 200km² fringing reef of Bolinao in Pangasinan, Philippines (16°25' N and 119°56' E) is an important habitat for the Lingayen Gulf, a major fishing ground in Northern Philippines with an estimated yield of 6 500 t in 2001 (Silvestre & Hilomen, 2004). The extensive reef flat and slope straddles four municipalities and provides livelihood to more than 9,000 subsistence fishers and their dependents (Cruz-Trinidad *et al.*, 2009). The reef has been intensively fished since the early 1980s resulting to significant declines in observed fish biomass based on fishery-independent visual census surveys.

While still subjected to intense fishing, the Bolinao reefs were severely hit by the global massive bleaching event in 1998 brought about by an extreme El Niño anomaly. Between June to August 1998, live coral cover on the reef slopes of Bolinao was reduced from 45 % to 17 % (Arceo *et al.*, 2001). Despite this immediate and drastic change in benthic community composition, immediate post-bleaching effects were not apparent on reef fishes or fisheries (Pet-Soede, 2000).

In order to assess changes in Bolinao's coral reefs and gauge the relative impacts of possible causes (e.g., fishing, refuge declines, and increased productivity), we created two Ecopath models of the reef slope system with base years at 1997 (pre-bleaching and relatively less nutrient input) and 2008 (post-bleaching with greater nutrient inputs from proliferation of nearby mariculture structures). Fish benthic functional groups were parameterized from underwater fish visual census and benthic community transects for both years as well as in 1998 and 1999. The 1997 model was then fitted to time-series data and ran until 2008 under various forcing and mediation functions to analyze the ecosystem impacts of benthic changes brought about by mass coral bleaching (i.e., reduced live coral cover, topographic complexity, and increased benthic algal cover) and continued fishing. Results were compared to how the 11-year simulation of the 1997 trophodynamic model captures the 2008 true balanced Ecopath model of the same reef area.

Comparison of parameter inputs for 1997 and 2008 reveal increased fish biomass and catches from 1997 to 2008 with majority of the increase attributed to generalist feeding guilds such as detritus, macroalgal (e.g., Scaridae – parrotfishes), and invertebrate feeders (Table 1). This is contrary to studies on effects of bleaching on reef fishes which usually report declines in fish biomass and density following intensive reductions in live coral cover due to bleaching of crown-of-thorns starfish infestation, implying that other factors beyond habitat control affect fish community changes in Bolinao reefs.

An 11-year trophodynamic simulation using only fishing as the forcing function (i.e., gradual doubling of fishing effort) captured most of the increase in fish biomass estimated in the 2008 Ecopath model but fishery targeted groups (i.e., invertebrate feeders; piscivores; carnivores; Acanthuridae – surgeonfishes, tangs, unicornfishes; and Siganidae – rabbitfishes) decreased to almost zero indicating that other factors were at play in structuring reef fish communities in Bolinao from 1997 to 2008 (e.g., habitat effects and movement of adults from adjacent reefs). Mediation functions helped explain relative importance of habitat while the remaining difference in biomass estimates from the 11-year Ecosim results and the 2008 parameterized Ecopath model were assumed to be due to adult migration. Fishery policy scenarios are also explored such as varying effort reductions of the different gear types and continued reduction or increase,

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due to restoration efforts, of live coral cover and increase (or decrease) in benthic algae for the next 10 years.

Incorporating non-trophic benthic interactions (e.g., competition for space) and refining benthic-fish interaction terms can help improve the utility of Ecopath with Ecosim for nearshore, habitat-associated fisheries and move beyond fishery carrying capacities to ecosystem function carrying capacities, a critical step towards ecosystem-based management.

Table 1. Inputs and calculated parameters (in italics) for the 1997 and 2008 trophic model of Bolinao reef slope, Pangasinan, Philippines (16°25' N and 119°56' E).

Group name *	Biomass (t·km⁻²)		P/B (yr⁻¹)		Q/B (yr⁻¹)		EE		P/Q		Catch (t·km⁻²·yr⁻¹) [+]	
	1997	2008	1997	2008	1997	2008	1997	2008	1997	2008	1997	2008
Phytoplankton	2.74	3.22	511.00	511.00	-	-	*0.85*	*0.42*	-	-	0.00	0.00
Macroalgae	50.27	83.42	*0.96*	*1.22*	-	-	0.30	0.30	-	-	0.00	0.00
Other algae	8.04	18.68	*1.88*	*4.55*	-	-	0.95	0.95	-	-	0.00	0.00
Corals	105.00	41.42	1.10	1.10	7.30	7.30	*0.01*	*0.11*	0.15	0.15	0.00	0.00
Zooplankton	*7.97*	*4.68*	80.00	80.00	200.00	200.00	0.60	0.60	*0.40*	*0.40*	0.00	0.00
F invert feeder	0.23	1.45	1.26	1.14	10.31	9.90	*0.91*	*0.12*	*0.12*	*0.12*	0.23	0.03
F carnivore	0.12	0.34	*1.82*	*1.71*	13.86	7.97	0.95	0.90	*0.13*	*0.22*	0.19	0.48
F corallivore	0.06	0.39	1.73	2.25	15.34	22.74	*0.23*	*0.18*	*0.11*	*0.10*	0.00	0.00
F detritus feeder	0.11	1.56	1.76	1.76	25.96	26.58	*0.22*	*0.06*	*0.07*	*0.07*	0.00	0.00
F herbivore – others	0.09	0.80	1.92	1.89	56.17	61.22	*0.14*	*0.28*	*0.03*	*0.03*	0.00	0.00
F omnivore	0.12	0.59	1.91	1.55	29.78	38.91	*0.11*	*0.18*	*0.06*	*0.04*	0.00	0.00
F piscivore	0.01	0.14	*0.81*	0.98	6.19	11.12	0.99	*0.51*	*0.13*	*0.09*	0.00	0.02
F zooplanktivore	0.09	1.62	1.78	1.50	16.13	11.90	*0.14*	*0.07*	*0.11*	*0.13*	0.00	0.01
Acanthuridae	0.08	0.89	0.93	0.79	20.79	19.11	*0.94*	*0.23*	*0.05*	*0.04*	0.06	0.00
Scaridae	*0.05*	0.35	0.93	1.07	17.34	21.53	0.90	*0.70*	*0.05*	*0.05*	0.02	0.10
Siganidae	0.43	*0.23*	1.61	2.97	24.58	38.69	*0.28*	*0.90*	*0.07*	*0.08*	0.17	0.46
Sea urchins	*0.06*	*0.68*	7.00	7.00	30.42	30.42	0.30	0.30	*0.23*	*0.23*	0.00	0.00
Crustaceans	5.71	5.71	11.47	11.47	26.89	26.89	*0.04*	*0.21*	*0.43*	*0.43*	0.00	0.08
Other sessile benthic inverts	16.54	16.54	6.96	6.96	15.18	15.18	*0.52*	*0.57*	*0.46*	*0.46*	0.00	0.00
Detritus	1000.00	1000.00	-	-	-	-	*0.95*	*0.46*	-	-	0.00	0.00

* F = fish functional group
[+] Total catch in 1997 is 0.69 t·km⁻²·yr⁻¹ and 1.18 t·km⁻²·yr⁻¹ in 2008

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Fisheries in Baja California Sur:

A Trophic-Based Analysis of Management Scenarios[1]

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Using published fisheries and ecosystem data for the Baja California Sur (BCS) region in Mexico, we constructed an Ecopath with Ecosim (EwE) version 6 model to represent current ecosystem and fishing dynamics and the outcomes of various fisheries management scenarios. We also used novel applications of the program to evaluate the economic effects of specific fisheries policy measures, particularly those that are attainable and provide overall benefits in a multi-stakeholder setting.

During the last 30 years and particularly in the last decade, BCS has embraced the tourism industry, most noticeably in the Los Cabos region, where fishing is one of the main tourist attractions. Meanwhile, the commercial long-liner fleet continues to operate and is widely held to be chiefly responsible for diminishing shark populations. Billfish stocks are also experiencing slight but steady declines, with some allegations that this is mainly due to bycatch in long-lines (The Billfish Foundation, 2008). Conflicts between the sectors were recently worsened by the approval of a shark fishery management law which does not specifically prohibit bycatch of billfish (Diario Oficial de la Federación (DOF), 2007). Social and political groups view this as a direct threat to the economic benefits of the local sport fishing industry (valued by industry to be worth 1.2 billion USD/year in the region; Southwick Associates, Inc., 2008). Amid calls for the complete shutdown of long-lining in the region, government scientists carried out an evaluation of shark bycatch, followed by a mandate setting a bycatch limit for billfish (DOF, 2008). However, no scientific studies have yet been conducted to gauge the impact of fishing fleets on the BCS marine ecosystem.

We constructed a simplified ecosystem model using modified basic input data from a Central North Pacific EwE model by Kitchell *et al.* (2002), eliminating or aggregating data for functional groups that were either inapplicable or too specific for the purpose of this work (Table 1).

Table 1. Select input parameters for Baja California Sur Ecopath model.

Group name	Biomass (t·km²)	P/B (yr⁻¹)	Q/B (yr⁻¹)	EE	P/Q
Large sharks	0.50	0.250	2.5	0.178	0.100
Coastal sharks	18.30	0.30	2.8	0.107	0.107
Marlin	3.42	0.30	4.0	0.030	0.075
Dorado	30.45	3.0	20	0.085	0.150
Other billfish	5.88	1.40	10.4	0.262	0.135
Skipjack tuna	41.57	1.90	20	0.097	0.095
Flying squid	18.23	5.0	50	0.208	0.100
Small scombrids	243	2.0	10	0.782	0.200
Squid	410	2.5	25	0.850	0.100
Other pelagic fish	1,876	1.5	6.2	0.859	0.242
Zooplankton	3,496	8.3	41.5	0.796	0.200
Phytoplankton	2,903	100	-	0.500	-
Detritus	1.00	-	-	0.000	-

Landings for the main fleets in the region (sport, long-liner, squid and pelagic) were assigned considering that all fisheries currently operate at their MSY, as reported by the Mexican National Fisheries Institute (DOF, 2004). All bycatch and catch-release mortality rates were assigned according to published data for the region and specific groups (INP, 2007; Cramer, 2004; Ditton *et al.*, 1996).

Results show that current government-mandated bycatch limits will probably not have a significant positive effect on billfish population levels. In fact, billfish stocks will not recover significantly even if all commercial fishing in the region is banned (although this would effectively recover shark populations). Furthermore, any positive effects would likely be offset by subsequent increases in sport fishing if it is allowed to build up further.

Both tourism and commercial fishing are socially and economically important in the BCS region, so it would be unfeasible and undesirable to shut down either activity no matter what the positive environmental effects could be. However, it is possible to explore and find scenarios involving trade-offs between sectors which would have positive ecological effects without high (or perhaps any) socio-economic costs.

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IMPACT OF FISHING AND CLIMATE ON THE CELTIC SEA AND THE BAY OF BISCAY[1]

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The Celtic Sea and the Bay of Biscay have been fished intensively for at least a century. Already sizeable between the two World Wars, the fisheries resumed after 1945 with the support of governmental subventions to modernize the fleets and thus causing an unprecedented increase in fishing capacity in the region.

We built a model for the Bay of Biscay and Celtic Sea for 1980, using the Ecopath with Ecosim software (EwE) (Christensen & Walters, 2004). Of the numerous species that are exploited in the ecosystem only a mere dozen were the subject of stock assessment because of their importance for the industrial fleets while most coastal species were never assessed. The model is articulated around 14 industrial species, their prey and predators, for a total of 38 groups. Cod, hake and Norway lobster were separated in juvenile and adult stanzas to account for species size-structured interactions among themselves and the fisheries.

Starting from 1980 we fitted our model to biomass and landing data using time series of fishing mortality used as an index of fishing effort. We also used various climate indices, the North Atlantic Oscillation index (NAO) and sea surface temperature, to modify phytoplankton's production and obtain better fits.

Biomass and catch trophic spectra were built, for the starting and the ending years of the period (i.e., 1980 and 2006) using the ET-Transpose routine (Gascuel *et al.*, 2009) included in the EwE software. Such spectra represent the distribution over trophic levels of the whole ecosystem biomass, or of total catches. Thus, they provide a synthetic overview of the ecosystem state and of the major changes occurring during the period. Finally, the impact of fishing was estimated using the EcoTroph model (Gascuel, 2005; Gascuel & Pauly, 2009).

RESULTS

Using only fisheries effort, Ecosim predicted the general trend in landing and biomass for several demersal species such as hake, monkfish, while large discrepancies occur for other species such as cod, sole, plaice and whiting. Ecosim could not account for the observed decline in mackerel because the high initial biomass was due to the entry of very large cohorts in the population before 1975, the effect of which were still present in the early 1980s. Thus, fishing alone was not sufficient to have provoked the declined.

Forcing the primary production with the NAO index did not improve the fit to time series, although discrepancies in biomass and/or landing trends were corrected in some cases. The scenario that estimated both climate anomalies and vulnerabilities improved the accuracy of the model general predictions and indeed the sum of squares decreased. The NAO index and the anomalies estimated by Ecosim have similar trends although the anomalies are shifted in time, reaching maximum positive values ~3-4 years later than the NAO index.

Although total landings remained approximately constant from 1980 to 2006, several changes in the trophic structure are noted. First, the biomass of higher trophic levels decreased while it increased for the

lower ones. Biomass ratios 2006/1980 show a decrease of about 30 % for trophic levels higher than 4.0. The same ratio using accessible biomass (i.e., the biomass of exploited groups) suggests that the increase in low trophic levels biomass mainly concerns groups that are not fishable. Fishing mortalities increased for high trophic level groups, suggesting that the fishermen tried to compensate for the decrease in abundance of their traditional stocks. In the same period, landings of the lower trophic levels increased due to increased landings of some lower trophic level species and because the mean trophic level of some groups decreased slightly.

Finally, using Ecotroph, we found that the abundance of the total biomass decreased for all trophic levels higher than 3.5 (Figure 1). The rate of decrease exceeds 50 % for trophic levels higher than 4.0. As a consequence, the mean trophic level of the whole ecosystem biomass decreased from 2.42 to 2.35.

DISCUSSION

The model is still in a preliminary phase, but it was still able to predict biomass and catches of most exploited species, from 1980 to 2006. A notable exception to this is mackerel for which we suspect that the main factors influencing its dynamics may be happening outside the study area. Fisheries explain a large part of the trends for demersal species such as cod, hake, and monkfish, while the effect of indices of

Figure 1. Ratios of biomass per trophic class, between the ending year 2006 and thye starting year 1980 or the unexploited situation. B* refers to the accessible biomass, i.e. the biomass of all species or groups currently fished.

productivity were necessary to explain a good part of the trends of all fish and more importantly on whiting, sardine, herring and anchovy. It is clear that not all functional groups depend on the same resources, which would explain why the NAO index applies better on some species and the forcing function estimated by Ecosim on others. For example, the juveniles of flatfish are typically found in estuaries where the main influence on survival is likely to be linked to river flow and other factors that are only partly linked to the strength of the NAO index.

Even if biomass only slightly decreases and total landings remain more or less constant during the period, some significant changes occurred. The EcoTroph approach especially shows that the increasing fishing mortality induced a decrease in abundance of predator species. Globally, the ecosystem biomass and landings exhibit decreasing trophic levels, indicating a decrease in functional biodiversity of the underlying ecosystem (Pauly *et al.*, 1998).

Of course, one should not forget that the fishery does not start in 1980. The flat deterioration of the ecosystem health over the last 25 years, is likely to follow a strong and fast deterioration during the decades after World War II, characterized by an huge increase in the European fishing effort.

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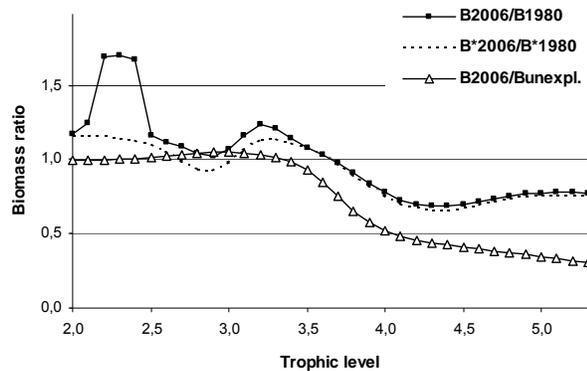
FISHERIES APPLICATIONS: POSTER PRESENTATIONS

RECOVERY SCENARIOS OF A HIGHLY EXPLOITED SPECIES, *MERLUCCIUS MERLUCCIUS*, IN THE NW MEDITERRANEAN SEA[1]

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The biodiversity in the Mediterranean is threatened by overexploitation of biological resources, direct habitat modification of sea and coastal areas, introduction of exotic species, pollution and climate change (Bianchi & Morri, 2000). In the North-western Mediterranean Sea, highly valued marine resources, e.g., hake *Merluccius merluccius*, are subjected to intense fishery pressure. Hake is overfished mainly due to: low selectivity of trawling nets (i.e., excessive capture of juveniles); the introduction of modern long lines during the 1970s; and the partial elimination of their spawning refuge (Sardá *et al.*, 2005; Aldebert & Recasens, 1996).

A new European Commission Regulation on the Management of Mediterranean Fisheries (CE 1967/2006) was approved in December 2006 on management measures for sustainable exploitation of fishery resources in the Mediterranean Sea. The new regulation enforces a higher selectivity of the current 40 mm diamond mesh codend in trawling. Several experimental case studies demonstrated the positive ecological effects of increasing trawling selectivity (e.g., Bahamon *et al.*, 2006; Guijarro & Massutí, 2006; Sardà *et al.*, 2005), although simulations predict that a drastic reduction of fishing effort in parallel with higher gear selectivity would be necessary for the recovery of highly exploited species such as hake (Coll *et al.*, 2008a). The new regulation also encourages European States to enhance new protected areas for fishing.

Here we explored if MPAs contribute an additional ecological value, in contrast with fishing effort reduction, to the recovery of hake in the NW Mediterranean Sea. Our simulations are based on a South Catalan Sea ecosystem model (Coll *et al.*, 2006) calibrated and fitted to catch time series for 1994 to 2003 (Coll *et al.*, 2008b) using Ecosim v. 6 (Christensen & Walters, 2004). The calibrated model was used to derive a new ecosystem model for 2003 (Coll *et al.*, 2008a), which represented initial conditions for the simulations. The baseline simulation was run for 25 years with constant fishing effort. Fishing effort for trawls and longlines was then reduced by 20 %, 30 %, 40 % and 50 % and changes in predicted biomass of adult and juvenile hake were compared to the baseline. The location of an MPA was also tested covering 20 %, 30 %, 40 % and 50 % of the study area.

a) Baseline simulation

b) 50%MPA

c) 50% reduction fishing effort
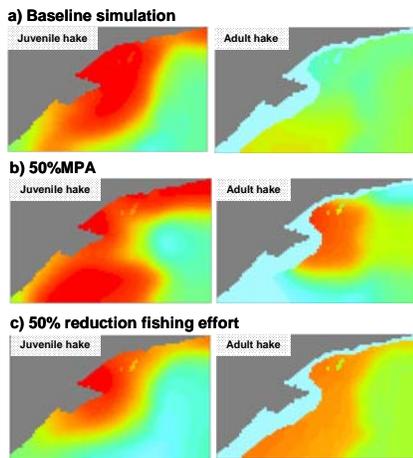
Figure 1. Biomass of hake in the South Catalan Sea under different management simulations

Reducing fishing effort increased adult hake biomass, while juvenile hake biomass was reduced (Figure 1, Table 1). This may be due to an increase of cannibalism by adults. The MPA has a positive effect on adult and juvenile hake biomasses, with broader benefits on juveniles. Full recovery of adult hake is obtained only within the protected area (Figure 1). The catch of both juvenile and adult hake generally increases with the MPA, while the catch of juvenile hake decreases when a reduction of fishing effort is simulated, in parallel with a noTable increase of adult hake catch (Table 1). Thus, both management options provide complementary results. When the MPA is implemented, the fishing effort surrounding the protected area substantially increases, with a noTable concentration of fishing effort at 50-100 m depths (Figure 2b). When fishing effort is reduced, a distributed reduction of both trawl and longline effort is predicted to occur on the area, although the effort is slightly concentrated in the continental shelf (50-100 m depth; Figure 2c). A smaller reduction of total final catch is predicted when MPAs are implemented, likely due to the fact that the total fishable biomass

is higher (Table 1). Both management options are predicted to benefit fish communities over invertebrates. In general, results reflect broader benefits of the MPA on the whole community, while the reduction of fishing effort has stronger positive effects on adult hake.

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Table 1. Results of various management simulations in the Southern Catalan Sea (scenario MPA or Effort Reduction/baseline).

	Biomass Juv. hake	Biomass adult hake	Catch Juv. hake	Catch adult hake	Total Cf/Ci	Binv / Bfish	BFf / BFi
MPA / Baseline							
MPA20/BS	1.05	1.29	1.03	1.11	0.95	0.93	1.05
MPA30/BS	1.08	1.46	1.07	1.03	0.92	0.87	1.07
MPA40/BS	1.09	1.67	1.14	0.91	0.88	0.83	1.07
MPA50/BS	1.08	1.9	1.29	0.77	0.84	0.76	1.06
Effort Red /Baseline							
Eff.R. 20/BS	0.70	1.54	0.56	1.38	0.83	0.91	0.78
Eff.R. 30/BS	0.58	1.8	0.37	1.48	0.74	0.84	0.67
Eff.R. 40/BS	0.48	2.07	0.23	1.50	0.66	0.78	0.58
Eff.R. 50/BS	0.42	2.36	0.15	1.45	0.60	0.72	0.53

C = total catch of exploited species, Binv = biomass of invertebrates, Bfish = biomass of fish, BF = fishable biomass, f = final, i = initial.
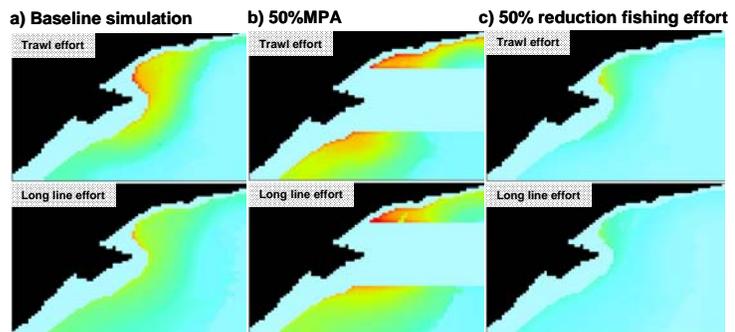
Figure 2. Fishing effort distribution in the South Catalan Sea under different management simulations.

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ON THE TRANSFER PAYMENT
OF THE FISHERY FUEL SUBSIDIES IN CHINA[1]

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Large scale summer fishing closure was implemented in East China Sea (ECS) by the Chinese government in 1995 in response to intensified anthropogenic impacts on the marine ecosystem. The area between 27°N and 35°N was annually closed to trawl and stow net fleets from 1 July to 31 August. Three years later, in 1998, the prohibited fishing area was extended to the South China Sea, the Yellow Sea and Bohai Sea (Yan *et al.*, 2006), the prohibited fishing gears were extended to cover the shrimp trawls and closed seasons were prolonged from 16 June to 15 September. It is now generally recognized that the summer fishing closure led to ecological, economic and social benefits in the last 14 years, and is important for sustainable fisheries development in the ECS (Zhang *et al.*, 2007). The closed season will cover three months and a half in 2009 according to the proclamation of the Ministry of Agriculture, P.R. China. However, subsidy for closed fishing is not established yet in China. In view of this, a subsidy for living expenses of the fishermen during summer fishing closure is considered by the government now.

Subsidies to the fishing industry are common worldwide, and it is well accepted that these subsidies contribute to overcapacity in fishing fleets and overexploitation of fisheries resources (Sharp & Sumaila, 2009). Subsidies showed a gradually increasing trend with the expanding of the Chinese fishing industry in recent years. However, the overall quantity of fisheries subsidies is lower in China than in other countries (Chen *et al.*, 2005). At present the primary goal of these subsidies is to control the marine fishing capacity, inhibit the decline of fishery resources and improve the quality of fishers' lives. Subsidies include a permit buyback policy of fishing vessel, financial support for training, education and for fishers changing to other jobs in coastal areas. China established fuel subsidies in 2006 due to rising oil prices. These have increased since, mainly due to economic and social pressure, i.e., from coastal fishers and fishery operators affected by the constant extension of summer fishing closures. Fuel subsidies are assigned to ship owners according to their fishing license and fuel consumption per unit operation of fishing gears. Trawls, stow nets and high-powered vessels benefit from more subsidies than the lighter gears, e.g, deep water drift nets and fishing tackles. These subsidies contribute to better maintenance of ships and gears, high catches, better jobs and thus discourage fishers from moving out of the fishing industry. These results are contrary to marine fisheries management goals of controlling fishing capacity. Based on the national financial situation and fishery production, fuel subsidies can be decreased in stages and used primarily to subsidize living expenses of fishers during the summer fishing closure in order to reverse negative effects of subsidies on the control of fishing capacity.

In this study, we estimated the impact of fuel subsidy (scenario 1) and the summer fishing closure subsidy (scenario 2) on fishing fleets and on the ECS ecosystem. Similations were based on the East China Sea Ecopath model of Jiang *et al.* (2008) starting from a baseline simulation, without subsidy (scenario 0). Differences in two fishery parameters (cost and profit) and three ecosystem parameters (longevity, total system trophic level and Simpson's BDI) between scenarios 1-2 and scenario 0 were calculated to represent the impact of subsidies on the fishery and on the ECS ecosystem.

Table 1. Impact of fuel subsidy (scenario 1) and summer fishing closure subsidy (scenario 2) on the fishery cost and profit.

	Changes of cost		Changes of profit	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Trawl	2.689	-0.062	-6.390	0.109
Stow net	0.833	-0.060	-3.358	0.113
Drift gill net	0.934	0.000	1.086	-0.003
Purse seine	1.820	-0.058	0.441	-0.020
Shrimp trawl	2.227	-0.058	-6.245	0.309
Fleet6	0.658	-0.058	0.201	-0.022
Total	1.796	-0.060	-4.610	0.158

Table 2. Impact of fuel subsidy (scenario 1) and summer fishing closure subsidy (scenario 2) on the ecosystem.

Ecosystem parameters	Absolute values			Changes of values (%)	
	Scenario 0	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Longevity>2	0.4302	0.4472	0.4293	3.9565	-0.2040
Total system Trophic Level	2.5187	2.4829	2.5205	-1.4224	0.0730
Simpson BDI	0.4253	0.4179	0.4258	-1.7299	0.1096

Results indicate that: (1) scenario 2 will decrease the fishery cost and increase the fishery profit of all fishing gears and the total fishery; (2) scenario 1 will induce a high increase in fisher cost of all gears and a high decrease in fishery profit of the trawl, stow net and shrimp trawl fisheries as well as the total fishery (Table 1). Ecosystem parameter trends, on the other hand, differed in scenarios 1 and 2 (Table 2). The positive impact of summer fishing closure on the ecosystem confirmed by previous studies is emulated here. Furthremore, scenario 2 represents a mature and sTable ecosystem, which when impacted by fuel subsidy, led to an immature and unsTable ecosystem. Without fishing capacity control, fuel subsidy triggered an increase of fishing effort, a negative impact on the fisheries and on the ecosystem and lead to an aggravation of overexploration. On the other hand, summer fishing closure subsidy brought a decrease of fishing effort, a mitigation of overexploration as well as increase in profits. Thus, chanelling payment for fuel subsidy to summer fishing closure subsidy will promote the sustainable use of fishery resources and the health of the ECS ecosystem.

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VULNERABILITY TO FISHING OF THE CENTRAL GULF OF CALIFORNIA ECOSYSTEM[1]

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Vulnerability, defined here as the degree to which ecosystems are likely to experience harm due to a perturbation or stress, has recently become a central focus, particularly relevant, for exploiting aquatic ecosystems. Knowledge of processes related to vulnerability provides key information for management. One way to deal with this is related with the construction and understanding indicators, which, in fact, are expected to express structural functional or organization attributes of ecosystems. The conservation of these attributes in the dynamics of living systems is probably one of the major challenges for management looking for sustainable use of ecosystems.

In this contribution we explore the responses of several ecosystem indicators to a simulated fishing pattern. We selected the Central Gulf of California model (Arreguín-Sánchez *et al.*, 2002), constructed with the Ecopath with Ecosim suite of programs, because this is a very important fishing region in Mexico. The Gulf of California provides about 65 % of the total fish capture of Mexico. We focused on the shrimp fishery, which causes the major perturbation in the ecosystem and also the most important from economic and social points of view. Based on Ecosim (Walters *et al.*, 1997) we simulated effects of a fishing pattern where harvesting rate gradually increased at a rate of 10 % per year from no-fishing until 80 % of the shrimp biomass was extracted, representing severe overfishing. Under this framework we considered target and incidental catches of the shrimp trawl

Figure 1. Top: changes in the Supply/Demand balance index with changes in fishing pattern of the shrimp trawl fishery, including bycatch. Different states of the shrimp fishery are shown; Present state refers to mid 1990's, Red point refers to ecosystem shift. Bottom: keyplayers relevant to propagation through the foodweb (dashed line), note they are mostly high trophic levels groups; and those relevant to fragmentation (solid line) of the trophic network; Note they pertain to different trophic levels. Trophic levels are represented by the vertical axes.

fishing, while other fisheries remain unchanged; this allowed us to assign observed changes due to simulated fishing pattern on the shrimp fishery. We tested 14 different indices namely: mean trophic level of catch, fishery-in-balance, Finn's cycling, predation cycling, respiration, biomass/production ratio, flows to detritus, resilience (O/C) , Kempton biodiversity (Ainsworth & Pitcher, 2004; Christensen & Pauly, 1992; Ulanowicz, 1986,), interaction strength, trophic replacement, functional impact (Shannon & Cury 2003), supply/demand balance (Bendrichio & Palmeri, 2005; Banavar *et al.*, 1999), loss of primary

production (Libralato *et al.*, 2006a). In addition, some of them were also associated to keystone species (degree, betweeness, closeness and mixed impacts) and keyplayers (related to fragmentation and propagation of the trophic network) indices (Jordan *et al.*, 2006; Libralato *et al.*, 2006b; Bogartii 2003).

Results show a gradual change for all indices with change in fishing pattern, and at high harvesting rates, trends shift abruptly indicating an ecosystem disruption (Figure 1a). All indices show similar behavior independently of the attributes they are expressing, structural, functional or organization. Centrality indices of keystone species represent topological attributes and even when groups with higher ranking are usually different according to the properties they measure, some of them appear continuously such as phytoplankton, zooplankton and sharks, while functional index also select as keystone groups sharks and shrimps, as well as fishing fleets and detritus, when included. Some of these functional groups corresponded to main changes expressed by the interaction strength index.

About keyplayers, sharks, serranids, other fishes, zooplankton and detritus are the relevant functional groups concerning the trophic network fragmentation; while marine mammals, seabirds, scianids, scombrids and sharks are the most relevant for the propagation properties of the foodweb (Figure 1b). Shark is a shared functional group for both indices which reveals its importance for the ecosystem. Three high trophic level functional groups, sea mammals, sea birds and scombrids, are also identified as relevant groups by the functional impact index. Results suggest all indices were sensible to changes in the fishing pattern, expressing different properties of the ecosystems; keystone and keyplayers indices identify relevant groups for the ecosystem and can potentially be used to monitor changes in the ecosystem. Results also agree with the concept that high trophic levels are of relevance for ecosystem maintenance.

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EFFECTS OF LOCAL FISHERIES AND OCEAN PRODUCTIVITY
ON THE NORTHEASTERN IONIAN SEA ECOSYSTEM[1]

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This study describes a marine ecosystem in the northeastern Ionian Sea, western Greece. The study area covers 1021 km² of sea surface (Figure 1). The bottom includes seagrass meadows (*Posidonia oceanica* and *Cymodocea nodosa*), sand, and mud (silt-clay) in areas deeper than 50 m (Zenetos *et al.*, 1997; Haritonidis & Tsekos, 1976). A study conducted by Casotti *et al.* (2003) shows that this area is extremely oligotrophic. Values of Chlorophyll a, nutrients and particulate organic carbon were among the lowest found in Mediterranean coastal waters (Pitta *et al.*, 1998). Most of the study area is quite shallow, ranging in depth between 100 to 200 m.

Commercial fisheries in the study area include bottom trawlers, purse seiners, beach seiners and artisanal boats operating longlines and trammel nets (Bearzi *et al.*, 2008). According to Tsikliras *et al.* (2007), about 70 species of fish, cephalopods and crustaceans are fished commercially in the area, with a few constituting the main targets: European

Figure 1. The northeastern Ionian Sea ecosystem in western Greece covering 1021 km² of sea surface.

pilchard (*Sardina pilchardus*); European anchovy (*Engraulis encrasicolus*); Mediterranean horse mackerel (*Trachurus mediterraneus*); Atlantic bonito (*Sarda sarda*); bogue (*Boops boops*); picarel (*Spicara smaris*); European hake (*Merluccius merluccius*); red mullet (*Mullus barbatus*) and striped red mullet (*Mullus surmuletus*).

An Ecopath with Ecosim model was constructed for the northeastern Ionian Sea for the baseline year of 1964. This year was chosen because catch time series was available from 1964 to 2003. A total of 22 functional groups were considered in the model, including 3 marine mammal species, 1 sea turtle species, 1 sea bird, 8 fishes, 5 invertebrates, and 2 primary producer groups. European hake, European pilchard, round sardinella (*Sardinella aurita*) and European anchovy as well as the three species of marine mammals were considered separately due to their importance in the food web. For each group, 4 input parameters were estimated: biomass, production per unit of biomass (P/B), consumption per unit of biomass (Q/B) and diet composition.

Ecosim was used to run dynamic simulations from the baseline Ecopath model for 1964, incorporating time series estimates (for the period 1964-2006) of biomass, bycatch, catch per unit effort (CPUE) and catches for those functional groups with available information. Time series of effort data (for the period 1964-2003) were then used to force the model. Ecosim scenarios were fitted by adjusting prey vulnerability and/or by searching for nutrient inload anomalies. Ecosim output scenarios were compared to observed time series data to get a goodness of fit (Christensen *et al.*, 2005). The fit that best represented the 'observed' data was chosen (Figure 2).

Figure 2. Time series fitting between predicted and estimated functional groups biomass, CPUE and yield from 1964 to 2003 in the northeastern Ionian Sea, western Greece.

Ecopath with Ecosim was able to reproduce quite well the biomass trend of important species such as common dolphins, sardines, anchovies, other pelagics and other demersals. The model suggested that the decline observed in various functional groups was a consequence of the intense fishing pressure that occurred in the area until the end of the 1990s. Moreover, Ecosim was able to explain the biomass trajectories of sardines, anchovies, other pelagics and other demersals, only when fishing effort pressure was combined with environmental factors, in particular changes in nutrient concentration.

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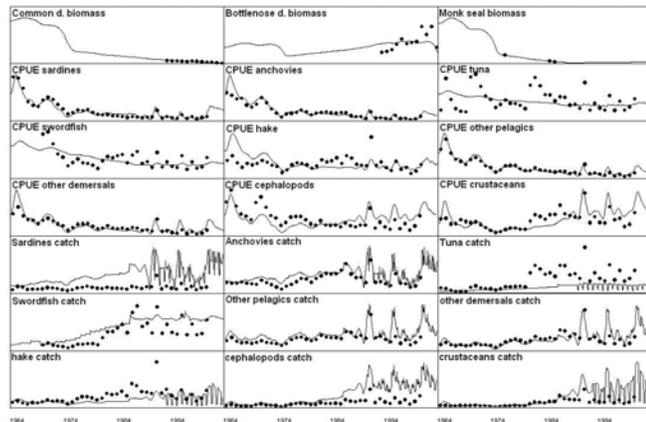
Trophodynamic modelling of the eastern shelf and slope of the South East Fishery[1]

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In eastern Australia, fisheries have been operating since the early 1900s but the most dramatic changes have occurred much more recently (Tilzey & Rowling, 2001). On the shelf of New South Wales and north-eastern Victoria, steam trawlers and Danish seiners were the main fishing methods used initially and tiger flathead was the main target species but with very little formal management or co-ordinated research. In the late 1960s and early 1970s, diesel-powered otter trawlers enabled the rapid expansion of the fishery into the upper- and mid-slopes, along with more formal management arrangements and research albeit focussed on single species (Klaer, 2001). Now, the emergence of Ecologically Based Fishery Management has inspired the development of a whole ecosystem approach towards management issues (Pitcher, 2001). In the South East Fishery (SEF), increasing seal populations (Goldsworthy *et al.*, 2003), discarding practices in the fishery and environmental variability on fishery production have been some of the issues of concern (Prince & Griffin, 2001). This project investigated their impact in an area of the SEF situated in the south-east corner Australia.

We developed Ecopath with Ecosim models to describe the past and present structure and dynamics of the food web of the area, although we present here only the present day model and investigations. The area is in eastern Bass Strait (EBS), between 36° and 39°S, and encompasses the shelf and slope from 25 to 700 m, at which point there is a major change in community composition. Bass Strait is the major influence but incursions from the East Australian Current occur seasonally as do wind-driven spring and summer upwellings on the outer shelf and slope. The surface water temperatures average around 13°C, but are significantly cooler on the slope in winter and warmer on the shelf in summer. The shelf area consists of soft and hard grounds interspersed with reefy outcrops, and steep canyons can occur on the slope.

We used CSIRO scientific data collected during multi-disciplinary surveys of the EBS during 1994-96 (Bax & Williams, 2000) and data from State and Commonwealth commercial fisheries. The 1994-96 study concluded that demersal fisheries were strongly linked to pelagic production. A hydrodynamic model of the average seasonal circulation demonstrated that this production occurs mainly in Bass Strait. Using a circulation model based on satellite altimetry and modelled winds, we computed the historical circulation for the period over which satellite estimates of plankton concentration and primary productivity (PP) were available (1997-2002). PP was estimated from ocean colour/chlorophyll concentration data from 1997

through to 2002 and a PP anomaly time series was derived to force the phytoplankton dynamics in the model.

The model consisted of 58 groups covering the shelf and slope but focussed on commercial fishes, particularly, the quota-managed fishes, seals and birds. The scientific surveys identified more than 200 fish species which were allocated into model fish groups. Sharks and rays were the most abundant, followed by species including jack mackerel (Carangidae), barracouta (Gempylidae), whiptails (Macrouridae), cardinal fish (Apogonidae), redfish (Berycidae), cucumberfish (Chlorophthalmidae) and leatherjackets (Monocanthidae), all of which, except barracouta and whiptails, were explicitly modelled. Most of the SEF quota species were also explicitly modelled including mesopelagic fishes, which support both slope and shelf species, and create a transfer of energy from deep to shallow waters. All other fishes were aggregated into shelf, slope or pelagic groups, and further subdivided into three size groups (<30 cm, 30-50 cm and >50 cm standard lengths), and two feeding types (> or < 40 % fish in the diet). The invertebrate communities are highly diverse and show quite high endemism (Bax & Williams, 2000), however, were more aggregated because we knew less about them and our focus was on fishes and seals.

Initial biomasses for most model groups were based largely on the 1994-96 CSIRO survey data. Catch and effort statistics were collated and used to construct catch, effort and CPUE time series. An observer monitoring program in the fishery provided information about the commercial and non-commercial bycatch, and was used to estimate the discarded catch not recorded in the fisher's logbooks. Dietary information was derived primarily from the trophic study of the 1994-96 surveys (Bulman *et al.*, 2001), supplemented by other studies in the SEF (Bulman *et al.*, 2001, 2002; Young *et al.*, 1997; Blaber & Bulman, 1987; Bulman & Blaber, 1986; Young & Blaber, 1986; Coleman & Mobley, 1984). Nine scenarios were devised to investigate the present system:

- Reduced levels of primary productivity in the future: decreasing to 80 % and 60 % of current levels;
- Growth in seal populations: annual biomass accumulation of 0, 5 or 10 % (=status quo);
- Elimination of discarding in the fishery;
- Changed rates of fishing effort: decreasing by 25 % or increasing by 25 % from current effort;
- Various combinations of these conditions were investigated over a 50 year period: the first 10 years simulated 1994 to 2003 using observed effort time series, and the remaining 40 years was simulated at a constant fishing rate assuming the rate of the last year (2003) of observed data.

We found that PP was sufficient to support the modelled ecosystem without the need to rely on importation of organisms such as phytoplankton and zooplankton by ocean currents. However, we predicted that if PP declined, e.g., as a result of warming as climate models predict, fish biomasses would also decline. When seal biomass increased, some commercial species such as sharks, blue-eye trevalla and ocean perch would also increase possibly because seals ate more of their predators even though their own prey declined. When seal biomass was not allowed to increase, predation pressure on prey species decreased allowing their populations to increase. However, gemfish, a seal prey species and a quota species that has been seriously overfished, did not stop declining as expected. Gemfish ate cardinal fish predominantly but so did some of those species released from predation by seals. Competition for cardinal fish increased, their biomass declined and consequently, gemfish continued to decline. Eliminating discarding by retaining all bycatch appeared to have little effect on the fish populations. Nearly all fisheries were predicted to have lower catches in the future, even if the fishing rate increased. Effort has declined over the past 10 years in most fisheries except the Commonwealth trawl fishery where it has risen. This has released fishing pressure on many species allowing some recovery. However this recovery was not necessarily sufficient to result in bigger predicted catches in the future compared to the current catches even if effort was increased.

ACKNOWLEDGEMENTS

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THE IMPACTS OF LONGLINE FISHERY ON THE PELAGIC ECOSYSTEM IN THE EASTERN TAIWAN WATERS[1]

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Eastern Taiwan waters pelagic ecosystem consists of 17 functional groups (Table 1). Input parameters include biological information, diet compositions and yields of 17 functional groups, which are the main target species of longline-fishery and their preys, are estimated by single specie methods such as VPA, or collected from literatures. The uncertainty of dolphin's biomass is also considered. Therefore, two different models are constructed in this study: one is run with a set biomass for dolphin, while the other sets dolphin biomass to be calculated. The impacts of the longline-fishery and of fishery management strategies on this marine ecosystem are simulated for a 15-years period with Ecosim.

Table 1. Inputs (in parentheses) and outputs of the pelagic ecosystem model 1 in the eastern Taiwan waters.

Group name	Trophic Level	OI	Biomass (t·km²)	P/B (year⁻¹)	Q/B (year⁻¹)	EE	Yield (t·km²)
Dolphin	4.07	0.157	(3.125×10-4)	(0.25)	(17.239)	0.448	(3.125×10-5)
Blue shark	3.99	0.166	(0.011)	(0.3)	(2.78)	0.793	(0.001)
Lamniformes	4.16	0.144	(0.011)	(0.22)	(2.2)	0.419	(0.0009)
Carcharhiniforms	4.16	0.144	(0.006)	(0.23)	(2.3)	0.515	(0.0007)
Bigeye tuna	3.78	0.154	0.0021	(1.05)	(10.5)	(0.9)	(0.0013)
Yellowfin tuna	3.78	0.243	0.0025	(1.71)	(11.64)	(0.9)	(0.0021)
Other tunas	3.75	0.177	0.0072	(0.6)	(6)	(0.9)	(0.0022)
Swordfish	3.94	0.121	0.0030	(0.33)	(3.3)	(0.6)	(0.0006)
Blue marlin	3.99	0.145	0.0012	(0.604)	(6.035)	(0.6)	(0.0005)
Other billfishes	3.89	0.133	0.0020	(0.57)	(5.7)	(0.9)	(0.0005)
Dolphin fish	3.65	0.082	0.0118	(1.681)	(8.48)	(0.9)	(0.006)
Scombrids	3.2	0.508	0.0231	(3.37)	(32.57)	(0.9)	(0.0296)
Cephalopod	3.16	0.022	0.0986	(2.5)	(25)	(0.9)	(0.006)
Flying fish	2.56	0.309	0.0242	(2)	(20)	(0.9)	(0.0001)
Epipelagic fishes	2.6	0.385	4.3160	(2)	(10)	(0.9)	(2.9556)
Epipelagic micronekton	2.11	0.111	4.0109	(50)	(200)	(0.5)	-
Phytoplankton	1	--	3.7196	(400)	--	(0.5)	-

In the eastern Taiwan pelagic ecosystem, sharks (lamniforms and carcharhiniforms) are the top predators, with trophic level of 4.16. The blue shark is the most abundant large shark species and has a lower trophic level than lamniforms and carcharhiniforms. The ecopath results of the two models are similar, even though the biomass of dolphins in model 2 was 10 times than that set for model 1. It is also suggested that dolphins had little effect on other species. Ecosim simulations indicate that lamniforms and carcharhiniforms are overfished. However, the exploitation rate of blue shark appears to be sustainable. Furthermore, various changes in the abundances of many species may occur, due to the removal of large sharks from this marine ecosystem. Biomasses of 'other billfishes', 'other tunas' and 'blue marlin' in model 1 increased by 180 %, 96.8 % and 42.5 %, respectively (Figure 1.). In contrast, 'cephalopod' and 'flying fish'

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biomasses decreased by 10.9 % and 20.9 %, respectively (Figure 1.). The keystoness index also suggested that large sharks played an important role in this pelagic ecosystem. A biological reference point of $F_{35\%}$ for lamniforms and carcharhiniforms species was proposed. Scombrids and dolphinfishes have the strongest keystone effects, which may be due to the decrease of top-down control by top predators, such as large sharks, tuna and swordfish species, which were heavily removed from this ecosystem by longline vessels. Longline-fishery had positive effects on dolphinfish and marine mammals by removal of both their predators and competitors for preys, though exerts a negative impact on other target species. Therefore, a decrease of longline-fishery efforts may result in a recovery of large sharks, tuna and swordfish species. The ban on dolphin fishery may increase the biomass of dolphins above 50 % of the current biomass (Figure 2.). The effects of increase in dolphin biomass might be due to the other species, besides dolphin fish, whose biomass decreased by 15 % in model 2 (Figure 2.).
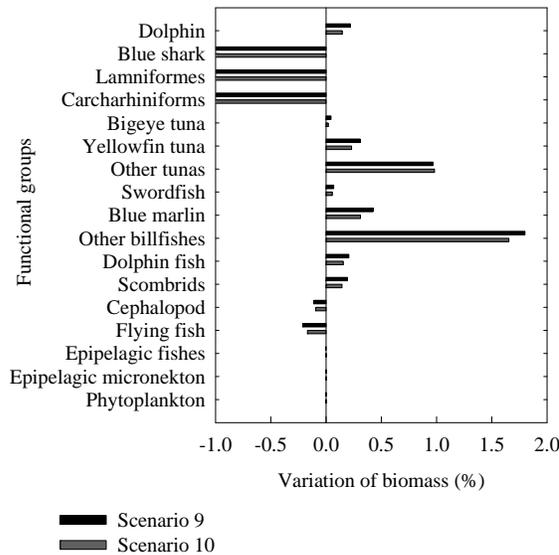
Figure 1. The variations of biomass in percentage of functional groups included in the the pelagic ecosystem of the Eastern Taiwan water (The removaling large shark from ecosystem).
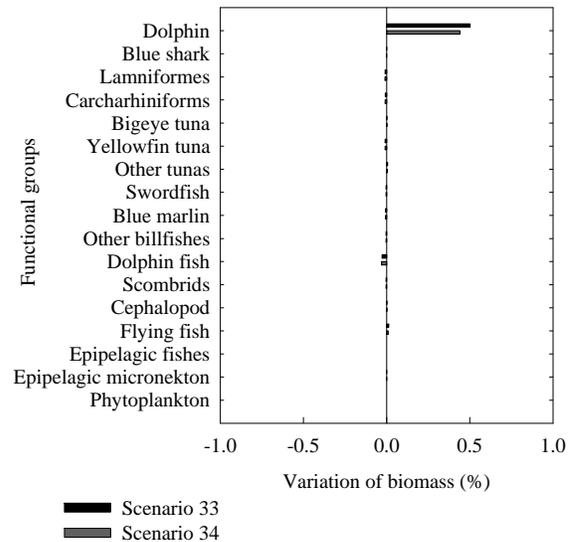
Figure 2. The variations of biomass in percentage of functional groups included in the the pelagic ecosystem of the Eastern Taiwan water (The dolphin fishery is banned).

INTRODUCING ECOSYSTEM-BASED MANAGEMENT IN THE GULF OF THAILAND[1]

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There is growing interest for ecosystem-based management in the Gulf of Thailand. The Thai sector of the Gulf has been intensively exploited since trawling was introduced in the early 1960s, and the ecological communities in the Gulf have been changed substantially because of high fishing pressure. To evaluate alternative management options we have further developed an ecosystem model of the Gulf in connection with a European Union project aimed at evaluating the societal cost of fishing. Our objective here is to propose and evaluate possible fishery management measures based ecosystem analysis. The model, which was constructed using the Ecopath with Ecosim approach and software, relies on extensive data series collected in the Thai sector of the Gulf. Time series of catch per unit effort of the various fish groups were obtained from research vessel data, while fishing effort of the six fleets in the model (otter board trawl, pair trawl, beam trawl, push net, purse seine and other gear) were obtained from statistical record from the years 1973 to 2004.

Outputs from the simulations were used to compare the fishery status and changes during 1973, 2005 and to evaluate the prediction for 2010. The results indicate lower catches, values and profit for all otter board trawler, pair trawler, beam trawler, and push netter from 1973 to 2005 and 2010, while the changes were minimal for the purse seiner and other gears. We conducted optimum policy searches by placing different weights on social, ecological, and economical criteria to evaluate the predicted changes in fishing effort for the six fleets that would be indicated for optimization. We found that if the effort of the otter board trawler was reduced it would benefit the pair trawler, the push netter and other gears, and vice versa. The relative catches of the total multi-species aggregate also decreased except for some pelagic fish groups. The relative biomasses of all groups are currently in a bad situation (values at 0.01-0.4 relative to the baseline). The medium demersal piscivores, juvenile pelagic fish and juvenile carangids are in a better situation. When considering the pressure caused by overexploitation, the excessive number of fishing boats, the lower catch levels, values, profits, the effects on economic, social and ecosystem, the yield and biomass of the fisheries in the Gulf of Thailand, it was concluded that a reduction in effort would be beneficial in the Gulf, and that in order to evaluate tradeoff between fisheries, the management of the fisheries in the Gulf of Thailand need to include an ecosystem-approach. Recommendations were made on a ban of push netter and beam trawler, reduction in effort of otter board trawler and pair trawler on a voluntary bases, introduction of a tenure system for purse seiner apart from bottom trawler and pair trawler that remains active, required registration for other gear, more areas and season closures (or introduction of MPAs), stock enhancement, and promotion of co-management for coastal small-scale fisheries.

TROPHIC ANALYSIS OF LAKE AWASSA (ETHIOPIA) USING A MASS-BALANCED ECOPATH MODEL[1]

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Lake Awassa is one of the most-thoroughly studied lakes in Ethiopia. In spite of this, , no attempt has been made to bring the available information together in order to understand the food-web relationship of this lake ecosystem. Perhaps one of the plausible reasons for not pursuing such studies so far in Ethiopia was the lack of comprehensive and easy-to-use models. To fill this gap, literature data were obtained to estimate parameters (see Table 1) to build an Ecopath model (using EwE version 5.0 beta) representing the lake ecosystem for the period November 2003-August 2004.

Table 1. Parameters used in the Ecopath with Ecosim model (v. 5.0 beta) of lake Awassa (Ethiopia) for November 2003 to August 2004. Food intake is calculated as Q/B*B and GE, i.e., gross efficiency is calculated as (P/B)/(Q/B) and is usually between 0.1 and 0.3 (see Christensen *et al.*, 2000).

Species/group	Trophic level	Yield (t·km⁻²·year⁻¹)	Biomass (t·km⁻²)	P/B (year⁻¹)	Q/B (year⁻¹)	EE	Food intake	GE
Catfish	3.34	5.11[a]	3.288[a]	1.4[a]	4.75[b]	0.96	15.6	0.295
Juvenile Catfish	3.45		0.358[d]	0.5[b]	9.2[b]	0.916	3.3	0.054
Large Labeobarbus	3.19		1.081[d]	0.33[b]	20.38[b]	0.992	22.0	0.016
Tilapia	2.02	6.97[b]	3.71[b]	1.8[b]	29.53[b]	1	109.6	0.061
Juvenile Tilapia	2.61		2.4[d]	1.2[b]	41.64[b]	1	99.9	0.029
Aplocheilichtys	3.1		0.714[b]	3.5[b]	36.51[b]	0.999	26.1	0.096
Small Barbus	3.18		1.093[d]	2.59[b]	18.51[b]	0.992	20.2	0.14
Garra sp.	3.06		0.192[d]	2.68[b]	17.08[b]	0.894	3.3	0.157
Zoobenthos	2.09		41.95[b]	4.3[b]	21.05[b]	1	883.0	0.204
Carnivore zooplankton	2.72		2.53[c]	20[c]	93.88[b]	1	237.5	0.213
Herbivore zooplankton	2		1.78[c]	118.2[c]	538.86[b]	1	961.3	0.219
Phytoplankton	1		34.45[b]	238.5[b]		0.144		
Macrophytes	1		200[b]	1		0.644		
Detritus	1		63.79[b]			0.104		

a: Tekle-Giorgis (2002); b: present study; c: Mengistou (1989); d: guess estimates.

Thirteen functional groups including two ontogenic ones considered in the model resuted to the flow diagram for Lake Awassa illustrated in Figure 1. The producers particularly phytoplankton and detritus are under exploited in this lake ecosystem. Hence, energy transfer from lower trophic levels is low. On the contrary, all consumers have ecotrophic efficiencies (EE) close to 1 indicating that consumers are heavily exploited in the system. Flow from detritus was as important as flow from phytoplankton. Flows from both herbivorous and carnivorous zooplankton to consumers were high. Mixed Trophic Impact (MTI) analyses indicated that phytoplankton and detritus have positive impact on most other groups while zoobenthos has negative impact on some groups. Lake Awassa has low ecological efficiency with a value of 0.00144 for the gross efficiency of the fisheries. The system primary production/respiration (P/R) ratio of Lake Awassa is 5.834 showing that the lake is at developmental stage, with high autotrophy, and some attention should be given to human impacts. This trophic model analysis also enabled us to confirm/refute previous studies and pinpoint critical gaps in the present knowledge about Lake Awassa.
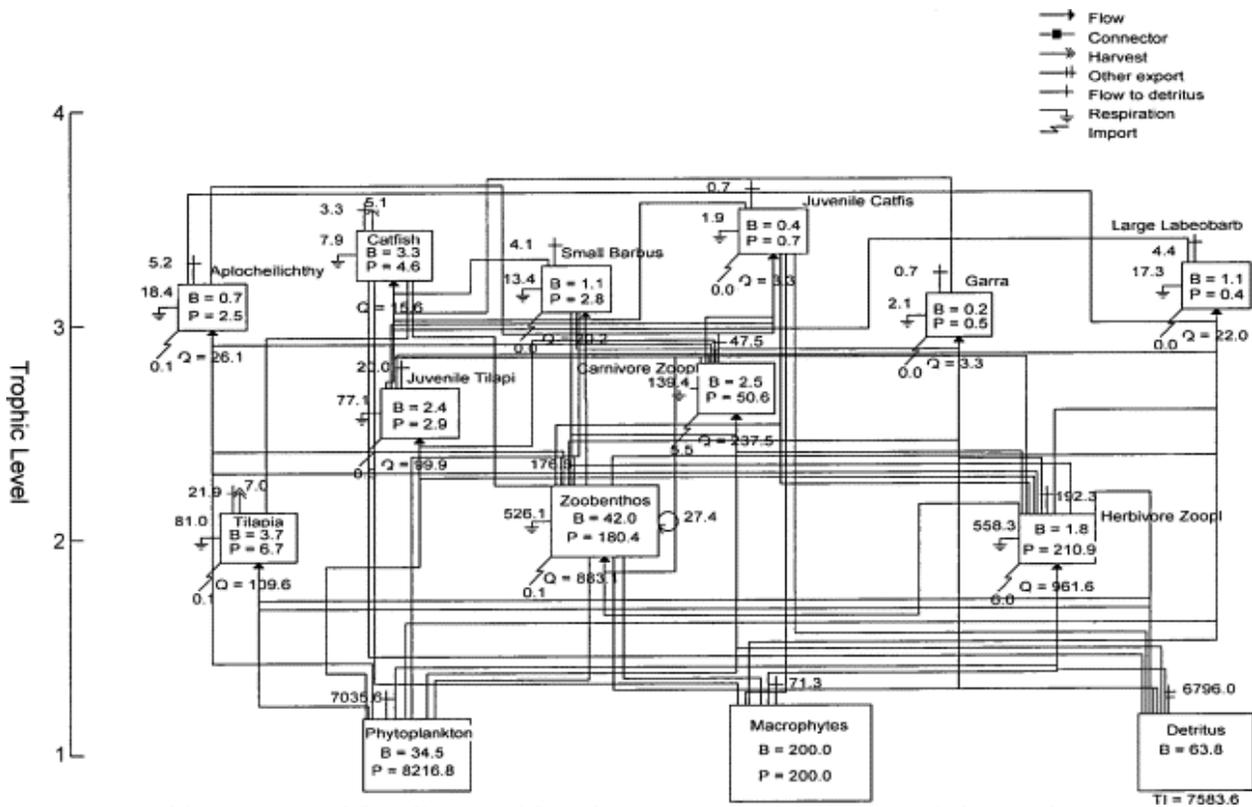
Figure 1. Trophic structure and flow diagram of the Lake Awassa ecosystem for the period November 2003 to August 2004.

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SPATIAL ANALYSIS: ORAL PRESENTATIONS

ECOSPACE: HAS ITS TIME COME?[1]

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Born in 2000, amidst rapidly growing international political and scientific interest on the use of Marine Protected Areas as fisheries management tools, Ecospace enabled users to probe the what if questions of spatial management. Beattie *et al.* (2002) developed Ecoseed, which provided the means to investigate trade-offs between the number, size and location of MPAs. Although applications of Ecospace (Walters *et al.*, 1998) are not as prevalent or as well developed as those of Ecosim, with spatial management plans becoming increasingly popular, the issues that need to be addressed are equally pressing. This session showcases applications of Ecospace, seeks to identify the type of problems for which this tool is well suited, and promotes future development on validation and linking with spatial planning tools.

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Evaluation of the usefulness of Marine Protected Areas (MPAs) for management of recovery of fish stocks and ecosystems in the North Sea[1]

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Marine Protected Areas (MPAs) are increasingly being promoted as an important component of precautionary management both by governments and environmental organisations. Several large MPA's have been established in the North Sea under the Bergen declaration and under the EU Habitat and Bird directives, many more are planned. In addition 'boxes' closed for fishing have been established as a result of the European Commission's efforts to protect fish stocks under the Common Fishery Policy.

By integrating organism dispersal rates, ecosystem interactions and fishing effort dynamics, Ecospace (Christensen *et al.*, 2005), a spatially explicit ecosystem-based modelling tool, allowed us to compare the ecological consequences of different management options, including existing and proposed North Sea MPAs.

Ecospace has been designed and is successfully applied to evaluate effects of Marine Protected Areas (MPA) on abundance and distribution of fish and associated fisheries and ecosystem changes (Martell *et al.*, 2005; Walters *et al.*, 1999,). The North Sea Ecospace model was developed on the basis of a detailed mass-balance trophic (Ecopath with Ecosim) model (Mackinson & Daskalov, 2007). Data from the International Bottom Trawl Survey (IBTS) and beam trawl surveys (for benthos) were used for validation of the Ecospace estimates. Data matrices of data per ICES rectangle were created for most of the functional groups (subject to availability of data) for the period 1983-2005.

We used modelled MPAs to evaluate the effects of different regimes of fisheries closure and compare existing ('Sandeel box', 'Plaice box', 'Cod box') and planned MPAs. Simulated fisheries closures proved to have significant effect in terms of fishery yield, spatial patterns of fishing effort displacement and impacts on predators, competitors and prey.

The effects of an MPA are illustrated by the simulations with the 'sandeel box' – an area along the Scottish coast where the sandeel fishery has been banned since 2001. The fisheries closure in our simulations had a significant effect on sandeel biomass, which increased by 10 % (Figure 1).

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In addition, the effects on sandeel also had indirect consequences for predators. Within the 'sandeel box' seabird biomass increased, but decreased elsewhere. Within the 'sandeel box' many higher trophic level fish predators (especially whiting) also increased in biomass by up to 11 %. Similar effects were found to be associated with the 'plaice' and 'cod boxes'.

Modelling of MPAs in the North Sea highlighted the problem of re-allocation of fishing fleets. In the model, increases in the target species were observed within the MPAs, but catches were higher elsewhere as a result of displaced effort, and this led in some cases to overall stock decrease following the a introduction of an MPA.

ACKNOWLEDGEMENTS

Figure 1. Change in biomass density (t/km2) of sandeel after 'closing' the fisheries in the 'sandeel box' within Ecospace. MPA 'sandeel box' is shown on the embedded basemap in right lower corner.

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Modelling spatial closures and fishing effort restrictions in Jurien Bay, Western Australia: a case study of the western rock lobster (*Panulirus cygnus*) fishery[1]

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Temperate Western Australia supports the valuable western rock lobster fishery and the production of fish for commercial and recreational fishers. The western rock lobster fishery has been Australia's most valuable single species fishery for many years with an average annual catch of about 10 000 tonnes, valued from about 200 to 400 million USD (Department of Fisheries, WA, 2004). The centre of this fishery is located at about 30°S, near Jurien Bay about 200 km north of Perth. The Jurien Bay Marine Park, declared in August 2003 (CALM, 2005), protects the biological communities in an important section of Western Australia's central west coast and provides shelter and nursery areas for marine life, including finfish and crustaceans and it is likely to be representative of the marine biodiversity of the central coast of Western Australia (see Wernberg et al., 2006). Despite the lack of any major upwelling zones and the presence of low nutrient marine waters (Caputi et al., 1996), the temperate waters of Western Australia support important commercial and recreational fisheries targeting western rock lobster, West Australian dhufish (Glaucosoma hebraicum), pink snapper (Pagrus auratus), baldchin grouper (Choerodon rubescens) and Roe's abalone (Haliotis roei) (Department of Fisheries, WA, 2006). This marine park contains different levels of protection with 'no-take' sanctuary zones (~4 % of the total area), scientific reference zones (~18 %) that allow fishing for rock lobster and minor fisheries from the shore, and general use zones (~78 %) where all activities are allowed. This means that over 20 % of the park is no longer accessible to fishing for finfish and around 4 % is closed to lobster fishing and all forms of fishing.

Understanding the impacts of fishing on the trophic structure of systems has become increasingly important because of the introduction of Ecosystem Based Fisheries Management and the legislative requirements of fisheries to demonstrate that they are not having a negative impact on other species in the environment. Knowledge of trophic linkages and food webs is also critical for developing zoning plans for marine parks and gaining an understanding of the potential effects of no-take or sanctuary zones on trophic flows. The closures to fishing declared as part of the Jurien Bay Marine Park are administered by the Western Australia Department of Environment and Conservation are intended to conserve marine biodiversity and ecosystem function. However, the potential effectiveness of the fishing closures for protecting both fished and unfished species of fish and invertebrates (at scales relevant to fisheries) is very uncertain and has been a source of controversy (e.g., Hilborn et al., 2004; Nardi et al., 2004; Mayfield et al., 2005; Edgar et al., 2007).

The aim of this study was to develop a biomass-based dynamic model of Jurien Bay Marine Park to investigate the effectiveness of fishing closure areas on both the western rock lobster fishery and the overall functioning of this system. The Ecopath model comprised 80 functional groups including primary producers, the main species of benthic, demersal and pelagic invertebrates, fishes and non-fish vertebrates and five detritus groups. The Jurien Bay Marine Park map (latitude 31°N-30°N; longitude 114.95°E-

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115.05°E) used for Ecospace simulations (area=823 km2) was drawn on a grid of 60 by 100 cells (each approximately 2.25 km2) with dispersal rates assumed to be of 3, 30 and 300 km yr-1, representing nondispersing, demersal and pelagic groups, respectively. All Ecospace parameters were retained at default setting unless otherwise specified. The Ecospace habitat base map was designed on the detailed marine biological surveys carried by Burt & Anderton (1997) over 60 km of coastline off the central west coast of Western Australia, from Cervantes to Green Head. Using this comprehensive survey, it was possible to include the major habitat types and management zones of the park. The effectiveness of the closure areas were explored using three Ecospace scenarios (with 5, 10, 15 and 20-year simulations each; and 2007 as baseline): (1) sanctuaries zones covering 4 %of the total area; (2) sanctuaries zones increased to 25 % of total area; and (3) No sanctuaries.

Our simulations suggest that the introduction of the current management zones with 4 % of sanctuaries produced a modest benefit of ~5 % in the biomass of rock lobster after 20 years. However, rock lobster biomass increased to ~20 % when the sanctuary area covered 25 % of the park, indicating the positive effect of protection provided by this zone. Similar trends were observed for exploited fish species (e.g., pink snapper, dhufish, sharks, among others) were the benefits of increasing the sanctuary areas from 4 % to 25 % produced increments up to 30% in their biomass (Figure 1). On the contrary, a clear decline in the abundance of the main resources of the region was displayed when the closure zones (sanctuaries and scientific reference zones) were removed from the model. After 20 years of open fishing in the park, the biomass of rock lobster declined to 85 % of the 2007 level and the abundance of other target species such as dhufish and pink snapper were reduced to 70% of the baseline abundances (Figure 1). The present simulations indicate

Figure 1. Simulated biomass responses of the main target species in Jurien Bay Marine Park, Western Australia to three MPA simulations.

that the fishing closures in Jurien Bay Marine Park can lead to increments in the abundance of exploited resources. However, an outcome beneficial to fisheries and overall abundances is not guaranteed. At this stage of the model development, the reliability of the spatial patterns and abundances predicted have to be verified with experts before running further scenarios and evaluate the impact of closures in the fishery and system status. Results from this study improved our understanding of the dynamics and interactions of the components of this marine ecosystem, a key factor in predicting the influence of closed areas within the Park.

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A TROPHIC MODEL TO SIMULATE THE COMBINED EFFECT OF ARTISANAL AND RECREATIONAL FISHERIES ON A MEDITERRANEAN ECOSYSTEM: THE BONIFACIO STRAITS NATURAL RESERVE (CORSICA, FRANCE)[1]

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Human activities have provoked unprecedented threats on coastal marine systems including direct and indirect effects of fishing (Halpern *et al.*, 2008). Indeed, major changes in exploited biological assemblages, and ultimately, biodiversity loss may disrupt ecosystem functioning and then alter the sustainability of goods and services provided by marine ecosystems to humanity (Lotze *et al.*, 2006; Worm *et al.*, 2006). To reduce such impacts of global overexploitation of fish stocks, stakeholders and managers of marine protected areas (MPA) are waiting for scientists to provide tools enabling them to test the effectiveness of environmental control. Assessment methods and predictive models such as EwE can be adapted for investigating the benefits of MPAs on adjacent fisheries.

Our study is applied to the Bonifacio Straits Natural Reserve (BSNR, 80 000 ha, Figure 1) created in 1999 in Corsica (France, Mediterranean Sea). The BSNR is

Figure 1. Map of the Bonifacio straits natural reserve, Corsica, France, Mediterranean Sea. Discontinued line designates the no-take zone; long dashed line the fishing cantonments; dotted line the semi protected areas where spear fishing is forbidden; and white line the reserve's perimeter.

characterized by a predominantly rocky substrate which is an archetypal ecosystem known to be one of the most impacted by human activities around the world (Halpern *et al.*, 2008). Several controlled perimeters are defined within the reserve; no-take zones closed to fishing (reserves, cantonments) and strengthened

protected areas (spearfishing prohibited) opened to fishing (Figure 1). The artisanal fleet operating within the perimeter of the reserve is monitored annually since 2000. However, recreational fleets (boat, spear-fishing) still need to be studied. An Ecopath model was created on the entirety of the BSNR, including 32 trophic groups, of which 12 are fish. The majority of the data used to build the model were obtained from the database of BSNR (e.g., fleets, crustacean studies, species list), and of EwE models built previously for Corsica and the Mediterranean. Ecopath indicators of ecosystem maturity show that the BSNR model is in accordance with other Ecopath coastal models (Libralato *et al.*, 2008; Christensen & Pauly, 1993) and with the theory of trophic flows, which suggests realistic features of the model despite uncertainties.

An Ecosim model was built to study the combined effects of artisanal and recreational fisheries on a Mediterranean ecosystem within a multi-specific context. Simulations of variations in fishing efforts were conducted during 20 years. The initial value of fishing effort was set to 1 for both fishing types (effort measured in 2000-2001) and varied from 0 to 4 by steps of 0.2 (a total of 440 simulations). We demonstrated that both fishing activities have an

Figure 2. Combined effect of changes in fishing effort of recreational and artisanal fleets on three modelled groups of the Bonifacio straits natural reserve, Corsica, France, Mediterranean Sea.

additional top down effect on the food web and decreased the biomass of targeted groups such as piscivorous species (Figure 2.). We also found non trivial patterns of biomass variations that emerge for some groups when the two fishing activities produce unexpected trophic cascades. Our trophic approach revealed that some species groups may provide negative signals of biomass decrease (Figure 2.) when MPAs are set or reinforced due to a combined effects of artisanal and recreational fisheries.
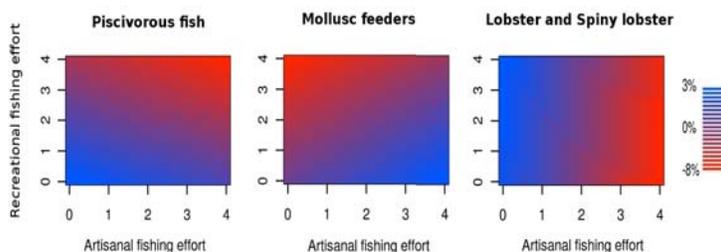
Following this analysis an Ecospace model was developed taking into account reserve areas, together with their degrees of protection, the different types of fleets (recreational and professional), fishing zones, and affinities of species to their substrates. Different scenarios, a decrease of the Posidonia oceanica meadow and an increase of non take areas were tested to demonstrate the effectiveness of management measures throughout the food web.

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TROPHIC MODELING OF A TEMPERATE MARINE ECOSYSTEM THROUGHOUT MARINE RESERVE PROTECTION IN NEW ZEALAND[1]

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Marine Reserves (MRs) in New Zealand are being monitored and investigated to determine implications for conservation and management strategies. This research project employs a variety of techniques to answer questions about how MRs impact biological communities and what this means for the management of coastal resources. Underwater research at three central New Zealand MRs (Kapiti MR, Long Island MR and the newly implemented Taputeranga MR; see Figure 1) conducting seasonal size and abundance surveys of reef fish, invertebrates and algae at both protected and unprotected locations is used to determine biomasses of trophic groups. Monitoring data also exists prior to and throughout MR protection, which is used to determine ecosystem response to protection in temperate central New Zealand waters. This monitoring information is used in combination with biological data from the literature to describe trophic linkages within the ecosystem.

An ecosystem model that was created for Te Tapuwae o Rongokako MR located midway up the east coast on the North Island, New Zealand has identified that the region is relatively poor in invertebrate biomass when compared to Leigh MR, which lies further

Figure 1. Map of New Zealand showing marine reserve locations with three study sites shown in red (Kupe/Kevin Smith is now known as Te Taputeranga). Image modified with permission from New Zealand Department of Conservation.

north (Pinkerton *et al.*, 2008, Lundquist & Pinkerton 2007). It was determined that the diet of lobsters is composed of a large amount of macroalgae, which has not been observed in other regions of New Zealand. This ecosystem appears to be strongly influenced by lobster abundance, which has been increasing since implementation of the MR.

This study is focused in the Cook Strait region located between the North and South Islands, which is characterized by colder waters in comparison to the north and is a highly dynamic area where three ocean currents converge. Temporal data is also used to evaluate ecosystem response to MR protection. This approach allows for an understanding of how MR design and placement, fisheries regulations and coastal resource use affect the dynamics of a biological community. Each of three marine reserves investigated have different designs with respect to boundaries, size and shape. Commercial, recreational and traditional fisheries for reef fish and invertebrate species are important in these regions and we wish to understand how ecosystems respond to MR protection and the impact of factors such as size, placement and design.

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Estimating the carrying capacity of monk seals using the French Frigate Shoals Ecopath[1]

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Carrying capacity for the endangered Hawaiian monk seal was estimated using an updated version of the original Ecopath model (Polovina, 1984) developed for the French Frigate Shoals (FFS) ecosystem. The subpopulation of seals at FFS is the largest breeding colony for the species and has declined precipitously over the last two decades. Field data was collected to update model parameters, diet vectors and generate a reference biomass using spatially explicit surveys of demersal fish assemblages. Model boundaries were set using information from seal foraging studies to better represent the central-place foraging behavior of the seals. Because the seals fed across the atoll, neighboring banks, the mesophotic slope, and in portions of the subphotic the trophic components of the model were defined in relation to the ecological subsystem they belonged (e.g., atoll jacks *vs.* bank jacks). The biomass of monk seals and other top level predators were maximized using Ecopath yielding a total of 47.4 mt·km^{-2} of monk seals or roughly 356 seals could be produced as the theoretical carrying capacity for the FFS region. This estimate was ~5 % greater than the independent field census data of the FFS monk seal population and is consistent with notions that the FFS seal population is close to or at carrying capacity.

EXPLORATION OF ECOLOGICAL AND ECONOMIC BENEFITS FROM IMPLEMENTATION OF MARINE PROTECTED AREAS IN RAJA AMPAT, INDONESIA[1]

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The Raja Ampat archipelago extends over 45 000 km² and consists of more than 600 islands including the 'four kings', i.e., Batanta, Misool, Salawati and Waigeo. The area encompasses a variety of marine habitats, including some of the most biodiverse coral reef areas on earth (Donnelly *et al.*, 2003; McKenna *et al.*, 2002). It is estimated that RA possesses over 75 % of the world's known coral species (Halim & Mous, 2006).

A decree by the Bupati (Regent) in 2003 declared Raja Ampat a Maritime Regency, and helped to establish a new network of marine reserves in 2006 covering 4 793 km² of sea area and 44 % of reef area in Raja Ampat. A total of 7 Marine Protected Areas (MPAs) were declared in Raja Ampat around different Islands (see Figure 1), *viz.*: Ayau (28 km²), Southwest Waigeo (162 km²), Sayang-Wayag (178 km²), South Waigeo (202 km²), Mayalibit (277 km²), Kofiau (328 km²) and Southeast Misool (943 km²).

This study includes analysis based on a Raja Ampat Ecospace model that includes all but 2 of the above mentioned MPAs: (1) the Ayau MPA was excluded because the geographical map of the original Ecopath model for Raja Ampat did not include Ayau; and (2) the
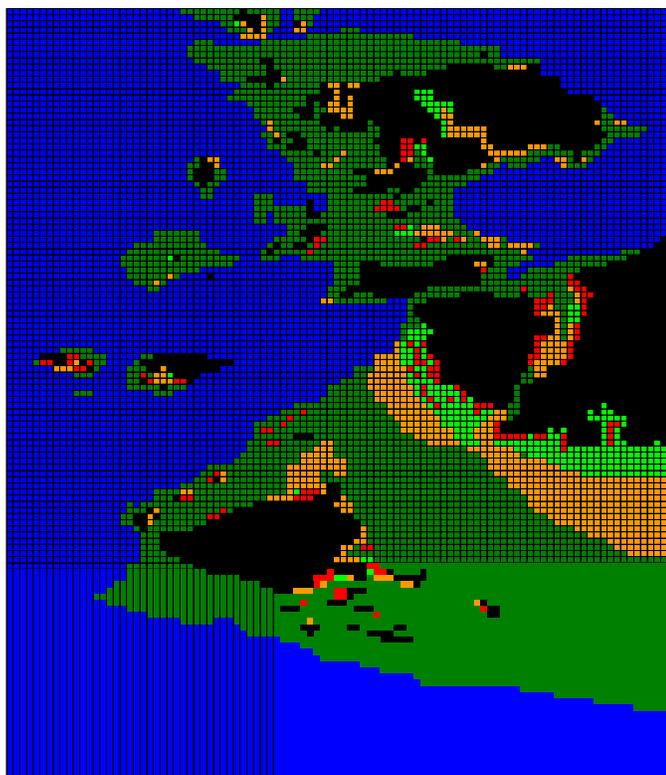
Figure 1. Ecospace map of the Raja Ampat Maritime Regency, West Papua, Indonesia.

Mayalibit bay MPA was excluded because the bay has very little reef area and therefore was not suitable in a comparison of MPAs for coral reefs.

Following discussions with the Fisheries Officer in Raja Ampat and the partner institutions in the project on the motive of the setting up MPAs for the region, spatial EBM research questions of interest were identified, *viz.*: (1) ecosystem effects of eliminating all commercial fishing in the MPAs; and (2) ecosystem effects of eliminating all destructive fishing in the MPAs.

Ecopath and Ecosim parameters inherited from a 2007 Raja Ampat model (see Ainsworth *et al.*, 2007) were used to build a Raja Ampat Ecospace model (see Walters *et al.*, 1998 for a description of Ecospace) of the spatially explicit feeding interactions of this ecosystem's functional groups. A 2-dimensional grid matrix of spatial habitat cells, with GIS data from the BHS EBM project and oceanographic and biological data from the literature, was used to represent the study area (see Figure 1). Each functional group was allocated to its appropriate habitat(s), i.e., where individuals in the group must find enough food to eat, grow and reproduce, while providing energy to its predators as well as the fisheries. Each cell hosts its own Ecosim simulation and cells are linked through symmetrical biomass fluxes in four directions; the rate of transfer is affected by habitat quality. Optimal and sub-optimal habitats were distinguished using various parameters such as the availability of food, vulnerability to predation and immigration/emigration rate. By delimiting an area as a protected zone, and by defining which gear types are allowed to fish there and when, we explored the effects of MPAs and tested hypotheses regarding ecological function and the effect of fisheries (see also, e.g., Ainsworth, 2006; Pitcher & Buchary, 2002a, 2002b; Salomon *et al.*, 2002; Beattie, 2001; Walters *et al.*; 1998). The results of these Ecosim simulations were published in Ainsworth *et al.* (2008).

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SPATIAL ANALYSIS: POSTER PRESENTATIONS

HABITAT SUITABILITY MODEL FOR THE BUSH WARBLER (*CETTIA DIPHONE*) AT JEJU EXPERIMENTAL FORESTS OF KOREA[1]

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Since 2004, the Jeju Experimental Forests (JEFs) of Korea are under sustainable forest management (SFM) fulfilling Forest Stewardship Council requirements. However, there is further need to understand the response of keystone species, like the Bush Warbler (*Cettia diphone*), White-backed Woodpeckers (*Dendrocopos leucotos*) and Fairy Pittas (*Pitta nympha*), to forest practices. Such studies will contribute in building integrated habitat models for these keystone species in Korean JEFs.

In order to predict the number of breeding pairs and the location of Bush Warbler nests, quantitative measures of the vertical structure of these forests were obtained with play/back and point count methods (Huff *et al.*, 2000; Bibby *et al.*, 1997). Foliage coverages were recorded at 5 m diameter circular plots in each 50x50 m study areas. The foliage height was classified into six layers ('A', above 10 m; 'B', 8~10 m; 'C', 6~8 m; 'D', 4~6 m; 'E', 2~4 m and 'F',<2 m). Four categories of foliage coverage were recorded in each height layer (0, 0 %; 1, 1~33 %; 2, 34~66 %; 3, 67~100 %; see Park & Lee, 2000). We selected 30 nest and non-nest sites to derive

Table 1. CATMOD regression analysis variables based on 30 nest and non-nest points, for the habitat suitability model ofthe Bush Warbler, *Cettia diphone,* in the Jeju Experimental Forests, Korea.

Variable type	Variables	Category and Class	Code
Independent	Forest type (FT)	Coniferous forests	CF
		Mixed forests with coniferous & broad-leaved forests	MCBF
		Deciduous broad-leaved forests	DBF
		Evergreen broad-leaved forests	EBF
		Mixed Broad-leaved forests	MF
	Forest height (FH, m)	0	FHA
		1~9	FHB
		10~12	FHC
		13~15	FHD
		16~20	FHE
	Forest practice (FP)	Done within three years	FPD
		No action	FPN
	Distance to trail (DT, m)	50~182	DTA
		183~375	DTB
		376~633	DTC
		634>	DTD
Response		Nest	Y
		No nest	N

a spatial model for the Bush Warbler. A spatial database was constructed and analyzed, with ArcMap version 9.0 (ESRI), for the effects of FT, FH, FP and DT on the location of nests. We derived independent estimates of the locations of trails and the value of forest height from a 1:5,000-scale forest vegetation map produced by the Korea Forest Research Institute. All variables were similarly transformed into nominal values. A multinomial logistic regression was performed using the PROC CATMOD tools of SAS version 9.1.3 (SAS Institute Inc., 2004). The residual maximum likelihood (REML) method for unbalanced parameters (Robinson, 1987) was employed. Initially all variables were applied to model development, and a 5 % significance level was used as the criterion to accept or reject variables.

Breeding density was low in Japanese cedar forests, but the other forests showed no significant difference of breeding density. Coverage ratio of shrub layer below 1.5 m was high at the nest of Bush warblers, and nest height ranged from 0.86 m to 1.11 m. The nest of Bush Warbler was located between 5.9 m to 27.5 m of trails. Among eleven parameters, FHA, FHB, FHC, FPD, DTA, DTB and DTC were used in the final model equation. Habitat suitability for Bush Warbler can be predicted from the function: $P=1/(1+\exp(-(-1.37FHA-1.18FHB+1.69FHC-1.51FPD-1.20DTA-0.58DTB+1.49DTC)))$. Habitat suitability of the Bush Warbler was high near trails at low-height forests where forest practices have been conducted for at least three years. In conclusion, the habitat of Bush warbler can be detrimentally affected by forest practice, like thinning and trail construction accompanied with the diminishing of shrub layer. However, development of shrub layer after forest practice can provide the suitable nesting resources for the Bush Warbler. In future, it is need to reveal the effect of spatial configuration of suitable habitat on the breeding success for the Bush Warbler, and to integrate the habitat suitability for forest interior species like White-backed woodpeckers and Fairy Pittas.

Table 2. CATMOD regression analysis results for the habitat suitability model of the Bush Warbler, *Cettia diphone,* in the Jeju Experimental Forests, Korea.

Variables	DF	Chi-square	P
Forest type (FT)	4	0.34	0.99
Forest height (FH, m)	3	8.86	0.03
Forest practice (FP)	1	8.83	0.00
Distance to trail (DT, m)	3	8.51	0.04
Likelihood ratio	20	61.07	<.0001

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ECOSYSTEM COMPARISONS & NETWORK ANALYSIS: ORAL PRESENTATIONS

COMPARING INDICATORS OF ECOSYSTEM CHANGE USING ECOLOGICAL NETWORK ANALYSIS[1]

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Long term changes in ecosystems as diverse as the northern Benguela upwelling system in the South Atlantic, the Chesapeake Bay estuarine system and the Baltic Sea have been studied using food web models in Ecopath with Ecosim. Indices of ecosystem change were calculated using ecological network analysis and decadal regime shifts were estimated for these systems and indices using PCA, STARS and chronological cluster analysis. Results show that in most systems at least 2 regime shifts have occurred over the past 40 years. For instance, in the northern Benguela shifts occurred in 1963 and 1984 while in the Chesapeake shifts occurred in 1971 and 1986. These shifts in physical drivers did not always cause regime shifts in the ecosystems, but ecological regime shifts mostly occurred when anthropogenic stressors such as fishing were analysed in addition to large scale environmental drivers such as SST.

Ecopath with Ecosim models fitted to time series and environmental drivers of the northern Benguela upwelling system, the Chesapeake Bay, Baltic Sea and the Central North Pacific were subjected to Network Analysis algorithms to obtain monthly time-step time series of indices such as the total systems throughput (TST), development capacity (C), ascendency (A), overhead (Ø), redundancy (R), overhead on respiration, Finn cycling index (FCI), average path length (APL), proportion of flow to detritus (PFD), fish in balance index (FiB), primary production required for catches (PPRc), trophic level of the catch (TLc) and the total production to biomass ratio (TP/TB).

These indices as well as the environmental drivers used to fit the models and estimates of total biomass, catch and respiration were then subjected to sequential regime shift analysis (STARS; Rodionov, 2004) after correcting for autocorrelation using probabilities of 0.05, cutoff lengths of 60 months, Huber parameters of 2, and different AR(1) and subsample sizes and after prewhitening. Principal component analysis (PCA) was then used based on the long-term series of all variables. Sudden changes on the network analysis indices STARS were performed on the first 2 PC score time-series. Finally, chronological clustering (Legendre *et al.*, 1985) of normalized data detected abrupt shifts, in addition to the STARS method.

The northern Benguela system was forced with sea surface time series anomaly (Heymans *et al.*, 2009) adapted from Sherman *et al.* (2007). The STARS analysis of this anomaly showed a regime shift in 1984 (Figure 1). The shift in total systems respiration (Figure 2) in 1974 and 1984 are followed by change in throughput, capacity, ascendancy, overhead on respiration and entropy and the 1974 shift is also mirrored by the shift in biomass at that time. The increase of juvenile horse mackerel and modelled jellyfish (Heymans *et al.*, 2009) could possibly explain the increase in respiration in 1974. However, both these 1974 and 1984 shifts could be related to the Benguela Niño that occurs sporadically in this system from as early as 1910, 1934, 1949, 1963, 1974 and 1984 (Shannon & Taunton-Clark, 1988). In addition, the 1963, 1974 and 1984 shifts are all seen in the SST anomaly of Figure 1, while only the 1984 was a proper regime shift according to the analysis.
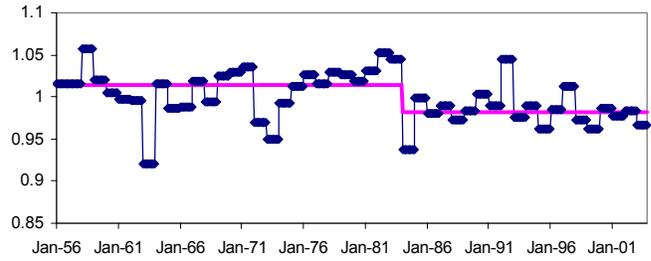
Figure 1. SHIFTS analysis of SST anomaly (blue) and weighted mean of the regimes using the Huber's weight function with the parameter 1.
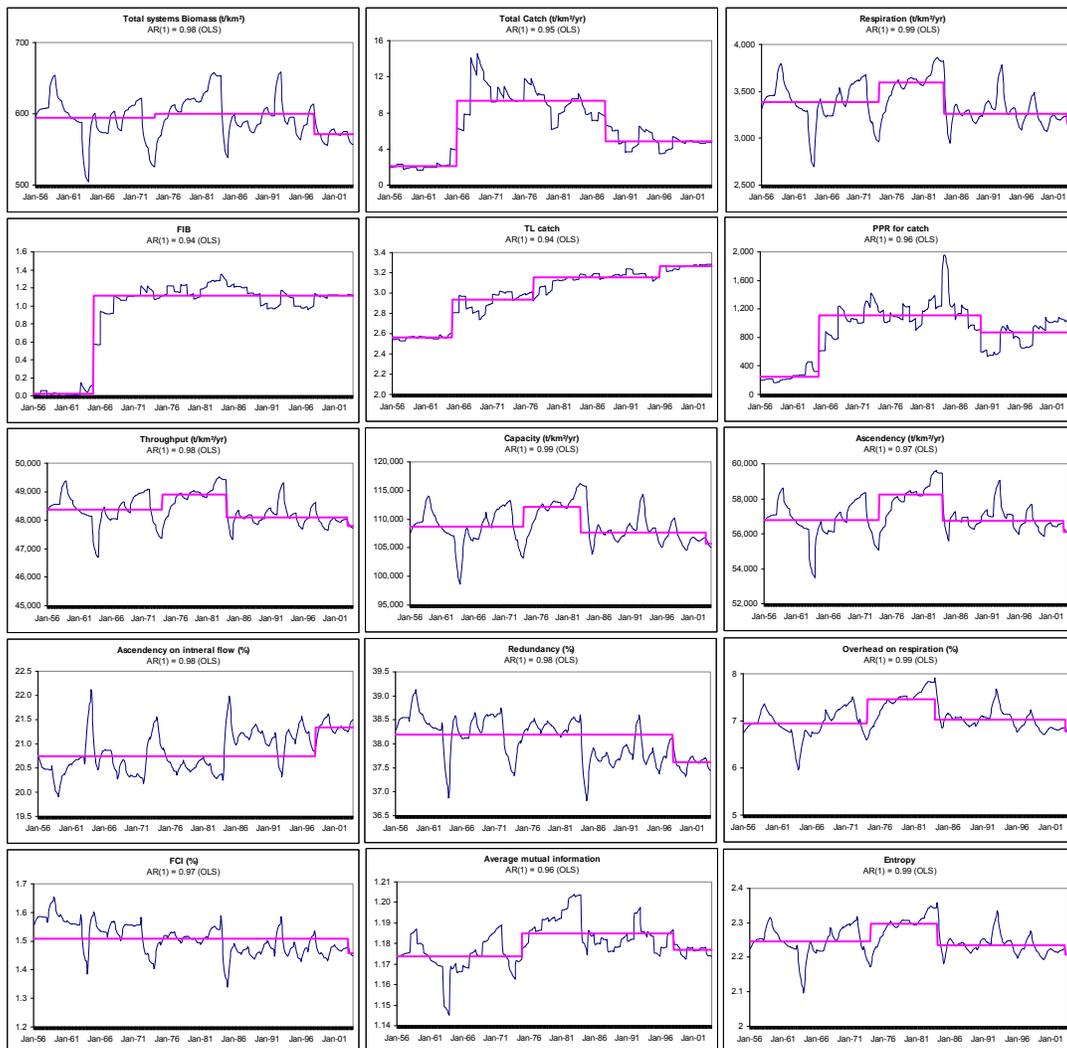
Figure 2. SHIFTS detection in the mean for 15 indices of ecosystem change over time.

The 1974 and 1984 SST regime shifts was also seen in the throughput, respiration, ascendancy and entropy and overhead on respiration (Figure 2). However, other ecosystem indices show regime shifts in different years. Primary production required for catch (PPRcatch), FIB and TLcatch all showed a regime shift in 1965 when the anchovy, sardine and hake fisheries became big (Heymans *et al.*, 2009). In addition, the PPRcatch shifted again in 1990 and the TLcatch in 1996. The 1990 shift in PPRcatch is related to the reduction in fishing that was instituted by the new Namibian government, while the increase in TLcatch in 1996 is due to the lack of catch of lower trophic species such as anchovy, sardine, seaweed, etc. and an increase in the catch of monkfish, other demersal fish and seals. Regime shift detection in the last 10 years of the analysis should be viewed with

Figure 3. Sum of all regime shift indices for the northern Benguela, Aleutian Islands, Chesapeake Bay, Central North Pacific, Eastern Bering Sea and Baltic Sea (preliminary results).

caution though, as this is a decadal shift detection algorithm. Thus the change in the biomass, FCI, ascendancy on internal flow and redundancy should be viewed with suspicion. However, the marked decline in biomass in the last 10 years seems evident (Figure 2).

The sum of all the regime shift indices shows that the large change in the FIB in 1965 outweighed the changes in most other years (Figure 3). The increase in the catch in the early 1960s caused many of the catch related indices to shift in the mid-1960. The 1974 and 1984 Benguela Niño's caused shifts around those times. These regime shifts are compared to those in other systems (Figure 3) that are also subjected to environmental drivers and anthropogenic change.

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Marine mammals – fisheries interactions:
how to use Ecopath with Ecosim to capture ecological complexity[1]

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Understanding the trophic role of marine mammals in ecosystems is not an easy task. In order to get an adequate overview of the different interactions they can have with the other species of the system (and with fisheries), it is thus important to analyse the whole food web (Bax, 1998). In that sense, an ecosystem modelling approach becomes an interesting tool to address marine mammal issues under different circumstances. For example, ecosystem modeling is considered to be the only reliable method to address the issue of competition between marine mammals and fisheries (IWC, 2004). Within the many types of software available, Ecopath with Ecosim (EwE) is one that is emerging as a reliable and convenient tool for ecosystem modelling.

EwE models are generally constructed in a fisheries context, and often deal mainly with commercially important fish species. However, in many cases marine mammal groups are included, making a better representation of all trophic interactions in these ecosystems (Morissette *et al.*, 2006). Studying marine mammals in an ecosystem context, based on modelling, allows to (1) explore the direct interaction between these two top-predators (i.e., fish and marine mammals); and (2) asses the indirect impacts of (and on) other species and species groups in these foodwebs. In that sense, the EwE software provides innovative results. For example, consumption by predators has important influences on the dynamics of both predator and prey populations, and in a complex ecosystem containing many generalists, multi-species interactions may result in counter-intuitive effects on predator and prey population dynamics (Yodzis, 2001). While marine mammals are known to be top-predators in most systems, they also represent a source of beneficial predation for their prey (Figure 1).

The EwE approach have been lately used in a wide variety of marine mammal projects, for example, (1) in comparing the methyl mercury exposure from consumption of pilot whale meat and fish in the Faroe Islands (Booth & Zeller, 2005); (2) in explaining the decline of Steller sea lions in Alaska (Guénette *et al.*, 2006); (3) in explaining the decline of short-beaked common dolphins in the Mediterrean Sea (north-eastern Ionian Sea) where food resources and bycatch were detected as reasons of their collapse (Piroddi, 2008); and (4) assessing if whales are a threat to fisheries in tropical breeding areas (Gerber *et al.*, 2009).

In this study we assess the different tools available in the EwE software package to address marine mammal issues, i.e., in ecotoxicology, competition with fisheries, bycatch of marine mammals, etc. Out of a sample of 50 EwE models representing marine ecosystems around the world (Morissette, 2007), 88 % included at least one trophic group for marine mammals, and 79% divided marine mammals into categories such as pinnipeds, toothed whales, and baleen whales. From these models, we assess the kind of result generated from EwE tools, their strengths and weaknesses. In particular, we investigate the use of Ecosim (a time dynamic simulation module for policy exploration), Ecotrace (allowing to trace the transfer and bioaccumulation of pollutants through all ecosystem functional groups based on diet transfers and direct uptake from the environment), and Network Analysis tools (e.g., primary production required, PPR,

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to sustain marine mammals' consumption; mixed trophic impacts, MTI, of marine mammals in ecosystems). We present the strengths of using the EwE approach to address the trophic role of marine mammals in ecosystems. The different biases of using this modelling technique to address the issue of competition between marine mammals and fisheries are also discussed.
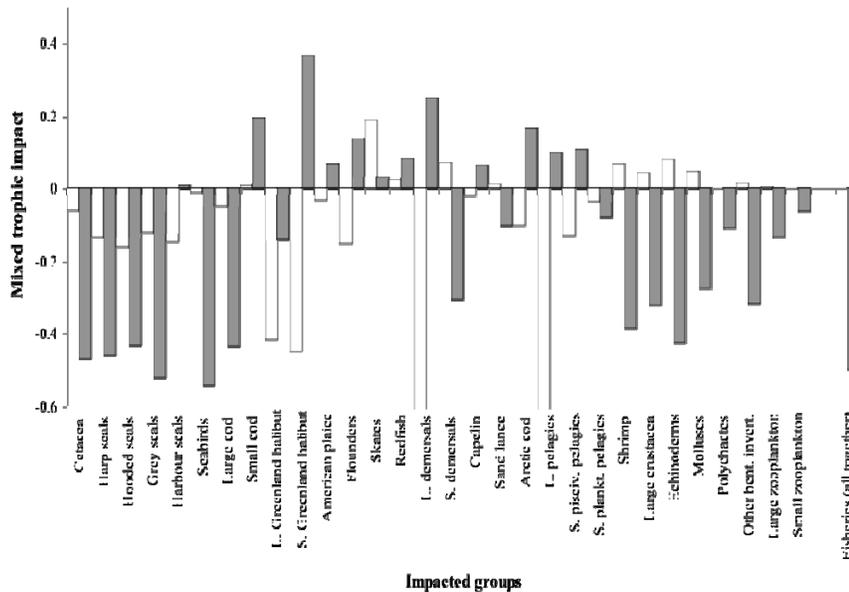
Figure 1. An example of the mixed trophic impact of harp seals (white) and fisheries (grey) on fish and fleet groups of the Gulf of St. Lawrence, Canada (Morissette *et al.*, 2003). Beneficial predation from harp seals is seen for skates, small demersal fish, shrimps, and large crustaceans.

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A SIMPLE APPROACH FOR ENHANCING ECOLOGICAL NETWORKS AND ENERGY BUDGETS (NAMELY ECOPATH): PLEASE, LET'S DO SOME PREBAL BEFORE WE START BALANCING[1]

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The widespread use of Ecopath (EwE) and related energy budget models has been laudable for several reasons, chief of which is providing a tool to present an ecosystem context for improved understanding and management of living marine resources (LMR). Having seen a veritable explosion of these models, it has been recognized that their content and use has spanned a range of quality. Thus, as these models continue to increasingly be used in a LMR context, review panels and other evaluators would benefit from a set of rigorous and standard criteria from which the basis for all EwE and related applications for any given system, i.e., the initial, static energy budget, can be evaluated. To this end, as one suggestion for improving the suite of models in the EwE package specifically and energy budgets in general, here I propose a series of pre-balance (PREBAL) diagnostics. These PREBAL diagnostics can be done in simple spreadsheets before any balancing or tuning is executed. Examples of these PREBAL diagnostics include biomasses, biomass ratios, vital rates, vital rate ratios, total production, and total removals (and slopes thereof) across the taxa and trophic levels in any given energy budget. I assert that there are some general ecological and fishery principles that can be used in conjunction with PREBAL diagnostics to flag issues of model structure and data quality before balancing and dynamic applications are executed. I give examples where these PREBAL metrics have been applied; identifying instances where the model inputs merited re-examination before further modeling steps were executed. I humbly present this PREBAL information as a simple yet general approach that could be easily implemented, might be worth incorporating into these model packages, ultimately resulting in a straightforward way to evaluate (and perhaps identify areas for improving) initial conditions in food web modeling efforts.

IMPACT OF OFFSHORE WINDPARKS ON
ECOSYSTEM STRUCTURE AND FLOW PATTERNS[1]

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In the scope of the project "Coastal Futures" (see e.g., Burkhard *et al.*, 2009; Lenhart *et. al.*, 2006) four trophic network models for three potential windpark sites (Butendiek, Dan Tysk, Sandbank 24) situated in the German Exclusive Economic Zone (EEZ) of the North Sea were produced based on: i) output data from two ERSEM runs for the area where the potential windpark sites are situated (for a description of the ecological simulation model ERSEM see, e.g., Lenhart *et al.*, 2006; Lenhart, 2001); ii) data from Environmental Impact Analyses for the three sites kindly provided by DHI (German Institute of Hydrography) in Hamburg; and iii) data published in the literature. The trophic network models were produced using the software package Ecopath with Ecosim (EwE), version 4.0. A model per windpark was produced for the so-called Standard Scenario, describing the ecosystem state before construction of a wind-park, and one model for Butendiek for the so-called Scenario B1 (year 2015), i.e., the situation after construction of the windpark.

Results show that with distance of windpark from the coast, the biomass per area is declining. However, the food web structures of the different parks do not show remarkable differences. This may be attributed to the fact that the same inputs from ERSEM were used for the three Standard Scenario models and the same diet composition was applied to all windparks and scenarios.

Food web structure analysis based on ecosystem indicators showed a mixed pattern for all food web models. Differing values for Sandbank 24 with lowest biomass values per area and with similar structure of food web showed the highest degree of organisation, indicated by an ascendancy value of 37 % of total system capacity. Butendiek showed the highest biomass value per area and the lowest degree of organisation, indicated by an ascendancy value of 28 % of total system capacity.

With a trophic level of 4.1, fish-feeding birds and mammals play the role of top predators in the food web at the potential windpark sites. The trophic system at the three windpark sites can sustain a standing stock biomass of mammals of 0.6 to 2.0 mg·cm^{-2} and of birds of 0.2 to 0.5 mg·cm^{-2}. Mammals consume 6.2 to 29.5 mg·cm^{-2} of system resources and birds 16.5 to 46.6 mg·cm^{-2}.

A hypothesized increase in biomass due to additional substrate available for epibenthic sessile organisms from kolk protection areas of piles after windpark construction had only a negligible impact on total system structure and flow pattern for the three windpark sites when assuming the same concentration on

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the kolk protection areas as in the surrounding environment. Based on the assumption that the kolk substrate might offer better settling conditions than the surrounding environment, a stepwise increase of substrate related biomass was simulated to identify the system´s potential for additional biomass production. For the three windparks, an additional biomass on piles of roughly 1 000 times the initial concentration of the three functional groups of sessile organisms was identified as the limit of the system´s carrying capacity. The system´s potential for production of additional biomass of sessile organisms, in particular epifaunal bivalves and macroalgae, not only stimulates an increase of predator populations, e.g., birds and fish, but may have relevance for potential future aquaculture activities in the windparks of organisms low in the food web, e.g., mussels, oysters and algae.

A mixed trophic impact analysis showed, in relative quantities, the positive direct and indirect impacts on their predators and negative impacts on their food competitors with an increase in biomass of these groups. Higher trophic level winners of additional biomass from sessile organisms are mammals, omnivorous birds and zoobenthos-feeding fish. A hypothesized increase of biomass concentration of sessile organisms on the kolk protection of piles of up to 1 000 times that of the surrounding environment provides a theoretical potential for increase of biomass of the beneficiaries of 15-20 %.

Furthermore, a selection of ecosystem indicators could be extracted from the models with the potential to substantially contribute to the analysis of ecosystem integrity in the investigated areas.

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COMPARISON OF TROPHIC STRUCTURES AND KEY PLAYERS FOR TWO PERIODS IN THE CONTINENTAL SHELF ECOSYSTEM OF THE CENTRAL PACIFIC OF MEXICO[1]

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The marine region of the southern coasts of Jalisco and Colima includes the fishing area of the shrimp fleet (20-100 m isobath) and the artisanal fleet (coastline to 40 m isobath). The continental shelf is very narrow where 200 m isobath lies at 7-10 km from the coast. The habitats include insular, coral reef, rocky, soft bottom, seagrass and macrophyte environments which support high productivity and biodiversity in the zone. Presently 500 species of fish and 400 of invertebrates have been reported, of which about 150 are commercially exploited by different artisanal fleets (*ca.* 1 000 fishers and 500 boats). The highest catch landed in the last decade was 16 000 metric ton, where snappers, sharks and octopus contribute with more than 80 %. Fishers suggest present low catches are associated to the impact of a seasonal shrimp trawl fishing that operates when in transit between larger fishing grounds, by reducing stock abundances as well as through by-catch and habitat degradation. A recent measure includes installation of artificial reefs to avoid both trawling of shrimp fleet and increasing to artisanal fishery production, but not evaluations of effect are avaiable.

This study describes aspects of the structure and function of this ecosystem and explores possible changes, which occurred during two periods 1995-1996 and 2007-2008, using ecosystem statistics estimated through Ecopath, e.g., system throughput (TST), consumption (SC), exports (SE), respiration (SR), flows into detritus (SFD), biomass (TB),

Figure 1. Comparison of attributes for the Central Mexican Pacific continental shelf ecosystem for 1995/1996 and 2007/2008. Top panel: summary statistics for the ecosystem; Bottom panel: Ulanowicz information magnitudes, Ascendency (A), Overhead (O) and capacity of Development (D).

primary production (TPP), production (TP), ascendancy (A), overhead (O), and capacity of development (C). We also explore possible changes through some indices of 'keystone species', *sensu* Jordan (2006), and 'keyplayers', *sensu* Borgatti (2003). Keystone index gives information on how a group is connected to others, emphasizing topological attributes of the trophic network. Keyplayer identifies the most important groups related to fragmentation of the trophic network and how information is propagated throughout.

Table 1. Ranking of keystone and keyplayer groups for the Central Mexican Pacific continental shelf ecosystem for 1995/1996 and 2007/2008. Only first five groups are shown. MTL: mean trophic level; 1: ; 2: ; 3: ; 4: ; 5: .

	Keystone groups		Key players Fragmentation		Propagation	
	1995/1996	2007/2008	1995/1997	2007/2009	1995/1997	2007/2009
1	Phytoplankton	Phytoplankton	Other fishes	Zooplankton	Marine mammals	Puffers
2	Sharks	Zooplankton	Zooplankton	Infauna	Seabirds	Seabirds
3	Infauna	Infauna	Shrimps	Other fishes	Sea turtles	Seaturtles
4	Zooplankton	Sharks	Mollusks	Crabs	Sharks	Sharks
5	Mar. mammals	Mar. mammals	Brachyurans	Large pelagics	Billfishes	Rays
MTL	3.35	2.89	2.74	2.62	3.51	2.97

Comparisons of ecosystem statistics are shown in Figure 1 revealing some changes between periods. In 2007/2008, the system demands more energy (SC/TST) presenting a higher metabolic rate (SR/TST) than in 1995/1996. The first period system showed a lower proportion of useful energy in relation to the metabolic cost (TPP/TR). This condition is also suggested by the quotient of total production to total systems flow, whose value is higher in the second period. These attributes indicate large production coupled with low utilization of this production, i.e., a clear sign that this ecosystem is under the process of maturation (Odum, 1969).

The organization of the ecosystem is higher in the recent period as suggested by the A/C ratio (see Ulanowicz, 1986). However, growth potential is slightly lower according to the O/C ratio (also interpreted as index of resilience), i.e., the ecosystem in the first period (1995-1996) exhibits a less mature state than the second period (2007-208).

The keystone and keyplayer indices show differences between both periods confirming two different ecosystem stages as shown in the ranking of groups in Table 1. A global comparison of the estimated mean trophic level (MTL) of the first ten groups in the ranking showed, for all cases, a lower MTL for the second period, i.e., assumed to be more impacted than the first period due to maintained/increased fishing.

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Trophic flow structure of four overfished coastal ecosystems around the Philippines[1]

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Trophic ecosystem models were constructed for four overfished systems situated in embayments in the Philippines (Pauly & Chua, 1988), which experience environmental perturbations through sedimentation and reduced water quality caused by substantial eutrophication and pollution. Their physical structure and trophic functioning vary in several aspects eliciting varying resilience or resistance mechanisms in order to sustain their fisheries (Figure 1).

The highly embayed and heavily polluted Manila Bay is characterized by high P/B and P/R ratios and high chl a concentration. Overheads are low due to low cycling and low B/P ratio, suggesting that the system is vulnerable to changes in nutrient or sediment input and has low capacity to withstand environmental perturbations resulting to low

Figure 1. Classification diagram from canonical correspondence analysis (CCA) of the experimental trawl surveys conducted in the four fishing grounds.

fisheries yield. Internal system production is greatly lost to the sediment or converted to algal cysts, i.e., algal blooms, rather than exported out of the system due to low bay flushing as indicated by circulation models.

The San Miguel Bay system is smaller than Manila Bay and the shallowest bay of the four systems. It clusters with Manila Bay in terms of water pollution and sedimentation load with low biomass. It efficient transfer of energy and higher cycling index suggest recycling of carbon from detritus and through its predator/ prey interactions within the system thus high fisheries yield. Being shallow, it is well-mixed by wind and tidal influences allowing species to interact substantially (Bundy & Pauly, 2001).

Ragay Gulf is the largest and with the deepest embayment area mainly characterized by its physical structure and the input of nutrient from coastal areas. It has unique hydrodynamic processes that interact with an inland sea. Outer high velocity sheer and flushing controls the deep basin with a high percentage of carbon recycled within the linear system. It has a diverse range of coastal habitats and processes with more compartments for carbon to flow within the system, thus having high primary production and

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standing stock (Lachica-Aliño *et al.*, 2009). The fisheries yield of the system is still relatively low due to inefficient transfer of energy within the trophic levels of the system.

Of the four fishing grounds, the San Pedro Bay is the smallest with the highest system overhead. It opens to a larger system, the Leyte Gulf embayment. The bay with high FCI indicating recycling of carbon uptake of detritus is characterized by having high gradient in addition to the high horizontal gradient from north to south that allows the materials to be flushed out of the system towards Leyte Gulf. There is import and export of materials in and out of the system.

The management of such overfished ecosystems would benefit from the understanding of the dynamics of their natural environments along with their associated social and ecological systems. This investigation adds to previous studies relating ecosystems' trophic dynamics and thier vulnerability to human perturbations. Specifically, this study helps explain multidimensional forcing interacting with ecosystem functions at varying scales such as: i) size, depth and shapes that influence attributes leading to functionality effects; ii) the oceanographic processes such as flushing and upwelling affecting system overhead, cycling and type of disturbances; iii) ecosystem trajectories showing non-equilibrium attributes; and iv) opportunities for improving management through reduction of exacerbating stressors and integrated ecosystem management perspectives necessary to meet the impending future changes in a rapidly changing world.

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Relationship between biodiversity and ecosystem functioning in Mexican aquatic systems[1]

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The accelerated loss of biodiversity and change in species composition produced by climate and global change has stimulated vigorous research into how biodiversity influences the properties of ecosystem function (Duffy *et al.*, 2006). There are few empirical or theoretical studies on the consequences of the loss of biodiversity in aquatic ecosystem functioning.

Table 1. Initial studied ecosystems located in different regions around Mexico.

Ecosystem	Characteristics	Location	Authors	Institutions
Caribbean coral reefs	Fringing reef associated with mangroves	Quintana Roo, Caribbean Sea	Arias-González *et al.*	CINVESTAV, UC
Chetumal Bay	Large bay in northern Belize and eastern Mexico	Quintana Roo, Caribbean Sea	Schmitter-Soto *et al.*	ECOSUR
Campeche Bank coral reefs	Off-shore large insular reefs	Yucatan Peninsula Campeche Bank	Arias-González *et al.*	CINVESTAV, UC
Veracruz Coral Reef System	Off-shore small insular reefs	Veracruz, Gulf of Mexico	Pérez-España *et al.*	UV
Alvarado lagoon complex	Is formed by 4 main lagoon systems	Veracruz, Gulf of México	Franco-López & Abarca	UNAM, UV
Alchichica lake	Crater lake	Puebla, Centra area of Mexico	Alcocer-Durán & Chiappa	UNAM
Upper Gulf of California	Ocean system	Gulf of California	Morales-Zárate *et al.*	CIBNOR
Pacific Coral Reefs	Shallow marginal reef associated with mangroves	Pacific Ocean, Mexico	Calderón-Aguilera *et al.*	CICESE, UBCS, UG

We have launched a Mexican national programme to study the relationship between biodiversity and ecosystem functioning in aquatic ecosystems (BEF). This programme emerges from an ecosystem national network initiative founded by CONACYT. The main objectives of BEF are to: 1) evaluate the biodiversity (in terms of species richness and composition), functional characteristics and functional groups of fish species; 2) estimate the structure and properties of different aquatic ecosystems; and 3) evaluate the relationship between biodiversity and ecosystem function. At this initial stage seven aquatic ecosystems representative of Mexico have been included (Table 1). We used fish species as an indicator to study biodiversity and as a main functional group to construct different mass balance models of the food web using Ecopath with Ecosim (v. 6.0). Biodiversity and mass balance models of aquatic food webs are under construction.

Here we present the departure of the models constructed from similar criteria used in coral reef ecosystems by Rodriguez-Zaragoza and Arias-González (unpublished data, in preparation) and Arias-González *et al.* (unpublished data, in preparation). These authors carried out two "natural" experiments from empirical observations in four reefs located in the Caribbean and Campeche Bank. In the Caribbean, three reefs with different ecological features were studied. One reef, Puerto Morelos, is a relatively simple reef with two geomorphic zones, the two other reefs, Yuyum and Mahahual, are more complex reefs composed of four geomorphic zones. Diversity for coral reef fish varied considerably between Puerto Morelos, and Yuyum and Mahahual reefs. Ecosystem indicators for each reef obtained from EwE showed that the reefs with greater biodiversity had the highest total system biomass, throughput, production, flow cycling, number of pathways, path lengths, and more stable and complex food webs (Figure 1).

In Campeche Bank, the spatial relationships between distinctive habitats and the interaction between spatial elements, notably biodiversity and flow of energy or materials among the component habitats, were investigated in one of the most complex off-shore coral reefs, i.e., Alacranes Reef. Biodiversity indices were measured and empirical trophic functioning models were constructed for 17 coral reefscapes surveyed by the Alacranes Reef Project. Differences in diversity produce a strong variation in reefscape functioning analyses. Species and functional group richness, composition and abundance of species, and ecological diversity for coral reef fishes varied considerably among reefscapes. Ecosystem functioning indicators for each reefscape obtained from trophic analysis showed that the reefscapes with greater coral structure, habitat complexity

Figure 1. Resilience of three coral reefs in the Caribbean under a standard fishing effect. Ma: Mahahual; YX: Yuyum; PMo: Puerto Morelos.

and depth had the highest trophic structure and trophic and ecosystem functioning macrodescriptor values. Results suggest that biodiversity enhance reefscape total production. From these pioneering results we would like to test how biodiversity influences ecosystem function in different aquatic ecosystems with distinct evolution development.

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ECOSYSTEM COMPARISONS & NETWORK ANALYSIS: POSTER PRESENTATIONS

METABOLISM OF AQUATIC ECOSYSTEMS[1]

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Species-level studies reveal that basal metabolism can be expressed in body mass as $Y=aM^b$, where a is a constant related to the type of organism, M is body mass and b is the scaling exponent. Rubner (1879) reported that b is equal to 2/3 in a log-log graph in a relationship of body surface expressed as a function of body mass for different animals. Kleiber (1932) obtained a b value of 3/4 using the basal metabolic rate as a function of body mass of several species, including humans. Since then, many studies support the concept of allometric scaling like a power law that varies around 3/4, mainly in living systems, i.e., from microorganisms, such as bacteria, to animals like the elephant (West & Brown, 2005; Garlaschelli *et al.*, 2003; West *et al.*, 1997; Hemmingsen, 1960). The interpretation of this scaling exponent at the ecosystem level has been sought, initially with a physical network, where the shape, size and number of nodes determines the efficiency of energy transport in the ecosystem. However, it may be an indicator of status according to the balance of supply-demand of energy (*SDB*) (Bendoricchio & Palmeri, 2005), with the assumption that an ecosystem is represented by a network of compartments and flows, and that the potential relationship between fluxes and biomasses has a slope similar to the allometric scaling exponent of the species. This study aims to demonstrate the possible regularity of the allometric scaling value of 3/4 in ecosystems by considering the input-output flows of all compartments as a function of total system biomass (without detritus) with an inter-ecosystem exponent that obeys the 3/4 law of species metabolism.

Figure 1. Ecopath with Ecosim models of 124 ecosystems in the world: oceanic, continental selves, reefs, islands, coastal lagoons, rivers, lakes and reservoirs.
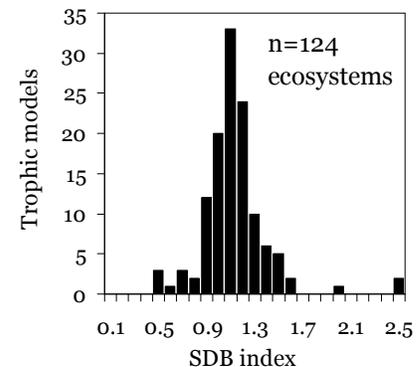
Figure 2. Frequency distribution of the balance of supply-demand of energy index (SDB) for the 122 Ecopath with Ecosim models illustrated in Figure 1.

Analysis of 124 EwE models representing different aquatic ecosystems in the world (Figure 1) indicate that most models (95%) had *SDB* values greater than 0.75 (Figure 2). This suggests an oversupply of resources characteristic of systems that can have a high proportion of supply/demand, a network that is highly indirect (increased flow to detritus), high resilience, among others properties (Bendoricchio & Palmeri, 2005). We obtained the coefficients a=2.3 and b=0.72 (t-student: P=0.28; $t_{0.05}$=1.66; not significantly different from 0.75) applying ordinary least squares for the relationship between biomass and outflow (Figure 3). This suggests that the ecosistem metabolism, characterized by the sum of outflow of its compartments, is allometrically scaled with biomass. Even with the spatial-temporal differences between ecosystems, scaling analysis reveals a common pattern in their metabolism, keeping the 3/4 law at higher levels of organization. These preliminary results require further analysis to understand the effect of the transfer

efficiency on SDB, as well as SDB's response to historical changes or to simulated environment and fishing pressure which contribute to the study of ecological indices.

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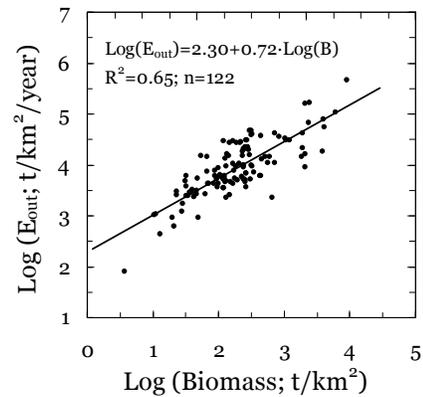
Figure 3. Simple linear regression (OLS) of the log-log relationship of biomass and outflow (i.e., Eout, the sum of flow in each model) of the 122 Ecopath with Ecosim models illustrated in Figure 1. Outliers (n=2) were excluded from this analysis.

A FISH CHAIN ANALYSIS OF NORTHERN GULF COD RECOVERY OPTIONS: EXPLORING EwE MODELING APPROACHES FOR POLICY SCENARIOS[1]

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This paper aims to provide a holistic understanding of recovery options and future scenarios for Northern Gulf cod fisheries through a fish chain modeling approach using Ecopath with Ecosim (EwE). The fish chain is an analytical framework and a governance perspective in understanding fishery systems through the inter-linkages and interactions in the fish production stages from 'oceans to plate'. Since the Northern Gulf cod stocks collapsed in western Newfoundland in the early 1990s, there has been no significant increase in stock abundance despite two moratoria (1994-1996 and 2003) as shown in Figure 1, with current stocks below limit reference points.

This poor recovery status has consequences for livelihoods and fishing communities as they face on-going socio-economic vulnerabilities. Moreover, most fisheries recovery research in Newfoundland has focused largely on natural systems with little research on the social systems such as market drivers, socioeconomics and governance mechanisms. The key research question focuses on how changes in marine ecosystems and socioeconomics pre- and post- collapse affect current recovery prospects for Northern Gulf cod fisheries. The fish chain perspective focuses on three main production stages and their interactions: pre-harvest, harvest and post-harvest as shown in Figure 2.

The pre-harvest stage consists of marine ecosystems, fishery resources and stock assessment on key parameters such as biomass, recruitment and growth. The harvest stage includes fish capture and harvesting methods, fishing fleets, fisher demography, catch and dockside value, income and labor mobility, as well as cost and earnings of fishing operations. Finally, the post-harvest stage includes processing activities, packaging and labeling, marketing strategies, distribution channels, employment and demography, return on

Figure 1. Estimated 3 year old plus and spawning stock biomass-SSB. (DFO, 2009).
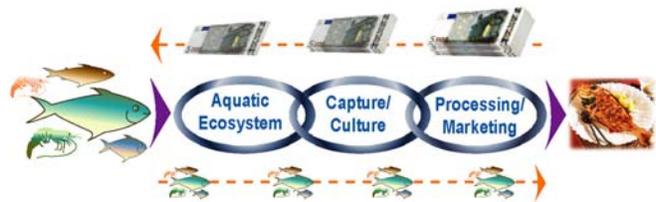
Figure 2. Schematic representation of the fish chain modeling approach (Thorpe *et al.,* 2005).

investment, purchasing and consumption. This final stage also depends on both demand and supply factors, such as consumer taste and preferences, income earnings, technological innovation, market

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competition, tariffs and trade barriers, and other aspects that may arise from the previous production stages. Externally driven pressures in global fish trade such as socio-political factors or market failure may also affect various stages of the fish chain which may have implications for meeting rebuilding targets.

Unlike most seafood value chain approaches that are limited to the harvest and post-harvest stages, the fish chain approach is holistic and encompasses marine ecosystems and governance mechanisms. Moreover, the conceptual and theoretical framework of fish chains (Kooiman *et al.*, 2005) incorporates supply chain organization literature and ecosystem-based management approaches. The three production stages in the fish chain do not operate in isolation. Rather, they are interconnected through formal and informal institutions as well as social networks at varying spatial scales from local to international. Moreover, the approach also focuses on policy instruments along the fish chain that shapes governance outcome ranging from conservation measures, fishing regulations, international agreements, subsidies and taxes, access rights and standards to consumer awareness. These instruments alter human behavior and ecosystem impacts through socio-political arrangements that affect governance outcomes.

Preliminary assessments of fisheries ecosystems in the Northern Gulf region, pre- and post-collapse, revealed ecological constraints, market forces and policy gaps for recovery efforts (Khan & Chuenpagdee, 2009; Khan *et al.*, 2009). Ecosystem modeling of the Northern Gulf of St. Lawrence using EwE by Morissette *et al.* (2009) indicated a major shift in biomass and catch landings for predatory fishes such as cod. There is also a corresponding regime shift to an ecosystem that is currently dominated by forage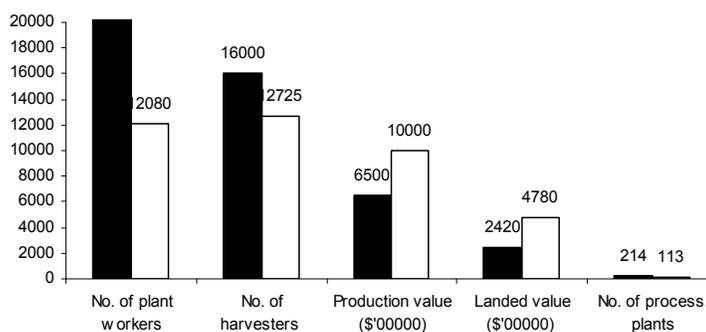 fishes and invertebrates as well as a decline in the Marine Trophic Index, a measure of biodiversity (Morissette *et al.*, 2009; Savenkoff *et al.*, 2007). Moreover, from the harvest and post-harvest perspectives, there is a shift in target species from collapsed predatory fisheries to shell fisheries with higher landed value and global niche markets (Schrank, 2005). Although the current fishery has higher production value than before, there is an associated socioeconomic concern in terms of distributional and intergenerational equity with loss of livelihoods as shown in Figure 3.

Three listing scenarios and associated recovery plans have been proposed following a cost benefit analysis: (i) no direct fishery with some allowable by-catch, (ii) prioritized rebuilding with 50 % by-catch; and, (iii) maximum rebuilding with a zero by-catch (DFO, 2005). Each of these scenarios has policy implications for fish stocks, foregone revenue and coastal livelihoods. In this contribution, I draw upon recent approaches developed by Christensen *et al.* (2009) to explore fish chain modeling for recovery options. Integrating the harvest and post-harvest stages in the ecosystem model by Morissette *et al.* (2009) may provide

Figure 3. Socioeconomic overview of the Newfoundland fishing industry (GNPFT, 2008). Solid bars: pre-collapse period of 1989; Clear bars: post-collapse period of 2007.

insights in assessing future recovery options. Three scenarios are proposed, partly based upon DFO (2005) socioeconomic listing criteria: i) recovery of large predatory fishes to the 1980 biomass as a rebuilding target (DFO, 2009); ii) high economic rent from the fishery with or without a recovery plan; and iii) high socio-cultural benefits with distributional quotas for fishing dependent coastal communities.

The optimal scenarios and the status quo would be explored further under different policy instruments such as complete moratorium and varying amounts of total allowable catch. The expected outputs are useful in identifying opportunities and viable policy options for recovery including institutional arrangements, policy reforms, stewardship mechanism and conservation incentives.

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Ecosystem structure and functional traits of the Northern Aegean Sea (E. Mediterranean, Greece)[1]

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Here we summarize some results regarding important structural and functional traits of the North Aegean Sea ecosystem (Eastern Mediterranean). For the first time, an Ecopath model (Christensen & Walters, 2004) was built to describe the North Aegean Sea (24-26°E, 40-41°N; Greece). The study area, despite the fact that it is an oligotrophic region, is one of the most productive areas in the Eastern Mediterranean which is reflected in the high relative fishing catch (30 % of Greek fisheries landings). Thus, the description of the structural and functional characteristics of this area is necessary to place both natural and anthropogenic drivers into an ecosystem context.

The ecosystem model was built for the period 2003-2006 and was restricted in the continental shelf (depths of 20-300 m) where most fishing vessels operate. In total, 40 functional groups (FGs) were defined including pelagic and demersal fishes, several benthic invertebrates, dolphins, turtles, seabirds, detritus and discards. Five fleets were included: trawls, purse seines, static nets, longlines and pots. Anchovy and sardine were described as multi-stanza groups, i.e., split into juveniles and adults. The rest of the fish species where integrated into 18 FGs depending on phylogenetic, behavioural and feeding criteria. Biomass data was obtained from surveys and published information concerning the study area. The rest of the parameters required were obtained from the literature or from results of the Hellenic Center for Marine Research (HCMR) projects. Fisheries data was collected with high regional and temporal detail from the HCMR. Species-specific and fleet-specific discards to marketable ratios were used to estimate the amount of discards generated in annual basis. The Pedigree index (i.e., P, a simple index to categorise the overall quality of the model) scored 0.61 implying a reasonable quality of data sources. Mass-balance was achieved after modifying (a) the diet matrix, notably for FGs whose initial input data were not specific for the region; and (b) biomasses, especially for FGs where the sampling method is known to produce underestimations (e.g., benthopelagic fish).

Estimated trophic levels of species and/or FGs were within the range of the known trophic levels for each species in the Mediterranean Sea (Stergiou & Karpouzi, 2002). Results of the mixed trophic impact and keystone species index by Libralato *et al.* (2006) indicate that mesozooplankton was a keystone group in the North Aegean Sea during 2003-2006, while detritus, suprabenthos, phytoplankton and non crustacean benthic invertebrates followed in terms of total effects and keystoneness. Concerning fish, adult anchovy had the higher overall effect and keystoneness.

The mean transfer efficiency of the area was higher compared to other Mediterranean areas, in line with higher oligotrophic conditions of the Eastern basin (Table 1). Several statistics and exploitation indicators such as the primary production required to sustain the catch (PPR %), the gross efficiency of the fishery and the mean trophic level of the catch (mTLc) indicated that the North Aegean Sea during 2003-2006 was a highly exploited ecosystem (Table 1). Moreover, the Loss in production index (Lindex, Libralato *et al.*, 2008) suggested that the ecosystem was unlikely to be sustainably fished (probability was moderate-low). The comparison of the indices to the Catalan Sea and Adriatic Sea ecosystems (Coll *et al.*, 2007; Coll *et al.*, 2006; Table 1) though, implies that the Aegean Sea was slightly less exploited, as revealed by the exploitation indices, the lower catches, and the higher mean trophic level of the catch. The North Aegean Sea was in a higher developmental stage according to Odum's (1969) theory of ecosystem maturity (Christensen, 1995). A further comparison of the different ecosystems could be useful for the exploration of gradients in exploitation patterns and/or ecosystem functioning in the Mediterranean Sea.

Table 1. Statistics, flows and indices for the model of N. Aegean Sea and comparison with other Mediterranean modeled areas (S. Catalan: Coll et al., 2006, N. Central Adriatic: Coll et al., 2007). TL = trophic level; PPR = primary production required; PP = primary production; det = detritus; L index = Loss in production index; Psust = probability of being sustainably fished; a = calculated using pp; b = calculated using both pp + det.

Index	North Aegean	Southern Catalan	NCentral Adriatic	Units
Sum of all consumptions	868.83	852.11	1305.04	t·km^{-2}·yr^{-1}
Total system throughput	1703	1657	3844	t·km^{-2}·yr^{-1}
Sum of all production	791	658	1566	t·km^{-2}·yr^{-1}
Total biomass (excluding detritus)	33.04	58.99	130.3	t·km^{-2}
Total transfer efficiency	17.4	12.6	10	%
Total catches	2.34	5.36	2.44	t·km^{-2}·yr^{-1}
Mean TL of the catch	3.47	3.12	3.07	
Mean TL of the community (excluding TL1)	2.57	2.37	2.13	
PPR to sustain the fishery (from pp)	3.45	9.45	6.59	%
PPR to sustain the fishery (from pp+det)	6.76	10.6	15	%
Gross efficiency of the fishery (catch/net pp)	0.004	0.014	0.002	
Finn's cycling index (of total throughput)	24.40	25.19	14.70	%
Finn's mean path length	6.26	4.27	3.34	
Connectance index	0.29	0.20	0.21	
System Omnivory Index	0.175	0.19	0.19	
Ascendency	17.64	25.5	27	%
L index a	0.026	0.057	0.024	
L index b	0.052	0.063	0.055	
Psust a	70.54	44.55	71.65	%
Psust b	44.71	28.71	38.48	%

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CLIMATE IMPACT EVALUATION: ORAL PRESENTATIONS

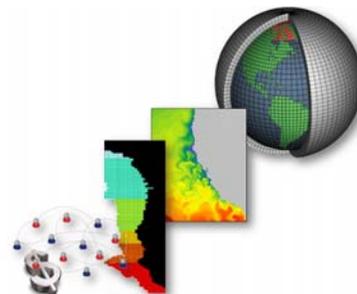ECOWORLD: EWE ONE LINK IN GLOBAL SYSTEMS MODEL[1]

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Climate change is a challenge that is capturing the attention of science, media, politicians and public alike. It has been the focus of some of the greatest acts of collaborative science the world has seen to date (e.g., the IPCC reports and model comparisons*).* There have been physical models (see the review in Randall *et al.*, 2007), predictions of shifts in species distributions (Ling *et al.,* 2009; Heikkinen *et al.*, 2006) and models of economic impacts (e.g., Hallegatte, 2009). The work on ecosystems has largely been through the use of the output of global climate models as drivers for multispecies or trophic models (Field *et al.*, 2006). While these studies have all produced insights into potential effects of climate change one significant facet that has typically been lacking is feedback. Ecosystems involve links, direct and indirect pathways between their many ecological, physical, chemical and human (social and economic) components. Feedback and change are at the core of ecosystems. While this has always been true (and is one of the major drivers for using ecosystem models to explore fisheries issues), global climate change has made it clear that the non-stationary nature ecosystems, and their dynamics, needs to be addressed explicitly.

The bulk of existing "ecological" or "ecosystem" climate models include plankton, typically phytoplankton, and any links to higher trophic levels (if they exist at all) are unidirectional. While these models are useful for understanding the potential distribution of future production and some of the implications for fish groups it is not enough if science is to provide insight into the dynamics of more complex species assemblages or how natural marine resources will need to be managed into the future. One of the most promising ways of bringing feedback to climate projects is through hybrid or coupled models. EwE (Christensen & Walters, 2004) has an extensive track record as a useful (and fast) tool for representing the trophic dynamics of marine foodwebs. The questions it can be used to address are only expanding with the addition of multi-stanza, spatial and economic options. Perhaps the weakest components of EwE have traditionally been its handling of the biogeochemical end of an ecosystem. This is typically not an issue for many of the questions it has been used to address, but it may prove to be a hindrance if environmental forcing (either bottom-up through production or top-down through environmentally related mortality) plays a major role in the key system processes that will shape ecosystems under climate change. An obvious first step then is to couple EwE with biogeochemical (nutrient-phytoplankton) models, and through them global climate models (GCMs), to begin to build truly end-to-end models that have dynamic feedback connections at every step in the chain. By intelligently using each model in the role it plays best and coupling at points that 'cut-out' the weakest representations in each model type (e.g., replacing static environmental forcing and production with a link to dynamic production and climate models) the set of coupled models can avoid the biggest limitations of each of the models in isolation.

Figure 1. Schematic diagram of the linking of different model types.

This chain of coupled models may be extended still further (e.g., Figure 1). First there is the potential to link it to any number of fully developed economic market, trade or network models. EwE already

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covers some of these aspects, but like their physical counterparts, global economic models have a long history and it makes sense to explore how their behaviour changes once linked into a truly dynamic framework.

However, the future of dynamically coupled 'world models' extends beyond these simple chains. Over the last decade, a range of models have been developed that try to span large portions of marine ecosystems (Travers *et al.,* 2007). Each of these modelling platforms has focussed on different aspects, on different processes or scales. Rather than being considered as competitors, these modelling platforms have the potential to be complementary. This opens up a swath of new opportunities, where GCMs or detailed regional hydrodynamic models are used to capture the physical system, biogeochemical models produce sophisticated projections of the patchy nature of primary production, ecosystem models like Atlantis (Fulton *et al.*, 2005) and EwE provide broad scale context, while other (species-level) models follow the life cycle of specific species of interest, or the dynamics of particular industries and their economic connections and governance. This kind of flexibility, playing to the strength of each modelling tool, can prove a significant scientific instrument.

There are significant scientific challenges involved in successfully and seamlessly coupling models with different temporal, spatial, ecological, anthropogenic and process resolutions. Nevertheless early examples already exist (e.g., in the Southeast of Australia, Figure 2) and are being used to give insight into potential ecosystem-level effects of climate change and the implications of these affects for the sustainability of fisheries.
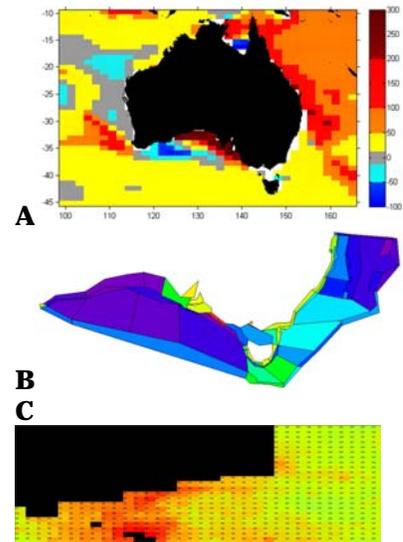
Figure 2. Representative maps from three models for the southeast of Australia (A) a downscaled regional nutrient-phytoplankton-zooplankton model, (B) Atlantis and (C) Ecospace.

ACKNOWLEDGEMENTS

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Experiences in integrating physical-biogeochemical processes into food web dynamics with EwE[1]

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The integration of hydrodynamic, biogeochemical, population and community processes represents a key issue for comprehensively accounting for potential cascading effects of natural variations and anthropogenic disturbances on marine ecosystems. Different stressors (e.g., climatic changes, nutrient inputs, exploitation and pollution) impact simultaneously the capability of the ecosystem to maintain itself (and its biodiversity) and to provide goods and services. Climatic changes, for example, might affect nutrient input to coastal areas (Cossarini *et al.*, 2008) producing biogeochemical processes with cascading effects up to commercial species (Loukos *et al.*, 2003). Physical changes might have important implications for exploited species (e.g., modification of the mixed layer depth; see Aydin *et al.*, 2005) or, conversely, fishing might impact on biogeochemical processes with positive feedbacks on commercial species (Pranovi *et al.*, 2003). Such interactions illustrate that in general, stressors might have counterbalance or synergistic effects. Fishing pressure, for example, might exacerbate or might benefit from effects of climatic changes in the marine ecosystem (Stenseth *et al.*, 2002; Walther *et al.*, 2002). Therefore, in order to study potential synergistic/antagonistic effects of different natural/anthropogenic changes in a truly ecosystem approach, dynamic representation of all involved features, from nutrients to top-predators, is required (de Young *et al.*, 2004).

The integration of physical, biogeochemical and ecological processes spanning over different trophic levels into an End-to-End approach, however, needs to account for the different pathways that energy, matter and nutrients might have in a food web. Thus, it is fundamental to describe ecological and functional roles of ecosystem components within each trophic level. Moreover, the integration of physical, biogeochemical and food web dynamics entail a good representation of detritus and related feedbacks that might be crucial in driving ecosystem dynamics (Fulton & Smith, 2004). These, together with the identification of appropriate scales for integration/parameterization of the model and the careful definition of main processes linking physical-biogeochemical-community scales, make the End-to-End modelling a non-trivial task (Cury *et al.*, 2008). Ecopath with Ecosim's flexibility, i.e., having been used in very different contexts, and ability to propose adequate biological resolutions (Christensen & Walters, 2004), makes such integration possible. Moreover, EwE might represent a straightforward tool for implementing the End-to-End approach with an ensemble of models (de Young *et al.*, 2004).

In this work, we present our experiences in linking EwE with other physical-biogeochemical models for an End-to-End approach for the Venice lagoon and the Adriatic Sea. The methodological integration is discussed and the conceived End-to-End tool is here used for analysing scenarios of simultaneous climatic and exploitation changes over time. Biogeochemical processes are represented by hydrodynamic-biogeochemical models forced with Regional Climate Model outputs (Giorgi *et al.*, 2004), while fishing effort is included in the EwE food web description.

Structural and functional changes of these ecosystems are analysed also through ecological properties and indices such as trophic level and cycling indexes. Scenario analyses were carried out for understanding the role of biological resolution in shaping the observed ecosystem changes.

Experiences gained in these preliminary coupling experiments might be very useful for future on-line integration. In addition, they might give useful insights on the choice of space and time scales for the integration and the associated aggregation of the necessary input/output parameters. Moreover, these experiments provide evidence of the large number of processes required to correctly link these models. Finally, advantages and limitations of the use of EwE for linking biogeochemical and food web models illustrate the theoretical and technical difficulties encountered in these coupling experiments.

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ECOLOGICAL INTERACTIONS WITHIN MARINE ECOSYSTEMS DETERMINE WINNERS AND LOSERS UNDER CLIMATE CHANGE[1]

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Climate change is the most widespread anthropogenic threat that ocean ecosystems face (Halpern *et al.*, 2008). Primary producers will respond rapidly to climate change due to their small size and high population turnover (Hays *et al.*, 2005) and already the distribution and amount of phytoplankton productivity has been altered by climate change (Behrenfeld *et al.*, 2006; Richardson & Schoeman, 2004). Other primary producers, such as seagrass, mangroves and macro-algae will also be strongly affected by climate change. Changes in the amount and type of primary production will have strong flow-on effects throughout the ecosystem (Scheffer *et al.*, 2005). Therefore, the impact of climate change on primary production and its effects throughout marine food webs needs to be understood to ensure robust ecosystem management to preserve biodiversity and support sustainable fishing.

Here we investigate the effects of climate-driven primary production change on biodiversity and fisheries across a broad range of marine ecosystems including coastal, deep sea and open ocean environments. Twelve existing Ecopath with Ecosim models of different Australian marine ecosystems were used to investigate flow-on effects of primary production change on community composition, fishery catch and value, and abundance of species with conservation importance. We simulated different trends in the amount of primary productivity in each Ecosim model to explore how primary production change affects marine ecosystems. Additionally, we considered multiple formulations for each Ecosim model to account for ecological uncertainty. These included the effects of habitat dependency and alternative predator-prey interaction strengths. To further illustrate the potential effects of climate-driven production we linked the CSIRO model of global climate change forced by a high greenhouse gas emission scenario to primary production models that force production rate in Ecosim models. Changes in the physical environment affected the production rate in the models of phytoplankton, macro-algae and seagrass, which were then
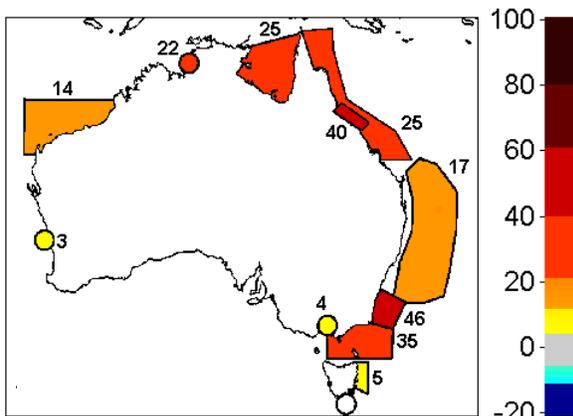
used to force the twelve Ecosim models and predict changes in abundance of organisms, fisheries catch and value and community composition.

Initially, an extensive sensitivity analysis was conducted to explore the influence of primary production change in the ecosystems. Primary production change had a large effect on the abundances of all consumer organisms in all ecosystem types. Generally, biomasses increased with increases in primary production and decreased for decreases in primary production. The mean change in biomass of consumer organisms for all Ecosim models and formulations was similar for all levels of primary production change. However, there was considerable variability between the magnitude of responses for different organisms. When predator-prey interaction strengths were estimated using ecological data, there were stronger and more variable predation and competition interactions. Predation and competition reversed the expected responses of some species, for instance some high-value tuna species declined under productivity increases, due to greater abundances of their predators.

Relative community composition was not strongly affected by primary production change if all producers responded similarly to climate change. However, changes in the relative productivity of different types of primary producers, such as sea grasses and phytoplankton, could strongly affect relative community composition. For instance, increases in benthic production (seagrass and macro-algae) in coastal models tended to cause increases in the abundance of higher trophic level organisms, whereas increases in phytoplankton production tended to cause the reverse. Comparison of model simulations with and without habitat dependency showed that abundance of habitat dependent organisms was affected, but that overall community composition, fishery catch and fishery value were not affected. However, lack of data on the response of organisms to habitat change and aggregation of life history stages limited our ability to consider habitat associations in the Ecosim models.

We then performed a projection of the ecosystem impacts based on the output from the CSIRO climate model under a high emission scenario. Predicted climate change from the climate model generally led to increases in nutrient availability around Australia and greater primary productivity in most regions. Thus, the Ecosim models generally predicted greater fishery catches (Figure 1) and greater abundances of species of conservation interest, such as turtles and sharks under future climate change. However, ecological interactions reversed the expected responses for some populations, resulting in declines in animal populations and reductions in catch value per kilogram in some regions. Changes in community composition were generally small.

Figure 1. Change in fishery catch (%) over 50 years from linked climate and Ecosim models for Australia Ecosim model regions.

The predicted magnitude of climate-driven production change will have large effects on marine ecosystems. Increasing awareness of the role ecological interactions play in determining population level responses to ecosystem change has seen greater consideration of ecological interactions for management of ecosystems (Christensen & Walters, 2004, Fulton *et al.*, 2004). Our research demonstrated that ecological interactions will regulate the responses of species to climate change from a diverse range of taxa and ecosystems. However, the predictive ability of our models given projected greenhouse gas emission scenarios was limited by understanding of habitat dependencies and responses of different types of primary producers to climate change. Investigation of a broader range of processes in marine food web models will improve the efficacy of models for predicting effects of climate change on marine ecosystems. The inclusion and improved description of ecological interactions will enable predictive models to become effective tools for the management of biodiversity and fisheries under climate change.

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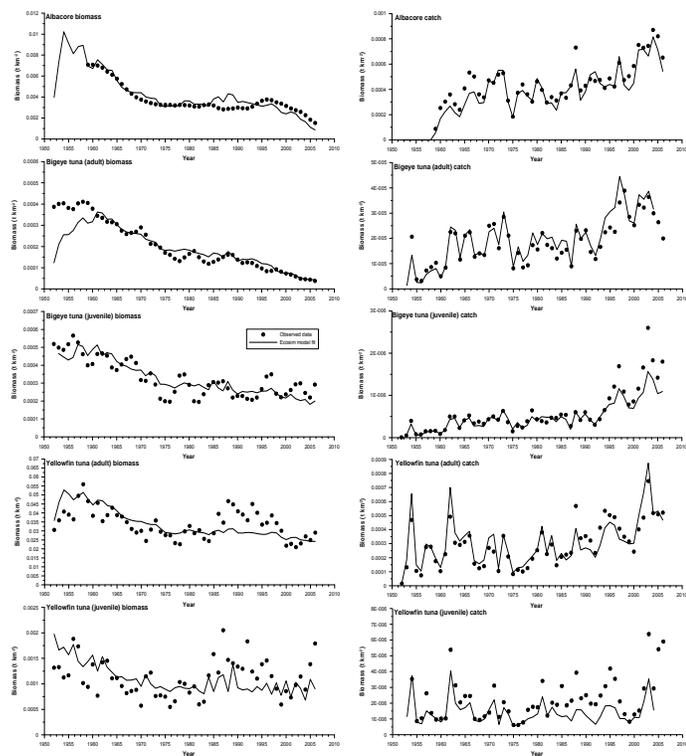# Ecological effects of fishing and climate change on the pelagic ecosystem off eastern Australia[1]

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The tropical and subtropical waters off eastern Australia host a highly dynamic pelagic ecosystem that supports one of Australia's largest and most valuable Commonwealth fisheries, the Eastern Tuna and Billfish Fishery (ETBF). This large multi-species fishery targets apex predators and, therefore, has the potential to disrupt the functionality of the ecosystem if not properly managed.

An Ecopath model was constructed to explore the ecological effects of longlining and climate change from 1998 to 2018. The model reliably reproduced historic time series data of biomass and fishery catch from 1952 to present for commercially-important species (Figure 1), indicating that the model is capable of predicting the future state of the ecosystem after a specific perturbation.

A 50 % reduction in ETBF effort resulted in only modest (2-20 %) increases in the biomass of target species and their predators. Doubling the fishing mortality on individual ETBF target species again resulted in small (< 20 %) changes in the biomasses of any functional group. However, climate change scenarios involving a 20 % decrease in micronekton fish biomass and a 50 % increase in squid biomass both resulted in trophic cascades (Figure 2), highlighting their importance as key prey groups in the system.

Figure 1. Fits of the Eastern Tuna and Billfish Fishery Ecosim model to standardised biomass and catch data for five large pelagic fish species between 1952 and 2006.

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[1] Cite as: Griffiths, S.P., Young, J.W., Lansdell, M.J., Campbell, R.A., 2009. Ecological effects of fishing and climate change on the pelagic ecosystem off eastern Australia. *In:* Palomares, M.L.D., Morissette, L., Cisneros-Montemayor, A., Varkey, D., Coll, M., Piroddi, C. (eds.), Ecopath 25 Years Conference Proceedings: Extended Abstracts, pp. 94-95. Fisheries Centre Research Reports 17(3). Fisheries Centre, University of British Columbia [ISSN 1198-6727]. 167 p.
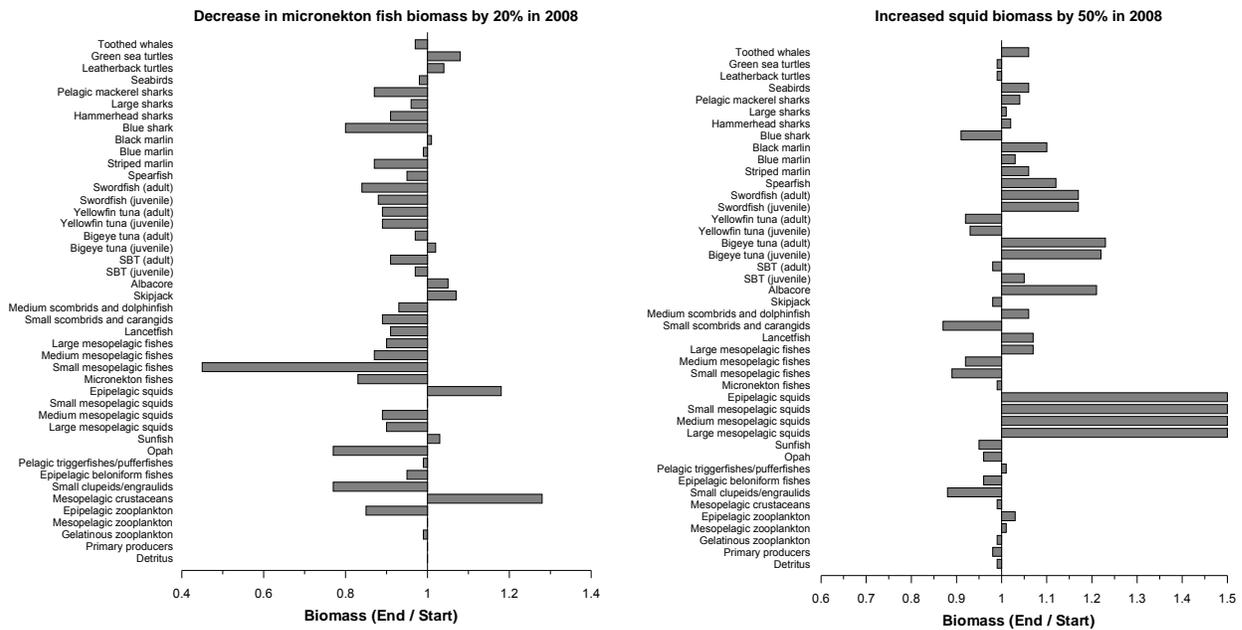
Figure 2. Predicted relative changes in the biomass of species groups in the ETBF ecosystem after adjusting the biomass of micronekton fishes and squid groups in 2008 to reflect predicted changes due to climate change (see Young *et al.*, 2009). Results show the change in biomasses in 2018 relative to 1998 and after decreasing the biomass of micronekton fishes by 20 % (left) and increasing the biomass of squids by 50 % (right) in 2008.

Our results suggest there may be ecological redundancy among high trophic level predators since they share a diverse suite of prey and collectively only represent < 1 % of the total system biomass. Consequently, the removal of a single apex predator group can be compensated by small changes in the biomass of several competing groups within the same trophic level. However, when the biomass is altered in groups having high biomass and production rates that serve as important prey and predators, more dramatic cascading effects in biomass changes take place throughout the system. We advocate that these species may be contributing to a 'wasp-waist' type of control of ETBF ecosystem rather than top-down or bottom-up processes reported to drive other pelagic systems.

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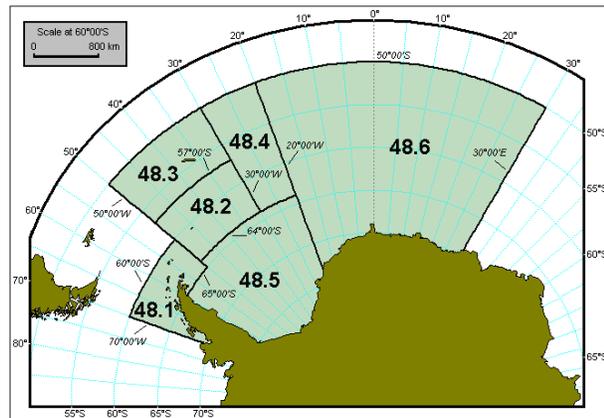# ECOSYSTEM EFFECTS OF CLIMATE CHANGE IN THE ANTARCTIC PENINSULA[1]

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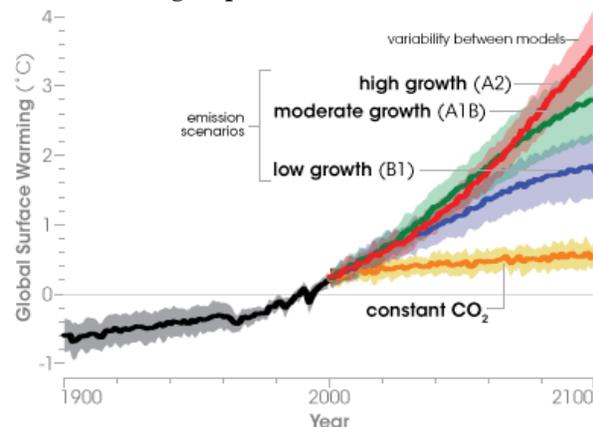
The Antarctic Peninsula is a highly productive system, in which numerous local and migratory top predators are dependent. In addition, the Antarctic Peninsula (Figure 1) is also one of the fastest warming areas in the world, with an average sea surface temperature increase of 2.5°C over the last 50 years (Marshall *et al.* 2006; Rogers *et al.* 2006) causing substantial decreases in sea ice. With the declining sea ice cover come changes to the ecosystem structure. Krill (*Euphausia superba*) are an important source of food to top predators within this system, and are highly dependent on the sea ice for survival (Atkinson *et al.* 2004; Loeb *et al.* 1997). Decreased sea ice has shown to cause a reduction in the amount of krill within the system, and in turn causes increased mortality on juvenile penguins and seals (Brierley & Reid, 1999). It is expected that as

Figure 1. FAO statistical areas (FAO, 2001). The Antarctic Peninsual model is based on area 48.1.

temperature increases, years of low sea ice and low krill abundance will increase, causing a strain on the ecosystem. I have built an ecosystem model in order to understand the ecosystem level changes that will occur due to climate change. The model incorporates 59 functional groups to represent all species within the area, the krill fishery which operates in the area, as well as environmental factors such as the amount of sea ice to drive the model through time. One important function group of the model is ice associated algae, which has been included to represent an important source of food for krill and other organisms throughout the winter. Environmental data from the PALMER Long Term Ecological Research dataset has been integrated into the model to drive the phytoplankton groups through time.

Previous research focussed on how climate change is likely to impact krill through alterations of sea ice, with speculations on how the remainder of the ecosystem may be altered. By incorporating environmental data such as sea ice extent and open water extent, different primary producer groups can be forced in order to simulate plausible climate scenarios. Using varying levels of climate change as put forth by the IPCC (Figure 2), and linking them to expected sea ice extent (Smith & Stammerjohn, 2001), we can show the potential future ecosystem states.

Figure 2. Future climate change simulations in the Antarctic Peninsula ecosystem are based on predicted warming trends and green house gas emissions (IPCC, 2007).

Under these scenarios, the model is run to show what the effects to krill populations would be, and ultimately, how this will affect top predators and ecosystem structure.

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On the use of both unconventional and traditional time series data in constructing dynamic models of a marine ecosystem[1]

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We constructed an Ecosim model of the Strait of Georgia to examine bottom-up and top-down ecosystem mechanisms related to historic changes in salmonid populations from 1950 to the present. Populations of chinook and coho salmon in the Strait of Georgia declined dramatically between the mid 1990s and early 21st century. There is strong evidence to suggest that processes occurring early in the marine life history of these salmon are causing the decline (Beamish *et al.*, 2008). This Ecosim model is being used to explore potential mechanisms of salmon declines such as predation, competition and production changes. When model predictions of salmon population changes are tuned to stock assessment data, the results suggest that bottom-up forcing is a very likely source of declining salmon populations. Also of interest was the capacity of the model to resolve changes in species with less well understood dynamics like marine birds and hake. Rather than confounding the predictions made by the model, the use of non-conventional time-series for birds and hake suggest that pervasive changes in the Strait of Georgia have also affected species not targeted by fisheries. The model also helps show how bottom-up processes are filtered through an ecosystem and that the effect of such production changes may actually be even more pronounced in species at higher trophic levels like orcas and seals.

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Development of an ecosystem model for Galveston Bay: evaluating the influence of freshwater inflows, nutrient inputs and fisheries[1]

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Galveston Bay is the most productive bay along the Texas Coast (Lester & Gonzalez, 2002). The largest commercial and recreational fisheries in terms of landings and numbers have been reported from this bay system. It contains the most productive and extensive oyster, *Crassostrea virginica*, reefs along the Texas coast and supports numerous recreational and commercial fisheries for finfish and shrimp. Galveston Bay exhibits a typical estuarine salinity gradient with considerable spatial and temporal variability (0.5-30 psu) (Orlando *et al.*, 1993). The primary factor regulating salinity within the bay system is the Trinity River that contributes approximately 55 % of the freshwater inflow. Portions of the bay system have been characterized as being eutrophic (EPA, 2001).
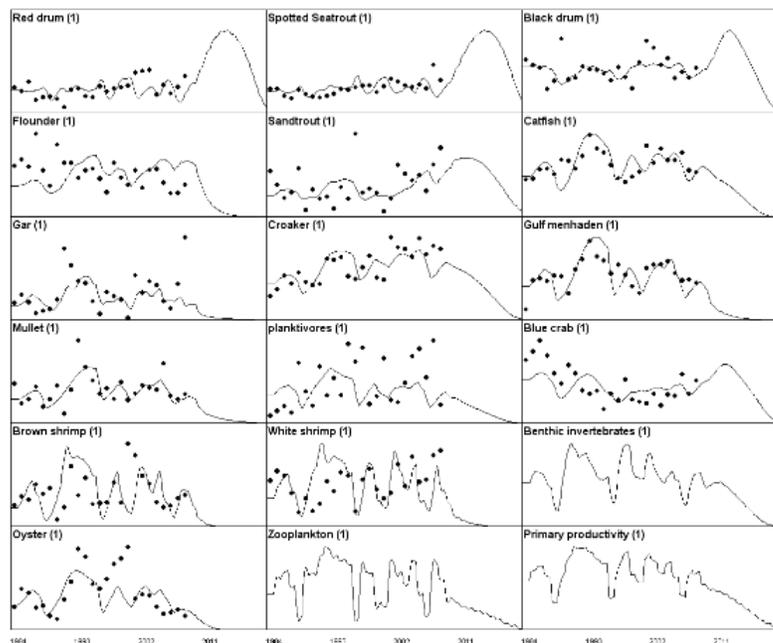
Figure 1. Predicted long and short term effects of reducing fresh water inflow by 10 % each year in the Galveston Bay (Texas) estuarine ecosystem.

Management of estuarine fisheries has traditionally relied on single species population modelling, and management. Unfortunately, this approach neglects the complex interactions of various trophic levels and changes in environmental conditions. For example, within Texas estuaries blue crabs, *Callinectes sapidus*, play a key role in estuarine environments, supplying a critical food source to many inhabitants. While there appears to be a strong relationship between declining blue crab populations and increased effort (Sutton & Wagner, 2007), other alternatives cannot be ruled out. One widely held belief is that reduced fresh water inflow is to blame. The other is increased predation by endemic fish populations. A predictive management tool is needed that can incorporate these often non-linear interactions that are inherent in ecological processes and may materialize as a result of interaction with management actions.

Ecopath with Ecosim (EwE) is one such ecosystem based stock assessment modelling tool that can incorporate complex interactions between fisheries and abiotic factors such as nutrient inputs, freshwater inflows and salinity fluctuations. We attempt to develop a predictive model of estuarine fish and invertebrate populations using an approach that can evaluate the relative impacts of fishing pressure and other environmental fluctuations. We use time series abundance data from TPWD-Coastal fisheries independent fisheries monitoring data to describe trends in the main biomass groups and examine the influence of predation, freshwater inflow and fishing on blue crabs in Galveston Bay, with a view of putting into perspective the degree of influence each will have on reviving stocks.

The model predicts both short and long term responses to reduced freshwater inflow. Long term responses are an overall decline in productivity starting at the base of the food chain, while short term responses are less obvious and appear to temporarily benefit top predators. Gulf Menhaden (*Brevoortia patronus*), Mullet (*Mugil cephalus*), and eastern oysters closely follow predicted primary productivity trends estimated using a freshwater inflow forcing function. Spotted seatrout (*Cynoscion nebulosus*) for example prefers a mid to high range salinity and will avoid fresher portions of the bay. Better data fits for this group can be obtained by adjusting its vulnerability index using a salinity time series forcing function, in agreement with predictions made by foraging arena theory. That is, prey species taking refuge in low salinity regions become more available to predation as salinity increases. Long and short term effects on the Galveston Bay food web were predicted by reducing inflow at a rate of 10 % per annum after the time series ends in 2008 (Figure 1).

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STRUCTURE OF TWO HIGH LATITUDE NORWEGIAN FJORD ECOSYSTEMS ANALYSED USING ECOPATH[1]

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At high-latitudes, fjord systems formed during glaciations often show distinct ecosystem properties that differ from oceanic offshore ecosystems. Along the coast of northern Norway, fjords differ with regard to environmental conditions and ecosystem characteristics. In the high-latitude (69-70°N) of the Ullsfjord-Sørfjord system, an ecological program was run from 1989 to 1997. Top-predators, fish, as well as pelagic and benthic invertebrates were intensively sampled and analyzed with regard to trophic interactions and population dynamics. To investigate factors affecting fjord ecosystem structure, an Ecopath model was developed for the lightly exploited cod-dominated Sørfjord ecosystem for the time period 1993-96 (Pedersen *et al.*, 2008). Trophic level estimates from this model has also been compared to trophic level estimates from stable isotope analysis (Nilsen *et al.*, 2008) to evaluate model structure and suggest further improvements. Sørfjord (area 55 km²) is the relatively shallow inner part of the fjord system and is separated from the deeper Ullsfjord by a shallow sill (Figure 1).

In this investigation, another Ecopath model covering the same time period was developed for the outer part of the fjord system, Ullsfjord (area 400 km²). Ullsfjord has higher water temperatures, is deeper and have greater fish diversity than Sørfjord. The Ullsfjord model was compared to the Sørfjord model to investigate if energy flow patterns and trophic structure differed between the two systems. We analyzed and compared the trophic interactions and impacts, keystoneness and system properties of the two ecosystems and discussed how differences in water depth and water temperature may affect the coastal ecosystem structure.

Large gadoids (Atlantic cod, saithe and haddock) are the main targets for exploitation and are fished by small boats using gill nets, long-lines and hand-lines. Groundfish trawling is prohibited both in Ullsfjord and Sørfjord, but shrimp trawling is allowed in Ullsfjord. In Sørfjord, all commercial trawling is prohibited. During 1993-96, coastal Atlantic cod (*Gadus morhua*) was the most abundant fish species in terms of biomass, but cod was more important in Sørfjord than in Ullsfjord. Haddock (*Melanogrammus aeglefinus*), other gadoids and shrimps (deep-water shrimp, *Pandalus borealis*, and pelagic shrimp *Pasiphaea multidentata*) were more important in Ullsfjord than in Sørfjord and euphausiids were abundant in both systems (Figure 2). In contrast, benthic invertebrates may be more important in Sørfjord than in Ullsfjord. The abundance of Norwegian coastal cod peaked during 1993-96, but has decreased to low levels in recent years. Thus, both the Ullsfjord and Sørfjord Ecopath models reflect ecosystems where cod was a dominant top-predator.
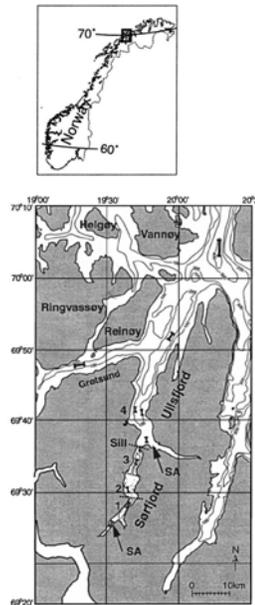
Figure 1. Overview of the Ullsfjord and Sørfjord system, Norway. A shallow sill separates the two fjords. The two main spawing areas (SA) for coastal cod are indicated by arrows. Bottom trawl haul locations are indicated by bars.
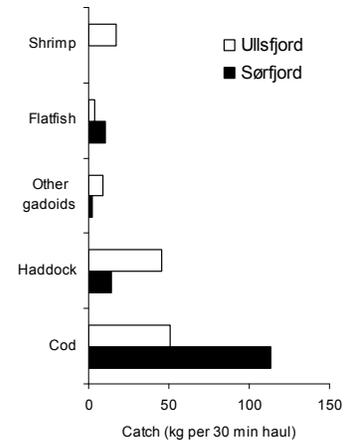
Figure 2. Catch per unit effort for various fish and shrimp groups caught by a fine meshed bottom trawl in the Ullsfjord and Sørfjord system, Norway.

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CLIMATE IMPACT EVALUATION: POSTER PRESENTATIONS

MECHANISMS AFFECTING RECOVERY IN AN UPWELLING FOOD WEB: THE CASE OF THE SOUTHERN HUMBOLDT[1]

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Although bottom-up forcing and overfishing are known to induce shifts in ecosystem states, system changes and their reversibility under each factor are still poorly understood (Steele, 2004). In this paper, dynamic food web simulations are conducted to evaluate when and why ecological thresholds may be exceeded, and whether bottom-up forcing or fishing is more likely to induce irreversible ecosystem states. Simulations are conducted using a calibrated food web model of the upwelling system off central Chile (33º-39ºS) and the Ecopath with Ecosim software version 5.1 (Christensen *et al.*, 2005). The effects of fishing scenarios are explored by changing fishing mortality according to trophic level. The effects of bottom-up forcing scenarios are explored by changing phytoplankton biomass, as a function of sea temperature, at El Niño Southern Oscillation (ENSO) and decadal scales. Simulations are carried out for 150 years and impacts, system recovery and regime shifts from each scenario are evaluated using trophodynamic indicators and limit reference points for biomass of functional groups as proxies of food web state and ecological thresholds, respectively.

Proportionally distributed fishing along trophic levels is the least harmful fishing scenario, resulting in biomass limit reference points rarely being exceeded and high system recovery. Results are summarized in Table 1. Concentrating fishing at higher and lower trophic levels more likely causes reference points to be exceeded and induces ecosystem changes with low-to-medium recovery potential. No limit reference points are exceeded (or regime shift induced) under ENSO scale bottom-up forcing. Decadal scale bottom-up forcing has different effects on the system depending on the sequence in which the high and low phytoplankton biomass periods are simulated. A shift from low phytoplankton biomass towards high phytoplankton biomass does not result in biomass limit reference points being exceeded, whereas the opposite sequence results in a large number of limit reference points being exceeded with medium recovery. The interplay between fishing and decadal scale bottom-up forcing indicates that bottom-up forcing can dampen the effects of fishing, whereas fishing increases the number of limits reference points exceeded and decreases the recovery observed under decadal scale bottom-up forcing. Results suggest that

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fishing (especially unsustainable strategies) is more likely to cause ecological thresholds to be exceeded and to induce regime shifts of low recovery than decadal scale bottom-up forcing. We consider these results of relevance for the management of fisheries in their ecosystem context.

Table 1. Number of Biomass limit reference points (BLimit) exceeded and recovery observed under simulated scenarios.

Scenario	Description	Number of B_{Limit} exceeded	%	Number of recoveries	%
Fishing 1	Concentrating fishing at higher trophic levels	9	43	5	56
Fishing 2	Concentrating fishing at lower trophic levels	11	52	8	73
Fishing 3	Proportionally distributed fishing across trophic levels	5	24	4	80
Bottom-up 1	Interannual variability (one ENSO per decade)	none		none	
Bottom-up 2	Interannual variability (two ENSO per decade)	none		none	
Bottom-up 3	Interannual variability (one ENSO per decade increased intensity)	none		none	
Bottom-up 4	Decadal variability (low to high phytoplankton biomass)	none		none	
Bottom-up 5	Decadal variability (high to low phytoplankton biomass)	15	71	11	73
Fishing 1 and Bottom-up 4		8	38	4	50
Fishing 1 and Bottom-up 5		14	67	10	71
Fishing 2 and Bottom-up 4		5	24	2	40
Fishing 2 and Bottom-up 5		13	62	8	62
Fishing 3 and Bottom-up 4		5	24	3	60
Fishing 3 and Bottom-up 5		14	67	6	43

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Spatial and temporal trophic dynamics of terrestrial arctic ecosystems[1]

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In a global change context, natural wildlife and habitats will suffer from overexploitation or climate change (Visser, 2008; Berteaux *et al.*, 2006; Thomas *et al.*, 2004; Myers & Worm, 2003). A major challenge in ecology and conservation is to forecast the ecological effects of future climate change (Visser, 2008), using the reported effects of recent climate change on ecological processes. Recently, Thomas *et al.* (2004) predicted that future climate change may cause the extinction of between 15 % and 37 % of species by 2050, based on species-specific climate envelopes. However, these projections were based on habitat loss with extinction risks for polar ecosystems being underestimated (Jenouvrier *et al.*, 2009).

Indeed, nowhere else on earth are the effects of global warming more threatening than in the Arctic. All models predict that warming trends will be strongest in the Polar regions as annual temperatures in the Arctic will increase by as much as 3° to 5°C over the course of the 21st century (ACIA, 2004). As climate warms, the distribution and abundance of species will be altered and thus trophic links disrupted. Hence, there is an urgent need to develop programs for conserving biodiversity in response to likely losses of a significant proportion of Arctic species assemblages (Krebs *et al.*, 2003).

ArcticWOLVES (Arctic Wildlife Observatories Linking Vulnerable EcoSystems) is an International Polar Year project that is aimed at understanding food webs and ecosystem processes that affect the tundra. The main objectives of this circumpolar project are to: i) determine if the tundra food web is primarily bottom-up or top-down controlled; ii) measure current impact of climate change on wildlife; and iii) predict future impacts on the food web through monitoring and modelling. Throughout the circumpolar world, terrestrial food webs contain relatively few species and are often dominated by the same groups, making them and the systems in which they occur suitable for comparative research (Krebs *et al.*, 2003).

Figure 1. Map of the ArcticWOLVES study sites.

While Ecopath has been widely used in fisheries studies (e.g., Gerber *et al.*, 2009), it has been rarely used to describe terrestrial food webs (but see Ruesink *et al.* 2002; Krebs *et al.*, 2003). Owing to the existence of Ecosim and Ecospace packages included in Ecopath, both temporal and spatial modelling can be conducted. The different sites included in the ArcticWOLVES project (Figure 1) and the long term

monitoring on Bylot Island allow us to address several issues on the tundra arctic food web dynamic using Ecopath.

For spatial modelling, we used data that were simultaneously collected at seven study sites (Figure 1) on primary production and the abundance and consumption of the major functional groups in 2007 and 2008 using the same protocols. The comparison across sites allows us to depict the functioning of the tundra ecosystem through a gradient of primary production and shed some light on the questions of relative strength of bottom-up *vs.* top-down effects in structuring arctic communities.

For temporal modelling, we used the long term monitoring of most components of the food web (from plants to top predators) on Bylot Island from 1983 to 2008 to investigate temporal variation in the food web and to assess the effect of lemming cycles and grazing by a large snow goose colony on the food web structure (Figure 2).

Finally, the temporal model of Bylot Island allows us to investigate and predict the effect of climate change on the food web through the input of long term series on climate (precipitation, NDVI, snow cover etc.) as well as climatic predictions for the next century (Jenouvrier *et al.*, 2009; Thomas *et al.*, 2004).
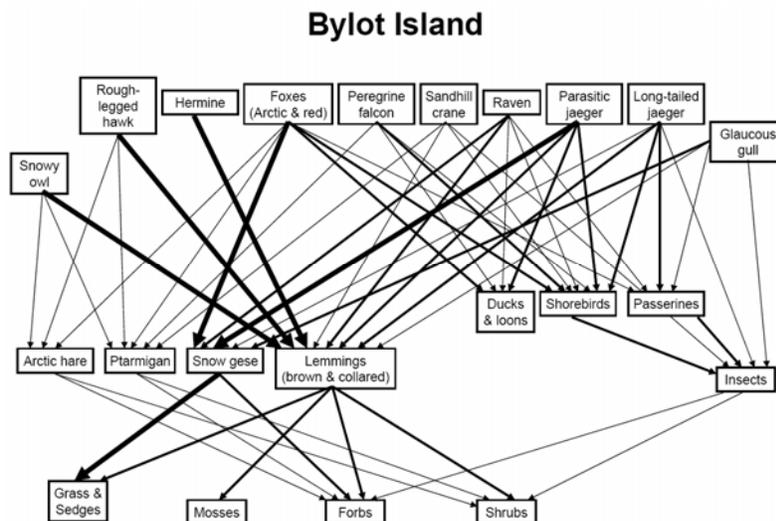
Figure 2. The Bylot Island food web, based on 15 years of data collection.

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IMPLEMENTING ECOSYSTEM-BASED MANAGEMENT: ORAL PRESENTATIONS

HOW CAN EWE ASSIST US IN IMPLEMENTING ECOSYSTEM-BASED FISHERIES MANAGEMENT? DRAWING FROM THE SOUTH AFRICAN EXPERIENCE[1]

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South Africa is actively attempting to implement an ecosystem approach to fisheries by 2010, using a large variety of tools, diverse studies and considering a range of possible management measures (Shannon *et al.*, 2008a; Shannon *et al.*, 2006; Shannon & Moloney, 2004; Shannon *et al.*, 2004a). Ecopath with Ecosim has provided a useful modelling framework for examining ecosystem effects of fishing in the foodweb of the southern Benguela upwelling ecosystem, ranging from plankton at the bottom of the food web to marine birds and mammals at the top (Shannon *et al.*, 2003; Jarre-Teichmann *et al.*, 1998). We have been fortunate to be able to build on important insights gained from a long-term ecosystem research programme, which has been running in South Africa for over 25 years (Moloney *et al.*, 2004). By constructing suites of trophic flow budgets and taking them further into simulations of the past 25 years (Shannon *et al.*, 2004b), we have summarized and enhanced our understanding of the ways in which several species interact, and what their respective roles are. In this process, gaps were identified, and have been at least partly addressed in subsequent iterations of our model-building process.

EwE models have been developed for a series of time periods ranging from pre-fishing to the modern era (Watermeyer *et al.*, 2008), enabling model effects of fishing to be examined in the southern Benguela foodweb, which has changed in structure over time. EwE simulation experiments have been undertaken to investigate ecosystem effects of heavier/lighter fishing strategies, in an attempt to improve understanding of the dynamic roles of key species, and as input to ongoing discussions around possible alternative management strategies and associated trade-offs (e.g., Shannon *et al.*, 2009a; Shannon, 2002; Shannon, 2000). Ecosystem changes in the southern Benguela are driven by fishing to some extent, but the environment plays an important role as well. Environmental changes have manifested in different ways, depending to a certain extent on the trophic structure and functioning of the food web. EwE has provided a means for exploring possible combined impacts of environmental and fishing drivers of ecosystem changes, and has shed light on how these drivers may interact (Shannon *et al.*, 2008b; Shannon *et al.*, 2004b).

Comparison with similar EwE models from other upwelling systems, notably the Humboldt, has led us to further examine our models, and to identify unique characteristics of the southern Benguela that need careful management consideration and further investigation. Comparative simulations using other ecosystem modelling approaches, notably OSMOSE (e.g., Travers *et al.*, 2006; Shin *et al.*, 2004), have helped to revisit gaps and improve confidence in our understanding of the ecosystem and how it is affected by fishing. Indicators derived from EwE models of the Southern Benguela have been helpful in assessing

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trophic-driven impacts of fishing (Shannon *et al.*, 2009b) and, together with data-based ecosystem indicators, will form an important contribution to monitoring future progress with EAF in South Africa.

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Ecosystem approach to the mutispecies fishery in the south-austral zone of Chile[1]

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The south-austral marine zone of Chile (41°S-55°S) sustains several artisanal and industrial fisheries on demersal species. For practical reasons, fish stocks have been considered as 'isolated species' and managed using a single-species approach. However, well documented ecological and technical interactions between target stocks and their fleets led fishing authorities to recognize the need for a much broader approach for the analysis of the fisheries in this management unit. For that reason, the Fishing Research Fund (Fondo de Investigación Pesquera, FIP) in Chile is providing financial support to a project carried out by Universidad de Concepción; the aim of which is to design and implement a multispecies approach for the south-austral fisheries in Chile (SAFCh). This paper describes the parameterisation and application of an ecosystem model of the region, developed using the Ecopath with Ecosim software (EwE; see Pauly *et al.*, 2000; Walters *et al.*, 1997; Christensen & Pauly, 1992).

The model represents the food web that supports target species in the SAFCh. It considers phytoplankton, zooplankton, benthos, other pelagic fish, other demersal fish, hoki (*Macruronus magellanicus*), southern blue whiting (*Micromesistis australis*), kingklip (*Genypterus blacodes*), skate (*Raja falvirostris*), southern hake (*Merluccius australis*) and other predators (marine birds, cetaceans and sea lions). Because strong ontogenetic changes in diet and cannibalism have been documented in hoki, we split this group into adult and juvenile stages. The model includes the main fleets operating in the study area (purse seine, industrial trawl, long-lines, bottom-lines and artisanal). Results of the model are used to analyse biological interactions (contribution of predators to total predation mortality of each stock) and technical interactions (contribution of each fleet to total fishing mortality of each stock). The input data needed to feed the model (e.g., biomasses, production/biomass and consumption/biomass ratios, catches, diet compositions, etc.) are gathered from reports from the yearly (fishery-dependent and fishery independent) assessments carried out for target species, landing statistic yearbooks from the National Fisheries Service, gut content analysis, primary and secondary production, etc.).

Simulations of changes from 1978-2006 are performed in Ecosim and fitted to time series of relative abundance (biomass, catch per unit of effort). We use the fitted model to analyse, through simulations, the effect of implementing individual single-species total allowable catches (TAC's) in a multispecies context, e.g., implementing maximum sustainable yields with and without full predator-prey interactions.

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Table 1 presents the balanced basic Ecopath model representing the food web supporting the main stocks in the SAFCh. Predation mortality results high in hoki due to strong predation by kingklip, southern hake, as well as canibalism. The main fleet interactions are industrial trawl and purse seine in hoki, and industrial trawl, long-line and bottom-line in kingklip and southern hake.

Results of the ecosystem model are compared with results obtained from single-species and MSVPA approaches applied to the same stocks. Avenues for the implementation of the ecosystem approach to the management of these fishing resources are discussed.

Table 1. Inputs and results from the balanced model constructed for the south-austral fishery in Chile in 1990.

Group	Trophic level	Biomass (t km^{-2})	P/B (year^{-1})	Q/B (year^{-1})
Phytoplankton	1.00	0.16	2242.80	-
Zooplankton	2.25	2.23	45.00	154.00
Benthos	2.00	8.74	3.60	14.00
Other pelagic fish	2.63	1.05	3.00	25.00
Other demersal fish	3.25	0.89	0.70	3.50
Hoki (juveniles)	3.29	1.76	2.20	6.00
Hoki (adults)	3.52	2.00	1.00	4.40
Southern blue whiting	3.35	0.75	0.36	2.50
Kingklip	3.94	0.10	0.70	3.50
Skate	3.08	0.04	0.36	2.50
Southern hake	4.11	1.93	0.36	2.50
Predators	3.81	0.00	0.01	0.47
Detritus	1.00	-	-	-

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Trade-offs between conservation and socio-economic objectives in managing a tropical marine ecosystem[1][2]

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Background

Understanding the trade-off relationships between ecological, economic and social objectives is important in designing policies to manage or restore ecosystems. Particularly, the trade-offs between conservation and socio-economic objectives are complex in multi-species or ecosystem context. Fisheries that achieve maximum sustainable yield of some species may over-exploit, deplete or even extirpate some less productive species. Simultaneously, when the ecosystem has already been over-exploited, most management policies that restore depleted populations or improve the profitability of the fisheries would require reduction of fishing capacity. The associated social problems may be more serious in developing countries where alternative livelihoods are lacking and social benefit systems are not well-developed. Thus a holistic approach is needed to understand the trade-offs that may emerge from different management objectives at the ecosystem level.

Study area

The northern South China Sea (NSCS) is defined as the continental shelf (less than 200 m depth) ranging from 106°53'-119°48' E to 17°10'-25°52' N. It falls largely within the Exclusive Economic Zone of the People's Republic of China, but Vietnam also shares part of the Gulf of Tonkin. It is a tropical ecosystem where diverse habitat including coral reefs, estuaries, mangroves, seagrass beds, and others provide habitats for a rich marine biodiversity. Rapid expansion of fisheries in the region resulted in depletion of most fishery resources and loss of biodiversity.

Objective

This paper attempts to identify the trade-offs between conservation and socio-economic objectives in managing a tropical marine ecosystem exploited by multi-species fisheries. Also, the possibility of using vessel buy-backs to achieve conservation goals is assessed. The northern South China Sea (NSCS) is used as a case study.

Methodology

An Ecopath model of the early 2000s NSCS was used as a case study to evaluate the trade-offs between different objectives in managing tropical multi-species fisheries. The model consists of 38 functional groups with six fishing sectors. Multi-objective decision analysis was applied to identify and display policy trade-offs under conflicting objectives that include: economic rent, employment, ecosystem integrity and conservation of vulnerable species. The cost of restructuring the fishing fleet to achieve the optimal fishing fleet configurations given the range of objectives was estimated by evaluating the cost of a hypothetical buy-back scheme to buy-out the estimated surplus fishing effort under each management scenario.

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RESULTS AND DISCUSSION

This study shows that current management of the NSCS is sub-optimal both in terms of conservation and economic objectives (Figure 1a). Economically, the current status of the NSCS fisheries appeared to be maximizing for net economic benefits under a high discount rate. Improvement in both conservation status and economic benefits can be achieved by reducing fishing capacity. Such improvement could be achieved by reducing fishing effort of sectors that have large impacts on intrinsically vulnerable stocks and rebuild these stocks.

However, the implementation of conservation plans may be hindered by the reduced number of fisheries-related jobs and the lack of alternative livelihoods (Figure 1b). Socially, in the past few decades, the NSCS fisheries appeared to have developed with strong focus on employment benefits. Fishers maintain their income from fishing by targeting species further down the food web and, in some cases, using destructive fishing methods. Achieving conservation objectives is likely to reduce fisheries employments.

Similar trade-offs are apparent in many tropical marine ecosystems. Thus, this analysis supports claims from previous studies that solving the alternative livelihood problems appears to be a priority for improving management and conservation in these ecosystems. Based on calculations from the model outputs, a buy-back scheme that is funded by fishers might be effective in reducing fishing capacity. However, public funds are required if management objectives focus strongly on conservation. This might be justified by the direct or indirect benefits to society that could be provided by well-conserved ecosystems. This study highlights the conflict between maximizing conservation and social objectives, although win-win solutions between conservation and economic objectives may be possible.
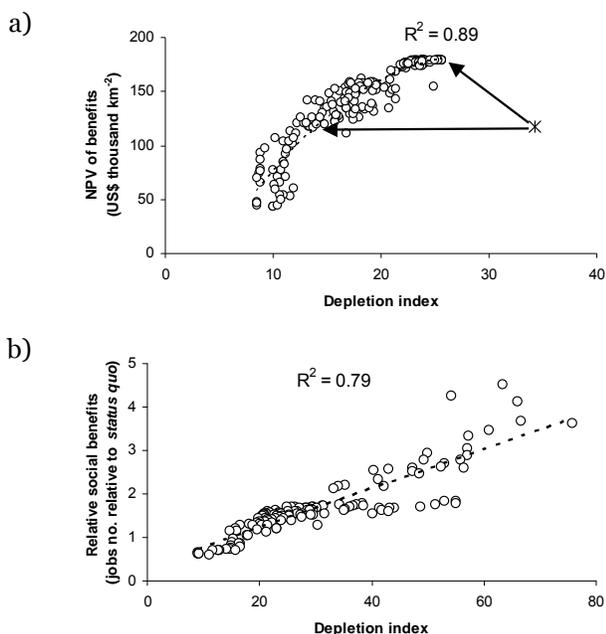
Figure 1. Pareto-frontier between (a) the net present value of benefits (profit) of the fisheries, social (expressed in number of jobs created relative to the status quo) and estimated depletion index assuming a 3 % discount rate.

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Supporting ecosystem based management
on the west coast of Vancouver Island[1]

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Computer-based ecosystem models play a fundamental role in the transition to ecosystem-based management because they can represent complex systems with multiple species, trophic interactions, environmental forcing factors, habitat preferences, fisheries impacts, as well as scenario analysis (Christensen & Walters, 2004), thereby facilitating the decision making process in marine management.

On the West Coast of Vancouver Island (WCVI), sea otters were reintroduced in the 70s after extirpation in the 19th century. Their recovery and expansion along the WCVI has been controversial because of the impacts on their prey – species with high commercial (principally shellfish), cultural and existence values. However, direct and indirect benefits (e.g., profits from tourism, provision of complex habitat by increasing kelp cover) can also emerge from sea otter presence and expansion (COSEWIC 2007; Markel, 2006). For this reason, as sea otters spread down along the WCVI, the potential effects of this expansion must be anticipated with an ecosystem-based management approach for the design of regional management polices.

To explore the potential effects, we built a nearshore ecosystem model to represent the sea otter reintroduction, and their hypothesised expansion along the WCVI. The model is implemented in Ecopath with Ecosim 6 (EwE6) as a linear EcoSpace model with 30 cells of 10 km^2 hypothetically representing the area. It accounts for two types of dynamics in the ecosystem; those related to trophic cascades and those related to indirect effects provided by kelp (e.g., provision of complex habitat, refugia for juveniles and food retention for predators; see Markel, 2006). Indirect effects were represented using mediation functions. The model also considers the contribution of kelp to primary production by adding kelp particulate detritus as a functional group.

We implemented two scenarios to represent the spatial distribution of sea otters in Ecospace. For scenario a), we established two habitats (habitat 1 occupied the first cell and habitat 2 the 29 remaining cells), assigned sea otters biomass to habitat 1 and made habitat 2 equally suitable. For scenario b) we established a protected area in the first cell and added a sea otter fishery with high effort in the first years

to drive down the population in the rest of the cells. We applied EwE 6 and Individual based Modeling (IBM) model options of Ecospace.

The model only shows a logical expansion of sea otters when using scenario b) and the IMB model option. It does well reflecting a number of important dynamics (e.g., sea otters expansion along the WCVI; in the areas where sea otters are present, kelp and some fish populations increase while sea urchin and crab populations decrease) and demonstrates the utility of formally representing whole ecosystems to support the spatial and temporal analysis of different management policies.

The model will benefit from the integration of fishing impacts and socio-economic information. Ultimately, the model will be useful to evaluate effects of various management policies by predicting changes in species populations, and in the distribution of cost and benefits over different stakeholders in the study area.
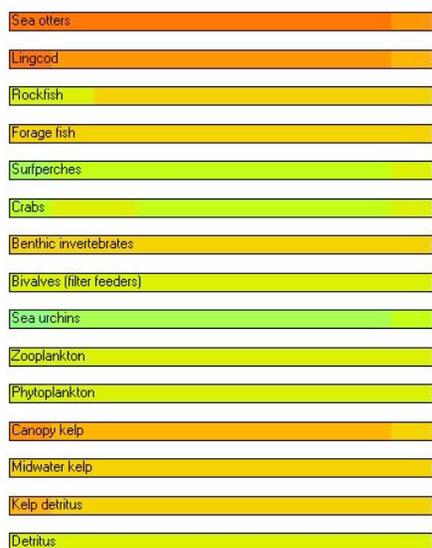
Figure 1. Example of hypothesised sea otter expansion along the the 30 cells. Red represents high abundance and green low abundance.
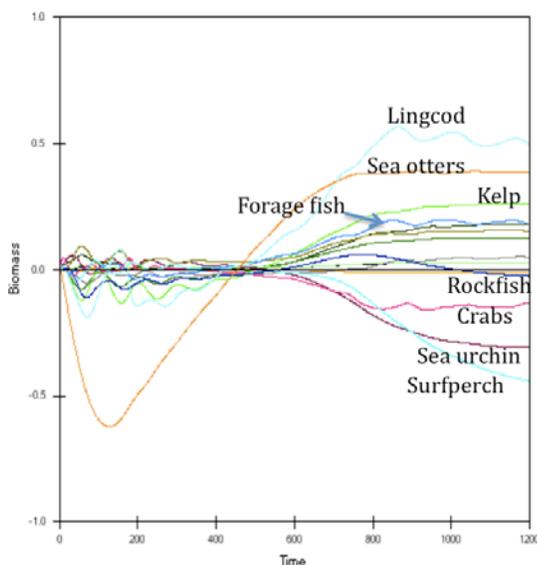
Figure 2. Predicted ecological effects of sea otters expansion.

Ultimately, we used the model to conduct scenario analysis, and evaluate the effects of three management policies. We valuate effects such as changes in species populations, and the range of impacts to different stakeholders in the study area.

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Progress in ranking species importance in whole biological communities using food web models[1]

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There is a growing interest in approaches that can be used to rank the relative ecological importance of species such as those that quantify dimensions of functional importance (e.g., interaction strength and 'keystoneness') and structural importance (e.g., weighted topological importance). It is rarely feasible to employ direct empirical studies (i.e., field experimentation) to derive such rankings within whole biological communities, but there are ongoing advances in the use of ecological models for this purpose.

The challenge lies in developing metrics that represent dimensions of species importance that are logical, that do not confuse or confound conventional ecological concepts, and that can be used to rank all species or functional groups in a community rather than just a few featured species. Some

Table 1. Spearman rank correlation coefficients between the 5 evaluated functional importance indices and the five of the 13 evaluated structural importance indices for which significant correlations were revealed (selected from Jordán *et al.*, 2008). Bold is significant (>0.29 and <-0.29). Each index is compared also to trophic level (TL).

	wD	WI[1]	WI[2]	WI[3]	WI[8]	TL
Community importance (CI)	0.28	0.28	**0.29**	**0.30**	**0.30**	-0.26
Community longevity support (CLS)	0.16	0.20	0.20	0.19	0.18	**-0.32**
Interaction strength index (trophic) (ISI)	**0.44**	**0.55**	**0.54**	**0.53**	**0.49**	-0.15
Keystoneness index (dynamic) (KI)	**-0.75**	**-0.54**	**-0.63**	**-0.66**	**-0.71**	**0.66**
Keystoneness index (network) (KS)	0.21	**0.52**	**0.49**	**0.47**	**0.42**	0.09
Trophic level (TL)	**-0.85**	**-0.41**	**-0.52**	**-0.56**	**-0.63**	**1.00**

CI (Okey, 2004; Mills *et al.*, 1993); CLS, ISI, KI (Okey, 2004); KS (Libralato *et al.*, 2006); wD, WI[1], WI[2], WI[3], WI[8] (Jordán *et al.*, 2003)

promising approaches have emerged recently, but results vary. One approach employs virtual removal experiments (dynamic simulation) using empirically-based whole food web models (Ecopath with Ecosim models) where the relative role of each species or functional group is assessed by removing them and summarising biomass responses of the remaining groups using metrics derived for that purpose (e.g., Okey, 2004; Okey *et al.*, 2004a). Another is to express results of static input-output analyses of these food web models using metrics derived for that specific purpose (Libralato *et al.*, 2006). Both of these approaches can produce (functional) indices of 'keystoneness', for example, but differences in the rankings

produced by these different approaches reflect differences in how the underlying ecological concepts are represented.

Other types of approaches, such as network-based structural indices, have also provided important insights (Jordán *et al.*, 2003; Jordán *et al.*, 2007). One way to evaluate the utility of these various approaches to ranking species importance is by applying them to the same model. The Prince William Sound Alaska model, originally constructed using Ecopath with Ecosim by a broad collaboration of experts (Okey and Pauly, 1999), was used for the first phase of this comparative work (Jordán *et al.*, 2008). Some results of that initial comparison are shown in Table 1.

We describe the expansion of this comparison to the West Florida Shelf model (Okey *et al.*, 2004b) and the Galapagos rocky reef model (Okey *et al.*, 2004a) to begin evaluating the generality of the initial published results. An evaluation of these key emerging approaches to ranking species importance is informing new frameworks for conceptualizing and visualizing species importance. For instance, the Keystone Index (KI), a top performing functional index in the present comparative research, is depicted in Figure 1 (also from Jordán *et al.*, 2008).
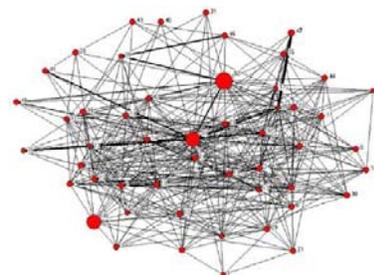
Figure 1. The Prince William Sound Alaska food web of 48 living components and 3 nonliving components expressed as keystoneness. Radius of nodes is proportional to the keystone index (KI) and the link width is proportional to biomass flows. Drawn using UCINET (Borgatti *et al.*, 2002).

Reliable and meaningful methods for estimating and ranking the relative importance of species or functional groups in whole biological communities would enable conservation prioritisation and strategy making that is effective both ecologically and financially. For example, the structural and functional integrity of stressed ecosystems might be protected or maintained with highly focused efforts to protect key species or functional groups which themselves interact strongly with other species in the system. Some of these species or functional groups are inherently vulnerable due to their naturally small populations or biomasses, or due to exotic stressors that are at odds with aspects of their life histories or population structures. This is particularly true of keystone species, which have low biomasses (or abundances) relative to their interaction strength. Refinement of these approaches and frameworks will allow their incorporation into emerging mandates for implementing ecosystem-based management, for restoring or enhancing ecological resilience, and possibly for maintaining the functionality of 'non-stationary' biological communities in the context of global climate change.

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Using ecological thresholds to inform targets for marine ecosystem-based management[1]

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Practitioners of ecosystem-based management (EBM) require sensible tools to support ecosystem-scale management decisions. A major challenge to advance EBM has been a lack of scientifically based approaches for defining management targets. We outline an approach for identifying management targets that is based on the existence of nonlinearities in the relationship between important structural and functional components of marine food webs and human-induced perturbations. In this approach, we 1) identify a set of important structural and functional components, or attributes, of the ecosystem; 2) use an Ecopath with Ecosim model of present-day Northern British Columbia's marine food web to simulate increasing perturbation, and measure the response of the attributes to those perturbations; 3) locate a threshold on the ecosystem attribute-perturbation curve when the relationship between attribute and perturbation is nonlinear (Figure 1); 4) identify empirically tractable indicators for the ecosystem attributes which are tightly correlated with the attribute values observed in the simulations; and, 5) suggest methods for designating management targets. This method draws attention to trade-offs inherent in implementing EBM, and in so doing enhances the ability of policymakers to understand and manage natural ecosystems.
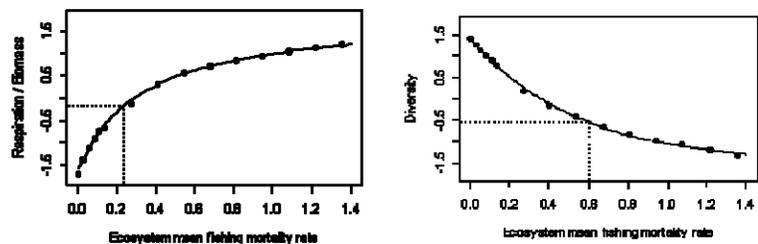
Figure 1. Attribute-perturbation relationships for 2 ecosystem attributes not related to fisheries yield and ecosystem mean fishing mortality rate. Solid lines indicate best-fit nonlinear relationships with the ecosystem mean fishing mortality rate. Dotted lines indicate ecological thresholds.

Acknowledgements

POACHING/PRESERVATION: THE CASE OF THE MERU NATIONAL PARK, KENYA[1]

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The Meru National Park (300 km north from Nairobi, the capital city of Kenya) was famous in the early eighties due to its high biodiversity and abundance of mammals and birds. After 1985, due to increasing mismanagement and poor protection, poaching increased drastically leading to the decrease of the abundance of most prestigious species: elephants, giraffes, rhinos, buffaloes, zebras, which were monitored, at least at the beginning of this decline (Atharin, 1980). Some species were eliminated. In 1998, the park management started to improve, reducing poaching activity to an extremely low level. Regular countings showed that species abundance started to increase through reproductive success and recolonisation of the area under protection. In addition, the Kenyan Government received a loan from the "Agence Française de Développement" for the recovery of the Park and simultaneous improvement of the life standards of the human riparian populations (Ganzin *et al.*, 2003).

An Ecopath model was established for the early eighties using what was known on the abundance of the various species inhabiting the Park. Numbers of individuals of each species considered were converted to weights. The model was based on estimates provided by local scientists (past and present abundance of key groups, main trends in terms of feeding and habitats), data from the literature (longevity, quantitative data on food consumption) and recent unpublished data on vegetation for 37 groups. For groups with no known abundance, an EE value of 0.95 was assumed (i.e., mortality through predation or poaching). In a further step, a data base describing the simultaneous variations of the biomass and level of poaching was established and used for Ecosim (Table 1).

Table 1. Variations of abundance (numbers) of some key mammal species of the Meru National Park, as documented from various sources (mostly data from the Kenyan Wildlife Service).

Year	Elephants	Giraffes	Zebras	Buffalos	Waterbucks
1980	2500	1600	600	4100	940
1985	2000	1200	500	3300	700
1995	200	60	200	1580	155
1998	230	110			
2000	250		65	1860	165
2001	400	225	210	2500	
2002	450	250		2800	340
2003	480	275		3050	

The main result is a summary of the history of the park from 1983 to 2003, i.e., from the first translocation of animals into the park initiated, for some species, in June 2003 to June 2006. The simulation exercises showed the strong correlation between the level of poaching and the abundance of key species. Trends of abundance variations for the groups in Table 1, from 1980 to 2003, are illustrated in Figure 1. The relevance of EwE for such terrestrial ecosystems is discussed.
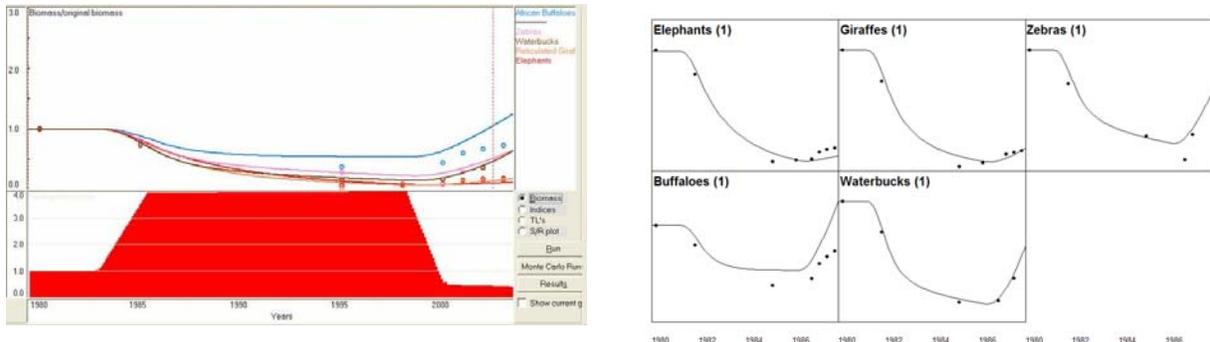
Figure 1. Trends of variations of the abundance of some key species in the Meru National Park, Kenya, as summarized by using Ecosim. Left panel: the run of ecosim as appearing on the screen of the computer; Right panel: the trend of evolution of the abundance of key groups as displayed by ecosim on request from the user).

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Ganzin, N., Toustoiu, P., Fosting, J.M., Mulama, M., 2003. Contribution des SIG à l'élaboration d'une méthode d'aide à la gestion des ressources pastorales en milieu semi-aride. Colloque in Orléans, géomatique et applications, Apport des SIG au monde de la recherche.

Using Ecopath with Ecosim and local ecological knowledge to examine conflicts between artisanal and indsutrial fisheries in the Red Sea[1]

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As in many resource usages, conflicts between small-scale artisanal and industrial fisheries are common in the Red Sea. During formal and informal interviews with fishermen of both categories and of fisheries managers, we learned the details of these conflicts. Artisanal fishers blame industrial fishers for (i) taking too much fish; and (ii) discarding a big amoung of this catch. Artisal fishers claim that these are the main causes for declining resources in addition to destruction of habitats of areas fished by artisanal fishers for centuries before the advent of industrial fisheries. Industrial fishers, on the other hand, blame the artisanal fishers for lack of efficiency and not contributing enough to the national economy, which they claim they could achieve. Policy makers and managers acknowledge the pros and cons of each sector and their decisions are swayed based on specific circumstances, usually political. They use lack of knowledge of the ecosystem and data as an excuse for bad and corrupt decisions.

The objectives of this research are, thus: (1) to model the Red Sea ecosystem as a whole, starting from primary producers to top predators, including humans as part of the system, and their trophic interactions; (2) to objectively quantify the effects of each fishing sector on the ecosystem and on each other through trophic interaction of the organisms they target. The end product will be the resource map of the Red Sea ecosystem which can be used in ecosystem based management.

Artisanal fisheries, which account for 70 % of the total landing (52 700 t·year^{-1}; see Sheppard, 2000), are typical tropical fisheries, i.e., multi-gear and multi-species. Most of the fishery is done by wooden boats of size range between 5-18 m, locally called '*sambuk*' and '*houris*'. Sambuks are bigger in size and have inboard engines. Houris are smaller and use outboard engines. Both sambuks and houris use similar fishing gears, *viz.*: hand-lining (targeting mainly coral reef fishes, e.g., snappers, groupers and emperors) and gill net (for large pelagic fishes, e.g., mackerels and tunas). The main differences in the operation of sambuks and houris are length of the fishing trip, crew size and capacity. Some fishers walk to the shore or use canoes for a day trip to catch fish in the shallow waters. The catch of artisanal fisheries is mainly for subsistence and local market. A small proportion is exported usually through merchants. The industrial fisheries operate trawlers for demersal fishes (main target being the lucrative shrimp), purse seines for schooling pelagic fishes and long lines. They are mainly owned by foreign companies and operate in a join venture with economically and politically influential local businesses. Their market is almost exclusively for export.

The approach used to tackle the above objectives was ecological modelling integrated with local ecological knowledge (LEK). Ecopath with Ecosim (EwE), a modeling tool originally created by Polovina (1984) and later developed by Christensen *et al.* (2005) was used. Data for the Red Sea were collected from two year-long field trips in 2004 and 2006, published scientific papers, reports, dissertations, magazines, unpublished materials and anecdotal sources. Data depositories such as FishBase and FAO were also used. Catch and effort data, including unreported catch, were reconstructed and used in the model. The Red Sea can be categorized as a data poor area. However, a lot of information is available in people's memory. Interviews were used to complement the data collection. Interviews also helped to understand the

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perception of fishers, i.e., an important tool in designing policy. A total of 412 fishers were interviewed from Sudan, Eritrea and Yemen, using a semi structured questionnaire.

The time series of catch per unit effort (CPUE in kg·day^{-1}·crew^{-1}) calculated from the interviews showed a significant decline. It also revealed that 39 % of the catch was not reported.

The Red Sea, a subtropical system, has high marine biodiversity. There are more than 1 200 fish species (Froese & Pauly, 2009). It is not practical for each species to be represented by itself in the model; hence grouping of similar species was necessary. To do the grouping objectively, cluster analysis was done using parameters which affect the energy flow, i.e., trophic level, habitat, and von-Bertallanfy growth parameters asymptotic weight (log W$_\infty$) and K. Once the organisms were grouped by cluster analysis, special consideration was given to the economically important species which often appear in the catch. In order to be able to see the changes to them due to fishing, they were put as separate groups.
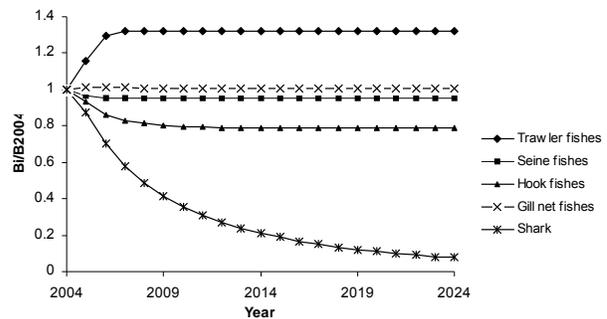
Figure 1. Relative change in biomass as a proportion of 2004 due to fishing policy where social is given the weight of 2, economic 1 and ecological 1.

The model was balanced and used as a base for the time dynamic Ecosim simulations runs. The four major policy exploration facility in EwE: maximize fisheries rent (economic), social benefits (such as employment and food security), mandated rebuilding of species and ecosystem structure or "health" (Christensen *et al.*, 2005) were explored separately and their combinations by assigning different weights. The optimal scenarios for the objectives were studied by allowing a range of fishing possibilities from open access to complete closure of fisheries and different combinations of the various fishing sectors. The simulation exercises also showed the trade offs during changes in the policy objectives or the fishing sectors. Figure 1 shows what will happen to the biomass of fish groups targeted by different gears giving if a weight of 2 is given to social objectives, 1 for economic and 1 for ecological. This combination of weight to different objectives is very realistic for the area. This result is in line with the results obtained from interviews where Shark fishery was the one which experienced the highest rate of decline based on knowledge from the fishers. The results can be used to inform policy makers and guide the decisions.

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IMPLEMENTING ECOSYSTEM-BASED MANAGEMENT: POSTER PRESENTATIONS

RESTORATION OF *CHELONIA MYDAS* POPULATION IN THE CARIBBEAN: ECOSYSTEM IMPACTS RESULTING FROM REDUCTION OF SEAGRASS HABITAT COMPLEXITY[1]

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Since the extinction of the diverse dugongid fauna in the Caribbean, green turtles have had the strongest ecological and evolutionary impacts on seagrass habitat. Evidence suggests that green turtle grazing of seagrasses can cause changes such as increased productivity and adjustments in nutrient composition of leaves (Moran & Bjorndal, 2007; Moran & Bjorndal, 2005). However, the community-wide impacts that a restored green turtle population would have on seagrass community dynamics are less clear.

To investigate this, we developed a Caribbean coral reef ecosystem model, using the modelling

Figure 1. Map of the US Virgin Islands reproduced from Grober-Dunsmore *et al.* (2007).

software Ecopath with Ecosim; where Ecopath, the foundation of the EwE suite, is a static, mass balanced snapshot of the system; and Ecosim represents a time dynamic simulation module for the exploration of past and future impacts of fishing and environmental disturbances (in this case an increase in green turtle abundance).

The coastal waters around the USVI and Puerto Rico were chosen as representative of a Wider Caribbean region coastal system (Figure 1) and modelled for an average mid-1990s situation based on Opitz (1996). Data were obtained for a total of 36 functional groups including 17 fish and 19 non-fish groups. For each group, four input parameters were estimated: biomass, production per unit of biomass (P/B), consumption per unit of biomass (Q/B), and diet composition. Estimates, in order of preference, were based on: local ecological studies, other regions of the Caribbean, or extrapolated data from comparable

reef systems. Restoration of green turtle abundance in the region was simulated through a hypothetical bio-accumulation. Non-trophic interactions were of key significance to model dynamics and represented changes to: (i) the shelter capacity from predation of seagrass beds; and (ii) abundance in prey populations; i.e., changes to the nursery function of seagrass beds as a result of increased turtle grazing.

Preliminary results indicate that at greater abundance levels, green turtles display a negative impact on their competitors, such as green turtles and other seagrass herbivores, e.g., parrotfishes and sea urchins (Figure 2). More green turtles also mean a reduction in the biomass of seagrass. Shorter blades have negative implications for the nursery (protective) function seagrass plays for the juveniles of certain species. Fewer juveniles making it to adulthood, in turn, reduces the biomass of these species (e.g., here carnivorous reef fish A). Fewer of these carnivorous fish mean less predation pressure on their prey.
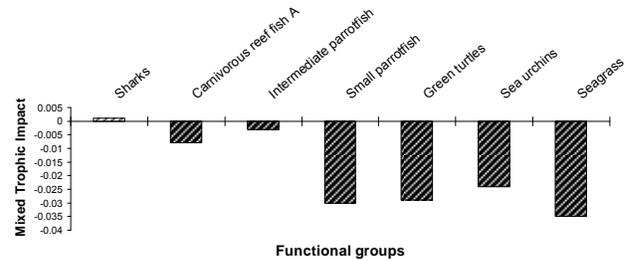
Figure 2. Mixed trophic impact of green turtles at high biomass in a Caribbean coastal ecosystem in the mid 1990s.

The system's response was particularly sensitive to changes in the vulnerability of seagrass to turtle grazing, i.e., increasing the vulnerability value led to larger differences in biomass gains/losses in the functional groups. The most significant changes were registered when the amplitude in vulnerabilities between the start and the end of the simulations was the greatest.

The degree to which and precisely how predator-prey interactions are affected by changing amounts of vegetation, the scale at which simulations were conducted and the potential trophic impacts resulting from the higher quality forage made available to herbivores as a result of turtle grazing is discussed.

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MODELLING MARINE FOOD WEBS IN THE MEDITERRANEAN SEA[1]

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Ecopath with Ecosim (EwE) enables to integrate large body of data and information in a coherent description of marine food webs and allows placing human activities and natural changes in an ecosystem context (Browman & Stergiou, 2004; Christensen & Walters, 2004). Here we review main applications of EwE in the Mediterranean Sea, where it has been applied to assess different scientific questions at different scale on coastal and shelf areas. We evidence the potential of this tool for an ecosystem approach to several human impacts and provide insights on future directions of research.

In the Venice Lagoon (Italy), Ecopath models were used to: (i) describe the trophic structure (Carrer & Opitz, 1999); (ii) compare food webs of two habitats evidencing higher maturity of seagrass meadows compared to clam fishing grounds (Libralato *et al.*, 2002); and (iii) compare the ecosystem through time evidencing the stress induced by a new fishery (Pranovi *et al.*, 2003). In the Orbetello Lagoon (Italy), the key role of cormorants and the decrease of eutrophication level were assessed by comparing mass-balance models of two different years (Brando *et al.*, 2004). Food web models for the South Catalan Adriatic Sea (Coll *et al,.* 2007, 2006a) allowed to evidence ecosystem effects induced by fishing through analysis of synthetic indices, and cross-system comparison of standardized models enabled to examine differences between ecosystems (Shannon *et al.*, 2009; Coll *et al.*, 2006b) and ecosystem effects of protection (Libralato *et al.*, 2005a). A comparison of mass-balance models with binary network models enabled to bridge both methodologies and highlighted that Mediterranean ecosystems are more degraded and less robust to species extinctions compared with non-Mediterranean areas (Coll *et al.*, 2008c). EwE model has also been developed for the Gulf of Calvi (Pinnegar and Polunin 2004), where static and dynamic applications allowed to place fishing within the ecosystem context and to examine indirect effects of fishing. A similar application to the Black Sea allowed exploring trophic cascade driven by fishing (Daskalov, 2002; Gucu, 2002). A mass balance model has been used to explore the energy pathways of the Miramare Marine Protected Area food web (Libralato *et al.*, 2006a) and a spatial one has been used to assess the effectiveness of MPAs of different sizes in the North Adriatic Sea (Zucchetta *et al.*, 2003) and the Catalan Sea (Vargiu, 2008). Moreover, an EwE model for the South Catalan Sea has been used for setting selectivity measures for trawling (Coll *et al.*, 2008a), and for examining possible management options for the recovery of demersal rays (Coll & Palomera, 2006). Few cases explore the effects of environmental forcings on ecosystem dynamics (Coll *et al.*, 2009, 2008b, 2006a; Piroddi, 2008; Daskalov, 2002) because of the general lack of time series of biological data long enough.

Moreover, trophic flows estimated by Ecopath permitted the direct coupling with ecotoxicological information thus providing a realistic representation of the bioaccumulation of organic pollutants in the food web, as in the Venice Lagoon case study (Carrer *et al.*, 2000). First attempt to couple biogeochemical and EwE models showed a promising potential of this latter for linking low and high trophic levels in an End-to-End description of ecosystems (Libralato *et al.*, 2005b).Future research would benefit from the generalization of this methodology to the Mediterranean basin, through the development of new case studies (especially in the eastern and southern part of the basin). Availability of more examples, even of mass-balance models would allow the standardized comparison in fruitful meta-analyses, as was done, for

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example, with existing models for identifying keystone species (Libralato *et al.*, 2006b) and for defining a new measure of ecosystem effects of fishing (Coll *et al.*, 2008d; Libralato *et al.*, 2008; Tudela *et al.*, 2005).

Fitting models to time series of data for their validation should be a priority, as well as the application of spatio-temporal dynamics for capturing ecosystem features and patterns. The assessment of uncertainty of model inputs and propagation of errors to results should be considered of overwhelming importance.

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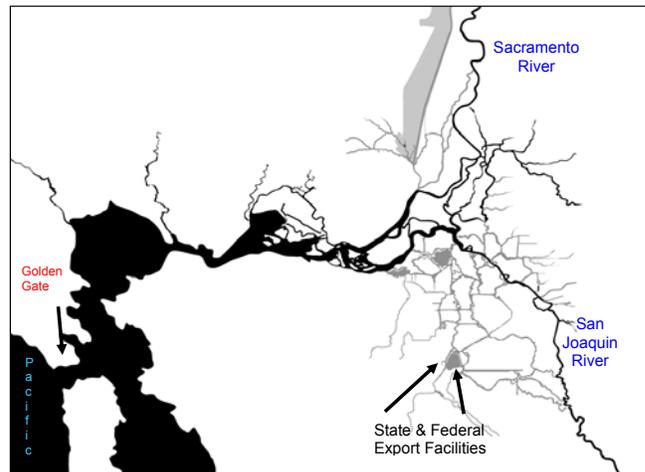# A PRELIMINARY MODEL OF THE SAN FRANCISCO ESTUARY ECOSYSTEM[1]

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The San Francisco Estuary connects the San Joaquin and Sacramento Rivers to the Pacific Ocean and includes both the San Francisco Delta and Suisun Bay (Figure 1). This is the largest estuary on the west coast of the United States and many commercially and recreationally important fish species and endangered species spend all or part of their life cycle in the estuary. The organisms in this ecosystem are subject to a wide range of stressors. Up to 5 million acre-feet of water per year is diverted for agricultural and municipal water for much of Southern California, result in major fluctuation in salinity. Scientists have catalogued approximately 250 non-native species. Large amounts of urban and agricultural pollutants enter the estuary every year from runoff. These stressors (and others) are thought to be the cause of precipitous

Figure 1. Schematic map of the San Francisco Estuary.

declines in populations in the estuary over the past decade. The focal pelagic organisms in decline include: Delta Smelt, Threadfin Shad, Longfin Smelt and Delta Smelt.

We are developing a mass-balanced trophic model for the San Francisco Estuary using Ecopath with Ecosim (EwE 6) software. Our objective is to use an ecotrophic approach to explore direct and indirect drivers of ecosystem dynamics of the San Francisco Estuary. Our emphasis is on the Pelagic Organism Decline (POD) species. The ecotrophic modelling approach incorporates trophic interactions and community food web structure to help understand the dynamic interactions between trophic groups. To do this, the model uses parameters such as biomass, production, and mortality estimates of 40 functional groups, including birds, fish, benthic invertebrates, zooplankton, phytoplankton, and detritus. Model parameters were calculated from published and unpublished data, taken from the literature, or, if necessary, estimated. The EwE modelling approach is likely to address multiple areas of concern for the POD fishes. For example, it can be used to evaluate ecosystem effects of fishing mortality (commercial, recreational, entrainment), explore management policy options, predict movement and accumulation of contaminants, and model effects of environmental changes. An initial version of the model is now operational and is being refined as updated data become available.

ECOPATH WITH ECOSIM AND BEYOND: ORAL PRESENTATIONS

USE OF EWE OUTPUTS TO INVESTIGATE ATTRIBUTES OF TROPHIC NETWORKS OF AQUATIC ECOSYSTEMS RELEVANT TO FISHERIES MANAGEMENT[1]

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While Ecopath model provides information under mass-balance assumption and allows standardized data for comparative purposes and overall summary, Ecosim and Ecospace, as dynamic models, offer greater opportunities for research, making possible the generation of a number of hypotheses and scenarios about different ecosystem states. Additionally, the recent development of EwE version 6 allows a wide range of new possibilities *via* the plugs-in, code-opening and interoperability, which enhance its analytical capabilities, including in combination with other programs and new *ad hoc* developments.

In this presentation, I will refer to investigations, some still under development, which exemplify the potential use of EwE outputs (particularly Ecopath and Ecosim) used to investigate attributes of trophic networks, within a framework, supporting management policies for conservation and fish resources management. These attributes relate topological features such as keystone species and key players; thermodynamics, particularly ecosystems metabolism; and organization, particularly resilience, ecosystem health and sustainability. Some aspects concerning the use of such attributes to represent and evaluate responses of ecosystems to disturbances (e.g., environmental and fisheries-induced) are also reviewed, as well as their relationship with conservation and resource management. The potential expansion to Ecospace is also discussed. Each case presented is based in a different number of ecosystem models (n_E) reported in literature.

Four indicators are considered to identify keystone species indices (as topological descriptors) and applied to coral reef ecosystems (n_E=10); three of them, degree, 'betweeness', and closeness indices, are based on consumption data; and a functional index based on the mixed trophic impact matrix. As expected, the response of each index depends on the attributes described by its own algorithm in relation to each particular ecosystem structure. The same happens when temperature is used as environmental driver acting on primary producers and its signal is propagated through the food web. Results suggest the possible use of keystone species indices to identify specific role of the functional groups, which is relevant for the ecosystem when perturbed.

The metabolism of ecosystems is a key process of interest because it represents the efficiency of energy (E) usage synthesized as biomass, i.e., the main currency relevant to the fisheries. Three processes are here illustrated, two of them using information at functional group level, the relationships, a) Consumption (E_{in}) vs. biomass (n_E=56), and b) Flows-out (E_{out}, i.e., predation, respiration, export) *vs.* biomass (n_E=124), both showing a metabolic constant no significantly different of the unity. These relationships should result in a proposed relationship E_{in} vs. E_{out}, also with a slope equal to unity; and c) the relationship between log B/P (representing metabolic rates) *vs.* log TL (representing size, in biomass) (n_E=98), whose slope is not significantly different from the 3/4 (=0.75) scaling constant, as described in literature for many living systems. The identification of these metabolic constants, based in a number of ecosystems is compatible with the concept of supply-demand balance (of energy) in ecosystems. Results suggest the potential use of these scaling constants as indices to identify the state of ecosystems and impacts of perturbations, which

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in turn, if they are caused by fishing, could be used for management purposes. Within this framework the concept of elasticity of demand is being explored as an index of resilience.

On the other hand, from a functional point of view, the relations PPR (primary production required) to support catches (PPR_{Catch}) and predation (PPR_{Pred}) are explored, both in relation of trophic levels (TL). The slopes (β) of the relationship between PPR_{Catch} and PPR_{Pred} vs. TL of various ecosystems (n_E=70) were computed. Balanced states (β-PPR_{Catch} = β-PPR_{Pred}) and unbalanced states (β-PPR_{Catch} ≠ β-PPR_{Pred}, with β>1, suggesting potential for increase exploitation; or β<1, indicating a negative effect of fishing on ecosystems) were identified. A preliminary diagnosis for the global state of ecosystems resulted in β= 0.6, suggesting a negative impact of fishing on ecosystems.

In terms of organization, particularly based on information theory, three concepts are analyzed: resilience, sustainability and ecosystem health, which are based on estimates of ascendency, capacity and overhead. An example is presented with the application of these concepts to determine the state (=health) of the ecosystem, the potential definition of a limit reference point at the ecosystem level, as well as a discussion of indices of robustness and sustainability of ecosystems, relevant to management.

Ecospace models represent the spatial distribution of biomass, which is a spatial expression of the same ecosystem processes represented in Ecosim, with the addition that biomass distribution is linked to habitat. The possibility of evaluate the effect of loss of habitat and their impact on the ecosystem is discussed based on the attributes (indices) above mentioned, in despite of the potential meaning of their own spatial distribution.

Finally, it is recognized that one of the great advances supported by EwE is the possibility of making information conceptually homogeneous and therefore comparable, for a large number of ecosystems (n_E > 300). Thanks to the new features of EwE6, the interoperability with other programs, code-opening and plugs-in facilities, a similar effect can be conceived for investigations beyond (but based on) EwE.

EwE6: INTEROPERABILITY USAGE, CAPABILITIES, TECHNOLOGY, STRUCTURE AND BEYOND[1]
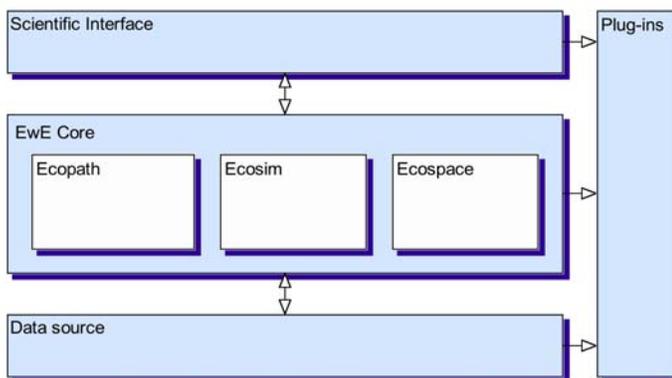
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Ecopath with Ecosim 5 has reached its technical limitations when extending the true essence of Ecopath, Ecosim or Ecospace. There have been groundbreaking technologies released under the hood of what we see as EwE6. This work will shed light on some of the interoperability usages, capabilities, technologies, structures and beyond for Ecopath with Ecosim 6.
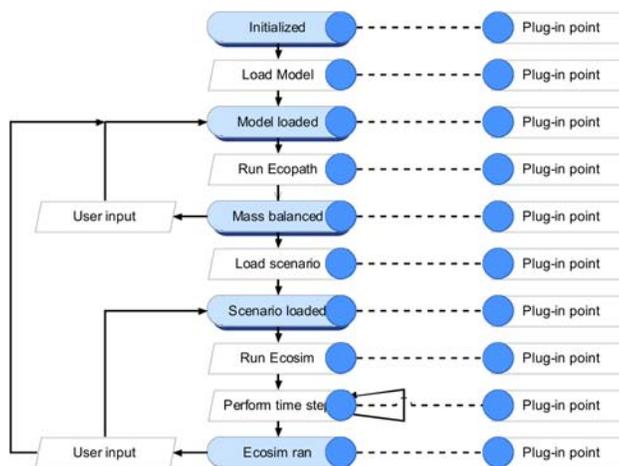
It has been close to 3 years since the first EwE6 interoperability model was announced to the public. The interoperability structure has been strengthened and polished since its initial conception, and is now a key driver to several major releases of interoperability

Figure 1. Underlying framework of EwE6. The EwECore is the central computational brain that is accessed: (1) directly by the Scientific Interface; and (2) externally, via the plug-ins.

structures. Most of you may know the Network Analysis plugin; less prominent plug-ins are Ecotroph, the Value Chain economic model, EcoBIO, and the Ecopath games.

The EwE6 interoperability technology can be split into two main streams: (1) direct core; and (2) plugin structure (Figure 1). The direct core approach utilizes the EwE6 computational core as a stand-alone component that offers all EwE6 functionality. The plugin structure has the ability to initiate code that is invoked at key moments during EwE6 execution. Plug-ins thus allows extension or overrides of EwE6 core capabilities. The most suitable technology to use is determined by the level of complexity of the intended project as seen in (Figure 2).

With these technologies, the options to extend EwE6 with new functionality, and the options to integrate the EwE6 computational core into other projects are near endless.

Figure 2. Basic outline of EwE6 plugin points where interoperability can be accessed. These are the base locations, more plugin points can and will be added in the future.

[1] Cite as: Lai, S., Steenbeek, J., Buszowski, J., 2009. EwE6: interoperability usage, capabilities, technology, structure and beyond. *In:* Palomares, M.L.D., Morissette, L., Cisneros-Montemayor, A., Varkey, D., Coll, M., Piroddi, C. (eds.), Ecopath 25 Years Conference Proceedings: Extended Abstracts, pp. 130-131. Fisheries Centre Research Reports 17(3). Fisheries Centre, University of British Columbia [ISSN 1198-6727]. 167 p.

These structures have paved the way for many of the new features Dr. Christensen will uncover in the closing session such as a Decision Support System, Big Skipper a fishing game released to the mass audience, Ecopath on the web, Value chain, model driven movies such as the Chesapeake Bay and the Blatic 2020 project.

These possibilities are growing as people start catching on to the power of this tool. You will definitely hear a lot more from this framework that unleashes the power of EwE's ecological modelling.

ACKNOWLEDGEMENTS

A GLOBAL MAP OF THE RELATIVE IMPACT OF FISHING ON THE BIOMASS OF MARINE ECOSYSTEMS FROM 1950 TO 2004[1]

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Marine ecosystems are affected by fisheries globally and it is essential to understand their historical and current impact at this scale. We present here an index to quantify the impact of fishing on the top predators and total biomass of the ecosystems of the world's oceans since the 1950s. The index is based on an ecosystem model called EcoTroph, whose representation of energy fluxes in ecosystems is equivalent to that of Ecopath models but is focused on trophic levels instead of species/species group (Gascuel *et al.*, 2009). The EcoTroph model is available as a plug-in to the Ecopath with Ecosim software version 6.

The world's oceans were divided into a grid of half degree squares. For each cell, the model uses as input parameters primary production, annual catches (available from 1950 to 2004 from the *Sea Around Us* Project's global catch database), a theoretical value for the ecosystem transfer efficiency and a relationship between the speed of biomass flow through trophic levels (TL) and temperature (Gascuel *et al.*, 2008). An algorithm based on EcoTroph and virtual population analysis, called 'Catch Trophic Spectrum Analysis' (CTSA), is used to estimate biomass by trophic levels under both the historical patterns of catches and under a hypothetical unfished state of the ecosystem ('pristine'). The index of relative impact of fishing on the ecosystem is calculated for each decade from the 1950s as the ratio of exploited to pristine biomass.

Our analysis confirms the higher impact of fisheries on predators (TL>3.5), with the decline in predator biomass occurring faster than that of total biomass (TL 2-5) (Figure 1-1). It highlights the temporal spread of fisheries from the coasts to the High Seas (Figure 1-2) and from northern to southern waters (Figure 1-3). These trends are captured in the current worldwide distribution of predator biomass (Figure 2), with a strong spatial heterogeneity and a pronounced depletion along the coasts, especially in northern countries.

Even though we use a simple approach to the modelling of ecosystems, based on trophic levels instead of species, EcoTroph and CTSA allow capturing the main impacts of fishing on ecosystems, as well as account for ecological and environmental factors such as primary production, temperature and top-down effects. We note that results show little sensitivity to the parameters of transfer efficiency, but that accounting for top-down effects can alter the effects of fishing in heavily exploited ecosystems. The global maps presented here give a first synthetic vision of the global impact of fisheries and confirm trends in ecosystem biomass that were previously inferred through proxies (Morato *et al.*, 2006; Pauly & Watson, 2005) but never directly demonstrated.

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[1] Cite as: Tremblay-Boyer L., Gascuel D., Pauly D., 2009. A global map of the relative impact of fishing on the biomass of marine ecosystems from 1950 to 2004. *In*: Palomares, M.L.D., Morissette, L., Cisneros-Montemayor, A., Varkey, D., Coll, M., Piroddi, C. (eds.), Ecopath 25 Years Conference Proceedings: Extended Abstracts, pp. 132-133. Fisheries Centre Research Reports 17(3). Fisheries Centre, University of British Columbia [ISSN 1198-6727]. 167 p.
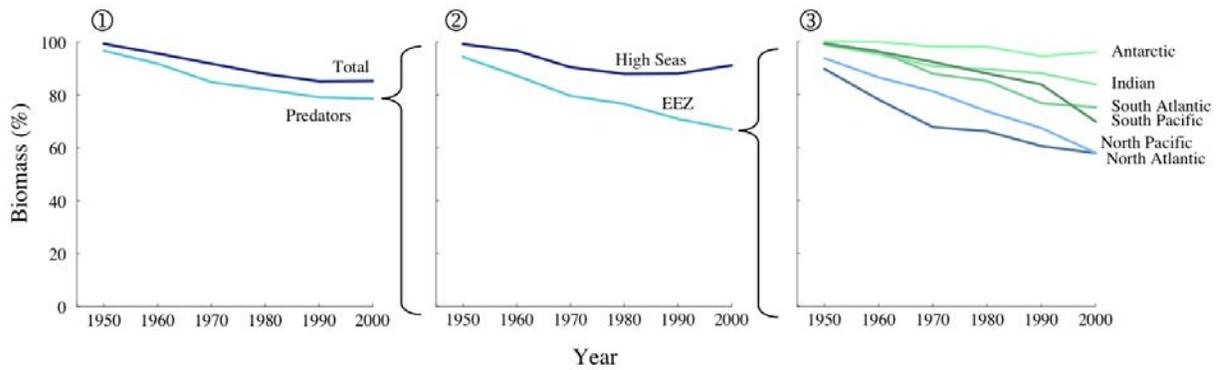
Figure 1. Global trends in biomass remaining compared to pre-1950 levels for (1) total (TL 2-5) vs. predators (TL > 3.5); (2) predators in High Seas and Economic Exclusive Zones (EEZs); (3) predators in EEZ by oceans, from South to North.
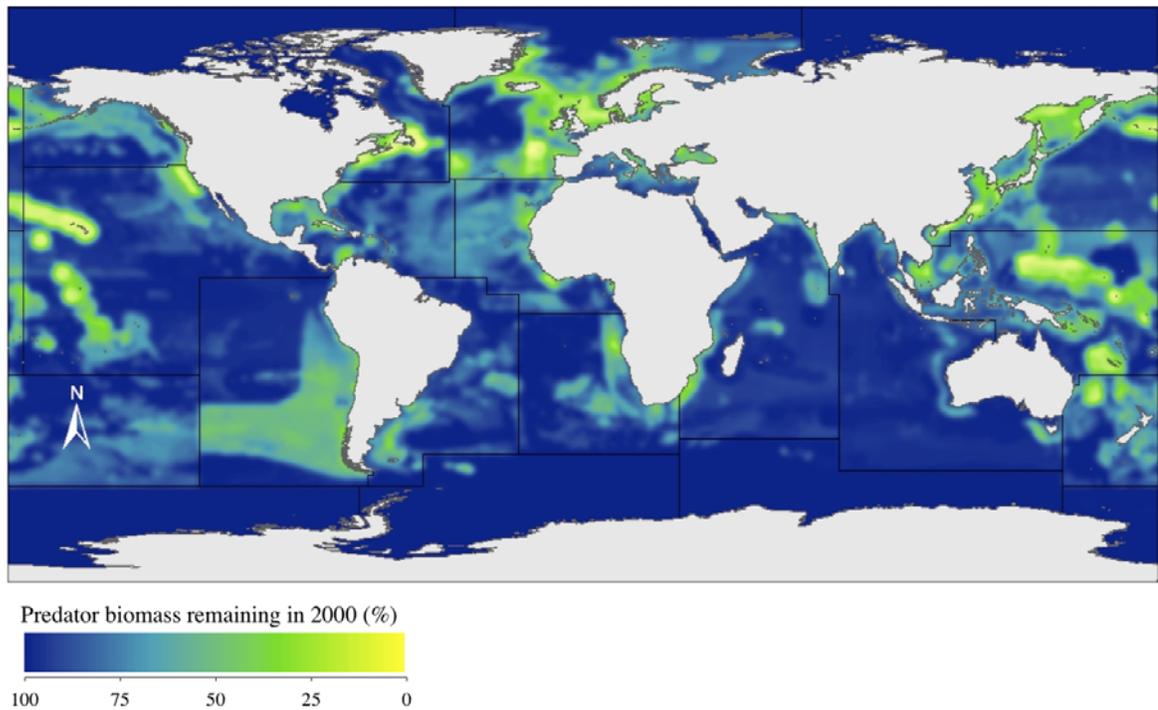
Figure 2. Predator biomass remaining compared to pre-1950 levels.

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Dynamic linking of Ecosim and the GOTM
biogeochemical model using plugins[1]
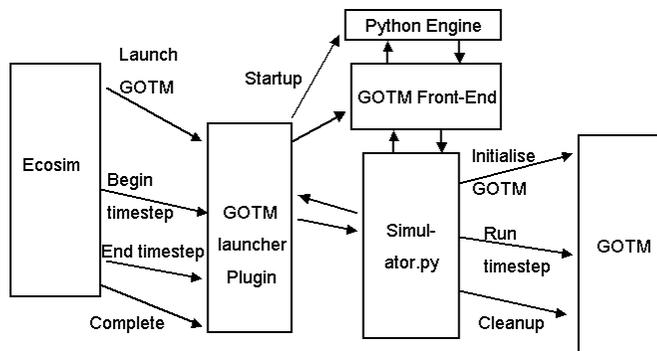
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The plugin manager that is part of version 6 of EwE was used to create a link with the existing model GOTM (General Ocean Turbulance Model; Burchard & Bolding, 2007). GOTM is implemented in FORTRAN with a Python Front end and is a 1-dimensional water column model. The link is a dynamic one with GOTM being loaded from within EwE at runtime and set up so that data can be exchanged with the Ecosim component of EwE whilst the model is running.

Python is an interpreted language. We use a '.net' version of the Python interpreter (Pythonnet, 2006) as a dynamic library (dll) within a EwE plugin to run the python scripts for the front end. 'Python.net' allows the Python interpreter to access the variables of the whole '.net' system including those of EwE. When the Python interpreter launches GOTM, both EwE and GOTM share a common process and can share information.

Most of the functionality of the EwE-GOTM interface resides in a middleware layer implemented as the main EwE plugin. This middleware layer implements the overridden interface calls for the EwE plugin. These are the plugin initialisation, GUI, model initialisation, start and end of Ecosim timestep and end of run interfaces. The GUI is currently a file picker and launcher for the Python part of the model (although could potentially be expanded to accept a wider range of run time options such as functional group picking and length of run selection). Upon Launch the standard GOTM interface allows GOTM parameters to be loaded and the

Figure 1. The link between Ecosim and GOTM showing the components and calls of the linked system. Data such as timestep length may be sent and returned by these calls.

simulation started. The two simulations negotiate the biological model step size so that the two programs will be synchronized, with the EwE simulation length being supplied by GOTM (Figure 1).

The two programs run in a synchronized way, with each part run in a separate blocking thread. All thread handling is carried out by the middleware layer which is called by both Ecosim and GOTM (so that the plugin is multithreaded). GOTM controls the semaphore to stop and start Ecosim and vice-versa. GOTM runs for a month of simulation and then releases the Ecosim thread, which is stopped at the start of the Ecosim timestep, before itself blocking. When Ecosim reaches the end of the timestep it unblocks GOTM and stops itself.

The Interface layer has access to much of the internal data of Ecosim. When a functional group is represented in both programs Ecosim can deal with the data in three ways, viz.: i) ignore it and use its own representation of that functional group; ii) shadow the external data by allowing the biomass of a functional group with no Ecopath interactions to be overwritten externally; and iii) collect the external biomass data and then perform calculations on it within Ecosim. The latter method is the most complicated because there is a mismatch between mass flows within that functional group and those in the rest of the Ecosim model.

We must also be careful when dealing with passing entities between models that the data is consistent, particularly in terms of the units. Whereas units for biomass in EwE are typically given in tonnes·km^{-2}, GOTM deals in concentration of carbon, nitrogen, phosphorous and silicon using molar units. Whilst the conversion for carbon is simply one of multiplication by a conversion factor, the potential for error is high. A future middleware layer should incorporate the reading in of critical metadata such as units and implementing what conversions are necessary (or alternatively flagging an error if data cannot be converted). The EwE plugin interface is well suited to this marshalling task because it is object oriented and can be extended with additional functions and GUI interaction to accept user input.

The EwE-GOTM interface can be turned into a more generic coupler, using the object and interface model that the plugin system incorporates (Figure 2). The coupler will incorporate a generic object model for storing the data and will implement the converters or 'casts' in the terminology of object oriented programming to convert import and export data in the format required by each client program including Ecopath, Ecosim and Ecospace. The metadata for each model can be stored in an 'xml' format, which has the advantage, that, it is machine and human readable and extensible. The Python front end for the GOTM model uses 'xml' as the means of storing parameter lists and their metadata. Because 'xml' is a format where data is tagged it is possible to

Figure 2. Using a generic object model accessible as a EwE plugin alongside similar generic models in other systems with a TCP (SOAP) bridge between the different middleware components. Netcdf is a common format for file storage of scientific data.

accept an incomplete model description (for example a list of changed parameters) and merge this with a description of all the model parameters and their defaults. Finally by using a technology such as SOAP (W3c, 2007) it would be possible for the EwE plugin to be used as part of a distributed system with data being transferred between machines running different operating systems and different means of encoding binary data.

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Chesapeake Bay fisheries ecosystem model:
computer-generated graphics for creating a gaming experience
with ecosystem data and management[1]

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We have worked with numerous colleagues in the Chesapeake Bay for many years to develop Fisheries Ecosystem Model of the Chesapeake Bay using the EwE software. The Chesapeake Bay is the largest estuary in the continental United States, located midway along the Atlantic coast of the United States. Because of it's location near Washington, DC, the Chesapeake ecosystem is not only important ecologically, but also the subject of much political concern. Thus, quantitative tools with user-friendly outputs to help understand implications of management action and human behaviour on the ecosystem are useful for providing information to a wide-ranging audience. We are en route to developing such tools using the gaming interface of EwE version 6. As an intermediate step we have developed a 6-minute documentary of life in waters of the Chesapeake Bay.

The documentary is developed using a 3D gaming engine, and tells the story of how the oyster populations have plummeted, of the current state, and it finishes with a 'dream-scene' expressing how the Bay may look in the future if we were able to restore it. The power of the animation is that we are able to communicate scientific information to a much wider range of people than what our normal scientific products allow. We believe that this form for communication has a very strong potential in an education setting, and anticipate that the underlying methodology – which includes linking a scientific ecosystem model of the Chesapeake Bay to a

Figure 4. Snapshot from Chesapeake Bay Ecosystem movie.

gaming engine – will be a very powerful tool for communicating scientific simulations in a management context. Figure 1 illustrates the computer generated graphics from the ecosystem model movie. This enables viewers and game players to see what the bay ecosystem may have looked like 50 years ago before the oyster population was drastically reduced.

[1] Cite as: Christensen, V., Lai, S., Townsend, H., 2009. Chesapeake Bay fisheries ecosystem model: computer-generated graphics for creating a gaming experience with ecosystem data and management. *In*: Palomares, M.L.D., Morissette, L., Cisneros-Montemayor, A., Varkey, D., Coll, M., Piroddi, C. (eds.), Ecopath 25 Years Conference Proceedings: Extended Abstracts, pp. 136. Fisheries Centre Research Reports 17(3). Fisheries Centre, University of British Columbia [ISSN 1198-6727]. 167 p.

MINOE: OPEN SOURCE TOOL TO NAVIGATE OCEAN GOVERNANCE IN THE CONTEXT OF A USER-DEFINED ECOSYSTEM[1]

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Transitioning ocean governance into an integrated ecosystem-based approach requires improved knowledge of ecosystems and existing governance arrangements. There has been an increased effort to compile and synthesize ecological and biophysical data. However, relatively little scholarship has focused on improving understanding ocean management systems and even less has developed techniques to generate governance syntheses based on ecosystem type, site-specific stressors, and societal values. Together these factors shape the way EBM is implemented in any given place or at any scale. As such, this paper presents MINOE, an open source tool, currently in its beta version, to assist stakeholders and others involved in ecosystem-based management initiatives access existing information about ocean and coastal management.

This system allows users to navigate and retrieve existing laws and regulations related to any user-defined ecosystem. The tool uses a conceptually modeled ecosystem, defined by the user, to set up the analysis of laws and regulations. A user may opt to use an ecosystem model developed with Ecopath with Ecosim (EwE), a more qualitative stakeholder-guided process, or a combination of quantitative and qualitative techniques. The MINOE program then performs text analysis of laws and regulations to determine which ecosystem linkages are potentially acknowledged in the documents. Those ecosystem components that do not co-occur in any section of law are potential 'gaps'. A user can then further examine the sufficiency, history, and efficacy of those laws that do contain acknowledgement of linked ecosystem components. The primary features offered through this tool include: (i) construction of ecosystem; (ii) system performance of text analysis; (iii) two modules, i.e., a) numeric, quantitative analysis and display of law and b) regulation information aligned with ecosystem model and visualization to graphically depict data.

The tool takes the user through a series of steps in the form of a wizard. First the user constructs an ecosystem model by inputting the ecosystem elements. Each element is defined by a single term or phrase or a set of terms and phrases. For example, if coho salmon is one of the ecosystem elements, the user may input coho and also *Onchorhynchus kisutch*, *O. kisutch*, or silver salmon. Or, if the user is interested in more laws and regulations dealing more generally with the fish, she/he might choose to include salmon and salmonid. Once all elements are entered, the program uses them to generate an empty symmetrical matrix (spreadsheet format). The user inputs a number representing the strength or existence of relationship in each cell between the corresponding elements. For elements unrelated in the ecosystem model, the user inputs a zero in the corresponding cell. This ecosystem model can be saved directly in the program. The user may also import an existing ecosystem model from a spreadsheet program, such as Excel if it is saved as a comma delimited file (.csv). A user can input ecosystem models that incorporate not only foodweb dynamics, but also socio-ecological system elements and relationships. For the latter, the models entered will likely be conceptually generated based on economic activities, human impacts, and ecological elements and the relationships among one another (dependencies, positive and negative impacts).

Once the filtering options are set, the system performs the analysis on the text of the documents selected using the ecosystem model. The program organizes the laws and regulations of our analysis as a matrix of the same dimensions as the target ecosystem. Each cell contains the number of sections of law and regulation in which each dyad of terms co-occurs. Cells that contain ecosystem relationships in the model

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are highlighted, while those cells that were zero in the ecosystem model remain white. Each cell contains the number of sections of laws and regulations in which the corresponding terms (representing ecosystem elements) occurs. If a cell represents a linkage in the ecosystem model (>0) and contains zero sections of law, it is marked as a 'gap'. If a cell represents a linkage in the ecosystem model (>0) and contains one or more sections of law, it is marked as a potential linkage in law.

The user may retrieve more specific information for each cell. The user can opt to view: (1) what laws and regulations contain these elements; and (2) what agencies are responsible for these laws and regulations that contain the elements and relationships of interest. Selection of the first option brings up a list of laws and regulations, each of which the user can open and search the text of individual sections containing the ecosystem elements. The second option of responsible agencies creates a bar graph of the agencies involved in the cell's corresponding elements. The y-axis is the number of relevant sections under each agency and the x-axis contains the relevant agencies.

Additional features of the program include: a visualization module; internal search engine to retrieve laws and regulations for general traditional query; statistical analyses of network comparison between ecosystem model and related law data; and export and saving of analysis results.

We recognize no application will replace the domain specific expertise of an experienced practitioner in the field for understanding how a specific activity or resource is managed. However, our tool does provide a myriad of benefits even in its basic form. Such benefits may assist domain experts as well as non-experts as a first step to further investigation, *viz.*: offers a system to retrieve laws and regulations using the context of an ecosystem; provides objective estimation of agency involvement using a suite of laws and regulations from comprehensive suite of sectors; provides information in a transparent manner, allowing easy access to the source text for determining context.

There are several potential applications for MINOE including the government, non-governmental organizations, policy advocates, resource users, concerned citizens, and policy course instructors and students. As a tool for agencies, it could be used to improve collaboration, enhance strategic resource sharing, and increase strategic policymaking. The tool could assist lawmakers determine what agencies should be involved in a proposed law or policy based on an emerging issue such as ocean acidification or climate change adaptation. The technique could also be useful for individual agencies in writing new regulations to determine whether there are resource-sharing opportunities with other agencies in order to fulfill mandates. Beyond government uses, non-governmental organizations and other issue-focused advocacy groups could use such a tool to determine what agencies and through what laws could be targeted for lobbying in order to fulfill the groups' goals. Other types of stakeholders, including resource users or community members, may find MINOE useful in that it could promote accessibility to information about how various issues are managed. As such, the tool can provide a pathway for promoting increased public participation in decision-making, a critical component of ecosystem-based management.

The beta version of this free open source tool is currently available for download at http://minoe.stanford.edu. The completed first version of the tool will be available in September 2009.

ACKNOWLEDGEMENTS

Revealing changes in fish community at ecosystem level: use of trophic modelling and topological analysis[1]

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Biodiversity loss on marine systems could be impairing ecosystems services, although this is a process that occurs mostly in the long term, biodiversity changes, expressed as replacement in species composition, can occur in the mid-term. Those are usually detected through community analysis and correlated with environmental conditions. In this study, we use the Ecopath approach to model changes in biodiversity at community level detected in Terminos Lagoon reflected at ecosystem level. Ramos-Miranda *et al.* (2005) have pointed considerable changes in fish biodiversity and suggest a loss of functional diversity in recent years. The Terminos lagoon (southern Gulf of Mexico) is an estuarine ecosystem and a critical habitat for larval and juvenile finfish species, which supports commercial fisheries. Based on the ecological and economical value of the Terminos Lagoon, the Mexican government established the Terminos Lagoon region as a 'Protected area for Flora and Fauna' in 1994. However, continuous development of the oil infrastructure and extraction activities, urban growth, cattle and agricultural activities, and fishing make this natural protected area difficult to adequately manage. Almost 20 years after the first sampling campaign (carried out in the 1980s) an important research effort was carried out in 1998 highlighting some changes in the nekton distribution and environmental conditions (Ramos Miranda *et al.*, 2005).
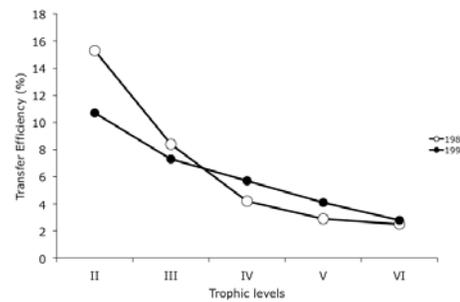
Using two trophic models representing two periods (1980/81 and 1998/99) for which important changes in biodiversity have been detected, we test the hypothesis that a decrease in biodiversity could compromise ecosystem functioning. We constructed two mass-balanced models using the Ecopath software. Data were collected from 2 biological surveys in the Terminos Lagoon using the same sampling stations in both surveys. Attributes of structure and organization at ecosystem level were compared for the two periods using summary statistics and energy network flow indices estimated by EwE software and complemented with topological aspects estimating with Ucinet software version 6.

Statistics describing the Lagoon as a whole were estimated using Ecopath and were used to asses the status of the ecosystem among two different periods. The Lagoon showed differences in the use of energy, i.e.,

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[1] Cite as: Zetina-Réjón, M., Nieto-Navarro, J.T., Ramos-Miranda, J., Arréguín-Sánchez, F., Flores-Hernandez, D., 2009. Revealing changes in fish community at ecosystem level: use of trophic modelling and topological analysis. *In*: Palomares, M.L.D., Morissette, L., Cisneros-Montemayor, A., Varkey, D., Coll, M., Piroddi, C. (eds.), Ecopath 25 Years Conference Proceedings: Extended Abstracts, pp. 139-140. Fisheries Centre Research Reports 17(3). Fisheries Centre, University of British Columbia [ISSN 1198-6727]. 167 p.

there was higher energy demand, expressed as the ratio total consumption/total flows, in 1999 than in 1980. The exports from the system and flows into detritus were relatively lower in 1999 than 1980 indicating than more energy was consumed in the system in recent years, but at the expense of a higher metabolic cost as indicated by the ratio total respiration/total flows. Also, in general terms, in 1999 the ecosystem spent more energy to support its functioning despite the reduction in biomass, expressed as total biomass/total flows. Looking at the transfer efficiency by trophic level (Figure 1), we can identify the reason of the differences in the mean transfer efficiency between 1980 and 1999. This occurs in the second trophic level, the herbivores; in 1980, more energy was incorporated into the system. However, an interesting pattern was detected, in the upper trophic levels, i.e., the transfer energy was higher in 1999 than in 1980. Again this could be supported with the evidence of the incorporation of more biomass of marine species that usually have higher trophic levels and size. The latter is related with the inverse of P/B, typically considered as an indicator of longevity and higher metabolic efficiency.
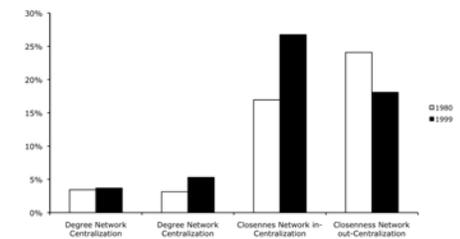
Ascendancy (A), Overhead (O), and development capacity (C) were calculated for the two periods, based on the theoretical and computational methodology suggested by Ulanowicz (1986). We estimated, viz.: the A/C ratio, an indicator of how well organized and developed the system is under actual circumstances; the O/A ratio, system resilience indicator; and the O/C, growth potential indicator. The results indicate that in 1999, the ecosystem is relatively less organized than in 1980. However, apparently there is an increase, not only in resilience. but also in the potential of the ecosystem to develop.

We estimate the 'Betweenness topological index' (Figure 2), which indicates how frecuently a node (species/group) is on the paths between every pair of nodes. We use this index to have an estimation of participation of every group in the trophic

Figure 1. Transfer efficiencies between trophic levels in two periods (1980 and 1989) for Terminos Lagoon.
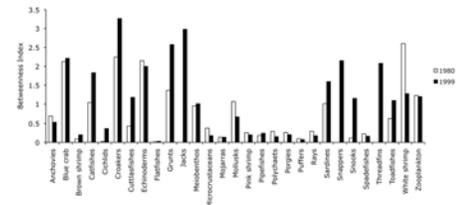
Figure 2. Betweenness index comparison in two periods, 1980 and 1989, of Terminos lagoon.

Figure 3. Topological indicators for two ecosystem states of Terminos lagoon.

network. This indicated that there is more participation of marine species in the food web in 1999 than in 1980. For example, croakers, cuttlasfishes, grunts, jacks, snappers and toadfishes (i.e., groups considered with species with marine affinity) have higher betweenness index values during 1999 than in 1980. Additionally, we estimated topological indicators for Terminos lagoon (in as predators and out as preys). The Degree index, expressed an average percentage number of connections among compartments, indicates that in 1999, the ecosystem is relatively more connected, and this difference is from the bottom up perspective. The larger the closeness index, expressed as the average distance of each compartment, the more rapidly will effects spread through the food web. For in-flows, the results indicate that in 1999 bottom up effects have more relevance than top down processes as indicated by out-flows.

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Using Ecopath with Ecosim to explore nekton community responses to freshwater input from a Mississippi River diversion in Breton Sound, Louisiana[1]

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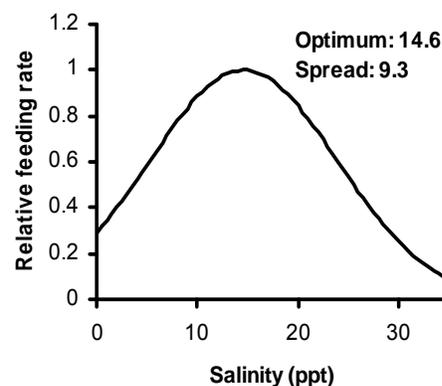13 Natural Resources bldg, East Lansing, MI 48824 USA; rothbri@msu.edu*

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Historically, freshwater flooding from the Mississippi River was responsible for creating and maintaining wetlands in Louisiana. River diversions like the Caernarvon Freshwater Diversion (CFD) can mimic flooding of the Mississippi River and are thereby expected to restore wetlands and wetland function. Wetland restoration is vital to fish and fisheries, since more than 50 % of US fisheries yields have historically been derived from estuarine or estuary-dependent species.

One concern about using river diversions as a restoration tool is that reductions in salinity associated with freshwater inputs may negatively affect estuarine nekton, especially valuable recreational and commercial species. To study the effects of the CFD on nekton biomass and community composition in Breton Sound, we used Ecopath with Ecosim (EwE) to simulate how salinity changes could affect nekton communities.

For this approach, we first created an Ecopath base model derived from five years of monitoring data collected prior to the opening of the diversion (1986-1990). Once the base model was complete, we simulated the effects of freshwater discharge on

Figure 1. The optimum salinity and standard deviation of *Cynoscion nebulosus*, derived from 21 years of monitoring data in the Louisiana Coastal area. Sub-optimal salinities will result in a reduction in relative feeding rate with a fraction defined by the standard deviation.

food web dynamics and community composition using a novel application of Ecosim, which allows the input of salinity as a forcing function, coupled to user specified salinity tolerance ranges for each biomass

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pool. The latter was done by assigning a salinity optimum and standard deviation to each species (adults and juveniles separately). This has an effect on the biomass of the species because it is linked to the relative feeding rate as shown in the example in Figure 1.

The fish assemblages at the end of the Ecosim runs, that simulated 21 years from 1986 to 2007, were compared to the fish assemblage in the Ecopath model. Three scenarios were simulated in Ecosim. These scenarios used the average monthly salinity measured from 1986 to 2007 at different distances from the diversion, at ~ 10, 25 and 35 km from the diversion respectively, to simulate the effects of three salinity regimes. By using ANOSIM subprogram in PRIMER v6 (Clarke & Warwick, 2001), statistical differences in fish assemblages were tested. For each scenario, the 5 best outcomes of 10 Monte Carlo Ecosim trial runs were used as samples in the ANOSIM analysis.
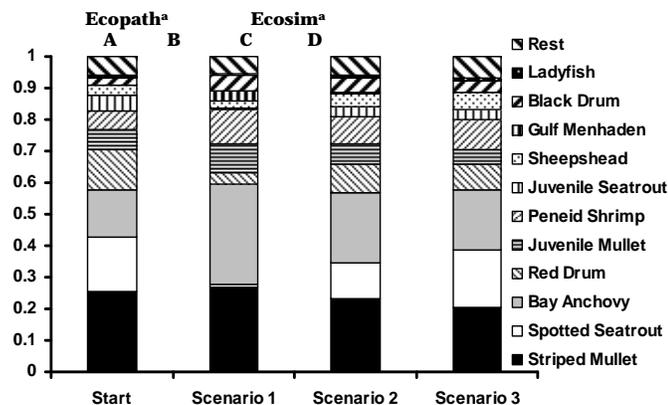
Figure 2. The relative contribution of nekton species in the fish assemblages of the start (Ecopath model) and the three Ecosim end scenarios. The letters A-D indicate that all individual scenarios are significantly different from each other; [a] indicates there is no significant difference when the end scenarios are all included in one comparison with the start.

The results show that the fish assemblages in all three scenarios are different from each other and from the fish assemblage in the Ecopath base model (Figure 2). A SIMPER analysis showed that striped mullet, spotted seatrout and bay anchovy together explained 50% of the dissimilarities between the four assemblages. However, when all the Ecosim outcomes were pooled in a comparison with the base assemblage, there was no significant difference.

This means that the CFD may not significantly alter the nekton assemblage of the Breton Sound estuary as a whole. This result also implies movement of species within the estuary instead of expatriation.

To study movement of species as a result of salinity changes, we are currently developing an Ecospace model, which is the temporal and spatial dynamic module of EwE. We aim to model a 21 by 36 km area that covers the complete salinity range in the Breton Sound estuary, divided in 1 km cells. Nekton will be given the option to stay in a cell or move to the next based on habitat and salinity requirements.

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ECOPATH WITH ECOSIM AND BEYOND: POSTER PRESENTATIONS

USING TRUE GIS DATA WITH ECOSPACE[1]

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Scientific evidence gathered over the last few decades indicates that the magnitude, rate and extend of environmental changes are the result of a complex interaction between nature and human-related systems. The growing awareness that global environmental changes are inexorably linked to human activities has fuelled the demand for environmental modelling for academic, commercial and governmental purposes (Steenbeek, 2009; Valavanis, 2002; USGCRP, 1999). Geographic Information Systems (GISs) have emerged as the prime software tool for analyzing and visualizing spatial data, but are traditionally unfit for modelling complex dynamic systems due to their restrictive two-dimensional view of the world, with limited support for both the third dimension and time. Traditional environmental models simulate dynamic systems more adequately, but often lack the facilities to visually represent results in a spatial context (Steenbeek, 2009; Livingstone & Kidd, 1999). Most present-day environmental modelling software tools were initially developed to address specific solutions in academic settings using proprietary data formats, and offer by design limited or no ability to interface with GISs. Here, a strategy is introduced to provide Ecospace, the spatial module of the Ecopath with Ecosim (EwE) software (Christensen & Walters 2004), with a true GIS interface to offer its modelling capabilities to the GIS-using community, and to facilitate the use of true GIS data in Ecospace analyses.

Conceived in 1999, Ecospace is a spatial version of Ecopath, incorporating all the key elements of Ecosim as a spatial explicit multi-species ecosystem model for fisheries policy evaluation, allowing, for example, for considering the impact of Marine Protected Areas (MPAs) in a trophic context (Walters *et al.*, 1999). Ecospace requires users to provide data in proprietary formats, supporting only the CSV (comma-separated variable) file format to interface with industry-standard GIS software, assuming constant raster data with square cells, without any reference to spatial orientation or projection. These technical limitations severely constrain the adaptation of Ecospace by communities outside the field of ecological modelling.

We are currently developing framework as summarized in Figure 1. This framework reflects a data exchange structure for Ecospace and GIS, where a GIS logic layer will convert true spatial data to and from Ecospace raster data structures on demand during the three stages of execution of Ecospace. In the initialization phase, users will select GIS datasets to connect to static or time-driven Ecospace variables. A rich preview environment will be available to assist choosing a spatial extent and resolution to sample GIS data into Ecospace. In the time-dynamic stage,
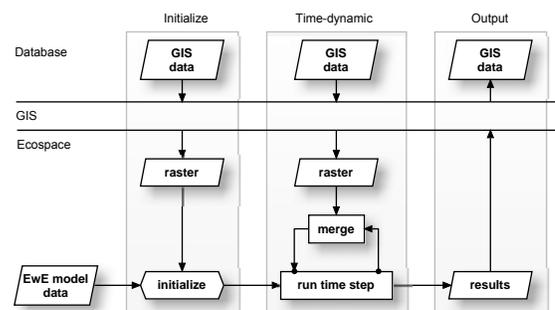
Figure 1. GIS data exchange in Ecospace.

selected GIS data will be read, converted to Ecospace compatible structures and inserted into the Ecospace computing core. When Ecospace completes, Ecospace results will be exported to GIS data formats for further consumption by external software.

This solution will require compatibility with common used GIS data formats for ecological and marine purposes. For this, GIS data formats described by the Open Geospatial Consortium (Open Geospatial Consortium, 2009), marine GIS approaches described in Breman (2004), and de-facto industry formats such as the ESRI shapfile format (Environmental Systems Research Intitute Inc., 1998) will be considered.

Ecopath with Ecosim is an open source software. The GIS logic layer that will interface between Ecospace and true GIS data cannot restrict users in terms of licencing, and needs to be open to adjustments to ensure adequate integration with the Ecospace engine. Due to its widespread industrial adaptation and broad support structure, we propose to use FWTools (Maptools.org, 2009) to serve for this purpose.

We foresee potential challenges to using this framework. For one, scientific sound procedures will have to be defined for missing spatial-temporal data. Ecosim offers solutions depending on the type of variable that this data represents, and similar assessments need to be made for every variable in Ecospace. Differences in spatial resolution will be taken care of by the GIS interpolation framework. Differences in temporal resolution can be handled either by interpolation of data or by rejecting temporal mismatching data. In this initial phase, we assume that temporal resolution is of such scientific significance that users will need to provide data at a temporal resolution matching the definitions in Ecospace.

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PRODUCTION AND CONSUMPTION IN ECOPATH MODELS: A GLOBAL OVERVIEW[1]

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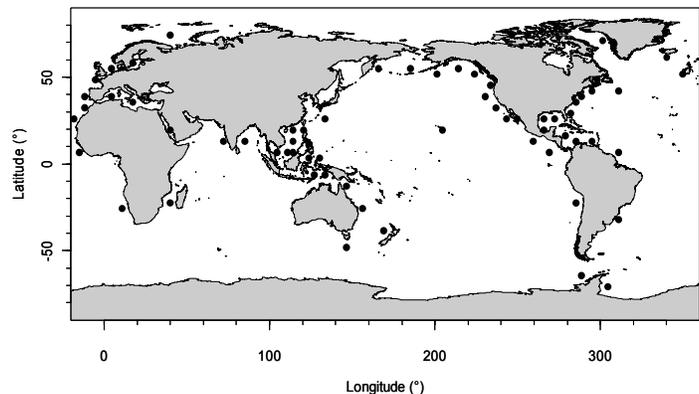VILLY CHRISTENSEN
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Ecopath with Ecosim is the most used ecosystem model throughout the world and the number of publications that use it has increased exponentially in the last decade (Christensen & Walters, 2005). In 2007, it was named as one of the ten biggest scientific breakthroughs in NOAA's 200-year history (NOAA, 2007). Ecopath is a mass balanced aquatic ecosystem model that describes the principal autotrophs and heterotrophs species individually or by aggregating them into functional groups (species with similar ecotrophic role) and inserting data on their biomass, consumption, production and efficiency; furthermore, fishing activities are included by adding data on landings, discards as well as bioeconomic parameters (i.e., value and cost). With the increasing popularity of ecosystem based management, many researchers are adapting their methodologies to deal with complicated ecosystem wide interactions, rather than single species models. Ecopath with Ecosim is the most popular candidate modelling tool for the purpose because of its existing popularity and the progress towards building Ecopath with Ecosim models for all large marine ecosystems (Christensen *et al.*, 2009).

A quality of a model depends on the input parameters, data used in the model and the theory on which the model is based. The theory of Ecopath models have been widely published and reviewed (Christensen & Walters, 2004; Plagányi & Butterworth, 2004), the data quality to a great extent depends on the fisheries regime in the area. In this paper, our aim to devise ranges for input parameters to reduce uncertainty due to parameter specification error for Ecopath with Ecosim models. We collate basic input parameters of the Ecopath with Ecosim models: production/biomass (P/B) and

Figure 1. Ecosystem models constructed with Ecopath.

consumption/biomass (Q/B) into broad functional groups. P/B and Q/B vary considerably depending on the geographic areas and on the studied species. Our purpose was to be able to combine different P/B and

Q/B from previously built Ecopath models and to define the range of intervals in which these 2 parameters fall in.

To do so, we analyzed 130 balanced Ecopath models, part of which where taken from Lyne's Morissette updated database of pedigreed models (Morissette, 2007), that cover approximately all the 66 Large Marine Ecosystems (Sherman *et al.*, 2005; see Figure 1). P/B and Q/B were grouped according to their geographic location (tropical and temperate) and the following broad functional groups: marine mammals, sea birds, turtles, elasmobranchs, pelagics and demersals fish, cephalopods, crustaceans, invertebrates, jellyfish, zooplankton, primary producers. Certain functional groups were subsequently split into subcategories as follow, *viz.*: (i) marine mammals, i.e., Mysticetes, Odontocetes, pinnipeds, sirenians, otters/bears; (ii) elasmobranchs, i.e., sharks and rays; (iii) pelagic and demersal, i.e., 'small' (asymptotic lengths <30 cm), 'medium' (asymptotic lengths 30-89 cm) and 'large' (asymptotic length =>90 cm) following the same category definition described by Christensen *et al.*, 2009 (in press); and (iv) primary producers, i.e., phytoplankton, algae and marine plants.

In order to represent the trend and the range of intervals of these 2 parameters we decided to plot P/B and Q/B versus the asymptotic length (L_∞) of each species. In models where the species were not specified but there was only a generic functional group (i.e., large pelagics) we decided to select the candidate species that constituted a large proportion (in catch) for the functional group in the ecosystem (i.e, Mediterranean Sea: tuna) using information gathered from the literature and from the *Sea Around Us* database (www.seaaroundus.org*).* The ecosystem models were also separated in tropical and temperature ecosystems to show how different P/B and Q/B could be depending on diverse climate conditions. Some preliminary results of these analyses are shown in Figures 2, 3, and 4.

Parametrising an Ecopath model is one of the biggest challenges during the construction of the model. In this study we wanted to improve our knowledge on production and consumption parameterization based on built models and to provide a useful tool to new Ecopath users for the construction of their models.
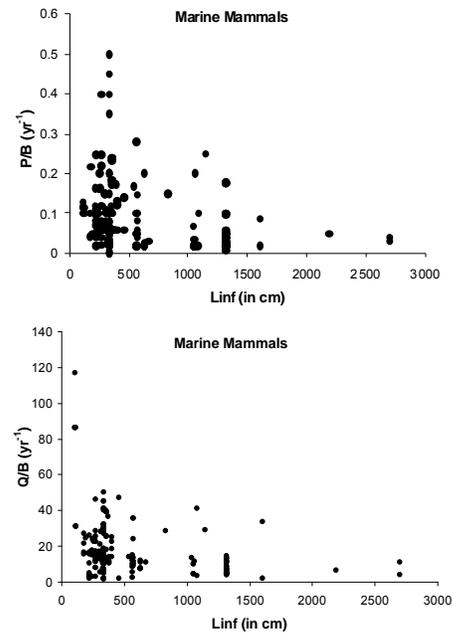
Figure 2. Graphic representation of P/B and Q/B for marine mammals functional group.
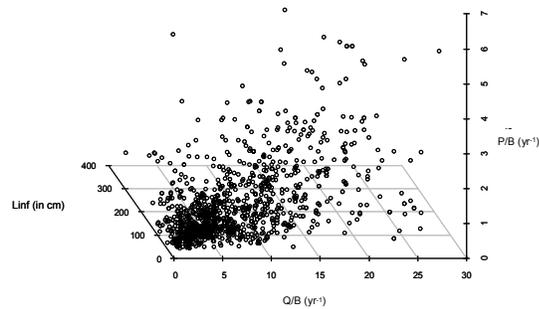
Figure 3. Graphic representation of P/B and Q/B against L_∞ for demersal and pelagic fish species.
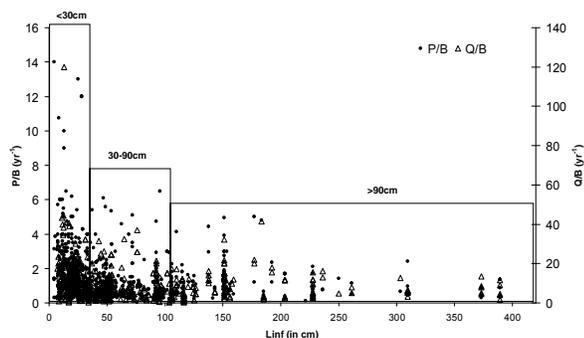
Figure 4. P/B and Q/B values for Large, medium and small demersal and pelagic fish species.

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Main drivers of marine resources and food-web changes in the Mediterranean Sea[1]

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The Mediterranean Sea is subjected to different anthropogenic and climatic drivers (e.g., Grbec *et al.*, 2008; Sangiorgi & Donders, 2004; Agostini & Bakun, 2002; Papaconstantinou & Farrugio, 2000; Dulčić *et al.*, 1999) with important effects on the marine resources (e.g., Santojanni *et al.*, 2006; Azzali *et al.*, 2002; Jukić-Peladić *et al.*, 2001; Sardà, 1998; Aldebert, 1997) and food webs (Coll *et al.*, 2008, in press, Piroddi *et al.*, submitted). Here we review these changes, as well as the main drivers, by comparing the results of food web modelling applied to three well documented case studies: the Southern Catalan Sea (in the western Mediterranean basin), the Adriatic Sea (in the central basin) and the Ionian Sea (in the eastern one). Our ultimate goal is to drawn common patterns and highlight peculiarities.
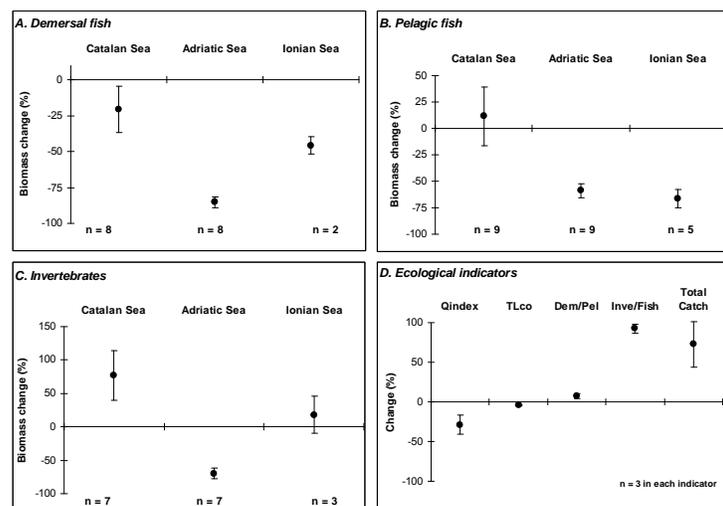
Figure 1. Overall changes (%) on biomass of demersal fish (a), pelagic fish (b), invertebrates (c), and ecological indicators (d) in the Catalan, Adriatic and Ionian Sea through time.

Mass-balance models representative of these areas had been previously fitted and calibrated to time series of data using Ecosim (Christensen & Walters, 2004). The Southern Catalan Sea was calibrated from 1978 to 2003 (Coll *et al.*, 2008), the Adriatic Sea from 1975 to 2002 (Coll *et al.*, in press) and the Ionian Sea from 1964 to 2003 (Piroddi *et al.*, submitted). Using results of these models, we first compare the trajectories of commercial and non commercial species with time applying a meta-analysis approach, and identifying the direction and magnitude of changes. Then, main drivers of these changes are summarized by quantifying the importance of trophic interactions, environmental factors and fishing activities, and various trophodynamic indicators are used to explore the structure and functioning of the food webs.
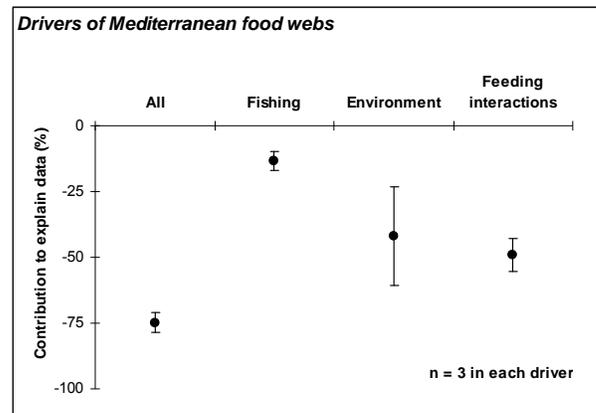
Figure 2. Overall contribution (%) of main drivers to the calibration of the Catalan, Adriatic and Ionian Sea models with time.

Our results highlight that a general decrease is observed in the three areas considering demersal fish biomass (Figure 1a), although the magnitude of decline is higher in the Adriatic and the Ionian Sea. Pelagic fish biomass have also declined in both the central and eastern areas (Figure 1b), while overall changes are positive but not significant in the western side. This is due to opposite changes observed in exploited species such as *Engraulis encrasicolus* and *Sardina pilchardu*s and in non-exploited species, such as benthopelagic fish (Coll *et al.*, 2008).

Both the Catalan and the Ionian Sea, on the contrary, show an overall increase of invertebrates groups (Figure 1c), although commercially important species such as Nephrops norvegicus have declined in the Catalan basin as well as in the Adriatic Sea (Coll *et al.*, 2008, in press), which shows an overall decline in invertebrate groups.

These changes are translated into significant declines of the Kempton's Biomass diversity Index and mean trophic level of the community in the three study areas, whereas there is an overall increase in the invertebrates/fish biomass (Figure 1d). Overall, the total catch from these areas have increased during the decades analysed. The three food web models notably captured the dynamics of available data (Figure 2). Feeding interactions and environmental data substantially contributed to explain time series, and were followed by fishing which contributed to explain about 13 % of the variability.

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A preliminary model of coastal resources of the Pantagonian marine ecosystem[1]

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The Patagonian Marine Ecosystem (PME) extends roughly over the entire continental shelf off South-eastern South America, from 23° to 55°S, and is the largest shelf in the Southern hemisphere. The PME is one of the most productive ecosystems in the world, providing a favorable reproductive habitat for species such as hake, anchovies, squid, red shrimps, sardines and supporting seabird and marine mammal populations (Bakun, 1993). General aspects of the PME have been described (Jaureguizar and Milessi, 2008; Villasante & Sumaila, 2008; Agnew *et al.*, 2005;Csirke, 1987), and only quantitative modeling of the Falkland Islands has been developed (Cheung & Pitcher, 2005a, 2005b).
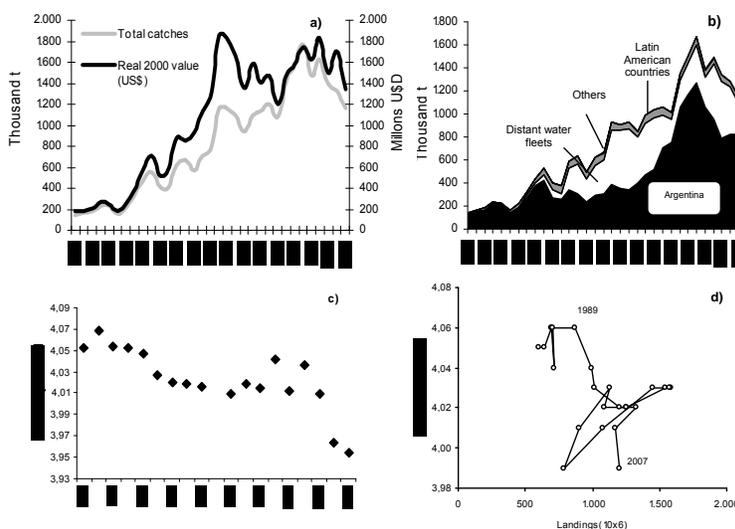
Nevertheless, a comprehensive description of the rest of the ecosystem is lacking. Using the basic analysis function of ECOPATH (Christensen *et al.*, 2005), a multispecific trophic ecosystem approach on trophic relationships in the 1990s is being constructed to represent the main biomass flow as well as to study the degradation trend of the ecosystem. The ecosystem chosen is the Southern area of the Argentine EEZ. This area borders on the Southern part of the Argentinean-Uruguayan common fishing zone, and on the Northern limit of the Fisheries Interim Conservation Zones and the Fisheries Outer Conservation Zones. Required input parameters were obtained from literature and other models applied to similar ecosystems and coherently quantify state variables as well as mass and energy flows between system components. The model consisted of 44 functional groups; 43 living and 1 non-living group (detritus) were considered representing all trophic levels in the food web structure. Functional groups were categorized based on similarities in habitat, maximum body size, feeding habitat, physiological behavior and ecological distribution in order to obtain homogeneous characteristics amongst the species within a group. A functional group includes those species having a similar trophic role, and those of particular commercial interest are kept as individual groups such as Argentine hake (*Merluccius hubbsi*), Patagonian grenadier (*Macruronus magellanicus*), Southern blue whiting (*Micromesistius poutassou*), and Argentine shortfin squid (*Illex argentinus*).

Our modeling effort and assumptions lead to three key results (see Figure 1). First, the results indicate a high impact of fishing in the PME, comparable to that in the most intensively exploited temperate shelf

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ecosystems of the world (Pauly *et al.*, 1998; Christensen *et al.* 2003). In addition, fishing has adverse effects on main commercial fishery resources such as the Argentine hake, Patagonian grenadier and Argentine shortfin squid. Second, the results obtained demonstrate that the ecosystem seems to have been greatly altered by the activity of distant-water fishing fleets. Simulations also show changes in biomass, total yields and properties such as flows, consumption and production, but some parameters needs improving because of the sensibility of the values assumed.

Finally, the results show the evidence of the *fishing down marine food webs* in the ecosystem, with a strong decline of the mean trophic level of catches, from TL=4.07 to TL=3.95 between 1989-2007, at a rate average 0.0725 trophic level per decade.

Figure 1. Some key results of the preliminary ECOPATH model of the Patagonian marine ecosystem a) Total catches from the Patagonian Marine Ecosystem (volume and value) b) Catches by countries from the Patagonian Marine Ecosystem c) Trends in Mean Trophic Level d) Plot of Mean Trophic Level vs. Landings. Source: *Sea Around Us* Database and personal compilation.

However, this decline is not due to the sequential addition of newly exploited species of low trophic level to the multi-species catch.

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EXPLORING NOVEL METRICS OF ECOSYSTEM OVERFISHING USING ENERGY BUDGET MODEL OUTPUTS[1]

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With the plethora of energy budget analyses and associated outputs, we are now able to explore and detect some emerging patterns. We examined two simple relationships for over 50 ecosystems, representative of a full range of global aquatic ecosystems. These types of ecosystems include continental shelves-seas, open ocean-islands, reefs, upwelling, estuaries, and lakes. We found three main things. First, patterns of biomass vs. trophic level and biomass vs. production are generalizable in all marine ecosystems, but estuaries and lakes are different. Second, from this observation the implication is that ecological theory needs to be revisited as that developed from lakes and estuaries (i.e., easier to access aquatic systems) may not be applicable to all aquatic ecosystems, particularly larger marine systems. Finally and arguably most germane, we can use the generalized results from marine systems as a basis to develop novel metrics of ecosystem overfishing. There have been several recent efforts to explore measures of whether or not a marine ecosystem, as a system, has been exploited at sustainable levels or not. Particularly using the intercept and first (partial) derivative of biomass vs. production pattern (largely understanding the basis provided for that by the biomass vs. trophic level pattern) we develop similar such ecosystem overfishing reference points. Contrasting this to the levels of catch and productivity, we can then determine whether an ecosystem is facing exploitation that is sustainable. We present this approach as a simple way to integrate a broad range of information and to move towards an Ecosystem Approach to Management.

WHY NOT ECOPATH FOR TERRESTRIAL ECOSYSTEMS?[1]

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THE PROBLEM:

Ecopath has been a great success in fisheries research but it has rarely been used for terrestrial research. Of 225 papers in the *Web of Science* that used Ecopath since 1995, only 2 have been for terrestrial ecosystems. We ask WHY?

HYPOTHESES:

In the complete absence of data, we suggest the following four hypotheses which are neither mutually exclusive nor exhaustive: 1) trophic levels are much less clear in terrestrial communities and consequently trophic dynamics has been of little interest; 2) terrestrial ecosystems are largely driven top-down, so there has been little interest in estimating ecotrophic efficiencies; 3) most energy-flow in terrestrial ecosystems moves through the decomposer food chain, which is poorly understood and poorly studied; and 4) most terrestrial ecology focuses on behavioural studies or the conservation biology of charismatic species, and thus community dynamics is of little interest.

ANALYSIS:

Hypothesis #1 (muddled trophic levels) seems unlikely and we know of no evidence that trophic levels are more or less clearly defined in terrestrial communities compared with aquatic communities.

Hypothesis #2 (top-down control) seems correct in many undisturbed terrestrial ecosystems but is increasingly not correct in many human-modified systems in which large carnivores have been eliminated. But this does not seem a sufficient reason for not wishing to have estimates of ecotrophic efficiencies in terrestrial communities.

Hypothesis #3 (decomposer domination) seems correct but again irrelevant. Again this does not seem a sufficient reason for not wishing to have estimates of ecotrophic efficiencies.

Hypothesis #4 (individual species studies) seems the most likely explanation to us. The current terrestrial ecological literature is dominated by sophisticated studies of individual populations with a focus on behavioural ecology, conservation biology, or models of simple systems. There is no focus on community dynamics. Wildlife management agencies are largely divorced from university scientists, and have neither the funding, nor the data to use an Ecopath approach to solving their management issues.

ACKNOWLEDGEMENTS

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FISHBASE, SEALIFEBASE AND DATABASE-DRIVEN ECOSYSTEM MODELING[1]

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Building trophic network models in ecosystems consists of the following steps: (1) determine the species or species groups occurring in it and the niches they occupy; (2) establish the predator-prey matrix; (3) determine how much of each prey is consumed by each predator; (4) establish how much of these groups stay in the ecosystem in terms of mass and surface area; and (5) quantify how fast each component renews itself. These data requirements make trophic network modeling tools, e.g., Ecopath with Ecosim (EwE), currently used in ecosystem-based resource management, rather 'data hungry' (Christensen *et al.*, 2009). Moreover, these parameters are not easy to measure, are often not included in sampling designs and usually entail tedious and time consuming literature searches. A Biodiversity Information System (BIS) which includes data on life-history parameters and which can 'speak' to modeling software such as Ecopath with Ecosim is one solution to this problem.

FishBase and SeaLifeBase are two such Biodiversity Information Systems, which, by nature of the data they contain, can become mainstay companions to EwE.

FishBase (www.fishbase.org) is an online information system on key life-history parameters of the world's fish species, conceived in the late 1980s by Daniel Pauly and developed by a team of marine biologists led by Rainer Froese in the 1990s (see Froese & Pauly, 2000). It has since grown into a popular online resource, averaging 33 million hits per month with a network of more than 1 700 collaborators (individuals and institutions). FishBase's structure has more than 250 tables holding more than 4 million records of information for more than 31 000 fish species of the world, 5 000 of which are commercial fish species. These tables are related in this manner: (a) FishBase assigns a species to a taxonomic group, i.e., Family, Order, Class, etc.; (b) once clearly established nomenclaturally and taxonomically, a fish species is then assigned to geographical areas where it is known to occur, i.e., country, FAO zones, established ecosystems (e.g., large marine ecosystems, rivers, lakes, etc.); (c) biological (growth parameters, maximum sizes, spawning and reproduction, etc.), ecological (habitat, food items, diet composition, trophic levels, predators, etc.) and fisheries information are then attached to a species. These 'related' data allow FishBase to make lists of species, viz.: (i) in a given taxonomic group; (ii) found in a country or given geographic zone; (iii) in a given habitat (e.g., pelagic, demersal, etc.); (iv) in a given trophic level; and (v) combinations of (i) to (iv) sorted by maximum size. These lists respond to the data needs of EwE as enumerated in 1-3 above as provided by the 'Ecopath data', 'Species Ecology Matrix', 'Trophic pyramids' tools in the 'Information by Country/Island' and 'Information by Ecosystem' searches of the FishBase online version. However, these were provided for fish groups alone.

In response to the need to cover organisms other than fishes also occurring in marine ecosystem, the *Sea Around Us* Project, with additional funding from the Oak Foundation (Geneva, Switzerland), initiated work on SealifeBase (www.sealifebase.org) to produce a similar service for all of the world's marine animals. This joint project with the WorldFish Center is an activity endorsed and monitored by the FishBase Consortium since 2006, thus benefitting from FishBase's 21 years of experience. SeaLifeBase was developed from an empty FishBase database shell adapted to the different forms of metazoans, but with as few changes as possible, making the adaptation of SeaLifeBase data to the common web interface shared with FishBase more efficient with less programming and development (i.e., skipping at least 5 years of work on database structure and web interface construction) and thus, maintaining a consistent form of data access for fish and metazoan species. Unlike FishBase, which was started without a taxonomic standard (though the current standards followed are that of the Catalog of Fishes (Eschmeyer, 1998) and hierarchy proposed by Nelson, 2006), SeaLifeBase's taxonomic structure was adapted from that of the Catalogue of Life (www.catalogueoflife.org) which is itself enhanced by expert-reviewed taxonomic data of the World Register of Marine Species (www.marinespecies.org); again saving development and encoding time for the SeaLifeBase team. These two global catalogues are the source of 56 % of the nearly 98 000 scientific names of metazoan species in SeaLifeBase (excluding data on algae from another BIS, AlgaeBase (see www.algaebase.org), which takes the species count currently available in SeaLifeBase to more than 105 000), including comprehensive information for commercially important non-fish metazoans.

FishBase and SeaLifeBase together, may respond to user demands in varying degrees (see Bailly, 2003). However, they both respond to the data needs of ecosystem-based models (see 1-3 above) for marine ecosystems and will allow for biological comparisons across species groups (e.g., Palomares & Pauly, 2009; Gascuel *et al.*, 2008), notably using the EwE approach (see, e.g., Pauly *et al.*, 2009).

Developments with EwE include extraction routines to turn FishBase and SeaLifeBase data into direct inputs for preliminary models of large marine ecosystems (see Christensen *et al.*, 2009). The use of FishBase and SeaLifeBase in ecosystem models are here demonstrated with models of the large marine
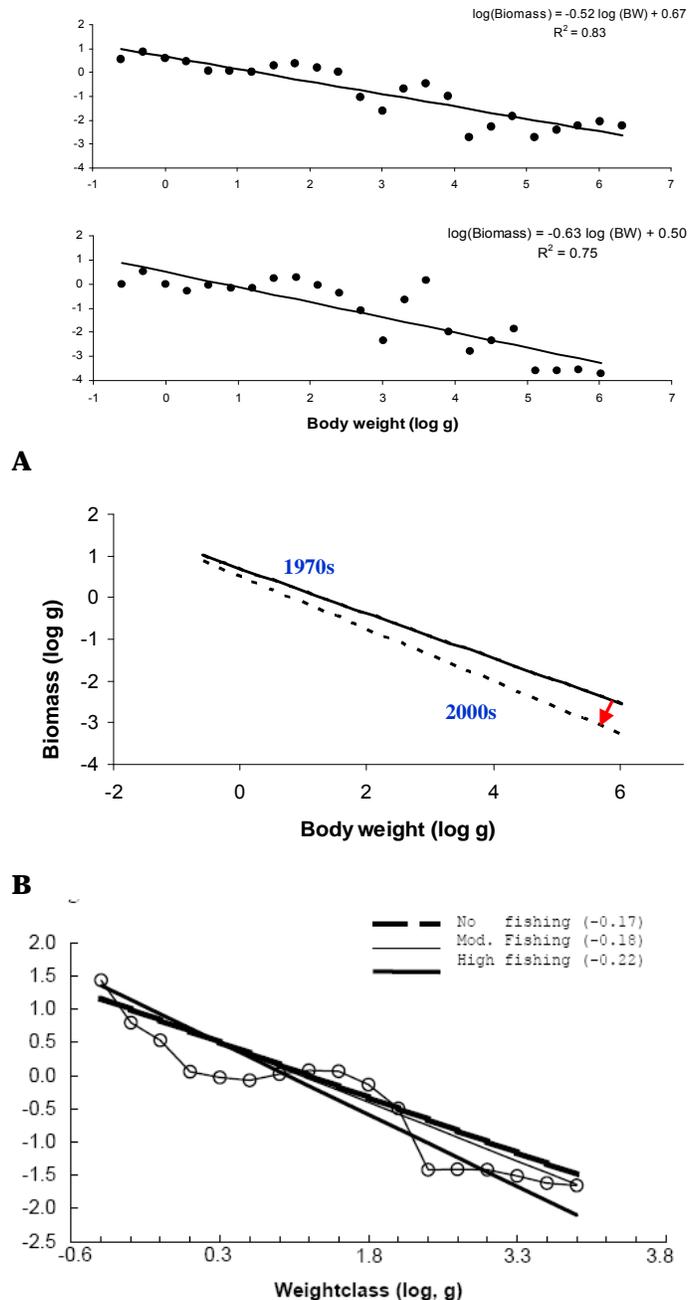
Figure 1. Results of Ecopath with Ecosim version 5 particle size distribution (PSD) routine for 35 fish and metazoan functional groups of the large marine ecosystem of the north South China Sea. Panel A: 1970s, top and 2000s, bottom; Panel B: comparison of the slopes of results in Panel A; Panel C: results of the Gulf of Thailand from Christensen (1998) emulated by results illustrated in Panels A and B.

ecosystem of the north South China Sea in the 1970s and 2000s (Cheung, W.W.F., University of East Anglia, pers. comm.) through the particle size distribution routine of EwE (v. 5). Growth parameters of the 35 fish and metazoan functional groups were extracted from FishBase and SeaLifeBase to obtain a log-log plot of biomass *vs* body weights (see Pauly & Christensen, 2002). The results (1970s model: log(biomass) = -0.52 log(body weight) + 0.67, r^2=0.83; 2000s model: log(biomass) = -0.63 log(body weight + 0.50, r^2=0.75; Figure 1a) show that the 2000s model has a steeper slope (Figure 1b), reflecting an increase in fishing pressure on the larger-sized groups and thus confirm and extend earlier results for the Gulf of Thailand (Christensen, 1998; see Figure 1c).

This exercise shows that FishBase and SeaLifeBase not only contribute to the global coverage of marine biodiversity, but makes feasible the modelling of, e.g., large marine ecosystems in which this biodiversity thrives.

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CLOSING SESSION

THE FUTURE OF ECOPATH[1]

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When a child is 25 years old, it is high time to start thinking about its future. Though, at 25, one is no longer a child but an adult with an independent existence, who may listen to her/his parents, but really needs to get a life of her/his own. We would like to see this happen to Ecopath.

To foster such independence, we have redesigned the Ecopath with Ecosim (EwE for the new reader, www.ecopath.org) software completely over the last few years, resulting in the release of EwE Version 6. This was long overdue, as the Ecopath software has been under continuous development since 1990, and during that time, has grown from a neat little, straightforward tool, to a big, complex but capable machinery. The development has largely been centralized, initially at ICLARM, later at the UBC Fisheries Centre, (Pauly, this volume), with only few people participating in the core developer group. In consequence, it has been difficult for the many modelers working with EwE to contribute to the development, apart from through publications. Modifying the actual software has been more difficult.

We would like to widen the group that is involved in the developing the EwE approach and software as part of the EwE independence. For this, we have taken some steps aimed at improving the software itself. First, we have set up a web-based bug tracking system, which we use consistently, and which we invite all users to use for bug reporting. We specifically invite users to test new (or existing features of the software), and report any bugs and suggested improvements. Secondly, we are currently developing an online Wiki system documenting features and allowing users to provide feedback and suggestions, including online edits. Further, we have published an online list of priorities for the development; mainly a result of some features of EwE5 not yet being implemented in EwE6. The missing features illustrate lack of resources, and we invite anyone with interest in implementing new or lacking features to join forces with us.

Our emphasis with the redevelopment of EwE has been on modularizing, that is, on breaking up the integrated software code to small, rather independent building blocks that can communicate with each other, but which do not interfere with the internal workings of one another. We have done this as it opens several avenues for use and development, in spite of the considerable challenges it poses.

One avenue is that we make it simple and straightforward for modelers to use the EwE framework to develop their own models, modules, or analysis. Knowing a bit of programming and using freely-available software tools, users can, in a few hours, at least get started with a 'plug-in' that can communicate with the core EwE, thus allowing exploration of the wide data source made available through Ecopath models. This makes it possible to conduct analysis going beyond what is built into the software, and which would otherwise call for reprogramming in a different environment with all the challenges this poses. With plug-ins, there is access to most of the variables in EwE (and we can probably expose those not accessible on request), including during time steps in Ecosim and time and space steps in Ecospace. One can use this to extract parameters, calculate derived indices and results, and report the results to the interface or to files. Or, for instance, one can bypass part of the EwE logic to replace model formulations.

Another avenue is that it opens use *via* different interfaces. We are no longer tied to the complex scientific interface of EwE5, but can use alternative interfaces, not just the slick, though increasingly complicated,

new scientific interface for EwE6, but also simpler interfaces for decision-support systems, and, notably, the gaming interfaces we currently are developing to link the integrated programming environment, .NET, to the 3D gaming engine, Blender. This development is a necessary foundation for the development of Ocean Summits, i.e., of a decision-support facility where the best available science is made accessible to decision-makers in a scenario-development mode. We are currently developing such methodologies as part of the Lenfest Ocean Futures Project (www.lenfestoceanfutures.org), with emphasis on providing a realistic visual representation of how an ecosystem may have changed in historic time, and how management interventions may make the ecosystem look in the future, as well as of how human enterprises may be impacted. We overlay the underwater representations of the ecosystem resources with a simple decision support interface with indicators representing the state of the system and its utilization, and with options to change ecosystem drivers, such as fishing effort.

A third avenue is represented by the ability to couple to other models. We can and should not create one 'Frankenstein Model' that does everything and has a life of its own. A much better strategy is to get models representing different aspects of the world we live in to talk together, and to do so in real time, not just linking them through files. Let each model do what it is best at (and let the individual modelers do the same), and get the complete picture by using a variety of coupled models. This approach is especially important for addressing impact of climate change on ocean resources. EwE has a very solid handle on how environmental change impact ecosystems and linking this with climate, hydrographic, and species productivity/vulnerability models provides a strong capability for such studies.

Further, with the re-developed EwE we can now produce a web version of EwE as a presentation and exploration tool. We have over the last months prepared a proof of concept, i.e., a browser loads a model from a central database on a server and displays a number of interfaces, including running of Ecopath and Ecosim. The web interface is still very rough and incomplete, and needs considerable development before it is really presentable. We are sure, however, that the prospects are great. With the web interface, it becomes possible to make publicly accessible versions of the scientific models used for management and lets the interested public, including stakeholders, explore alternative management options. It will also be a great teaching tool for exploring food web models, from grade school to university. Further development depends on identification of dedicated projects, which we hope to develop in partnership with interested colleagues.

Returning now to the independence of Ecopath, I think it is time that we, developers and users of Ecopath, make plans for forming a consortium, much along the same lines as was chosen for FishBase (www.fishbase.org) a decade ago. The rationale is clear: EwE has grown to a state where we need to focus on how best to provide long-term support and scientific collaboration for its further development.

LOGISTICS

CONFERENCE VENUE

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Yellow Cab	(604) 681-1111 or (1-800-898-8294)
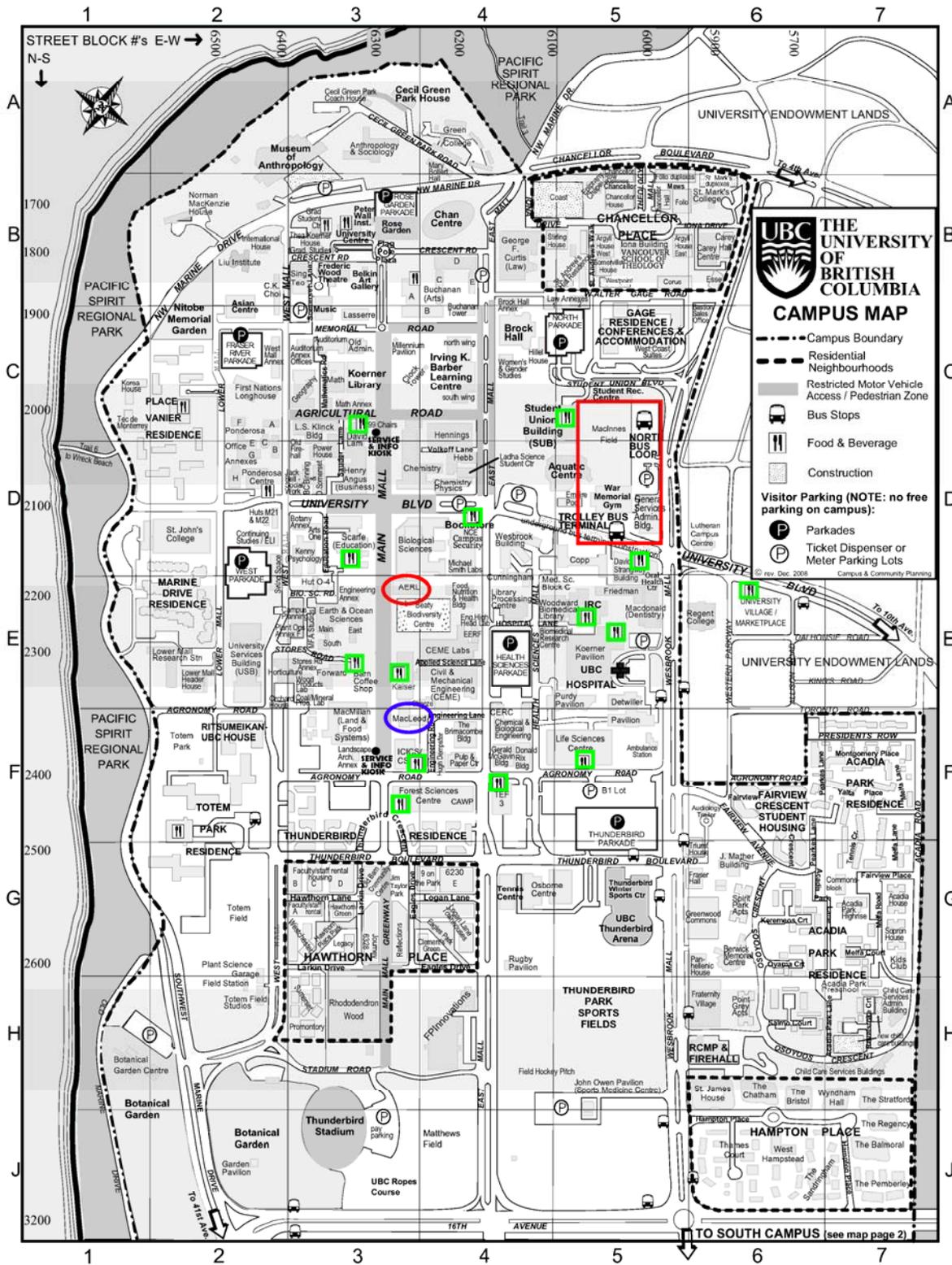
First circle: Aquatic Ecosystems Research Laboratory, Fisheries Centre, 2202 Main Mall. Second circle: MacLeod Building, 2356 Main Mall. Big square: Bus Station. Small squares: Nearby restaurants and coffee shops.

Map Directory

Site or Building Name & Address	Grid
Acadia/Fairview Commonsblock, 2707 Tennis Cres	G7
Acadia House, 2700-2720 Acadia Rd	G7
Acadia Park Residence	F/H-6/7
Acadia Park Highrise, 2725 Melfa Rd	G7
Acadia Park Preschool, 2750 Acadia Park Lane	H7
Animal Care Centre, 6199 S. Campus Rd	South Campus
Animal Science S. Campus Bldgs, 3473 Wesbrook Mall	South Campus
Anthropology & Sociology Bldg, 6303 NW Marine Dr	A3
Aquatic Centre, 6121 University Blvd	D5
Aquatic Ecosystems Research Lab (AERL), 2202 Main Mall	E3
Arts One Bldg, 6358 University Blvd	D3
Asian Centre, 1871 West Mall	B2
Audiology & Speech Sciences Classroom Trailer, 5830 Fairview Ave	F6
Auditorium, 6344 Memorial Rd	C3
Auditorium Annex Offices, 1924 West Mall	B3
Barn Coffee Shop, 2323 Main Mall	E3
B.C. Binning Studios (formerly Hut M-17), 6373 University Blvd	D3
Beaty Biodiversity Centre, 2212 Main Mall (under construction)	E3/4
Belkin (Morris & Helen) Art Gallery, 1825 Main Mall	B3
Berwick Memorial Centre, 2765 Osoyoos Cres	G6
Biological Archive Centre, 4000 Wesbrook Mall	South Campus
Biological Sciences Bldg [Science Faculty office], 6270 University Blvd	D3
Biomedical Research Ctr, 2222 Health Sciences Mall	E4
Biotechnology Laboratory, 2125 East Mall	D4
Bollert (Mary) Hall, 6253 NW Marine Dr	A4
Bookstore, 6200 University Blvd	D4
Botanical Garden Centre/Gatehouse, 6804 SW Marine Dr	H1
Botanical Garden Pavilion (enter at Gatehouse, 6804 SW Marine Dr)	J2
Botan. Gard. Greenhses/ Workshops, 6088 S. Campus Rd	South Campus
Botany Annex, 6386 University Blvd	D3
Botany Greenhouses & Trailer, 6182 S. Campus Rd	South Campus
Brimacombe Building, 2355 East Mall	F4
Brock Hall and Brock Hall Annex, 1874 East Mall	C4
Buchanan Building (Blocks A, B, C, D, & E) [Arts], 1866 Main Mall	B3/4
Buchanan Tower, 1873 East Mall	C4
C.K. Choi Building for the Institute of Asian Research, 1855 West Mall	B2
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Campus Security, 2133 East Mall	D4
Carey Hall, 1815 Wesbrook Mall	B6
Carey Centre, 5920 Iona Drive	B6
Cecil Green Park Coach House, 6323 Cecil Green Park Rd	A3
Cecil Green Park House, 6251 Cecil Green Park Rd	A3
CEME — see Civil & Mechanical Engineering Building	
Centre for Women's & Gender Studies, 1896 East Mall	C4
Chan Centre for the Performing Arts, 6265 Crescent Rd	B4
Chancellor Place	B5
Chemical & Biological Engineering Bldg, 2360 East Mall	F4
Chemistry Building, 2036 Main Mall	D3
Chemistry Physics Building, 6221 University Blvd	D4
Child Care Services Admin. Bldg, 2601 Acadia Rd	H7
Child Care Services Bldgs, 5580-5690 Osoyoos Cresc	H7
Civil & Mechanical Engineering Bldg (CEME), 6250 Applied Science Lane	E4
Civil & Mechanical Eng. Labs ("Rusty Hut"), 2275 East Mall	E4
Coal & Mineral Processing Lab, 2332 West Mall	E3
Continuing Studies Bldg [English Language Institute], 2121 West Mall	D2
Copp (D.H.) Building, 2146 Health Sciences Mall	D5
Cunningham (George) Building [Pharmaceutical Sc.], 2146 East Mall	E4
Curtis (George F.) Building [Law], 1822 East Mall	B4
David Lam Learning Centre, 6326 Agricultural Rd	C3
David Lam Management Research Ctr, 2033 Main Mall	C3
Donald Rix Building, 2389 Health Sciences Mall	F4
Dorothy Somerset Studios (formerly Hut M-18), 6361 University Blvd	D3
Earth & Ocean Sciences (EOS) - East, 2219 Main Mall	E3
Earth & Ocean Sciences (EOS) - Main and South, 6339 Stores Rd	E3
Earthquake Engineering Research Facility (EERF), 2235 East Mall	E4
Engineering Annex, 6298 Biological Sciences Rd	E4
Engineering High Head Room Lab, 2225 East Mall	E4
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Faculty of Law Annexes 1 and 2, 6050 and 6020 Walter Gage Rd	B4/5
Fairview Crescent Student Housing, 2600-2804 Fairview Cres	F6
Fire Department, 2992 Wesbrook Mall	H6
First Nations Longhouse, 1985 West Mall	C2
Flag Pole Plaza (Main Mall & Crescent Rd)	B3
Food, Nutrition and Health Bldg, 2205 East Mall	E4
Forest Sciences Centre [Faculty of Forestry], 2424 Main Mall	F4
Forward (Frank) Building, 6350 Stores Rd	E3
FPInnovations (formerly FERIC and Forintek), 2601/2665 East Mall	H4
Fraser Hall (public rental housing), 2550 Wesbrook Mall	G6
Fraternity Village, 2880 Wesbrook Mall	H6
Frederic Wood Theatre, 6354 Crescent Rd	B3
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General Services Administration Bldg (GSAB), 2075 Wesbrook Mall	D5
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Gerald McGavin Building, 2386 East Mall	F4
Graduate Student Centre (Thea Koerner House), 6371 Crescent Rd	B3
Green College, 6201 Cecil Green Park Rd	A4
Greenwood Commons (public rental housing), 2660 Wesbrook Mall	G6
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Hawthorn Place	G/H3
Hebb Building, 2045 East Mall	D4
Hennings Building, 6224 Agricultural Rd	C4
Henry Angus Building [Sauder School of Business], 2053 Main Mall	D3
Hillel House, 6145 Student Union Blvd	C4
Horticulture Building/Greenhouse, 6394 Stores Rd	E2/3

Site or Building Name & Address	Grid
Hugh Dempster Pavilion, 6245 Agronomy Rd	F4
Hut M-21 & Hut M-22, 2109 West Mall	D2
Hut O-4, 6365 Biological Sciences Rd	E3
ICICS/CS (Institute for Computing, Information & Cognitive Systems/ Computer Science - formerly CICSR/CS), 2366 Main Mall	F4
Instructional Resources Centre (IRC), 2194 Health Sciences Mall	E5
International House, 1783 West Mall	B2
In-Vessel Composting Facility, 6035 Nurseries Road	South Campus
Irving K. Barber Learning Ctr (former Main Library)	C4
Jack Bell Building for the School of Social Work, 2080 West Mall	D3
John Owen Pavilion & Allan McGavin Sports Medicine Centre, 3055 Wesbrook Mall	H5
Kaiser (Fred) Building [Faculty of Applied Science], 2332 Main Mall	E3
Kenny (Douglas T) Building, 2136 West Mall	D3
Kids Club, 2855 Acadia Rd	G7
Klinck (Leonard S.) Bldg, 6356 Agricultural Rd	C3
Koerner (Walter C.) Library, 1958 Main Mall	C3
Korea House (in Place Vanier), 1935 Lower Mall	C1
Ladha (Abdul) Science Student Ctr, 2055 East Mall	D4
Landscape Architecture Annex, 2371 Main Mall	F3
Lasserre (Frederic) Building, 6333 Memorial Rd	C3
Leon and Thea Koerner University Centre, 6331 Crescent Rd	B3
Library Processing Centre, 2206 East Mall	E4
Life Sciences Centre, 2350 Health Sciences Mall	F5
Liu Institute for Global Issues, 6476 NW Marine Dr	B2
Lower Mall Header House, 2269 Lower Mall	E2
Lower Mall Research Station, 2259 Lower Mall	E2
Macdonald (J.B.) Building [Dentistry], 2199 Wesbrook Mall	E5
MacLeod (Hector) Building, 2356 Main Mall	F3
MacMillan (H.R.) Bldg [Faculty of Land & Food Systems], 2357 Main Mall	F3
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Marine Drive Residence (student housing), 2205 Lower Mall	D2
Mathematics Annex, 1906 Mathematics Rd	C3
Mathematics Building, 1984 Mathematics Rd	C3
Mather (James) Building, 5804 Fairview Ave	G6
Medical Sciences Block C, 2176 Health Sc. Mall	E4
M.F.A. Studios (formerly B.C. Binning MFA Studios), 6363 Stores Rd	E3
Michael Smith Laboratories, 2185 East Mall	D4
Museum of Anthropology, 6393 NW Marine Dr	A2/3
Music Building, 6361 Memorial Rd	B/C3
Networks of Ctrs of Excellence (NCE), 2125 East Mall	D4
99 Chairs/Trek Express, 2015 Main Mall	C3
Nitobe Memorial Garden, 1903 West Mall	B/C2
Norman MacKenzie House, 6565 NW Marine Dr	B2
NRC Institute for Fuel Cell Innovation, 4250 Wesbrook Mall	South Campus
Old Administration Building, 6328 Memorial Rd	C3
Old Barn Community Centre, 6308 Thunderbird Blvd	G3
Old Firehall, 2038 West Mall	D3
Orchard House (formerly Header House), 2336 West Mall	E2
Osborne (Robert F.) Centre/Gym, 0108 Thunderbird Blvd	G4
Panhellenic House, 2770 Wesbrook Mall	G6
PAPRICAN Building, 3800 Wesbrook Mall	South Campus
Peter Wall Institute for Advanced Studies, 6331 Crescent Rd	B3
Place Vanier Residence, 1935 Lower Mall	C/D2

Site or Building Name & Address	Grid
Plant Ops Nursery/Greenhouses, 6116/6136 Nurseries Rd.	South Campus
Plant Science Field Building, 6182 S. Campus Rd	South Campus
Plant Science Field Station & Garage, 2613 West Mall	H2
Plant Operations Annex F, 6381 Stores Rd	E2/3
Point Grey Apartments, 2875 Osoyoos Cresc	H6
Police (RCMP) & Fire Department, 2990/2992 Wesbrook Mall	H6
Ponderosa Centre, 2071 West Mall	D2
Ponderosa Office Annexes: A, B, & C, 2011-2029 West Mall	C/D2
Ponderosa Office Annexes: E to H, 2008-2074 Lower Mall	C/D2
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Rodney Graham Millennium Pavilion	C3
Rose Garden	B3
Rugby Pavilion, 2584 East Mall	G4
Scarfe (Neville) Building [Education], 2125 Main Mall	D3
Sing Tao Building, 6388 Crescent Rd	B3
Sopron House, 2730 Acadia Rd	G7
South Campus Warehouse, 6116 Nurseries Rd	South Campus
Spirit Park Apartments, 2705-2725 Osoyoos Cresc	G8
St. Andrew's Hall/Residence, 6040 Iona Dr	B5
St. John's College, 2111 Lower Mall	D2
St. Mark's College, 5935 Iona Dr	B6
Stores Road Annex, 6368 Stores Rd	E3
Student Recreation Ctr, 6000 Student Union Blvd	C5
Student Union Bldg (SUB), 6138 Student Union Blvd	C4
Tec de Monterrey (in Place Vanier), 1935 Lower Mall	C1
Technology Enterprise Facility 3 (TEF3), 6190 Agronomy Rd	F4
Thea Koerner House [Graduate Studies], 6371 Crescent Rd	B3
Thunderbird Arena, 2555 Wesbrook Mall	G5
Thunderbird Residence, 6335 Thunderbird Cresc	F3/4
Thunderbird Stadium, 6288 Stadium Rd	J3
Thunderbird Winter Sports Ctr, 6066 Thunderbird Blvd	G5
Totem Park Bldgs, 2613 West Mall	H2
Totem Park Residence, 2525 West Mall	F/G2
TRIUMF, 4004 Wesbrook Mall	South Campus
Triumf House (TRIUMF Visitor's Residence), 5835 Thunderbird Blvd	G6
UBC Farm, 6182 Wesbrook Mall	South Campus
UBC Hospital, 2211 Wesbrook Mall	E5
UBC Tennis Centre, 6160 Thunderbird Blvd	G4
UBC Thunderbird Arena, 2555 Wesbrook Mall	G5
University Centre (The Leon & Thea Koerner), 6331 Crescent Rd	B3
University Services Building (USB), 2329 West Mall	E2
Vancouver School of Theology, 6000 Iona Drive	B5
Walter H. Gage Residence, 5959 Student Union Blvd	C5
War Memorial Gymnasium, 6081 University Blvd	D5
Wesbrook Bldg, 6174 University Blvd	D4
Wesbrook Place neighbourhood (under construction)	South Campus
Wesbrook Village shopping centre (under construction)	South Campus
West Mall Annex, 1933 West Mall	C2
West Mall Swing Space Bldg, 2175 West Mall	D2
Wood Products Laboratory, 2324 West Mall	E3
Woodward Biomedical Library, 2198 Health Sciences Mall	E4/5

SOUTH CAMPUS MAP

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Campus & Community Planning
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Note:

Local traffic only along Wesbrook Mall on South Campus

Construction Sites

Map Information

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INDEX OF AUTHORS

ADDENDUM

ELUCIDATION OF ECOSYSTEM ATTRIBUTES USING ECOPATH WITH ECOSIM (EwE): APPLICATION TO AN OLIGOTROPHIC LAKE IN HOKKAIDO, JAPAN[1]

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In the last decades, the status of the sockeye salmon population in the oligotrophic Lake Toya, Hokkaido, Japan has become a serious concern among the lake managers and policy makers. Whilst the decline of the sockeye salmon population has been well documented in Lake Toya, there is considerable uncertainty with regards to the impact on the broader system dynamics. We address this knowledge gap in this study by undertaking a synthesis of the Lake Toya food web using the mass-balance modeling software Ecopath with Ecosim (EwE). Lake Toya is located at the western part of Shikotsu-Toya National Park in southern Hokkaido (lat. 42°36'N, long. 140°51'E), Japan. Lake Toya is an oligotrophic system of volcanic origin with pyroclastic sediments. The lake has an almost circular shape with a surface area of 70 km² and a volume of 8.19 km³. The 173 km² catchment area of the lake is drained by 30 streams, although their discharge rates are relatively small. Sockeye salmon and masu salmon are the only fish species commercially exploited in Lake Toya, whereas the remaining species have little commercial importance.

We used the similarity of the habitat, diet and life history characteristics to build a model with 11 functional groups. The biomass estimates of sockeye salmon were derived from virtual population analysis (VPA). The masu salmon biomass was calculated using the ratio (=0.5) of masu to sockeye salmon in the angling surveys. Because of the lack of reliable data regarding the biomass of the remaining groups, the majority of the missing parameters were estimated by specifying reasonable ecotrophic efficiency (EE) values to solve the Ecopath master equation. Diet composition of masu salmon, sockeye salmon and Japanese smelt was obtained from the stomach contents of samples collected from 1999 to 2003. The diet content of amphipods, shrimp, insects, and zooplankton were specified from published literature. The potential implications of allochthonous matter on the food web dynamics of the lake were examined by introducing a second 'detritus-like' compartment that contributes to the diets of zooplankton, insects, and amphipods.

Total fish biomass density was 0.3911 t·km⁻², which is very close to the more recent empirical estimates for Lake Toya (Matsuishi *et al.*, 2002; Figure 1). In terms of biomass, the ecosystem is dominated by the Japanese smelt (303 kg·km⁻²), followed by sockeye salmon (45.5 kg·km⁻²) and masu salmon (about

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22.7 kg·km⁻²). Being a substantial portion of the masu sockeye salmon diet, the Japanese smelt has a direct positive impact on the top predator of the system. Masu and adult sockeye salmon dominate and negatively control the populations of all the smaller fish species of the lake. The anglers exert significant control on the masu and sockeye salmon populations, which then cascades as an indirect positive effect on the smaller fish populations (juvenile sockeye salmon, Japanese smelt, other fish) and as a negative impact on their prey (shrimp, amphipods). The relatively high values of the primary production/biomass more than 21.40 year⁻¹ and the biomass/total throughput less than 0.01 are indicative of a system in its early developmental stages. Connectance (0.43) and system omnivory (0.12) indices suggest a linear rather than a 'web-like' food chain structure. Internal redundancy and the system overhead are fairly high (>68% of the

Figure 1. The Ecopath outputs based on the Lake Toya food web conceptualization. Thickness and colour of the lines illustrate the magnitude of the flow rates. The vertical line demonstrates the functional TL of each biotic compartment. The estimated abundance values of the modelled groups are also displayed.

development capacity) indicating that Lake Toya possesses substantial reserves to overcome unanticipated external disturbances. Model quality obtained through the pedigree index routine of EwE was 0.413, indicating that our model is founded upon inputs that lie close to the dichotomy between local and literature-based information. We designed a wide range of scenarios using as reference existing estimates for masu (2.64 kg·km⁻²·yr⁻¹) and sockeye salmon (24.45 kg·km⁻²·yr⁻¹) catches from the mid-1990s. Using a vulnerability setting that postulates a balanced bottom-up and top-down control, our results show that the adult sockeye is quite fragile with high likelihood to collapse, while its population will not rebound unless the fishing pressure exerted is reduced by at least 50% of the reference levels.

ACKNOWLEDGEMENTS

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