Proposal for a SCOR working group on

Coupled climate-to-fish models for understanding mechanisms underlying low-frequency fluctuations in small pelagic fish

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Abstract

The low-frequency variability of small pelagic fish is one of the most emblematic and best-documented cases of fish population fluctuations not explained wholly by fishing effort. Over the last 25 years, diverse observations have been integrated into several hypotheses; however, due to limited-duration time series, hypothesis testing has proven extremely difficult with the available statistical and empirical tools. The Working Group (WG) we propose aims to incorporate and couple *ad hoc* modeling tools and expertise to tackle this scientific problem, including the gathering and updating of available datasets, historical information and knowledge from the different oceanic systems (e.g., Eastern and Western North Pacific, Southeast Pacific and Southeast Atlantic). The models we will use are a well-known physical circulation model (ROMS) already implemented in some of the systems (Curchitser et al., 2005), a recently developed Nitrogen-Phytoplankton-Zooplankton-Detritus model (NEMURO; Kishi et al. 2007), and its extension in NEMURO.SAN (Rose et al., 2006) to include individual-based models (including bioenergetics) for the small pelagic fish populations (sardine and anchovies) and their predators and fishing pressure. The WG requests three years of support to hold annual meetings, produce two scientific reports and at least one paper in a primary literature journal. Furthermore, we are committed to search for complementary financial support to broaden our capacities and outreach. The results of this WG will contribute to the understanding and managing small pelagic fish stocks in the context of climate change.

Scientific rationale and relevance

Climate-scale variability and its impact on fish resources have only recently become widely accepted (e.g., Lehodey et al. 2006), although they were first detected in the 1880s, by Ljungman. At the time, he published an analysis of the Baltic herring catch fluctuations showing a 55-year cycle due to natural conditions, apparently forcing the schools to change their spawning and feeding places (Parrish et al., 2000). The most compelling example of climate-driven fish stock changes is probably the fluctuations of sardines and anchovies described since the early 1980s, the so-called Regime Problem (Lluch-Belda et al., 1989, 1992; Schwartzlose et al., 1999). Landings of sardines show synchronous variations off Japan, California, Peru, and Chile, with populations flourishing for 20 to 30 years and then practically disappearing for similar periods. Periods of low sardine abundance have coincided with increases in anchovy populations. Benguela Current sardine and anchovies, in the Atlantic Ocean, appear to be in synchrony with Pacific stocks, but in opposite phase (i.e., Benguela sardine stocks flourishing during periods of high anchovy in the Pacific, and vice versa). As demonstrated through paleo-reconstructions based on sardine and anchovy scales deposited in anaerobic marine sediments (Baumgartner et al., 1992), and also because synchrony takes place even when different fishery management schemes exist among systems (Schwartzlose et al., 1999), fluctuations appear to be fishery-independent. Further, because of the large spatial and coherent temporal scales involved, a single global driver linked to large-scale atmospheric or oceanic forcing has been proposed to explain the variations in the different systems. The Regime Indicator series (RIS; Lluch-Cota et al., 1997), synthesized from the catch series of the four mentioned systems, has been related to the low-frequency component of different climate series, including the PDO and the NAO (Chavez et al., 2003) and the low-frequency signature in global ocean temperature (Tourre et al., 2007), but no mechanism linking the physics to the biology and synchronously operating in widely separated systems has been demonstrated. Understanding the mechanisms underlying these fluctuations is necessary for any projection or forecast of the naturaldriven amplitude and timing of stock fluctuations, and their responses to human interactions (fisheries) and climate change.

Background and proposal

It has been 25 years since the paper by Kawasaki (1983) first called attention to the synchrony among catch series of the three main sardine fisheries in the Pacific basin (Japan, California and Humboldt), and 20 years since SCOR WG 98 on Worldwide Large-scale Fluctuations of Sardine and Anchovy Populations was formed to explore the then-called Regime Problem. Other significant events were the development of the GLOBEC SPACC program (SPACC, 2008) and the IRI workshop in Honolulu in 2001 (Bakun and Broad, 2001). The early reports were highly successful in documenting the fluctuations, alternation and synchrony, and in pooling existing hypotheses to explain them; however, testing was out of their reach, mainly because a) retrospective studies are limited, in the best of the cases, to less than a century of catch series, to a few decades of physical oceanography and climate registers, and to even fewer long-term ecosystem observations; and b) the development of reliable modeling tools that allow adequate exploration of this problem have been developed only during the last few years.

The primary question for this working group is *which model forcings can generate low-frequency variations in the abundance of small pelagic fish (periods of increasing, high, decreasing, and low abundance), and whether or not they correspond to prevailing conditions observed during the different regimes in the four systems?*

We will approach this question by testing and contrasting what we consider the two main synthetic hypotheses of the Regime Problem today.

> 1. The flow-based hypothesis (MacCall, 2001) relates long-term variability signals in the biology to alternating strong and weak modes of boundary current flow, through the conditions of two distinct habitats (nearshore and offshore). In an extremely simplified version, the idea is that during conditions of slow-meandering boundary current flow, offshore habitat becomes suitable, due to increased retention of eggs and larvae and increased food concentrations offshore. This offshore habitat can then be used by the larger species (sardine) and is reflected in long-term increased biomass of sardines. When flow is stronger the only suitable habitat is the coast.
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> 2. School mix feedback (Bakun, 2001), which is actually a suite of hypotheses based on rapidly evolving adaptive response mechanisms, where individuals' affinities, ethological inertia (school trap), and strong selection pressure (fishing or predation) are used to explain low-frequency biomass and distribution changes.

We are convinced that these modeling comparisons will contribute to the solution of the Regime Problem.

Justification of the group

Our proposal is timely because state-of-the-art information on the topic is to be delivered by GLOBEC and SPACC in the very near future, as part of their syntheses. We can also capitalize on the recently established inter-disciplinarity between physical oceanographers, modelers, and fisheries scientists owing in part to international initiatives. Of particular relevance is that, during the last few years, some of the proposed WG members, fisheries and physical oceanography scientists, have already collaborated in workshops organized by PICES, GLOBEC, APN and CAPaBLE projects (Werner et al. 2005, 2007; Kishi et al., 2006), to discuss strategies and possibilities to deal with the Regime Problem with a completely fresh approach and a brand new toolbox of models and analysis techniques.

Our proposal is also opportune because small pelagic fish remain the most important large fishery and source of marine protein (about one third of total marine catch), as well as one of the most unpredictable and difficult to manage. These difficulties are occurring in times when fisheries management paradigms are changing rapidly, when yearly technological advances result in new levels of observational and analysis capabilities, and most importantly, when nations are fully committed to reduce extreme poverty and hunger in less than a decade (UN Millennium Development Goal).

Terms of reference

To accomplish our goals we propose meeting once a year for a three-year period, with participation of Full Members and (when possible and based on other funding sources) Associate and Corresponding members. The working group will

- Gather and update available datasets, historical information and knowledge from the different sardine-anchovy systems (e.g., Eastern and Western North Pacific, Southeast Pacific and Southeast Atlantic).
- Develop climate-to-fish models for some or all systems (depending on data availability), and test and compare the two synthetic hypotheses described above, the flow-based hypothesis (MacCall, 2001) and the school mix feedback hypothesis (Bakun, 2001), in each of the different systems (different study cases).
- Produce two technical reports, one on the state of the art of climate-to-fish models and the other on modeling tools and a final scientific paper to be published in a peer-reviewed journal. The technical reports will be published as digital books.
- Establish a Web site that can be accessed by WG members, other scientists interested in the topic of this group, and the public. This Web site will provide access to the two technical reports and any modeling tools and data compilations that are developed by the group.

Timetable

- Meeting 1 (2009)—Update methods, data and contacts, establish experimentation, data-gathering and modeling strategies, and generate a technical report on the topic's state of the art. We propose to hold this first meeting linked to the final International GLOBEC SSC meeting, taking place in either autumn or summer 2009.
- Meeting 2 (2010)—Discuss preliminary modeling results, make systems comparisons, deal with modeling milestones, and generate a second report on the modeling tools.
- Meeting 3 (2011)—Integration, discussion and writing of the final report, which will be a scientific paper reporting our results. We will further transmit our results through diverse scientific presentations at congresses and symposia, and in particular by bridging to as many related programs and groups as possible (PICES-FUTURE, IMBER, other SCOR WGs, etc.).

The chairs will be responsible for 1) implementing and maintaining a website for the working group, for members to share information, data and tools, and for other scientists and general public interested in the topic. 2) Delivering the annual reports and the scientific paper, 3) Dissemination of progress and main achievements through specialized newsletters, maintaining an updated calendar of events, and facilitating documents and material to all members willing to present at congresses or seminars, and interacting with other groups.

Deliverables

- Yearly reports to SCOR during the duration of the WG
- Contributed papers and presentations in scientific meetings
- One paper (final report) in a primary literature journal
- Publicly available data and modeling tools
- A web site for the group

Additional products may be possible as we rise complementary funding and incorporate more experts.

Membership

Membership was designed to cover knowledge on the regime problem and the four main small pelagic systems (California Current System, Japan, Humboldt, and Benguela), and expertise in each of the models and tools to be used. Also, we are including a socioeconomics modeler, eco

Fisheries Oceanography:

Salvador Lluch-Cota (Mexico)/ Northeast Pacific fisheries. Co-Chair
Akinori Takasuka (Japan)/ Northwest Pacific fisheries
Carl van der Lingen (South Africa)/ Southeast Atlantic fisheries
Luis Cubillos (Chile)/ Southeast Pacific fisheries

Physical Oceanography and modeling:

Enrique Curchitser (USA)/ North Pacific ROMS model. Co-Chair
Alejandro Parés (Mexico)/ Mexican Pacific ROMS, climate scenarios
Julia Blanchard (UK)/ Size-based models, Socioeconomic modeling QUEST_Fish
Kenneth Rose (USA)/ NEMURO.SAN model, bioenergetics and Individual based models
Yunne Shin (France) / Ecosystem models
Shin-ichi Ito (Japan)/physical oceanography and climate; NEMURO model

Associate Members. This is a preliminary list of participants fully involved in the activities, but not financed by SCOR. The number will depend on our ability to obtain funds from other sources.

Bernard Megrey (USA) / Fisheries scientists, ecosystem modeling
David Checkley (USA) / California Current System and small pelagic fish expert
Manuel Barange (UK)/ Ecological and socioeconomic models
Morgane Travers (France)/ Ecosystem indicators, end-to-end models
Michio Kishi (Japan) / NEMURO; coupled physical-biological modeling
Samuel Hormazabal (Chile) / Physical oceanography
Yasuhiro Yamanaka (Japan) / Climate change, Earth System Modeling
Francisco Werner (USA) / Physical modeling, coupling NEMURO

Corresponding Members. These are scientists with long experience in the Regime problem. All were members of SCOR WG98 that we will attempt to bring into the discussions, at least through electronic means.

Alec MacCall (USA)
Andrew Bakun (USA)
Daniel Lluch-Belda (Mexico)
Jurgen Alheit (Germany)
Tuyoshio Kawasaki (Japan)

Notes and considerations:

Relevant supporting material for this proposal is posted at the website http://www.ecosystemico.org/scogroupproposal/index.html, including suggested members short CVs, relevant publications, and key web links.

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