Report of the Yokohama 2003 MODEL Task Team Workshop to develop a marine ecosystem model of the North Pacific Ocean including pelagic fishes

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The goals of the Yokohama PICES MODEL Task Team 2003 workshop were to:

- develop a dynamically coupled lower and higher trophic level marine ecosystem model which included a prey-predator system connecting the lower trophic ecosystem to pelagic fishes; and
- to build a Lagrangian model describing fish migration and population dynamics which could be embedded into a basin-scale 3-D circulation model.

The target fish species for the workshop were Pacific herring (*Clupea harengus pallasi*) and Pacific saury (*Cololabis saira*). Preliminary work by the MODEL Task Team on the development of NEMURO and NEMURO.FISH models led up to this workshop. Descriptions of these models can be found in PICES Scientific Reports No. 17 (2001) and No. 20 (2002). A full report of the Yokohama Workshop will be provided in the PICES Scientific Report No. 26 (2003). Copies of model code, reports, and output from previous workshops can be found on the CCCC MODEL Task Team web site at http://161.55.120.140/FOCI/Model/index.html.

The venue was located at the Frontier Research System for Global Change (FRSGC) in Yokohama, Japan. 24 scientists (Fig. 1) from Korea, Japan, Canada and the United States convened between March 3 and March 6, 2003, to attend the workshop. Participants consisted of plankton scientists, modelers, and individuals with knowledge of herring and saury biology and key data sets from selected regions (for now, Vancouver Island and off the east coast of Japan). The Heiwa-Nakajima Foundation of Japan provided financial support for the meeting through the efforts of Dr. Michio J. Kishi.

During the Yokohama Workshop, the herring and saury bioenergetics models were expanded to the population-level and dynamically coupled to the lower trophic levels (LTL) of the NEMURO model. The individual fish bioenergetics model and the one-way coupling to NEMURO (*i.e.* NEMURO is run first and output is used to force the fish bioenergetics model) are described in detail in PICES Scientific Report No. 20 by Ito et al. (pp. 114-119) and Megrey et al. (pp. 80-88). In the sections that follow, we present selected results for the fully coupled lower trophic level NEMURO model NEMURO.FISH (Fig. 2) applied to herring and saury.

Fig. 1 Workshop participants at the entrance hall of the FRSGC. Left to right – Top row: Goh Onitsuka, Kazuaki Tadokoro, Yasuhiro Yamanaka, Naoki Yoshie, Francisco Werner, Taketo Hashioka, Douglas Hay, Fei Chai, Kenneth Rose, Makoto Kashiwai. Bottom row: Sinjae Yoo, Michio Kishi, Shin-ichi Ito, Toshio Katsukawa, Bernard Megrey, Daiki Mukai, Sachie Yoshimoto.

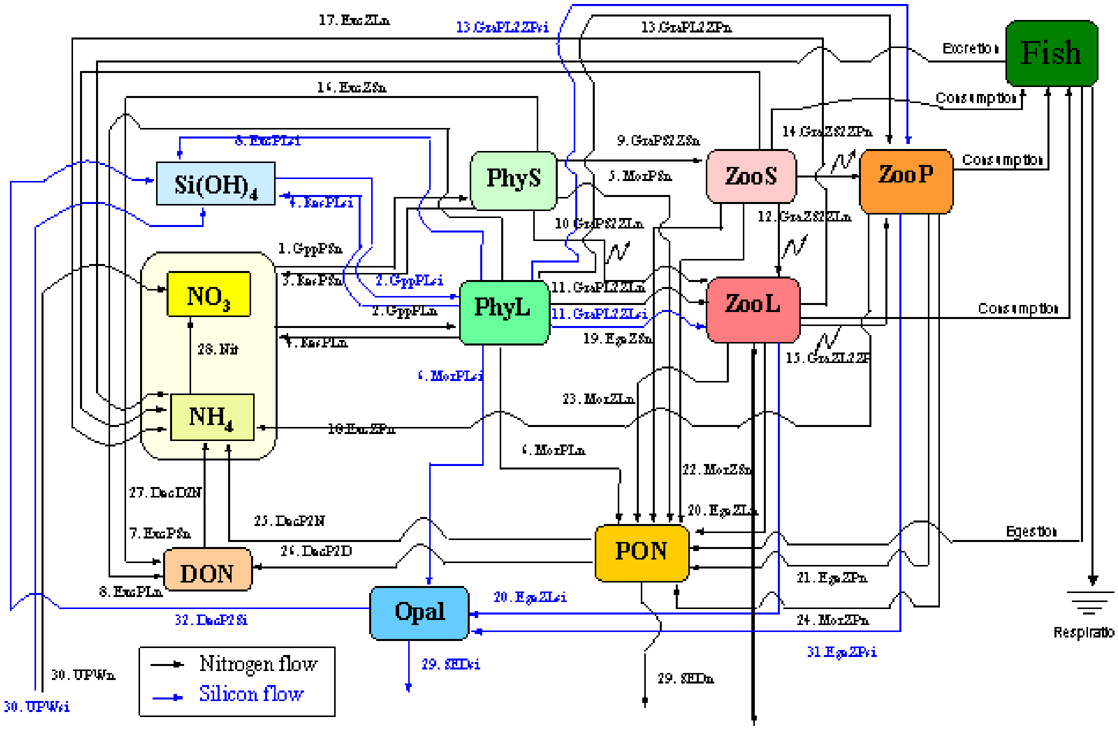

Fig. 2 Schematic of the LTL/HTL NEMURO.FISH marine ecosystem model.

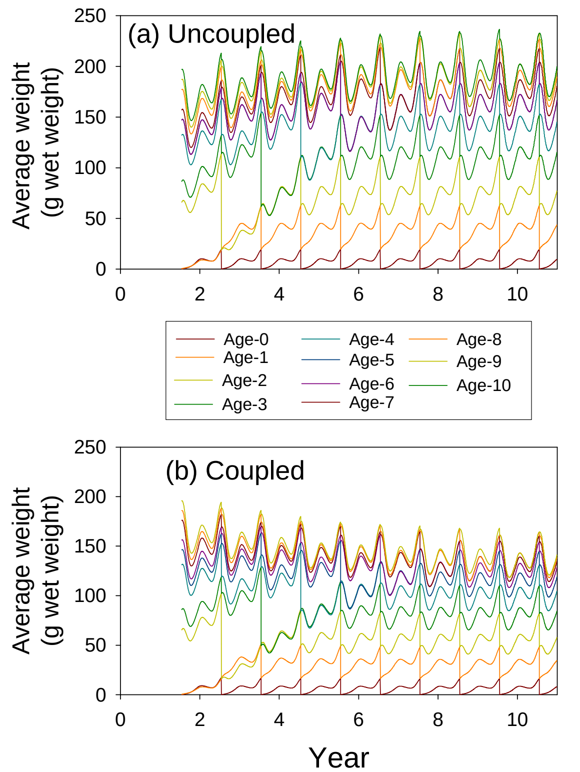

Fig 3 Predicted daily average weights per individual by age-class of herring from the 11-year (a) uncoupled and (b) coupled simulations of the NEMURO.FISH model applied to Pacific herring.

Herring model

We present two 11-year simulations of the NEMURO.FISH model applied to Pacific herring (Fig. 3). The simulations were identical except that the "coupled" simulation included dynamic feedback between the fish bioeneretics model and the LTL model. The dynamic feedback included the following processes: the three zooplankton groups in NEMURO (prey) determined the consumption rate of the average herring in each age-class (predator), and thereby influenced the growth rates and sizes of the herring; the densities of zooplankton eaten by all age-classes of herring were removed as a mortality rate on the zooplankton groups; herring excretion contributed to the LTL nitrogen dynamics by adding to the ammonia compartment; and herring egestion added to the LTL particulate organic nitrogen (PON) compartment (Fig. 2). Thus, the LTL dynamics and the herring dynamics are solved simultaneously in NEMURO.FISH. The other "uncoupled" simulation did not include the feedbacks. The NEMURO LTL component began on January 1, 1991. We did not introduce herring into the model until July 17 of year 2 to let the LTL dynamics spin up to their regular seasonal cycles. The simulations in Figure 3 illustrate the new capability of the coupled lower and higher trophic NEMURO.FISH model in a case where 10 year-classes (cohorts) of herring were considered.

Predicted herring mean weight-at-age was lower under the coupled simulation as compared to the uncoupled simulation (Fig. 3). Including herring consumption as a dynamic mortality term on the zooplankton resulted in a density-dependent feedback and lower herring growth rates in the coupled simulation.

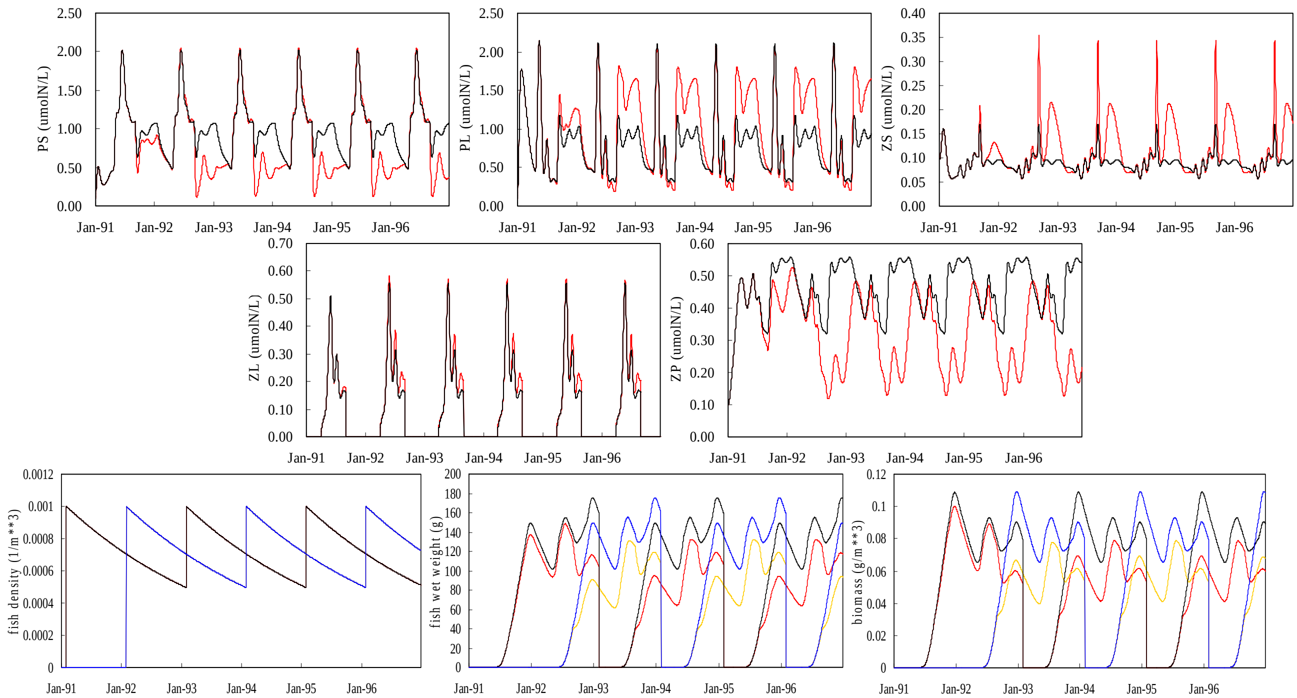

Fig. 4 NEMURO.FISH applied to saury for a six-year simulation. Plotted are phytoplankton (PS, PL) and zooplankton (ZS, ZL, ZP) density and numbers from the one-way coupling (black line) and the two-way coupling (red line). Fish density using the one-way coupling for a one-saury cohort model (black line) and a two-saury cohort model (blue line). Fish wet weight and biomass of saury calculated using the one-cohort saury model and the one-way coupling (black line) and the two-way coupling (red line) as well as the two-cohort saury model using the one-way coupling (blue line) and two-way coupling (yellow line).

The dynamics of NEMURO.FISH applied to herring require additional fine-tuning, and we are not yet ready to compare model predictions to field data for the lower trophic levels or for herring from the Vancouver Island area. We include these results to illustrate the capabilities of NEMURO.FISH and only compare predictions between the coupled and uncoupled herring simulations.

Saury model

A simulation with two-saury cohorts is shown in Figure 4. The effect of the two-way dynamic linkage is emphasized especially in the summer - autumn season. When two adult cohorts co-occur from July to January, the predatory pressure on zooplankton is high. In late winter, the temperature becomes too low to maintain a high predatory pressure, and as a result, fish growth is slowed down in comparison to cases where only one cohort is considered (additional details will be provided in the MODEL Task Team report in the PICES Scientific Report No. 26, 2003).

Concluding remarks

Applications and examples of NEMURO.FISH applied to herring and saury are planned to be the basis for a special issue of the journal *Ecological Modelling*. A proposal to the journal for a collection of papers on NEMURO and NEMURO.FISH has been submitted and accepted. The next steps to prepare these manuscripts are to: (1) synthesize the field data on lower trophic level and herring/saury dynamics from specific sites in the North Pacific; (2) continue the model calibration so that predicted dynamics better reproduce the known patterns of lower and higher trophic levels; and (3) use the model to simulate the effects of environmental changes (*e.g.*, climate change, regime shifts) on the food web (herring, saury and lower trophic levels) under a variety of biological conditions.

Work also continues to find sources of funding to support further model development and to develop the papers for *Ecological Modelling*. Two proposals have been prepared. The first, "*Development of a model to examine the coupled response of lower and higher trophic level of marine ecosystems in the North Pacific and the influence of climate variability*" by S. Ito, M.J. Kishi, B.A. Megrey and F.E. Werner, was submitted to the Japanese Fisheries Agency and funding has been approved. The second (pre) proposal, "*International Workshop on Climate interactions and marine ecosystems: Effects on the structure and function of marine food webs and implications for marine fish production in the North Pacific Ocean and marginal seas*" by F.E. Werner, B.A. Megrey, S. Ito and M.J. Kishi, was submitted to the Asian Pacific Network for Global Change Research (APN). Funding for this proposal is pending.