APPENDIX E: BASS/MODEL WORKSHOP TO *REVIEW ECOSYSTEM MODELS FOR THE SUBARCTIC PACIFIC GYRES*

Workshop objectives

The BASS/MODEL workshop on higher trophic level modeling (March 5-6, 2001, Honolulu, U.S.A.) recommended a 1-day workshop to evaluate the results of the inter-sessional workshop and initiate hypothesis testing using the models developed.

This follow-up BASS/MODEL workshop was held October 5, 2001, immediately preceding the PICES Tenth Annual Meeting in Victoria, British Columbia, Canada (see Endnote E1 for attendance). The objectives of the workshop were to:

- assess the results of the March 2001 workshop;
- review progress on model development and updated models; and
- begin to develop scenarios to test key hypotheses.

Review of baseline models

The two ECOPATH/ECOSIM baseline models developed at the March 2001 workshop on higher trophic level modeling should be viewed as work in progress. Estimates of biomass, productivity to biomass, consumption rate to biomass and diet composition were compiled from the literature and from research data provided by PICES member countries. In general, information available for 1990 (or 1990-1993) was used such that the two models could be viewed as representative of the early 1990s conditions. In total, 56 species groups (with three detrital groups) were included in the models, however some species were not common to both regions. Minke whales, common dolphin, Japanese sardines and anchovies were present in the Western Subarctic Gyre (WSA) model, but not in the Eastern Subarctic Gyre (ESA) model. Conversely, elephant seals were present in the ESA model only. Many of the estimates are at best only guesses. Some observations were derived from coastal ecosystems and therefore may not be applicable to gyre ecosystems.

In general, the total biomass estimated for the WSA was higher than for the ESA. Major differences between the two model regions include higher biomasses of flying squid and Pacific pomfret in the ESA, higher biomass of chaetognaths in the WSA, and higher salmon biomass in the WSA (pink salmon) than in the ESA (sockeye salmon). Marine mammal biomass estimates were identical for each region since they were derived from basic-scale North Pacific estimates. No biomass estimates of forage fish and micronektonic species groups were available from the literature or from research survey data, so these were evaluated by top-down balancing of each model. Biomass estimates for lower trophic level plankton groups were derived from outputs of the NEMURO model that had been calibrated for Ocean Station P in the ESA.

Productivity values were derived from mortality rates. Consumption rates were obtained from diet composition and laboratory descriptions of calories/gram for prey species. Both production and consumption estimates were weighted by residence time for migratory species. The estimates for lower trophic levels (*e.g.* large zooplankton) were taken from other ECOPATH models and, in some cases, from the NEMURO model.

All information on diet composition was poor. Marine mammal diets were not as detailed as fish diets. Salmon diets were specific and detailed with many stomachs sampled over large areas and seasons, however, only summer estimates were available for the WSA. The major difference between the WSA and ESA were the seasonal differences in the diet of salmon since WSA included sockeye salmon in May. Early spring diet estimates for the early 1990s were not available for the ESA. Physical forcing inputs to the NEMURO model can be generated to produce phytoplankton and zooplankton outputs.

Maximum photosynthetic rates, zooplankton growth efficiencies and microbial loops can be modified and initiated to provide various climate change scenarios. These outputs can be used in ECOSIM.

Update of ECOPATH/ECOSIM models

Kerim Aydin reviewed the updated ECOPATH/ECOSIM baseline models. Figures E1 and E2 show composite images of the food webs for the Eastern and Western Pacific Subarctic Gyres. These models were initially constructed from data assembled at the March 2001 BASS/MODEL workshop and updated by including results of lower trophic level modeling by the MODEL Task Team and upper trophic level data from a wide range of sources on both sides of the Pacific.

Future adjustments to the models based on additional data presented at the Victoria workshop will be incorporated into the final versions of these models and presented at an inter-sessional BASS/MODEL workshop to be convened in April 2002. This will lead to a PICES Scientific Report

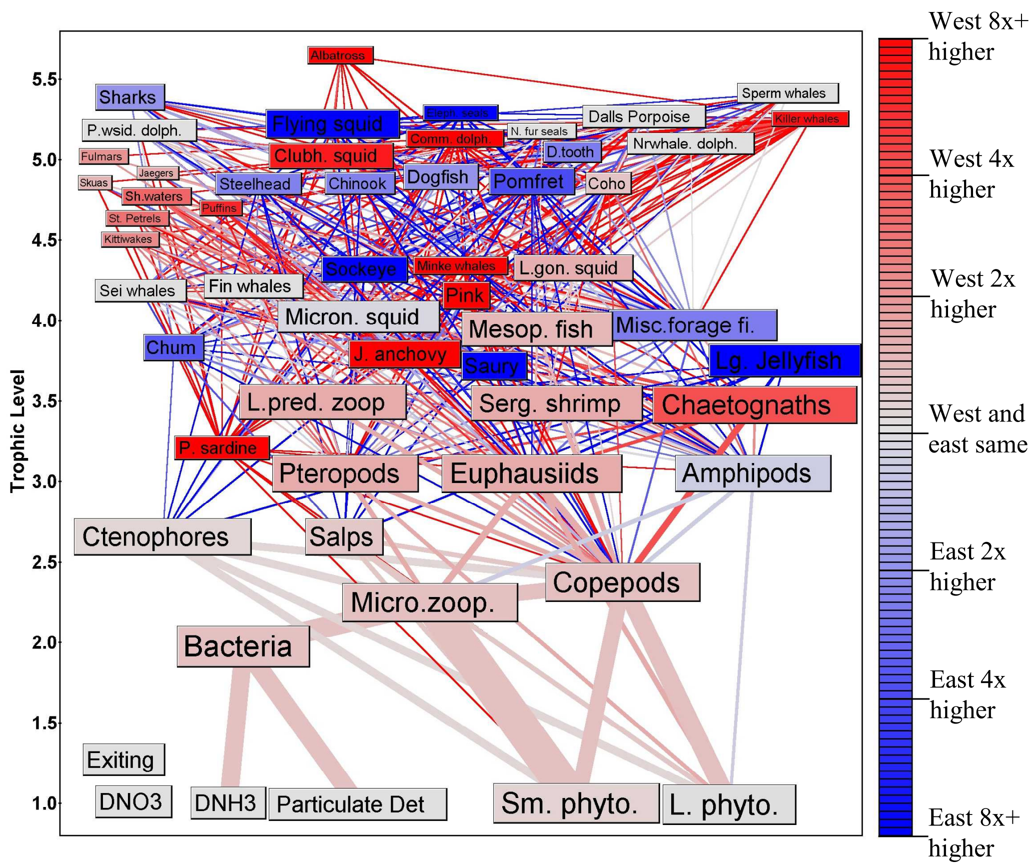

Fig. E1 A combined quantitative food web of the Eastern and Western Pacific Subarctic Gyres constructed from data assembled at the March 2001 BASS/MODEL workshop and presented at the PICES Tenth Annual Meeting. Species in both the Western and Eastern Gyres are shown. The area of each compartment is proportional to log of average biomass density (t/km^2), and the width of each connecting flow is proportional to the square root of the averaged yearly flow volume (t/km^2/year). Coloration shows the ratio of west *vs*. east biomass density and flow volume: where the ratio of west/east is higher (red) and where the ratio of east/west is higher (blue).

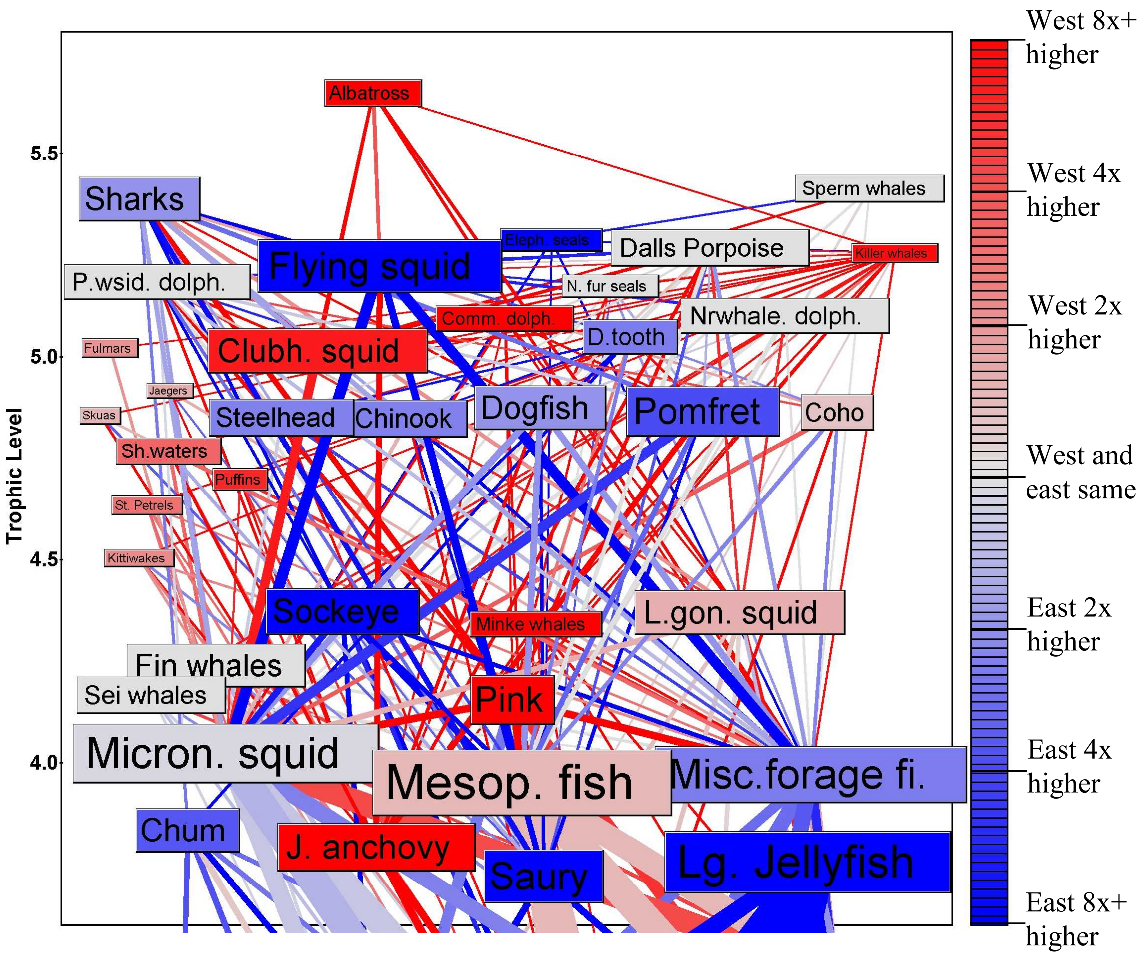

Fig. E2 An enlargement of the upper trophic level flows and biomass densities shown in Figure E1. Minor flows (the lowest 10% (cumulative) of prey mortality and predator diet) are removed for clarity. See Figure E1 for explanation of coloration.

to document the models and assess the overall state of knowledge of food web interactions and critical dynamic links in subarctic gyre ecosystems. In addition, the April 2002 meeting will focus on the potential to incorporate dynamic simulations of climate into these models.

This continuing synthesis highlighted some key areas for future research, for example, the exploration of dynamics of the intermediate trophic levels such as micronektonic squid, small forage fish, and mesopelagic fish (Fig. E2). The biology of these species is currently poorly understood and yet central to the functioning of the subarctic food web.

Another key direction for future work lies in developing methods to integrate gyre processes with boundary currents and near-shore processes. Specifically, concurrently examining the dynamics of boundary current species such as the Pacific sardine and Japanese anchovy in relation to the dynamics of the salmon-dominated subarctic gyre ecosystems that were simulated by these models, will increase our understanding of North Pacific-wide climate systems and their interrelations with coastal systems.

Recent improvements to NEMURO model

Bernard Megrey reviewed recent progress and improvements on the NEMURO lower trophic level modelling efforts.

Diagnostic calculations

Several diagnostic calculations were added to the NEMURO model. These included production/ biomass (P/B) ratios for phytoplankton and zooplankton, food consumption/biomass (C/B) ratios for small, large and predatory zooplankton, and ecotrophic efficiency (a measure of how much primary production transfers up the food web to the zooplankton species and ultimately to higher trophic level species).

Validation to Station P

The NEMURO model was parameterized for Ocean Station P and output was compared to data collected from that site. Results were favourable. NEMURO provides reasonable C/B and P/C ratios. Annual primary production from the model (149 gC/m^2/yr) is only 6% higher than the best current estimate (140 gC/m^2/yr) by Wong *et al.* (1995). Average chlorophyll concentration from the model (0.42 mg/m^3) is only 5% higher than the long-term value (0.4 mg/m^3) measured by Wong *et al.* (1995). An f-ratio (assuming that the production of the large phytoplankton is primarily fuelled by “new” nitrogen) is in a good agreement with the estimate by Wong *et al*. (1995): 0.23 and 0.25 respectively.

Zooplankton vertical migration

Results without ontogenetic migration of predatory zooplankton (ZP) show a large diatom bloom around day 73 (Fig. E3, top panel). The prevailing view is that there is no spring bloom at Station P. Thus the bloom is an artifact of the “box” nature of the model. Adding ZP migration, decreases biomass of phytoplankton by a factor of 2 (Fig. E3, bottom panel) and generates more reasonable diagnostics. The estimates of ecotrophic efficiency are not significantly affected.

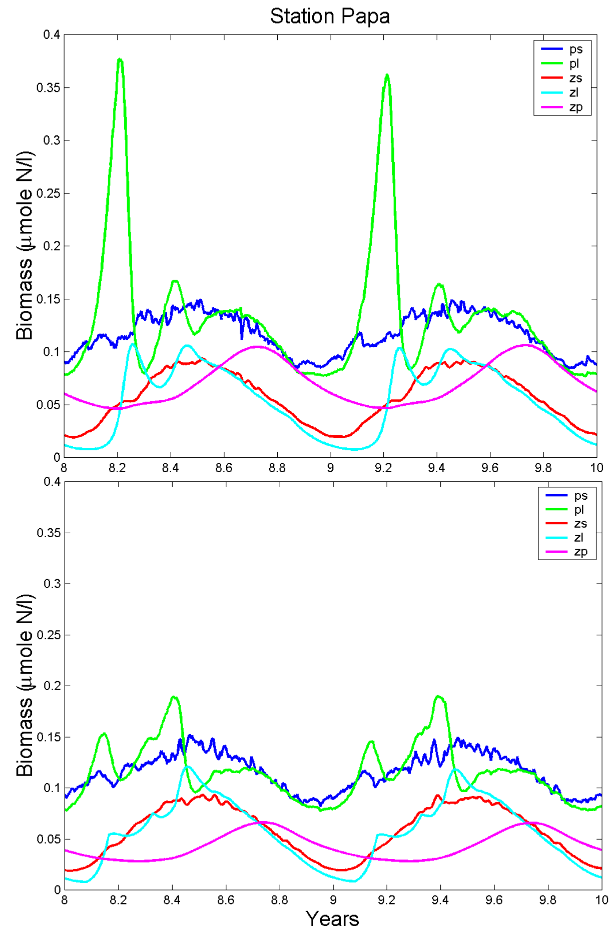

Fig. E3 Comparison of NEMURO output with (bottom panel) and without (top panel) ontogenetic migration of large zooplankton.

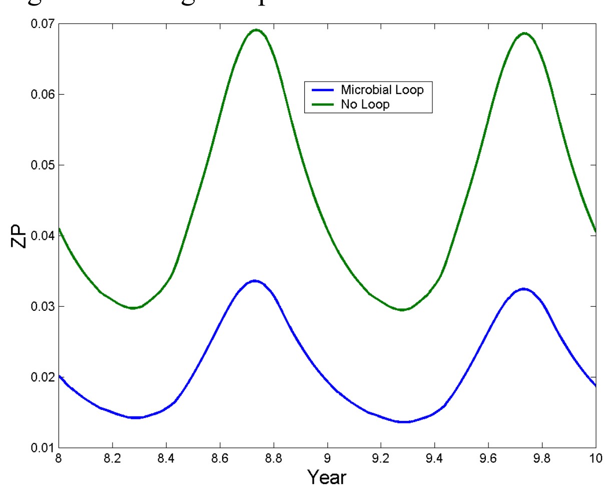

Fig. E4 Comparison of NEMURO output with and without the microbial loop approximation.

Microbial loop

Inclusion of a microbial loop had only a small impact on the standing stocks of small and large zooplankton (Fig. E4). Predatory zooplankton decreased by about one half, reducing potentially available biomass for fish production. These differences are due to the decreased net trophic efficiency of the system because a large portion of the primary production passes through a microbial community before entering the zooplankton community.

Recent progress

MODEL Task Team also conducted a sensitivity analysis and data assimilation for Station A7 (WSA) and added carbon fluxes to the LTL model.

The most recent improvements to the NEMURO model include:

- Acquired SST time series from Station P 1951-1988;
- Acquired equations to permit calculation of light at the surface;
- Modified primary production equations to explicitly include mixed layer depth (MLD) to permit simulation of regime shift scenarios.

Hypothesis testing scenarios

The following scenarios were suggested:

- Examine impact of changes in primary and secondary production on each gyre. Do they respond similarly or differently?
- Examine seasonality of changes in each system;
- Examine the role of primary production increases on sockeye salmon abundance;
- Examine role of predation in the regulation of population abundance:
    - shark/salmon
    - marine mammal/salmon
- Examine role of marine birds in each gyre;
- Examine role of forage fish in each gyre;
- Examine species competition for prey, *e.g.* pink/sockeye salmon; pomfret/squid, etc.

Recommendations

1. Convene a joint BASS/MODEL workshop in April 2002 to continue hypotheses testing of the models developed at the 2001 inter-sessional workshop and refined at the Tenth Annual Meeting;
2. Parameterize the WSA model, in particular finalize the boundary to exclude the transition area;
3. Calibrate and validate the NEMURO model to Station A7, which is more appropriate for the Western Subarctic Gyre;
4. For both the Eastern and Western Gyre models, incorporate time series (from the NEMURO model) for light, SST, etc., to generate primary productivity and zooplankton time series;
5. Hypotheses to be tested should be developed prior to the 2002 inter-sessional workshop and should focus on climate change scenarios;
6. Complete final data synthesis (including marine birds and mammals) prior to the 2002 inter-sessional workshop;
7. Following the inter-sessional workshop, prepare the two baseline models for publication in the PICES Scientific Report Series, including the results of hypotheses testing, and a data inventory;
8. PICES provide a means of accessing these models, and other workshop products on the web;
9. BASS/MODEL/REX Task Teams convene a joint session with GLOBEC at the PICES Eleventh Annual Meeting to examine *"Approaches for linking basin scale models to coastal ecosystem models"*;
10. Given the limited data on diet of many species inhabiting the gyres, PICES should encourage researchers to collect and collate diet data for species in these areas and sponsor the development of "Diet database" which would be peer-reviewed and citable.

Endnote E1

Participation List

Canada
- Jacquelynne R. King
- Gordon A. McFarlane (convenor)
- R. Ian Perry
- Marc Trudel

Japan
- Makoto Kashiwai
- Toshio Katsukawa
- Michio J. Kishi (convenor)
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