ICES CM 2014/3669 L:07

Evaluating the role of local and basin scale processes in an upwelling ecosystem using time-series observations and biophysical food web modeling

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Summary

How can we compare the roles of the physical environment and the complex network of trophic interactions in the regulation of pelagic ecosystem dynamics? We have developed a spatially explicit, intermediate complexity food web model platform that integrates physical and biological processes. Our aim has been to define physical and biological components generally enough to allow consistent comparisons among diverse ecosystem types (upwelling, downwelling, shallow bank, semi-enclosed sea) but still encompass the essential physics and trophic structure of each ecosystem. We present an application of the model platform to the Northern California Current upwelling ecosystem, drawing upon independent surveys of nutrient dynamics, plankton dynamics, and variability in higher trophic level community composition to define trophic relationships. Seasonal upwelling of nutrients has long been recognized as the primary driver of ecosystem productivity. The physical model therefore uses seasonal cycles of upwelling, mixed layer depth, advection through the spatial domain, and light intensity as ecosystem drivers. Model-derived ecosystem production rates under alternate plankton parameterization strategies are evaluated against observations of plankton dynamics from long-term monitoring surveys.

Materials and Methods

ECOPATH models estimate energy flow along each trophic linkage of the food web based on predation demand of each consumer upon each of its prey groups. A mass-balanced ECOPATH solution for the food web is a map of consumption demands of upper trophic levels upon lower levels for every consumer-prey pair. It is mathematically simple to transform a top–down linear solution (ECOPATH) into a donor-driven map of production fate up the food web (Steele 2009). With the addition of nutrient pools as functional groups fed primarily by the microbial metabolism of detritus, it is possible to account for nutrient cycling (with care of proper conversion between nitrogen and wet weight currencies between the nutrient and living functional groups). We refer to the transformation of an ECOPATH model to this format and the analyses performed as ECOTRAN ("ECOPATH transform") models (Steele & Ruzicka 2011). These are true end-to-end models in that they model the flow of fixed production across all trophic levels from the input of nutrients into the system, to the production of plankton, higher trophic level consumers and fisheries, and back to recycled nutrients. We can also account for the gains and losses from each modeled group due to physical advection, vertical mixing, and sinking.

Our first goal was use the model to test ecosystem sensitivity to variability in the rates of nutrient cycling and transport of plankton production. In particular, we were interested in sensitivity to the time-scale of variability among physical processes, retention processes that moderate the export of plankton production, and variability in the rate nutrient recycling via microbial metabolism of detritus. Our second goal was to evaluate the skill of models run under alternate phytoplankton growth rate and detritus recycling rate assumptions against observations of plankton dynamics from long-term monitoring surveys. For this purpose, we used observations of nutrients, phytoplankton, and mesozooplankton made along the Newport Hydrographic (NH) Line across the mid-latitude Oregon shelf (Peterson *et al*. 2002; Peterson & Keister 2003). NH Line surveys have been conducted biweekly, year-round since 1997.

Results and Discussion

Example figure 1 demonstrates an exploration of the effects of increasing upwelling intensity on ecosystem productivity (as expressed by fishery harvest) under two different assumptions of detritus recycling rates. While greater upwelling increases the nutrient input rate, and phytoplankton production, into the system, increased Ekman transport means greater loss of plankton production from the system. There exists an upwelling rate above which the physical export of plankton production exceeds the rate at which nutrients can be taken up by phytoplankton and transformed to biomass; ecosystem production declines above this point. The rate of detritus recycling (the bacterial conversion of detritus to ammonia or the consumption of detritus by detritovores) increases peak ecosystem productivity.

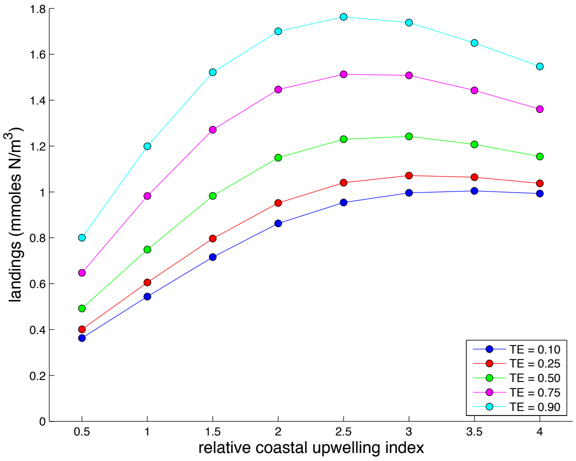

Figure 1. Changes in the rate of ecosystem productivity (as expressed by fishery harvest) as upwelling rate increases. Different curves represent alternate assumptions of detritus recycling rates (TE).

Example figure 2 shows model-derived estimates of two phytoplankton size classes plotted against time-series observations made across the central Oregon shelf.

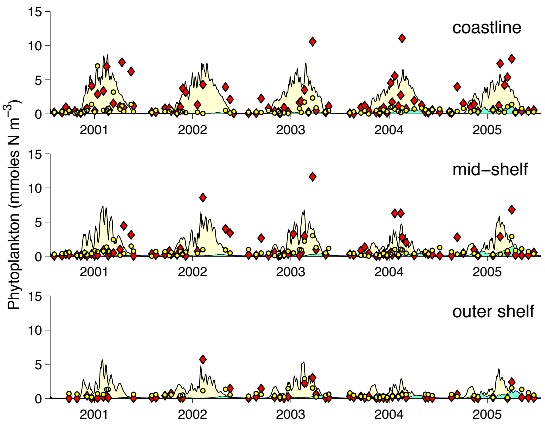

Figure 2. Model-derived estimates of large (yellow area) and small (green area) phytoplankton size classes plotted with NH Line observations of large (red diamonds) and small (yellow dots) phytoplankton.

References

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