Ecosystem modeling efforts at the NOAA/NMFS Southwest Fisheries Science Center

submitted as a background document to the:
3rd NMFS National Ecosystem Modeling Workshop (NEMoW 3)
18-20 March 2014, Seattle, WA

prepared by:
Brian Wells
Southwest Fisheries Science Center, NMFS/NOAA

Chinook salmon habitat, life-cycle, and DEB modeling

Pacific salmon use a wide range of habitats throughout their life cycle, including river, estuarine, and marine ecosystems. This poses a significant challenge to our understanding of their population dynamics, because habitat conditions in one ecosystem and life-stage can have consequences that manifest in the following ecosystem and life stage. However, most salmon models do not capture the habitat variability in each ecosystem or incorporate the critical linkages between ecosystems. The Salmon Ecosystem Simulation And Management Evaluation (SESAME) project aims to address these issues for Chinook salmon from California's Central Valley. SESAME uses a series of coupled physical-biological simulations to produce key spatiotemporally explicit habitat variables in each system: river, estuary, and coastal ocean. We use these habitat variables (temperature, flow, and food) to drive a Dynamic Energy Budget (DEB) model for Chinook salmon to explore how salmon grow from eggs to mature adults while moving across this complex landscape.

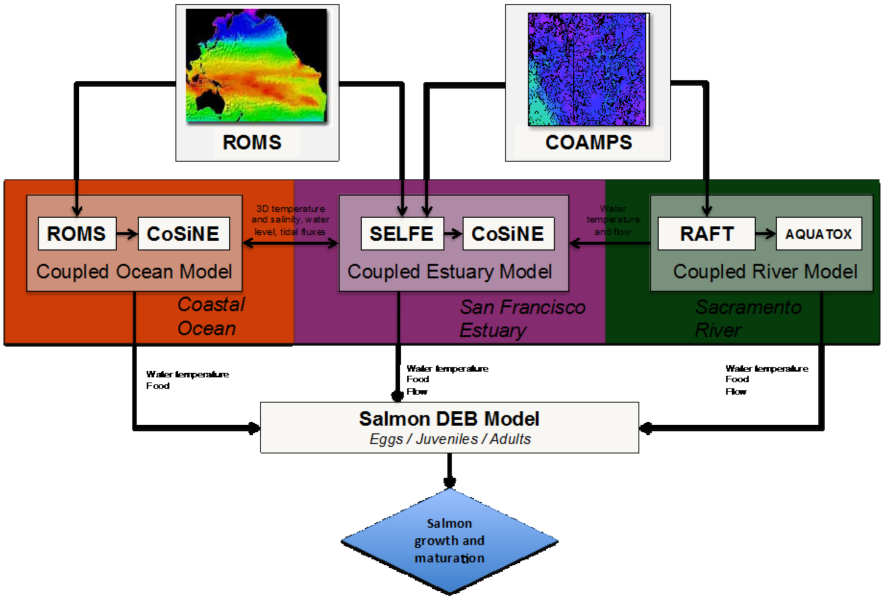
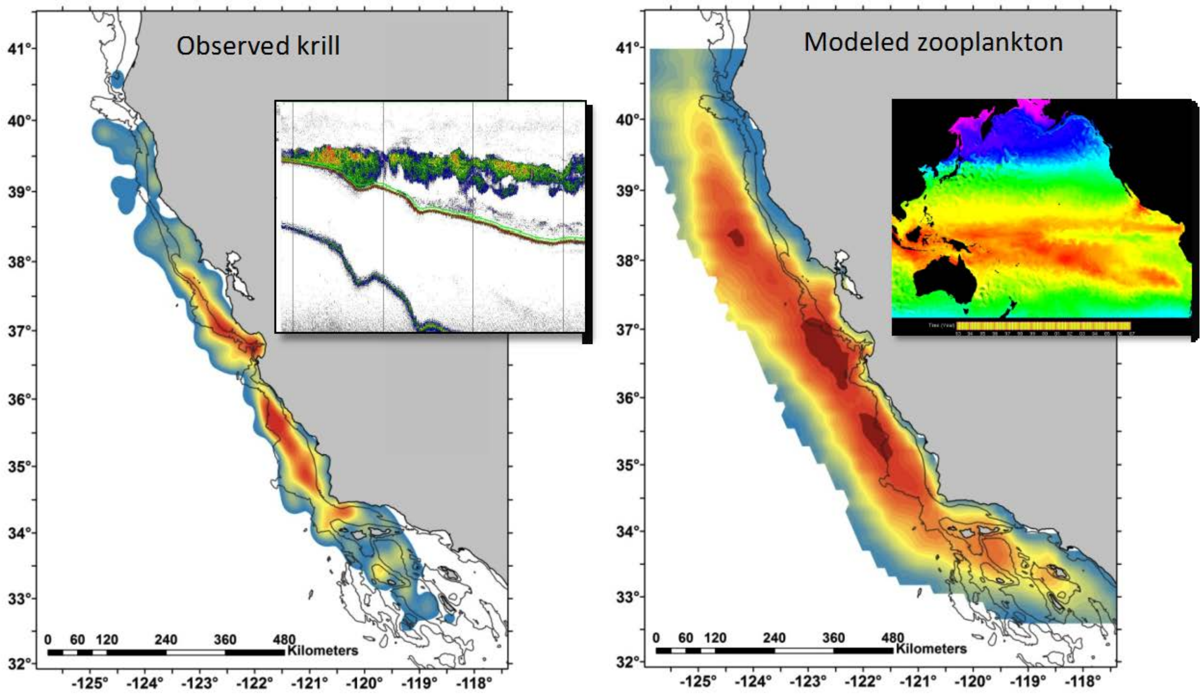


Figure above demonstrates the basic model structure for the SEAME project.

ROMS-CoSINE krill estimations

Below summary from: Santora, J.A, W.J. Sydeman, M. Messie, F. Chai, Y. Chao, S.A. Thompson, B.K. Wells, and F. Chavez. 2013. Triple check: Observations verify structural realism of an ocean ecosystem model. Geophysical Research Letters.40:1-6

Improvements in fisheries and ecosystem management could be made if the prediction of key zooplankton, such as krill, were possible using ocean ecosystem models. To examine structural realism, hence the validity of a coupled physical-biogeochemical model, we compared measured spatiotemporal dynamics of krill and seabird abundance off California to hindcasted mesozooplankton derived from an independently designed model. Observed krill and modeled mesozooplankton (Z2) displayed latitudinal coherence but distinct longitudinal offsets, possibly related to unrealistic bathymetry in the model. Temporally, Z2, *Thysanoessa spinifera* (a neritic krill species) and seabird density and reproductive performance were well correlated, indicating that quantitative prediction regarding marine predators in upwelling ecosystems is within reach. Despite its basin-scale framework, the ROMS-CoSiNE model captures zooplankton and top predator dynamics regionally in the central California region, suggesting its utility for management of marine ecosystems and highlighting rapid advances that can be made through collaboration between empirical scientists and ecosystem modelers.



Shown above is the observed (acoustics) and estimated krill distribution from CoSINE along the CCS. There is significance coherence between these data.

Habitat modeling for green sturgeon using ROMS-CoSINE products

Below summary from: Huff, D.D., S.T. Lindley, B.K. Wells, and F. Chai. 2012. Green sturgeon distribution in the Pacific Ocean estimated from modeled oceanographic features and migration behavior. Public Library of Science. 7:e45852

The green sturgeon (*Acipenser medirostris*), which is found in the eastern Pacific Ocean from Baja California to the Bering Sea, tends to be highly migratory, moving long distances among estuaries, spawning rivers, and distant coastal regions. Factors that determine the oceanic distribution of green sturgeon are unclear, but broad-scale physical conditions interacting with migration behavior may play an important role. We estimated the distribution of green sturgeon by modeling species-environment relationships using oceanographic and migration behavior covariates with maximum entropy modeling (MaxEnt) of species geographic distributions. The primary concentration of green sturgeon was estimated from approximately 41–51.5° N latitude in the coastal waters of Washington, Oregon, and Vancouver Island and in the vicinity of San Francisco and Monterey Bays from 36–37° N latitude. Unsuitably cold water temperatures in the far north and energetic efficiencies associated with prevailing water currents may provide the best explanation for the range-wide marine distribution of green sturgeon. Independent trawl records, fisheries observer records, and tagging studies corroborated our findings. However, our model also delineated patchily distributed habitat south of Monterey Bay, though there are few records of green sturgeon from this region. Green sturgeon are likely influenced by countervailing pressures governing their dispersal. They are behaviorally directed to revisit natal freshwater spawning rivers and persistent overwintering grounds in coastal marine habitats, yet they are likely physiologically bounded by abiotic and biotic environmental features. Impacts of human activities on green sturgeon or their habitat in coastal waters, such as bottom-disturbing trawl fisheries, may be minimized through marine spatial planning that makes use of high-quality species distribution information.

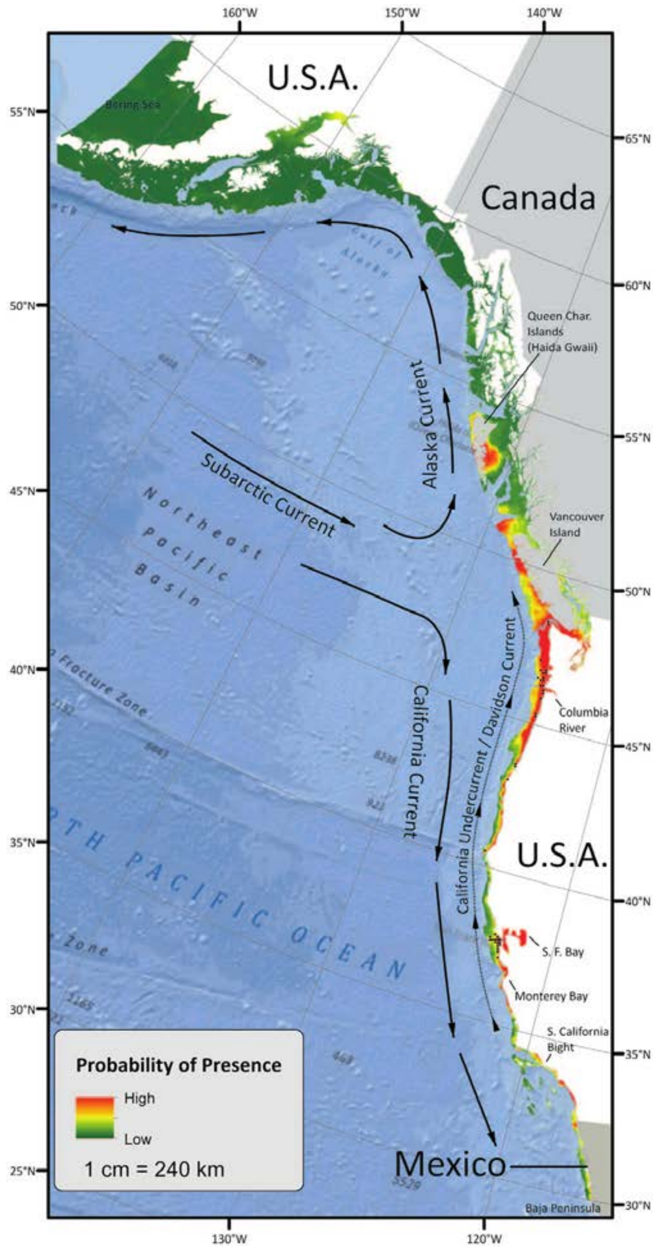


Figure above demonstrates model output for the sturgeon habitat models.

Krill fishery and ecosystem modeling

Below summary from: Watters, G.M., S.L. Hill, J.T. Hill, J.T. Hinke, J. Matthews, and K. Reid. 2013. Decision-making for ecosystem-based management: evaluating options for a krill fishery with an ecosystem dynamics model. Ecological Applications 23:710-725.

Decision-makers charged with implementing ecosystem-based management (EBM) rely on scientists to predict the consequences of decisions relating to multiple, potentially conflicting, objectives. Such predictions are inherently uncertain, and this can be a barrier to decision-making. The Convention on the Conservation of Antarctic Marine Living Resources requires managers of Southern Ocean fisheries to sustain the productivity of target stocks, the health and resilience of the ecosystem, and the performance of the fisheries themselves. The managers of the Antarctic krill fishery in the Scotia Sea and southern Drake Passage have requested advice on candidate management measures consisting of a regional catch limit and options for subdividing this among smaller areas. We developed a spatially resolved model that simulates krill–predator–fishery interactions and reproduces a plausible representation of past dynamics. We worked with experts and stakeholders to identify (1) key uncertainties affecting our ability to predict ecosystem state; (2) illustrative reference points that represent the management objectives; and (3) a clear and simple way of conveying our results to decision-makers. We developed four scenarios that bracket the key uncertainties and evaluated candidate management measures in each of these scenarios using multiple stochastic simulations. The model emphasizes uncertainty and simulates multiple ecosystem components relating to diverse objectives. We summarize the potentially complex results as estimates of the risk that each illustrative objective will not be achieved (i.e., of the state being outside the range specified by the reference point). This approach allows direct comparisons between objectives. It also demonstrates that a candid appraisal of uncertainty, in the form of risk estimates, can be an aid, rather than a barrier, to understanding and using ecosystem model predictions. Management measures that reduce coastal fishing, relative to oceanic fishing, apparently reduce risks to both the fishery and the ecosystem. However, alternative reference points could alter the perceived risks, so further stakeholder involvement is needed to identify risk metrics that appropriately represent their objectives.

Plankton ecosystem dynamics in response to wind forcing, using ROMS-NEMURO

E. Bjorkstedt's group is using a 2-D, cross-shelf slice model to simulate circulation and plankton ecosystem dynamics in response to wind forcing. The model is implemented in ROMS-NEMURO. Effects of low-frequency variability in sea level on thermocline depth are imposed by nudging alongshore-current structure. An individual-based model for rockfish early life history stages is used to simulate the growth of larvae released into the plankton at different times during the winter parturition season. NEMURO zooplankton fields (meso- and micro-) are used to construct the prey field for optimally foraging larvae. Potential survival, conditional on the date-of-birth, is calculated from average size-dependent mortality for each 'mini-cohort' over the course of the first 50 days.

An index of recruitment is calculated by integrating the product of the probability of survival (conditional on date of birth) and the distribution of birth dates.   This recruitment index is a per capita measure of recruitment success analogous to recruitment deviations from stock assessments.   We assume that the distribution of birth dates is constant from year to year, and find the distribution that yields the best correlation between the resulting recruitment index and recruitment deviations from stock assessments. Recruitment index performs reasonably well, successfully capturing 1999 year class missed by the MWT survey. Extensions of this work to examine the effects of variable predator fields (possibly indexed by PZoo in NEMURO) holds promise for improving fits, and explaining discrepancies between model predictions and RecDev associated with ENSO events.

Ecosystem modeling efforts at the NOAA/NMFS Pacific Islands Fisheries Science Center

submitted as a background document to the:
3rd NMFS National Ecosystem Modeling Workshop (NEMoW 3)
18-20 March 2014, Seattle, WA

prepared by:
Phoebe Woodworth-Jefcoats and Jeff Polovina
Ecosystems and Oceanography Division
Pacific Islands Fisheries Science Center, NMFS/NOAA

The Pacific Islands Fisheries Science Center is comparing two independent ecosystem models' projections of climate and fishing impacts in the central North Pacific (CNP). Similarities and differences in the models' treatment of the same climate and fishing scenarios lend insight into both projected impacts and areas of uncertainty.

We compare both a size-based and a species-based ecosystem model. Both ecosystem models are driven with output from NOAA GFDL's prototype Earth System Model 2.1 (ESM 2.1) and a range of fishing mortality levels. ESM2.1 is a coupled climate model (Delworth et al. 2006, Gnanadesikan et al. 2006) and biogeochemical model (Dunne et al. 2005), forced by the IPCC SRES A2 (Nakićenović et al. 2000). ESM2.1 outputs phytoplankton densities for three functional groups across two size classes. As a result of increased stratification and reduced nutrient input to the euphotic zone, ESM2.1 projects CNP phytoplankton biomass to decline by 9 – 19% over the 21st century.

The two ecosystem models in our comparison are structurally and computationally quite different. The size-based food web (SBFW) model uses size-based predation to drive continuous growth and mortality across all consumer sizes ranging from zooplankton to large fish (Blanchard et al. 2012). Conversely, the species-based model (Ecopath with Ecosim, EwE) uses detailed species-based diets and trophic relationships (Howell et al. 2012). Comparing these models' output provides insights that may not be evident when using each model individually, as is often the case. In particular, differences in their handling of identical climate and fishing scenarios can reveal previously overlooked uncertainties in both the impacts of climate change and fishing mortality, as well as in the ecosystem models themselves. Additionally, areas of model agreement lend confidence to projections of future ecosystem impacts.

Report of the 3rd National Ecosystem Modeling Workshop (NEMoW 3): Mingling Models for Marine Resource Management – Multiple Model Inference

H.M. Townsend, C. Harvey, K. Y. Aydin, R. Gamble, A. Grüss, P. S. Levin, J. S. Link, K. E. Osgood, J. Polovina, M. J. Schirripa, and B. Wells (editors)

NOAA Technical Memorandum NMFS-F/SPO-149
December 2014

U.S. Department of Commerce
Penny S. Pritzker, Secretary

National Oceanic and Atmospheric Administration
Kathryn D. Sullivan, Administrator

National Marine Fisheries Service
Eileen Sobeck, Assistant Administrator for Fisheries

Recommended citation:

Townsend, H. M., C. Harvey, K. Y. Aydin, R. Gamble, A. Grüss, P. S. Levin, J. S. Link, K. E. Osgood, J. Polovina, M. J. Schirripa, and B. Wells (editors). 2014. Report of the 3rd National Ecosystem Modeling Workshop (NEMoW 3): Mingling Models for Marine Resource Management – Multiple Model Inference. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/SPO-149, 93 p.

Copies of this report may be obtained from:

Office of Policy, National Marine Fisheries Service
National Oceanic and Atmospheric Administration
1315 East-West Highway
Silver Spring, MD 20910

Or online at:
http://spo.nmfs.noaa.gov/tm/