Bering Sea Integrated Ecosystem Research Project: BSIERP 74 – Behavioral foraging model

Project #: BSIERP B74

Title: Behavioral foraging model

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Contract Period and Amount of Funding: 1 April 2008-30 Sept 2011 & $356,536

Report Period: 1 April 2009 – 30 September 2009

Report Date: 1 October 2009

Lead Author of Report: William Satterthwaite

Proposed timeline and milestones within report period:

What	*Who*	*Start (2009)*	*Other key dates*
Update forage fish competition equations, allowing for seasonal reproduction and more than two competitors	Mangel	March 2009	Complete June 2009 (completed June 2009)
Expand model of predators beyond a single individual, allowing intra- and inter-specific interactions with other top predators to affect resource return in a patch	Satterthwaite	March 2009	Complete June 2009 (completed May 2009)
Add age structure to fish populations and annual reproduction of predators	Mangel & Satterthwaite	May 2009	Complete August 2009 (completed July 2009)
System-specific model parameterization and sensitivity analysis	Satterthwaite, Richerson & Mangel	August 2009	Complete October 2009 (completion deferred pending additional data collection and availability)
Development of State Dependent Life History Model (SDLH)	Satterthwaite & Mangel	October 2009 (initiated July 2009)	Complete October 2010

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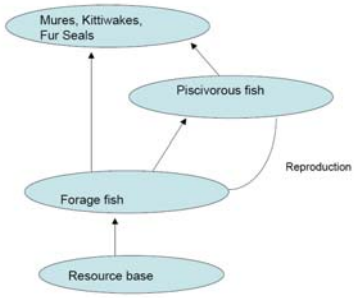
Project Summary: The core goal of our project is to develop models that allow us to assess the importance of facultative behavior by murres, kittiwakes, and fur-seals in a situation in which they are predators of piscivorous and forage fish, so that they are both competitors and predators of one trophic group and competitors with the fishery for both trophic groups, as in the food web shown below:



We are developing a suite of models to predict how changes in the prey base for these central place foragers are likely to affect their foraging behavior, their foraging success, and thus ultimately their success in raising offspring and the resultant impacts on population dynamics. Our work is directly tied to the hypothesis hypothesis 3a that competition with abundant piscivorous fish will cause declines in kittiwakes, murres, and fur seals. Our work is also relevant to hypothesis 4b that central place foragers will shift their diet, foraging locations or rookery locations to increase foraging opportunities.

Progress Summary:

We have met all milestones in the project period. For Model 1 (Coupling Diet Choice and Central Place Foraging) we have updated the forage fish competition equations, added age structure, and allowed for seasonal reproduction in the fish populations and allowed for interactions among and prey depletion by individual predators. We have initiated model parameterization and sensitivity analysis (original target date of October 2009 for completion) but based on our interactions with PIs from the patch dynamics project (see below) we have de-prioritized this task for now and moved ahead with development of the State Dependent Life History (SDLH) model of state-dependent foraging behavior.

In collaboration with PIs from the patch dynamics studies, we have laid out the basic assumptions and initiated coding for state dependent foraging models separately tailored to murres, kittiwakes, and fur seals. We will further refine model assumptions and continue code development after consulting with patch dynamics PIs at the October PI meeting in Girdwood. These models will ultimately allow for predictions of:

- Foraging locations (and distribution of dive depths in fur seals)
- Foraging trip duration
- Time budgets: foraging vs. attendance
- Provisioning rates
- Offspring growth and survival
- Adult condition at the end of rearing season

and how these factors may change given changes in the fish community.

Lessons learned and project adjustments:

- In consultation with patch dynamics PIs on the biology of our target species, we have chosen to de-emphasize classic prey choice models and emphasize using state dependent models to predict spatial and temporal aspects of foraging behavior, such as foraging location, trip duration, and provisioning rates to offspring. These will be more directly comparable to field observations than the predictions of classic diet choice models would be.

•We realize we will likely not receive prey field predictions from the vertically integrated modeling effort in the near future, so we are working with the patch dynamics group to integrate empirical data on prey distributions to derive prey fields to input into our models.

•The handling time parameters required by classic diet choice model formulations may be difficult or impossible to acquire by direct measurement. We are exploring alternatives such as measurements from surrogate species, the effects of time required to surface and dive again in order to handle large prey, and process-based pursuit models based on swim speeds of predators and prey.

•The final formulations for the state dependent model will be complex enough that the increased model execution speed resulting from translating the code into a compiled language like C rather than our usual R development environment is well worth the effort.

•We have changed our project title to "Behavioral Foraging Model" to emphasize our focus on behavioral adjustments that upper trophic level predators may make in response to changing prey base conditions. We also found the old title of "Competing fur seal-seabird-pollock model" potentially confusing it was unclear whether the "competing" referred to was between pollock and predators, between the behavioral model and the vertically integrated models, or both.

Integration activity: In addition to participation in the regular conference calls of both PIs and modelers, Will Satterthwaite (Co-investigator) participated in modeling workshop with the vertically integrated modeling team in June, collaborating with other researchers from the vertically integrated modeling effort (B70) and economic models (B71), and in an August workshop with the vertically integrated modelers (B70), economic modelers (B71), Fish studies (B58, B59, B60, B61, B62, and B90), and Patch Dynamics (B67) investigators. We have also initiated or maintained contact with various field people to ensure that our models are relevant and integrated with their work. These include David Irons, Kathy Kuletz, Heather Renner (all for seabirds, B63, B64, and B65), Andrew Trites (for fur seals, B67 and B77), and Kelly Benoit-Bird and Scott Heppell (prey base, B67). We have also discussed sea bird biology and model assumptions with George Hunt.

Education and Outreach: Marc Mangel discussed seabird and seal biology and foraging behavior with program managers at the Lenfest Ocean Program and both Marc Mangel and Will Satterthwaite described the uses of our modeling approach in assessing cumulative impacts on marine mammals in multiple systems, including the Arctic, at an Okeanus Foundation workshop on marine mammals.

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Next year's Work plan:

We will continue refining model assumptions, coding model implementation, and collaborating with patch dynamics PIs to facilitate the development of a model that can both make use of, and create testable predictions to compare against, data being collected by other BEST-BSIERP projects. We anticipate substantial model refinement following consultation with other PIs at the October 2009 PI meeting and Will Satterthwaite plans to visit Andrew Trites for further integration with Patch Dynamics studies in or around January 2010.

2009-2012 Tasks, Assignments, Timeline

What	*Who*	*Start (2009)*	*Other key dates*
Update forage fish competition equations, allowing for seasonal reproduction and more than two competitors	Mangel	March 2009	Completed June 2009
Expand model of predators beyond a single individual, allowing intra- and inter-specific interactions with other top predators to affect resource return in a patch	Satterthwaite	March 2009	Completed May 2009
Add age structure to fish populations and annual reproduction of predators	Mangel & Satterthwaite	May 2009	Completed July 2009
System-specific model parameterization and sensitivity analysis	Satterthwaite, Richerson & Mangel	August 2009	(completion deferred until more field data available)
Comparison of model outputs with FEAST and field data	Satterthwaite & Mangel	(deferred until more data and competing model predictions are available)	(deferred until more data and competing model predictions are available)
Development of State Dependent Life History Model (SDLH)	Satterthwaite & Mangel	August 2009	Complete October 2010
Results and sensitivity analysis of SDLH, comparison with behavioral foraging model, FEAST, and data	Satterthwaite & Mangel	October 2010	Complete April 2011
Completion of manuscripts	Satterthwaite & Mangel	Ongoing	Complete September 2011