Project #: B68

Title: Trophic Interactions - Retrospective analysis

Principal Investigator(s) and Recipient Organization(s):
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Contract Period and Amount of Funding:
October 1, 2007 to September 30, 2009
$ 95,325

Report Period:
1 April 2008 through 30 September 2008

Report Date:
25 September 2008

Lead Author of Report:
Franz Mueter

Proposed timeline and milestones within report period:
1. Compile environmental data, data checking, and exploratory data analyses (EDA), March 2008 and ongoing
2. Compile fish & crab datasets, data checking, and EDA, March 2008
3. Initial data sets to Ken Coyle by April 15, 2008
4. Compile seabird / mammal data, data checking, and EDA April-May 2008
5. Compute condition indices May 2008
6. Compute stock-recruit indices by May 2008
7. Compute indices of predation pressure (flatfish, cod) June 2008
8. Updated data sets to Ken Coyle by July 15, 2008
9. Data analysis: Covariation / correlation analysis; multivariate analysis of patterns and trends in fish, seabirds, & mammals July 2008 and ongoing
10. Report findings to modeling group September 2008
11. Prepare NPRB semi-annual report (Apr-Sep, due Oct 1)

Project Summary: Using available biological and environmental time series we will conduct retrospective analyses to (1) detect common trends and patterns and (2) test specific hypotheses about the effects of past climate variability on the productivity of fish, crustaceans, seabirds, and marine mammals in the eastern Bering Sea. We will address these BSIERP hypotheses:

1. Climate-induced changes in physical forcing will modify the availability and partitioning of food for all trophic levels through bottom-up processes. Specifically:
    a. Earlier sea ice retreat expected as a result of warming will result in a later (May-June), warm-water spring phytoplankton bloom, increased coupling with zooplankton and greater pelagic secondary productivity. Benthic secondary productivity will decrease.
    b. Growing populations of humpback and fin whales increasingly will both consume and compete with forage fish (juvenile pollock) for zooplankton (euphausiids and copepods). By reducing the

prey base of forage fish, whales not only reduce the amount of forage fish available to other predators, but also their quality (lipid content).

   c. In a top-down control community, fishing will reduce the degree of top-down control of forage species (including juvenile pollock) by adult pollock, cod and arrowtooth flounder. Owing to light exploitation rates, top-down control by arrowtooth flounder will increase, as will their level of competition with piscivorous fish, seabirds and marine mammals. As a result of these two processes, arrowtooth flounder will determine ultimate community composition, such that the climax community will be arrowtooth flounder-dominated (similar to the Gulf of Alaska).

2. Climate and ocean conditions influencing water temperature, circulation patterns and domain boundaries impact fish reproduction, survival and distribution, the intensity of predator-prey relationships and the location of zoogeographic provinces through bottom-up processes. Specifically:
   c. Strength of frontal boundaries will weaken due to absence of the summer cold pool, allowing expansion of the inner domain and juvenile and forage fish habitat there. Weaker winds will enhance this effect.
   d. Expected decreases in benthic productivity will negatively affect feeding and survival of small flatfish and crab, thereby lowering population levels.
3. Later spring phytoplankton blooms as a result of early ice retreat will increase zooplankton production, thereby resulting in increased abundances of piscivorous fish (pollock, cod and arrowtooth flounder) and a community controlled by top-down processes [Oscillating Control Hypothesis] with the possible trophic consequences:
   a. Competition with abundant, piscivorous fish species for forage species will lead to a decline in murres, kittiwakes and fur seals.

Progress Summary:

To date, we have compiled and examined approximately 100 annual time series and 20 monthly time series of biological and environmental data, including climate variables (Milestone #1), fish and crab stock productivity and abundance (#2), and seabird productivity and abundance (#4). In addition, we compiled data on nutrient availability and primary productivity. This activity was not part of the original work plan, but was added in response to discussions at the EMC meeting in Seattle in July 2008. Compilation of nutrient data has proven to be more time-consuming than anticipated and is as yet incomplete.

All data series were examined for outliers or unusual patterns and exploratory data analyses have been completed. The data sets were sent to the data manager in April (#3), with an updated copy provided in July (#8). Because of time spent on acquiring and analyzing nutrient, Chlorophyll *a*, and primary productivity data, and to streamline analyses, we decided to postpone the computation of condition indices (#5) until all 2008 data are at hand. For the same reasons and due to delays in acquiring marine mammal data series, we delayed the multivariate analyses involving seabirds and marine mammals (part of #9) until the 2008 field observations can be included in the database. Data on recruitment and spawning stock biomass for commercial fish stocks were used to construct time series of estimated survival rates (residuals from stock-recruitment models) and were examined for common time trends and regime shifts (#6). These will be submitted to the data manager as well as to the Alaska Fisheries Science Center for inclusion in the Ecosystem Considerations Chapter (due early October).

There have been some delays in acquiring diet information from the AFSC. These will be incorporated into the database as soon as they become available. Because of these delays, we have been unable to compute indices of predation pressure (#7). Multivariate analyses of fish data series (survey CPUE, biomass estimates, and recruitment estimates) have been largely completed through 2007, and will be updated with 2008 survey data in the coming quarter. Analyses of patterns and trends in these, as well as in the environmental data series are ongoing.

Lessons learned and project adjustments: As described above, there have been some delays in acquiring data. We have made adjustments by including additional data sets in the retrospective analyses, such as nutrient data and Chlorophyll/primary productivity data, and by proceeding with some analyses that were planned for a later date. In addition, we learned that some data, like nutrient data or zooplankton data, are not readily available and typically reside with individual researchers or in dispersed databases. Acquisition, QA/QC, and processing of these data sets have proven more time-consuming than expected and won't be completed for some time. We have made adjustments by postponing some analyses that were scheduled for the summer until the 2008 data become available, obviating the need for updating and re-running analyses in 2009.

Integration activity:
In April and July, we delivered a list of compiled indices for the retrospective analyses to the BSIERP data manager. We (Mueter) have had regular interactions with the modeling group through the July EMC meeting in Seattle, meetings with Fairbanks-based modelers in August (Hedstrom, Gibson), and through personal communications. At the EMC meeting we discussed the need for summarizing model output at the same spatial and temporal scales at which retrospective indices are computed to facilitate comparisons and model evaluation. The spatio-temporal scales of the indices compiled for retrospective analyses were provided along with the data to the BSIERP data manager. In subsequent discussions with modeling team members, it became apparent that it would be more efficient to make model output available for *post-hoc* comparisons, rather than computing indices comparable to those from the retrospective analyses within the model. For example, model output from the ROMS model is available via the Internet and will be used to compute stratification indices for comparison with field –based estimates of stratification. We have also participated in most of the monthly lead PI calls.

Education and Outreach: We have participated in a number of outreach activities related to the BSIERP project:

- Mueter prepared a presentation comparing several northern hemisphere ecosystems, including the Bering Sea, for the Ocean Science Meeting in Orlando, Florida (March 2008, presented by co-author George Hunt).
- Mueter was interviewed about responses of fish populations in the Bering Sea to climate variability by Ken Weiss from the LA Times for an article on climate warming and marine fishes (Article has not yet appeared in print).
- Mueter provided testimony on the impacts of climate change on fish and fisheries to a panel convened by the Aspen Institute in Fairbanks (August 12/13). A copy of the presentation was provided to Nora Deans.
- Mueter participated in the ESSAS (Ecosystem Studies of the Sub Arctic Seas) Annual Meeting in Halifax, Nova Scotia (Sep 13-16) and provided information on BSIERP to the ESSAS Steering Committee, which was considering an application from BSIERP to be formally affiliated with ESSAS.
- Kruse prepared a section on status of knowledge and proposed mechanisms linking climate change to the production of red king crab, Tanner crab and snow crab for a PICES Scientific Report, titled "Forecasting Climate Impacts on Future Production of Commercially Exploited Fish and Shellfish". The report, resulting from workshops sponsored by PICES and NPRB, will be published later in 2008.
- Kruse gave an invited presentation on potential impacts of climate change on red king crabs in the eastern Bering Sea at the "Effects of Climate Change on the World's Oceans" Symposium in Gijon, Spain, in May 2008.
- An article on climate change and Alaska's fisheries, written by Kruse, appeared in the May 2008 issue of Alaska Seas and Coasts, published by Alaska Sea Grant and the Marine Advisory Program of the University of Alaska Fairbanks.
- Kruse was interviewed and quoted in a newspaper article in the Fairbanks Daily News Miner (July 13, 2008) on the effects of climate change on marine ecosystems of Alaska.

- Alaska Sea Grant announced the 25th Lowell Wakefield Symposium to be held in March 2009 on Biology and Management of Exploited Crab Populations under Climate Change. The symposium steering committee is chaired by Kruse.
- Kruse participated in the Annual Science Conference of the International Council for the Exploration of the Sea (ICES) in September 2009.

Next year's Work plan:

Project B68, Trophic Interactions - Retrospective analysis
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Oct 2008-2012 Tasks, Assignments, Timeline

What	***Who***	***Start***	***End***	***Other key dates***
2008				
Formulate hypotheses for Pacific cod	Mueter, Kruse	Oct	Nov	*October*: PI meeting, Girdwood; *October* : PICES meeting
Compute indices of predation pressure (flatfish, cod)	Mueter w/ Aydin	Oct	Nov	
Data analysis: test Pacific cod hypotheses with empirical data	Mueter, Kruse	Nov	Dec	
2009				
Obtain remaining seabird and marine mammal data through 2008	Mueter	Jan	Jan	*January*: Alaska Marine Science Symposium
Compile 2008 SAFE data results	Mueter	Jan	Jan	
Update environmental data as needed	Mueter	Feb	Feb	
Incorporate seabird/marine mammal data into multivariate analyses	Mueter	Mar	Mar	*March*: Report to NPRB
Updated data sets to Ken Coyle	Mueter		Feb 15	
Manuscript preparation – Covariation & trophic interactions	Mueter, Kruse	Apr	May	
Formulate crab hypotheses and conceptual models	Mueter, Kruse, w/ Zheng	Apr	May	
Data analysis: test crab hypotheses with empirical data	Mueter, Kruse, w/ Zheng	May	Jun	
Obtain diet data from AFSC	Mueter w/ Aydin		Jun	
Formulate flatfish hypotheses and conceptual models	Mueter, Kruse	Mar 1	Jun 30	
Data analysis: test flatfish hypotheses with empirical data	Mueter, Kruse	Jul 1	Aug 15	*July*: Report findings to modeling group
Manuscript preparation – climate & cod / flatfish / crab productivity	Mueter, Kruse	Aug 1	Dec 31	*September*: Report to NPRB; *October*: PICES Annual meeting
2010				
Data updates (2008 seabird / mammal surveys, as necessary)	Mueter w/ Byrd, Trites			*January*: Report to NPRB; Presentation at AMSS
Updated data to Ken Coyle	Mueter		Feb 15	
Data analysis: Developing & testing	Mueter	Jan 1	Aug 15	*July*: Report findings to modeling

seabird & mammal hypotheses	w/ Byrd, Trites			group
Manuscript preparation – climate & prey availability for seabirds / fur seals	Mueter w/ Byrd, Trites	Aug 1	Dec 31	*September*: Report to NPRB *October*: PICES Annual meeting
2011				
Synthesis manuscript preparation	Mueter, Kruse (w/ others)	Jan 1	Aug 31	*January*: Presentation at AMSS *March*: Report to NPRB
Provide input to correlative biomass dynamics model	Mueter, Kruse, Student	Jan 1	Dec 31	*September*: Report to NPRB *October*: PICES Annual meeting
2012				
Final report preparation	Kruse, Mueter	Jan 1	Jul 1	*January*: Presentation at AMSS *April*: Report to NPRB *July*: Final report