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Tackling Ecological Complexity and Climate Change: Matches and Mismatches in the
Seasonal Cycle of California's Marine Flora and Fauna

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Project Hypotheses

Matches and mismatches in predator needs and prey availability account for changing reproductive success of top predators (fish and seabirds) in the California Current Large Marine Ecosystem (CCLME).

Project Goals and Objectives

Goals:

1. Improve understanding of the climate-ecosystem-fish-wildlife system through retrospective studies (modelling of the seasonal cycle of productivity and predator-prey relationships) of existing long-term data,
2. develop a series of physical oceanographic and food web (match-mismatch) indicators as tools for future management decisions, and
3. conduct targeted outreach (thereby increasing exposure) of managers (CFGC, PFMC, NOAA-NOS sanctuaries), policy-makers (state lawmakers), and user communities (PCFFA, etc.) on climate change and food web dynamics.

Objectives:

1. Create a dynamic, inter-disciplinary team of marine ecologists, statisticians and oceanographers with the necessary data resources, taxonomic knowledge, and quantitative expertise to address this issue,
2. Develop a quantitative set of biological-physical indices, including "match-mismatch indices" (MMI) that consider both phenology and abundance for all major functional groups in the study system,
3. Test for demographic consequences of climate change-induced matches and mismatches in key trophic interactions, and
4. Increase exposure of climate-ecosystem-trophic considerations to management and user communities as a strategic, long-term (rather than short-term) improvement for decision-making.

Briefly describe project methodology

In this project, we tested the hypothesis that trophic matches and mismatches explain reproductive failure/declines and changes in top predators' populations in northern California. To test this hypothesis, we conducted retrospective

analyses of spatial and temporal variation in prey availability and potential trophic interactions. Data contributions from NOAA-ERD, USFWS/PRBO, NMFS-SWFSC made this study possible. Originally, we planned to investigate how variability in phenology (seasonal cycle of abundance) across 4 trophic levels (primary productivity, zooplankton/krill, forage fish, seabirds and salmon) was associated with the breeding success of fish and seabirds. As the project developed, we focused more on spatial, rather than temporal patterns, especially in regard to krill. This study has broad applicability to understanding the impacts of climate change on status and trends of multi-species assemblages of significant interest to state and federal management agencies.

Describe progress and accomplishments toward meeting goals and objectives

We accomplished most goals. Our emphasis on 1) krill and 2) spatial match-mismatch rather than temporal considerations resulted in a better understanding of how oceanographic mechanisms, specifically currents, affected the availability of these critical prey in the Gulf of the Farallones. We were successful in meeting project goals of enhancing understanding as well as developing indicators for management. We were successful in published many papers in the scientific literature on the seasonal cycle of upwelling, prey, and predator populations. One of our primary findings was that upwelling in the wintertime is important to ecosystem dynamics.

Project modifications

As discussed above, the only major change was a focus on spatial match-mismatch in addition to temporal match-mismatch. This provided a more holistic viewpoint to system dynamics. We did not encounter any major problems, aside from lack of data at the mid trophic levels with which to assess changes in the seasonality of abundance.

Project outcomes

We develop a series of indicators used to describe and analyze the seasonal characteristics of upwelling. This material was published in Bograd et al. (2009). Indices include: (1) the spring transition index (STI), the length of upwelling season index (LUSI), and total upwelling magnitude index (TUMI). We developed these indices using NOAA-ERD's Bakun upwelling index database, and have calculations for every 3 degrees of latitude from 30-45 degrees N. These indices are available by request through NOAA-ERD or Farallon Institute's Integrated Marine Ecological Database (IMED).

Impacts of project

This project has increased awareness amongst managers and policy makers about the importance of climate and food web changes to fish and wildlife of California. The California Ocean Protection Council has heard, first hand, of some of our findings, specifically that changes in currents can cause a spatial mismatch between the availability of prey and the needs of dependent predators. This likely occurred in 2005 and possibly in 2006, leading in part to the chinook salmon declined in later years. This project also increased awareness of the importance of krill (euphausiid crustaceans) to the biology of fish and wildlife in central-northern California. Lastly, the project highlighted the importance of oceanographic conditions during the wintertime (January, February, March) to spring and summer ecosystem productivity, including the breeding success of seabirds and the likely early ocean survival of Central Valley chinook salmon. All of these foci are continuing to be investigated.

Benefits, commercialization and application of project results

NOAA-NMFS, CDFG, and PFMC are all interested in our results, though to our knowledge none of our results have been used yet in a management context. This will happen in time, and with additional investigations.

Issue-based forecast capabilities

The project was focused on developing a deeper understanding of an extreme event in 2005, when seabirds (auklets) and fish (rockfish) failed in their reproduction. The model PhD student Jeff Dorman has developed can be used to forecast future years with the same ecological conditions as 2005.

Publications

Technical reports

Title: The California Current

Authors: Bograd, S. J. and W. J. Sydeman (lead authors)

Date: December 2009

Chapter for the North Pacific Ecosystem Status Report, PICES

Title: "Plankton", Section in climate change report: Climate Change Site Scenario document

Authors: W. J. Sydeman

Date:

Report to the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries

Conference papers, proceedings, symposia

(text) Title: Climate and phenology in the California Current

Authors: Schroeder, I. D., W. J. Sydeman, and S. J. Bograd

Date: 2008

Conference Title: Fisheries and the Environment Annual Meeting

Location: San Jose, CA

Title: Winter pre-conditioning of seabird phenology in the California Current

Authors: Schroeder, I. D., W. J. Sydeman, and S. J. Bograd

Date: August 2009

Conference Title: NRL Stennis Space Center seminar

Location: Mississippi

Title: Rockfish, seabirds, and the importance of wintertime ocean conditions in the California Current.

Authors: Black, B., W. J. Sydeman, I. Schroeder, S. J. Bograd, and P. Lawson.

Date: November 2009

Conference Title: PICES Annual Meeting

Location: Jeju, South Korea

Title: Ecosystem-based fisheries management using seabirds.

Authors: Mills, K. L. and W. J. Sydeman

Date: December 2009

Conference Title: CalCOFI

Location: La Jolla, California

Title: Seabirds as indicators: Comparative ecosystem dynamics in temperate and tropical upwelling areas
Authors: Mills, K. L. and W. J. Sydeman.
Date: July 2009
Conference Title: Galapagos Science Symposium
Location: Galapagos Islands, Ecuador

Title: Response of predators to hierarchical krill patch dynamics in the Antarctic, California Current, and North Pacific.
Authors: Santora, J. A., W. J. Sydeman, C. S. Reiss, S. D. Batten, and S. Ralston.
Date: June 2009
Conference Title: GLOBEC Synthesis Meeting
Location: Victoria, BC, Canada

Title: The North Coast Program: Bodega Line and salmon management.
Authors: W. J. Sydeman
Date: September 2009
Conference Title: PaCOOS Board of Governor's Meeting
Location: Seattle, Washington

Title: Integrating the Indicators: A progress report.
Authors: W. J. Sydeman
Date: June 2009
Conference Title: Fisheries and the Environment (FATE) Annual Meeting
Location: Seattle, Washington

Title: Wrong place, wrong time: Recent mismatches in food availability to salmon and seabirds in California.
Authors: Sydeman, W. J. and S. J. Bograd
Date: 2009
Conference Title: Spotlight on Science
Location: California Ocean Protection Council, Scripps Institution of Oceanography, La Jolla, California

Title: Climate change and North Pacific marine ecosystems: What are the seabirds telling us?
Authors: Sydeman, W. J., K. L. Mills, V. Byrd, H. Renner, Y. Watanuki, and S. Minobe.
Date: 2009
Conference Title: Pacific Seabird Meeting
Location: Hakodate, Japan

Title: Modeling krill habitat suitability in the Northern-Central California Current System.
Authors: Sydeman, W. J., J. A. Santora, J. Field, S. Ralston, S. J. Bograd, N. Sarkar, and R. M. Suryan.
Date: 2009
Conference Title: PICES Annual Meeting
Location: Jeju, South Korea

Title: Thinking outside the stream: Salmon, seabirds, and ecosystem-based fisheries management (EBFM); a.k.a. "Integrating indicators for prognosis".
Authors: Sydeman, W. J., S. A. Thompson, J. A. Santora, and K. L. Mills.
Date: 2009
Conference Title: California-Nevada Chapter American Fisheries Society
Location: Santa Rosa, CA

Title: Do seabirds at sea in the California Current reflect krill distribution, abundance and patch structure?
Authors: Santora, J. A., W. J. Sydeman and S. Ralston.
Date: 2009
Conference Title: PICES Annual Meeting
Location: Jeju, South Korea

Title: Phenology of upwelling in the California Current
Authors: Bograd, S.J., I.D. Schroeder, N. Sarkar, W.J. Sydeman, F.B. Schwing,
Date:
Conference Title: PICES Annual Meeting
Location: Dalian, China

Peer-reviewed journal articles or book chapters

Title: February upwelling enhances rockfish growth and seabird reproduction in the central California Current Ecosystem
Authors: Black, B. A., I. D. Schroeder, W. J. Sydeman, S. J. Bograd, and P. Lawson
Date: 2009
Journal Name: Canadian Journal of Fisheries and Aquatic Sciences
Issue/Page Numbers: In revision for publication

Title: Phenology of coastal upwelling in the California Current
Authors: Bograd, S. J., I. D. Schroeder, N. Sarkar, X. Qiu, W. J. Sydeman and F. B. Schwing
Date: 2009
Journal Name: Geophysical Research Letters
Issue/Page Numbers: Vol. 36, L01602

Title: Estimating the impacts of fishing on dependent predators: a case study in the California Current
Authors: Field, J. C., A. D. MacCall, R. W. Bradley and W. J. Sydeman
Date: 2009
Journal Name: Ecological Applications
Issue/Page Numbers: in press

Title: Interannual indices of California Current krill spatial organization: an integrated approach
Authors: Santora, J. A., S. Ralston and W. J. Sydeman
Date: 2009
Journal Name: Canadian Journal of Fisheries and Aquatic Sciences
Issue/Page Numbers: In revision for publication
Title: Winter pre-conditioning of seabird phenology in the California Current.
Authors: Schroeder, I. D., W. J. Sydeman, N. Sarkar, S. A. Thompson, S. J. Bograd, and F. B. Schwing.
Date: 2009
Journal Name: Marine Ecology Progress Series
Issue/Page Numbers: Vol. 393, p. 211-223

Title: "Marine ecosystems, climate and phenology: impacts on top predators"
Journal Theme Session and Introduction
Authors: Sydeman, W. J. and S. J. Bograd
Date: 2009
Journal Name: Marine Ecology Progress Series
Issue/Page Numbers: Vol. 393, p. 185-188.

Title: Seabirds and climate in the California Current --A synthesis of change.
Authors: Sydeman, W. J., K. L. Mills, J. A. Santora, S. A. Thompson, D. F. Bertram, K. H. Morgan, B. K. Wells, J. M. Hipfner, and S. G. Wolf.
Date: 2009
Journal Name: CalCOFI Report
Issue/Page Numbers: Vol. 50, p. 82-104

Title: Predicting population consequences of ocean climate change for an ecosystem sentinel, the seabird Cassin's Auklet.
Authors: Wolf, S. G., M. A. Snyder, W. J. Sydeman, and D. A. Croll.
Date: 2009
Journal Name: Global Change Biology
Issue/Page Numbers: In press

Theses, dissertations

Title: Impacts of climate change on the population biology of *Euphausia pacifica* in the California Current
Authors: Dorman, J.D.
Schools: UC Berkeley
Date: June 2010

Media coverage

Name of publication/radio station, etc: *The Press Democrat* newspaper
City: Santa Rosa
State: California
Date of publication/broadcast: January 12, 2010
Headline or topic: A bad year for salmon, but there's hope

Name of publication/radio station, etc: *The San Francisco Chronicle, SFGate*
City: San Francisco
State: California
Date of publication/broadcast: May 2, 2009
Headline or topic: Hundreds of dead birds on Bay Area beaches

Student

Jeffrey Dorman
University of California Berkeley
Department of Integrative Biology
Degree program enrolled in: Ph.D.
Theses/dissertation title: Impacts of climate change on the population biology of *Euphausia pacifica* in the California Current
Supported by Sea Grant funds? [x] yes [] no
Start date: 7/1/2008
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Cooperating organizations

Federal

List under appropriate category below, those who provided financial, technical

NOAA-Environmental Research Division - Bograd - co-PI

NOAA-NMFS-SWFSC-Santa Cruz Laboratory - contribution of krill and juvenile rockfish datasets, co-authorship of publications