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US-GLOBEC NEP Phase IIIa: Effects of Climate Variability on Calanus Dormancy Patterns and Population Dynamics within the California Current

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Final Report for Period: 06/2007 - 05/2008

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Principal Investigator: Runge, Jeffrey .

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Organization: University of Maine

Submitted By:

Title:

US-GLOBEC NEP Phase IIIa: Effects of Climate Variability on Calanus Dormancy Patterns and Population Dynamics within the California Current

Project Participants

Senior Personnel

Name: Runge, Jeffrey

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc

Name: Johnson, Catherine

Worked for more than 160 Hours: Yes

Contribution to Project:

Catherine Johnson worked as a post doc on this award, in which capacity she analyzed data compiled on Calanus life cycles and participated in discussions and developments of hypotheses to explain Calanus dormancy patterns.

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

University of Rhode Island Graduate School of Oceanography

National Marine Fisheries Service Southwest Fisheries Center

Fisheries and Oceans Canada

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:

Calanoid copepods are a key component in the California Current (CC) ecosystem. They consume primary and secondary production at high rates, and in turn serve as prey for larval, juvenile, and small pelagic fish, other invertebrates and certain seabirds. The growth and reproduction of calanoids is directly and indirectly affected by climate variability, as temperature affects the physiological rates of these organisms, and changes in copepod prey abundance or prey type due to climatic change will have an indirect effect. A critical period in the life of several calanoid species is their overwintering period, during which they leave the unproductive surface waters in mid summer- fall, remain at depth for several months, and then ascend to the surface in the springtime, usually coincident with the spring bloom. The timing of the reemergence of these copepods in spring relative to the seasonal timing of the spring bloom is likely critical for both the copepods population dynamics during the rest of the year, and for fueling the first-feeding of many other organisms, such as larval fish. Similarly, the timing of when these copepods enter their dormant state, thus greatly reducing their abundance within the surfacelayers, may be critical to the life history of other surface planktivores. Surprisingly, the physical and biological cues that both initiate and terminate the dormant phase of several key copepod species within the CC are poorly known.

The goal of this research was to develop and test the hypothesis that the dormant phase of two major calanoid species, *Calanus pacificus* and *Calanus marshallae*, are in part controlled by changes in temperature and prey abundance. We compiled the existing data relating to the relative stage abundance and vertical distribution of the two target species for four distinct locations along the west coast of the U.S. and Canada. We then compared these data to observational bio-physical data sets, specifically temperature and proxies for prey abundance, much of which were collected as part of the GLOBEC NEP program. We have developed an Individual-Based Model (IBM) for each of the two species, based on several different conceptual models of how temperature and prey availability control the dormancy response. This model is forced with climatological data from the target regions, and compared with the analysis of the field data. With continued support from subsequent NSF awards, we are using this model to test the sensitivity of each species' population dynamics to initial conditions, interaction with the timing of the spring bloom, and expected levels of climate variability. We are also investigating the relative influences of local climate and advection due to large-scale changes in physical transport on variability in local population abundance of these two species.

In addition to data analysis and model development at the respective laboratories of the project participants and collaborating partners, we have met at a series of workshops in New Hampshire, California and Nova Scotia to review data and model results and collectively developed a new hypothesis, the lipid accumulation window hypothesis, to explain *Calanus* dormancy patterns.

Findings:

The work has involved analysis of environmental data sets and life cycle data of two *Calanus* species (*C. pacificus* and *C. marshallae*) for the purposes of 1) identifying environmental processes that control dormancy and 2) developing a mechanistic understanding of dormancy for inclusion in population dynamics modeling. Dormancy timing is variable for both the population and likely individuals on a year to year basis (?1 month), ruling out daylength as a controlling stimulus.

Our best correlations for dormancy timing of these species along the coastal Pacific Ocean were with changes in the strength of upwelling. Because upwelling is highly related to changes in primary production, we hypothesize this linkage points to food availability as a driver for dormancy timing.

Using a single simple dormancy controller based on the buildup and use of lipid reserves (which are in turn controlled by prey availability and temperature), we developed an Individual Based Life Cycle Model (IBM) that reproduces most of the population dynamics of *C. pacificus* and *C. marshallae* from throughout the California Current System.

Based on these findings from our sister project on *C. finmarchicus* in the NE Atlantic we conclude the following that no single environmental factor controls dormancy; rather, the combined effects of temperature and prey availability acting on the individual life history of a copepod, combined with its physiology, determine the timing and duration of dormancy. We propose a 'Lipid Accumulation Window (LAW)' hypothesis, whereby copepods enter dormancy only after passing through a favorable environmental window of the proper combination of food and temperature that allows an adequate buildup of lipids necessary to sustain the dormant period and oogenesis in the spring.

To date, there have been eight presentations at scientific meetings:

Leising, A.W. The role of copepods in linking ecosystem processes to climate models: What's in your 'Z' box? ASLO 2006. Feb. 2006

Leising, A.W., Bessy, C., Johnson, C., and Runge, J. Latitudinal variation in environmental forcing relevant to copepod overwintering and its effects on population dynamics for the copepod *Calanus pacificus* along the U.S. West Coast. PICES/GLOBEC climate Workshop, Apr, 2006.

Runge, J.A. A. Leising and C. Johnson. Obey the LAW: Calanus dormancy explained. U.S. GLOBEC Georges Bank/Northwest Atlantic Phase IV PI meeting. Woods Hole. Oct., 2006.

Johnson, C. Understanding copepod population variability in the western North Atlantic: Insights from data synthesis. Marine Biological Association, Plymouth, England, Oct. 2006,

Johnson, C. Understanding copepod population variability in the western North Atlantic: Insights from data synthesis. Danish Institute for Fisheries Research, Oct. 2006.

Runge, J.A. A. Leising and C. Johnson. Development of the Lipid Accumulation Window hypothesis to explain Calanus finmarchicus dormancy. Phase IV PI meeting. Woods Hole. Apr. 2007.

Runge, J.A. A. Leising and C. Johnson. Life histories and biogeochemistry. 2nd BASIN Workshop. Chapel Hill, North Carolina. May. 2007.

Johnson, C., A. Leising, J. Runge, E. Head, P. Pepin, S. Plourde and E. Durbin. 2007. Control of Calanus finmarchicus dormancy patterns in the northwest Atlantic: the Lipid Accumulation Window hypothesis. Abstract. 4th International Zooplankton Production Symposium. Hiroshima, Japan.

Two publications of research articles based on these presentations are in progress:

Leising, A.W., Bessey, C., Johnson, C., Runge, J, and Peterson, B. Effects of interannual and regional climate variability on the population dynamics of Calanus spp. in the California Current I: determination of dormancy controls from field data. In prep for Limnology and Oceanography.

Leising, A.W. Bessey, C., Johnson, C., Runge, J. Effects of interannual and regional climate variability on the population dynamics of Calanus spp. in the California Current II: Application of an individual-based model. In prep Limnology and Oceanography

Training and Development:

This project has provided research skills and experience to Dr. Catherine Johnson, who worked as a postdoctoral fellow with support from this award. Dr. Johnson is now employed as a research scientist with Fisheries and Oceans Canada at the Bedford Institute of Oceanography.

Outreach Activities:

Our outreach activities have been directed at fifth and sixth grade school children visiting the Cohen Center for Interactive Learning at the Gulf of Maine Research Institute. Because middle school is a critical time for the development of science interests and skills, GMRI focuses on developing rigorous and locally-relevant science learning opportunities for students in grades 5-8. We are contributing a presentation on zooplankton with special emphasis on Calanus species and their life cycle, citing results from this and related awards.

Journal Publications

Johnson, C.J. A.W. Pershing, J.A. Runge, E. Head, P. Pepin, S. Plourde, and E. G. Durbin., "Characteristics of Calanus finmarchicus dormancy patterns in the northwest Atlantic", ICES Journal of Marine Science, p. 339, vol. 65, (2008). Published,

Books or Other One-time Publications

Moloney, C.L. A. Jarre, S. Kimura, D. Mackas, E. Murphy, W. Peterson, J. Runge, and K. Tadokoro., "Dynamics of marine ecosystems: ecological processes.", (). Book, Submitted
 Editor(s): In: C. Werner, R. Harris, M. Barange, J. Field, E. Hoffman, and I. Perry (Eds.)
 Collection: Global Change and Marine Ecosystems
 Bibliography: Oxford University Press

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

This project contributes to a mechanistic understanding of the processes controlling dormancy of plankton copepods in the coastal and deep ocean. We have developed an individual based model that incorporates this understanding to produce realistic life cycle patterns that match field observations. Our findings resolve a major biological challenge for the development of realistic coupled physical biological modeling of key species of zooplankton in North Pacific and North Atlantic Oceans. This is a new research direction that will provide insight into the processes controlling the biogeochemistry and population dynamics and spatial distribution of secondary productivity in coastal ocean marine ecosystems.

Contributions to Other Disciplines:

This award is supporting the development of coupled physical biological modeling that has the potential to transform our understanding of climate and fisheries impacts on complex ecosystem dynamics, with applications to the interpretation of observing system data, biogeochemical cycling and spatially explicit fisheries management.

Contributions to Human Resource Development:

This research has provided the opportunity for a post-doctoral research associate (Catherine Johnson) to develop skills in physical and biological modelling of ocean environments, and has contributed to maintaining this skilled expert in the field of ocean sciences.

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Any Web/Internet Site

Any Product

Contributions: To Any Resources for Research and Education

Contributions: To Any Beyond Science and Engineering