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U.S.-GLOBEC: NWA Georges Bank: Effects of climate variability on Calanus dormancy patterns and population dynamics in the Northwest Atlantic

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Principal Investigator: Runge, Jeffrey .
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Submitted By:
Runge, Jeffrey - Principal Investigator
Title:
U.S.-GLOBEC: NWA Georges Bank: Effects of climate variability on Calanus dormancy patterns and population dynamics in the Northwest Atlantic

Project Participants

Senior Personnel

Name: Runge, Jeffrey
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: LEISING, ANDREW
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:
Dr. Catherine Johnson has actively participated in the data compilation, analysis, interpretation and presentation of project results. She was supported as a postdoctoral fellow on NSF OCE-

Graduate Student

Name: Thompson, Cameron
Worked for more than 160 Hours: Yes
Contribution to Project:
Graduate student working on zooplankton mortality, support from this award

Undergraduate Student

Name: Doubleday, Ayla
Worked for more than 160 Hours: Yes
Contribution to Project:
Research asssistant, zooplankton analysis

Name: Malcosky, Christopher
Worked for more than 160 Hours: Yes
Contribution to Project:
Research assistant, zooplankton analysis

Technician, Programmer

Name: Jones, Rebecca
Worked for more than 160 Hours: Yes
Contribution to Project:

Research assistant, with support from this award

Name: Braff, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:
Research assistant, with support from this award

Other Participant

Research Experience for Undergraduates

Organizational Partners

Bedford Institute of Oceanography
Provided analysis of data sets use in the project analysis

Institut Maurice Lamontagne
Partner provided data and analysis for project purposes

Northwest Atlantic Fisheries Centre
Partner provided data and analysis for project purposes

University of Rhode Island Graduate School of Oceanography
Partner provided data and analysis for project purposes

NOAA/Southwest Fisheries Science Center
Research collaborator working on modeling of Calanus species

Other Collaborators or Contacts

We collaborated with Catherine Johnson, currently at the Bedford Institute of Oceanography, Fisheries and Oceans, Canada.

We collaborated with Dr. Andrew Leising, NOAA Southwest Fisheries Science Center on the modeling of diapause in Calanus life cycles

We collaborated with the following investigators, who supplied data for our study. They will be coauthors on the first research article in preparation:

Dr. Erica Head, Bedford Institute of Oceanography, Fisheries and Oceans, Canada
Dr. Pierre Pepin, Northwest Atlantic Fisheries Center, Fisheries and Oceans, Canada
Dr. St?phane Plourde, Institut Maurice Lamontagne, Fisheries and Oceans, Canada
Dr. Ted Durbin, Graduate School of Oceanography, University of Rhode Island,
Dr. Jinyu Sheng, Department of Oceanography, Dalhousie University

Activities and Findings

Research and Education Activities:
The goal of the research was to identify the factors that control onset of and emergence from dormancy in Calanus finmarchicus in the Northwest Atlantic using both an inter-regional comparison of dormancy response and associated environmental conditions and individual-based model (IBM) simulations. This methodology was applied to C. pacificus and C. marshallae in the Northeast Pacific in an earlier GLOBEC-NEP project, and the proposed research extends the approach and also make an inter-specific comparison of dormancy cues. The research tested the hypothesis that inter-regional differences in population dynamics are caused by different environmental conditions

acting on copepods with similar dormancy and physiological rate responses to environmental parameters. Data sets from seven regions of the Northwest Atlantic were compiled and compared to observational bio-physical data sets to test hypotheses about dormancy control mechanisms. We conducted IBM simulations in individual regions to test the plausibility of a dormancy control hypothesis we have developed.IBM simulations were also be run to test the sensitivity of the model to uncertainty in dormancy and physiological rate functions, and to evaluate population responses to realistic interannual variability in surface and deep-water temperature and shifts in the timing and magnitude of the spring bloom. Modeled population responses to climate variability in C. finmarchicus were compared to similar analyses in C. pacificus and C. marshallae.

The research involved the participation and training of two undergraduate research assistants, one Masters student and one postdoctoral fellow. The research represented a continuing collaboration between scientists from the University of New Hampshire and NOAA's Pacific Fisheries Environmental Laboratory (PFEL), and it included collaborations with scientists at Dalhousie University and Canadian Department of Fisheries and Oceans Laboratories. In addition, the results from this proposal are applicable to current and proposed GLOBEC copepod population modeling efforts.

Findings:

In this research we developed a mechanistic understanding of dormancy in the life cycle of Calanus finmarchicus. Our approach involved compilation of Calanus life cycle and environmental data sets across regions in the NW Atlantic, examination of common patterns and cues and development of quantitative hypotheses using individual-based life-cycle models to explain the observed patterns. We collected, with the assistance of colleagues (E. Durbin, R. Jones, S. Plourde, E. Head, P. Pepin), life history data sets, including ambient water temperature, food availability (measured as mean chlorophyll a concentration in the surface water column), photoperiod and life stage abundance cycles, from six areas spanning 9 degrees of latitude in the region. We use as proxies for dormancy entry and exit the proportion of stage CV (year day when the CV proportion is at one half of its climatological maximum proportion) and the proportion of adult females (yearday when adult females reach 10% of the population), respectively. Our first results show that no single observed environmental cue explains the range of dormancy patterns; rather, dormancy entry and emergence occur over a broad range of times, both among years and regions. We proposed a 'Lipid-Accumulation Window (LAW)' hypothesis, in which dormancy entry and exit involves interaction of multiple environmental factors with the copepod's physiological responses, including lipid accumulation and development rates. We postulated that an individual enters dormancy when it has accumulated ≥ 50% of its dry weight as lipid by the end of stage CIV; if this condition is not met, it continues molting to adult. The lipid accumulation rate is dependent on ambient temperature and food availability. There is, therefore, a seasonal window in time of conditions that will allow dormancy. Upon entry, the length of the dormant period is a function of both ambient temperature during dormancy and the lipid level. Predation, especially at the early life stages, as well as advection, can significantly alter the demographic pattern of dormant individuals. We are presently testing this hypothesis using individual based models against the observed data. A similar approach is being carried out to examine dormancy of Pacific species of the genus, as part of the Northeast Pacific GLOBEC synthesis phase.

Tests of the life cycle model against data have yielded favorable results (Johnson et al. 2008). We hypothesize that there are fundamentally similar processes controlling Calanus life histories across species in the genus; different life history responses among species are the result of species specific parameters defining these general processes.

This award also contributed to support research on the rates and sources of predation mortality in Calanus finmarchicus populations in the Northwest Atlantic. Estimation of mortality is necessary for accurate modeling of Calanus life histories. The results, obtained in collaboration with M. Ohman and others, based on data collected during the GLOBEC program, showed spatial and temporal differences in mortality rates of C. finmarchicus life stages on Georges Bank, with invertebrate predation as the likely source of seasonal increases in mortality in late summer (Ohman et al. 2008).

This award also supported analysis of seasonal and interannual variability the abundance of Calanus finmarchicus life stages at a time series station located on Jeffreys Ledge in the western Gulf of Maine. A major result was the observation of an order of magnitude decline in Calanus abundance between 2003-2005, correlated with a decrease in water column salinity (Runge and Jones, submitted). Since lipid rich Calanus are a major food source for herring, mackerel, sand lance and northern right whales, it is hypothesized that this decline had an important impact on the trophic energetics and spatial distribution at the higher trophic levels in this important region for coastal fisheries.

Training and Development:

This award contributed to the training of a master's student, Cameron Thompson, in zooplankton ecology and population dynamics modeling. Mr. Thompson has started a master's research project to investigate the seasonal and cross shelf gradients in mortality rates of Calanus finmarchicus in the Northwest Atlantic. The award also contributed to the training of two undergraduate students, Ayla Doubleday and Christopher Malcosky, in the methods for sampling and analysis of zooplankton, measurement of vital rates, and zooplankton taxonomy.

Outreach Activities:

J. Runge participated in workshops held at the Gulf of Maine Research Institute involving exchange among researchers and members of the fishing industry to discuss factors controlling herring abundance in the Gulf of Maine. He worked with the Maine Department of Marine Resources (DMR) to understand the life cycle, abundance and distribution of Calanus finmarchicus, the major prey of the endangered northern right whale, in Maine coastal waters. This information is used in DMR's risk assessment analysis for regulations to prevent entanglement of right whales by the coastal trap/pot fisheries.

Journal Publications

Johnson, C.L., Leising, A., Runge, J., Head, E., Pepin, P., Plourde, S. and Durbin, E., "Characteristics of Calanus finmarchicus dormancy patterns in the northwest Atlantic", ICES Jour. Mar. Sci., p. 339-350, vol. 65, (2008). Published, 101093/icesjms/fsm171.

Ohman, M. D., E.G. Durbin, J.A. Runge, B.K. Sullivan and D. B. Field., "Relationship of predation potential to mortality of Calanus finmarchicus on Georges Bank, Northwest Atlantic", Limnology and Oceanography, p. 1643, vol. 53, (2008). Published,

Johnson, C., J. Runge, A. Bucklin, K. A. Curtis, E. Durbin, J. A. Hare, L. S. Incze, J. Link, G. Melvin, T. O'Brien and L. Van Guelpen., "Biodiversity and ecosystem function in the Gulf of Maine: pattern and role of zooplankton and pelagic nekton", PLoS Biology, p. , vol. , (2010). Manuscript: submission 3/2010,

Leising, A., C. Bessey, C. Johnson and J. Runge, "Effects of interannual and regional climate variability on the population dynamics of Calanus: Application of an individual-based model.", Limnol.Oceanogr., p. , vol. , (2010). Manuscript. Submission: Feb 2010,

Books or Other One-time Publications

Moloney, C., J. Field, A. Jarre, S. Kimura, D. Mackas, O. Maury, E. Murphy, W. Peterson, J. Runge, M. St John and K. Tadokoro., "Dynamics of marine ecosystems: ecological processes.", (2009). Book chapter, Accepted
Editor(s): C. Werner, R. Harris, M. Barange, J. Field, E. Hoffman, and I.Perry
Collection: Global Change and Marine Ecosystems.
Bibliography: Oxford University Press

Johnson, C.J., A.W. Leising, J.A. Runge, E.J.H. Head, P.Pepin, S. Plourde, and E. Durbin., "Understanding copepod life history patterns through inter-regional comparison of AZMP zooplankton data.", (2008). DFO Technical Report, Published
Collection: AZMP Bulletin (Fisheries and Oceans, Canada)
Bibliography: Volume 7: 21-26

Harris, R.P., L. J. Buckley, R. Campbell, S. Chiba, D. Costa, T. Dickey, X. Irigoien, T. Kiorboe, C. Mollman, M. Ohman, J. Runge and P. Wiebe, "Dynamics of marine ecosystems: observation and experimentation", (2010). Book, Accepted
Editor(s): C. Werner, R. Harris, M. Barange, J. Field, E. Hoffman, and I.Perry
Collection: Global Change and Marine Ecosystems
Bibliography: Oxford University Press.

Runge, J. A. and R. J. Jones, "Results of a collaborative project to observe coastal zooplankton and ichthyoplankton abundance and diversity in the western Gulf of Maine: 2003-2008", ( ). Book, Submitted
Editor(s): J. Watson, R. Stephenson, J. Annala and M. Hall-Arber.
Collection: Advancing Ecosystem Research for the Gulf of Maine
Bibliography: American Fisheries Society

Web/Internet Site

Other Specific Products

Product Type:

Presentations at scientific meetings

Product Description:

We have compiled a data base of life cycle patterns of Calanus finmarchicus across its latitudinal range in the northwest Atlantic and have put forward a hypothesis to explain these patterns.

Sharing Information:

We are sharing this product first through presentations at scientific meetings, then in publications in scientific journals and products distributed through our web pages.

This award contributed to the support of the following presentations at local, national and international meetings:

Runge, Jeffrey, Leising, Andrew, Catherine Johnson and Frederic Maps. Population responses to environmentally forced shifts in timing of diapause in Calanus finmarchicus in the Gulf of Maine. GLOBEC Open Sciences Meeting. Victoria BC, June, 2009

Leising,A., J. Pierson, J.Runge, and C.Johnson. Why doesn't C.marshallae live in the Atlantic; a comparison across the copepod genus Calanus' physiological rates with implications for mortality rates under climate variability. GLOBEC Open Sciences Meeting. Victoria BC June, 2009.

Runge, J., Leising, A,, Pierson, J., Kimmel, D., Pershing, A., Maps, F. and Johnson, C. Life histories of Calanus species in the North Atlantic and North Pacific Ocean and responses to climate forcing. ICES Working Group on Zooplankton Ecology. Torshavn, Faroe Islands. March, 2009

Runge, J., Leising, A,, Pierson, J., Kimmel, D., Pershing, A., Maps, F. and Johnson, C. Life histories of Calanus species in the North Atlantic and North Pacific Ocean and responses to climate forcing. GLOBEC Pan Regional Synthesis National Workshop. Boulder, CO. February, 2009

Runge, J. A. and R.J. Jones. Forage conditions for juvenile Atlantic salmon in coastal waters of the Gulf of Maine. SeaGrant Workshop: Investigation of Nearshore Migration of Atlantic Salmon in the Gulf of Maine Region. Portland, ME January, 2009.

Runge, J.A., A. Leising and C. Johnson. Control of Calanus finmarchicus dormancy patterns in the northwest Atlantic: the Lipid Accumulation Window hypothesis'. U.S. GLOBEC Pan Regional Synthesis Workshop. Seattle. September, 2008

Runge, J. A. Diapause and the recent decline of Calanus finmarchicus in coastal waters of the Gulf of Maine: Implications for the lipid budget in the western Gulf. Gulf of Maine Research Institute February, 2008

Runge, J. A., R. J. Jones and C. Manning. PULSE: A cooperative partnership for Coastal Ocean Ecosystem Monitoring in the Gulf of Maine. Gulf of Maine Zooplankton Workshop. Bedford Institute of Oceanography. Dartmouth, NS. Canada February, 2008

Runge, J. A. and R.J. Jones. PULSE: A cooperative partnership for Coastal Ocean Ecosystem Monitoring in the Gulf of Maine. GoMOOS session on Gulf of Maine Observing Systems. Maine Fisherman's Forum. Rockport, Maine. March, 2008

Runge, J. A. , R.J. Jones and C. Manning. Population dynamics of Calanus finmarchicus in relation to trophic transfer in the western Gulf of Maine: The role of storage lipids. ASLO Ocean Sciences Meeting. Orlando, Florida. March, 2008

Runge, J. and C. Johnson. Needs from models: approaches to the biological questions. ICES Working Groups on Zooplankton Ecology and Physical biological interactions. S?te, France. April, 2008

Salisbury, J and J. Runge. Fixed station samplling in the western Gulf of Maine: The UNH COOA and Northeast Consortium PULSE program. RARGOM Theme Session on the Role of Shipboard Sampling in Observing Sytems. University of New Hampshire. May, 2008.

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.

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

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.

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. Obey the LAW: Calanus dormancy explained. U.S. GLOBEC Georges Bank/Northwest Atlantic Phase IV PI meeting. Woods Hole. Oct., 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.

Contributions

Contributions within Discipline:

Our synthesis of data and hypothesis explain the control of dormancy of Calanus finmarchicus, a dominant member of the zooplankton community in the northwest Atlantic Ocean and key intermediary in the regions food webs. The project contributes to knowledge that will allow us to model the life cycle of Calanus and understand the impacts of environmental forcing on its abundance and distribution. These models can be linked to other ecosystem processes to provide a general understanding of how coastal north Atlantic ecosystems will respond to climate change.

Contributions to Other Disciplines:

Our findings contribute to the capability for coupling population dynamics models of marine populations to physical circulation models. These coupled physical-biological models have potential applications in fisheries science, as they provide quantitative predictive tools for how environmental forcing and climate change can impact fisheries populations, especially in their early life stages.

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

The results of our analysis of Calanus dormancy patterns and interannual variation in life cycles in coastal Gulf of Maine have contributed to the understanding of oceanographic conditions affecting distribution of herring that feed on lipid rich stages in the coastal Gulf of Maine. This is a subject of intense public concern as a regional fisheries issue, as the absence of herring in coastal waters has led to dispute withing the fishing industry about the impact of the coastal herring trawling fishery. This issue will be the subject of a report in the Christian Science Monitor, to which project PIs have contributed information on the status of the inshore Calanus stocks.

Conference Proceedings

Categories for which nothing is reported:

Any Web/Internet Site

Contributions: To Any Human Resource Development

Contributions: To Any Resources for Research and Education

Any Conference