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U.S. GLOBEC: NWA Georges Bank - Processes Controlling Abundance of dominant copepod species on Georges Bank: Local Dynamics and Large-scale Forcing

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Final Report for Period: 04/2009 - 03/2010

Submitted on: 06/29/2010

Principal Investigator: Runge, Jeffrey .

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Organization: University of Maine

Submitted By:

Runge, Jeffrey - Principal Investigator

Title:

U.S. GLOBEC: NWA Georges Bank - Processes Controlling Abundance of dominant copepod species on Georges Bank: Local dynamics and large-scale forcing.

Project Participants

Senior Personnel

Name: Runge, Jeffrey

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Woods Hole Oceanographic Institution

Lead institution for this collaborative award

University of New Hampshire

Contribution of staff and UNH R/V Challenger to collection and analysis of zooplankton time series used in this project.

Bedford Institute of Oceanography

Assistance in the comparative analysis of zooplankton time series

National Marine Fisheries Service Southwest Fisheries Center

Assistance with the development of a Calanus life cycle model

Other Collaborators or Contacts

Dr. Andrew Leising, PFEL, National Marine Fisheries Service Southwest Science Center, NOAA, La Jolla CA

Dr. Catherine Johnson, Bedford Institute of Oceanography, Department of Fisheries and Oceans, Dartmouth, NS, Canada

Dr. Rubao Ji, Department of Biology, Woods Hole Oceanographic Institution, Woods Hole, MA

Mr. Christopher Manning, Ocean Process Analysis Laboratory, University of New Hampshire, Durham, NH

Activities and Findings

Research and Education Activities:

This award supports J. Runge's contribution to the proposal entitled: 'Processes controlling abundance of dominant copepod species on Georges Bank: Local dynamics and large-scale forcing' awarded to C. Davis et al. at the Woods Hole Oceanographic Institution. J. Runge has participated in the research activities supported by this award as follows:

1. Participation in three workshops at Woods Hole, during which Dr. Runge has provided data and information on copepod reproductive rates and life cycles in the Gulf of Maine, as well as contributions to planning of future research activities for data acquisition relevant to modeling of zooplankton population dynamics in this region.
2. Analysis of time series data and report of findings in a number of oral presentations (listed below) and written publications about(a) the population dynamics of *Calanus finmarchicus* (e.g.: Ohman et al., 2008; Runge and Jones, submitted), b)the zooplankton species diversity in the Gulf of Maine and future directions in zooplankton biodiversity and phenology research (e.g.: Ji et al., in press; Johnson et al. submitted), and c) the relationship between zooplankton production and fish recruitment (Castonguay et al., 2008).
3. Participation in a workshop at the Bedford Institution of Oceanography, in which Dr. Runge established collaboration in the comparative analysis of zooplankton time series in the Gulf of Maine, the Scotian Shelf and the Newfoundland shelf. The initial product of this collaboration is a presentation submitted to the ALSO 2008 Summer meeting in St. John's, NFLD.
4. Presentation of findings at the Ocean Sciences Meeting held in Orlando in March, 2008.
5. Contribution of results to the RARGOM (Regional Association for Research on the Gulf of Maine) Theme Session on The Role of Shipboard Sampling in the Gulf of Maine Observing System. These results have also been reported at the NERACOOS (Northeast Regional Association of Coastal Observing Systems) Board of Directors Meeting in February, 2009 and the time series on *Calanus* and other copepod species in support of GoM modeling were also be reported at the NERACOOS Strategic Implementation Plan Subcommittee, of which J. Runge is a member, in May, 2009.
6. Presentation of results at the 3rd GLOBEC Open Science Meeting held in Victoria, B.C. in June, 2009.
7. Presentation of results at the Gulf of Maine Science Symposium held in St. Andrews, N.B., in October, 2009.
8. This award has contributed to the training of a graduate student, Cameron Thompson, who is working on a master's degree in the School of Marine Sciences at the University of Maine. Mr. Thompson's research project involves measurement of *Calanus* mortality rates to test the hypothesis that mortality of the large, lipid-rich late stage *Calanus* is higher in the nearshore coastal water, where they are susceptible to predation by planktivorous fish, than in the deep basins of the Gulf of Maine, where the number of predators and rate of mortality is thought to be significantly lower.
9. A complete list of oral presentations supported or partially supported by this award includes:

Runge, J.A., R. Jones, F. Maps and A. Leising. The life history of *Calanus finmarchicus* in the Gulf of Maine. Life histories of the planktonic copepods, *Calanus finmarchicus* and *Calanus helgolandicus*: Advances in understanding in the Gulf of Maine and across the North Atlantic. RARGOM Theme Session, Portland, ME. March, 2010.

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. Technical Workshop on Biodiversity in the Gulf of Maine. Gulf of Maine Symposium-Advancing Ecosystem Research for the Future of the Gulf. St. Andrews, NB. October, 2009.

Jones, R.J. and J.A. Runge. Results of a collaborative monitoring program of coastal zooplankton and ichthyoplankton in the western Gulf of Maine: 2003-2008. Gulf of Maine. Symposium-Advancing Ecosystem Research for the Future of the Gulf. St. Andrews, NB. October, 2009.

- Golet, W., J. Stockwell, G. Sherwood, A. Pershing, J. Runge and M. Lutcavage. Bottoms up: Potential effects of environmental forcing on apex predators in the Gulf of Maine. Gulf of Maine Symposium-Advancing Ecosystem Research for the Future of the Gulf. St. Andrews, NB. October, 2009.
- Maps, F., A. Leising, J. Runge and A. Pershing. Population response of the planktonic copepod, *Calanus finmarchicus*, to environmental change in the Gulf of Maine: the role of diapause. Gulf of Maine Symposium-Advancing Ecosystem Research for the Future of the Gulf. St. Andrews, NB. October, 2009.
- Runge, J.A., A. Kovach, R. Jones, S. Tallack, J. Churchill, C. Chen, G. Sherwood, H. Howell, J. Grabowski and D. Berlinsky. Understanding climate impacts on the spatial dynamics of Atlantic cod in coastal waters of the Gulf of Maine. GLOBEC Open Sciences Meeting. Victoria BC. June, 2009.
- Runge, J.A., Golet, W., J. Stockwell, G. Sherwood, A. Pershing and M. Lutcavage. Bottoms up: Potential effects of environmental forcing on apex predators in the Gulf of Maine. GLOBEC Open Sciences Meeting. Victoria BC. June, 2009.
- 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 II. 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.
- Salisbury, J and J. Runge. Fixed station sampling 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 Systems. University of New Hampshire. May, 2008.
- Runge, J.A. Linking the coastal ocean ecosystem to fisheries in the northwest Atlantic: the role of models. Biological Oceanography course invited lecture. University of New Hampshire. April, 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.
- 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. 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. February, 2008.

Findings:

This award supported research leading to the following major findings:

We observed dramatic interannual fluctuations in abundance of the planktonic copepod, *Calanus finmarchicus*, during summer in coastal waters of the Gulf of Maine (Runge and Jones, submitted and manuscript in preparation). This decline is hypothesized to result in a dramatically lower source of lipids for Atlantic herring growth and reproduction and is hypothesized to be related to changes in condition of bluefin tuna (which feed on herring) in this region over the past several decades (oral presentations by Runge et al. 2009 and Golet et al., 2009 and manuscript in preparation).

We characterized spatial and temporal gradients in copepod and overall zooplankton diversity in the Gulf of Maine (Johnson et al., submitted). Zooplankton community composition is different between among the neritic environment in shallow bays and estuaries, the coastal shelf and the deeper water offshore. Diversity of higher level taxonomic groups declined with distance offshore in the coastal transect, reflecting higher nearshore contributions of meroplankton. Zooplankton bioversity tends to increase in late summer, and significant interdecadal shifts in diversity were observed, the highest diversity indices occurring during the 1990's. A critical research question is whether the lipid-rich planktonic copepod, *Calanus finmarchicus*, that is predominant in coastal and deep basin zooplankton assemblages of the Gulf of Maine, where it is at the southern end of its subarctic range, will be subject to northward displacement due to climate forcing. The impacts of this potential diversity shift on pelagic fish (herring, sand lance, mackerel), northern right whales and other consumers that rely on this species as a principal, energy rich food source have not been quantified. Advances in approaches to studying biodiversity questions include continued progress in development of linked coupled physical biological models and trophic-centric and ecosystem models as integrative tools for interpreting biodiversity data. Ultimately, sustained observations and sophisticated modeling analysis of biodiversity will be effectively communicated and incorporated into ecosystem approaches to management of the Gulf of Maine resources.

We found evidence that environmental forcing of copepod production can influence on recruitment variability in groundfish and pelagic fish stocks in the northwest Atlantic, implying that such forcing is an important factor to incorporate into regional fishery management. Castonguay et al. (2008) report that mackerel recruitment in the southern Gulf of St. Lawrence is significantly related to copepod egg production rate, a proxy for availability of nauplius stages to the planktonic mackerel larvae.

We described seasonal and spatial variability of early life history mortality for the planktonic copepod *Calanus finmarchicus*, based on a large database of stage abundance and egg production rates collected during the U.S. GLOBEC field study on Georges Bank (Ohman et al., 2008). Instantaneous mortality rates for a combined egg-through-nauplius-3 stage show a recurrent seasonal pattern of a modest elevation in January followed by a seasonal peak in May. Spatial differences were observed, with a higher probability of mortality on the southern flank in winter and a pronounced seasonal maximum on the bank crest in May. Comparison of an index of daily rates of egg loss with an index of consumption rates of eggs by suspended hydroids, hydromedusae, and five species of planktonic copepods show general agreement between mortality and predation in both seasonal variation and spatial patterns.

Training and Development:

A graduate student, Cameron Thompson, in the dual science and policy master's degree program at the School of Marine Sciences, has been partially supported by this research award. He has been trained in hypothesis testing in oceanographic science, with specialty training to develop skill in zooplankton sampling methods, zooplankton taxonomy and the development of integrative physical biological models for application in regional approaches to ecosystem based management.

Outreach Activities:

The findings have been presented (1) to an audience of fishermen and fisheries managers at the Maine Fishermen's Forum, Rockport, Maine in March, 2008 (2) at a meeting of a Gulf of Maine Herring Working Group, composed of fishermen and scientists, sponsored by the Gulf of Maine Research Institute, and (3) At a region wide theme session on the role of shipboard sampling in the Gulf of Maine Observing System (May, 2008). The results have brought greater awareness of the role of climate and environmental forcing in determining distribution and abundance of harvested fish populations, and the need for regular fixed station sampling to capture seasonal and interannual copepod abundance and diversity cycles for development of ecosystem models of the Gulf of Maine coastal zone. One of the outreach contributions of this project is the consideration of support for fixed station sampling as part of the Northeast Regional Association for Coastal Observing Systems (NERACOOS).

Journal Publications

Ji, R., M. Edwards, D. Mackas, J. Runge and A. Thomas., "Marine plankton phenology and life history in a changing climate: Current research and future directions.", *Journal of Plankton Research*, p. , vol. , (2010). Accepted,

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). Submitted,

Castonguay, M; Plourde, S; Robert, D; Runge, JA; Fortier, L, "Copepod production drives recruitment in a marine fish", CANADIAN JOURNAL OF FISHERIES AND AQUATIC SCIENCES, p. 1528, vol. 65, (2008). Published, 10.1139/F08-12

Ohman, MD; Durbin, EG; Runge, JA; Sullivan, BK; Field, DB, "Relationship of predation potential to mortality of Calanus finmarchicus on Georges Bank, northwest Atlantic", LIMNOLOGY AND OCEANOGRAPHY, p. 1643, vol. 53, (2008). Published,

Books or Other One-time Publications

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.", (2011). Conference proceedings, Accepted
 Editor(s): R. Stephenson, J. Annala, M. Hall-Arber and J.A. Runge.
 Collection: Advancing Ecosystem Research for the Gulf of Maine.
 Bibliography: American Fisheries Society

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

In this project, I am contributing data times series and a conceptual model of copepod diapause to collaborative research led by C. Davis et al. at the Woods Hole Oceanographic Institution. The collective effort will result in a coupled physical biological model of copepod population dynamics in the Gulf of Maine. If successful, this model will be a major contribution not only to the region but also to the international effort to apply the tremendous advances in computer technology and physical oceanographic understanding of ocean currents to predict environmental control of distribution and abundance of planktonic organisms. The coupled model will be used to interpret regional ocean observing data and provide predictions of climate variability and change on distribution and abundance of zooplankton.

Contributions to Other Disciplines:

The coupled physical biological model of copepod population dynamics in the Gulf of Maine, to which I am contributing as a collaborator, will have applications to management of fisheries, marine mammals, harmful algal blooms and nutrient loading in the coastal zone.

Contributions to Human Resource Development:

With partial support from this award, Cameron Thompson, graduate student in the dual master's and science program at the School of Marine Sciences, will use the results from this project to develop his own research hypotheses and to receive training in the use of coupled physical-biological models for ecosystem approaches to management.

Contributions to Resources for Research and Education:

Presentations on zooplankton and their trophic role in marine food webs are now part of the curriculum content of the Cohen Center for Interactive Learning at the Gulf of Maine Research Institute.

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Any Web/Internet Site

Any Product

Contributions: To Any Beyond Science and Engineering

Any Conference