

1-29-2015

# Ocean Acidification-Category 1- Impact of ocean acidification on survival of early life stages of planktonic copepods in the genus *Calanus* in the northern

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## Recommended Citation

Runge, Jeffrey A. and Christensen, John P., "Ocean Acidification-Category 1- Impact of ocean acidification on survival of early life stages of planktonic copepods in the genus *Calanus* in the northern" (2015). *University of Maine Office of Research and Sponsored Programs: Grant Reports*. 365.

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## Preview of Award 1041081 - Final Project Report

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### Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1041081
Project Title:	Ocean Acidification-Category 1- Impact of ocean acidification on survival of early life stages of planktonic copepods in the genus <i>Calanus</i> in the northern
PD/PI Name:	Jeffrey Runge, Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	11/01/2010 - 10/31/2014
Reporting Period:	11/01/2013 - 10/31/2014
Submitting Official (if other than PD\PI):	Jeffrey Runge Principal Investigator
Submission Date:	01/29/2015
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Jeffrey Runge

### Accomplishments

#### \* What are the major goals of the project?

Our overall research objective is to assess the potential for predicted CO<sub>2</sub>/pH levels over the next century to affect reproductive success and population dynamics of species of *Calanus* that reside in the North Atlantic and

Arctic Oceans. With this award, we test the null hypothesis of no direct effect of ocean acidification on *Calanus* species, particularly the subarctic species, *Calanus finmarchicus* that dominates zooplankton assemblages in the North Atlantic Ocean, over the range of reasonable possibilities for change in CO<sub>2</sub>, pH and ocean temperature. We will test this hypothesis with a combination of laboratory experiments, field sampling and population dynamics modeling.

1. In laboratory experiments, determine: (a) the effects of increased CO<sub>2</sub>/lower pH on hatching success of eggs of *Calanus* species; (b) the effects of increased CO<sub>2</sub>/lower pH on growth and development of nauplius and copepodid stages of *C. finmarchicus*; (c) whether the hatching response to changes in pH is different in other zooplankton species common in the Gulf of Maine and (d) whether warmer surface layer temperatures expected at southern biogeographic boundaries (such as the Gulf of Maine) enhance the effects of ocean acidification
2. Conduct a research cruise in the Gulf of Maine for the purposes of determining surface and vertical distributions of pH across the coastal shelf and in the deep basins of the Gulf of Maine in late summer/early fall and collecting biological data on the abundance and life history characteristics of *C. finmarchicus*. The goal is to use these data to test model predictions about the impact of increased temperature and lower pH on *C. finmarchicus* abundance in the Gulf of Maine, where the species plays a key role linking primary production to fish, marine mammals and seabirds in the Gulf of Maine ecosystem.
3. Develop a life cycle model for *C. finmarchicus* in the Gulf of Maine and use it to evaluate the potential for impact of ocean acidification and combined temperature/pH stress on reproductive success and the capacity for *C. finmarchicus* to successfully maintain its life cycle in this region.

**\* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

1. Brian Preziosi, the University of Maine graduate student supported by this award, published the first of two research articles based on his Master's thesis, completed in December, 2012. The research article, entitled "The effect of warm temperatures on hatching success of the marine planktonic copepod, *Calanus finmarchicus*" was published in the Journal of Plankton Research. He also prepared, in collaboration with J. Christensen and J. Runge, a manuscript for peer reviewed publication describing the results of his laboratory experiments investigating the effects of increased CO<sub>2</sub> and temperature on the hatching success of *C. finmarchicus* eggs. It is expected that this manuscript will be submitted by March, 2015. These activities contribute to objectives 1(a) and 1(d) listed above.
2. J. Runge and research assistant, Cameron Thompson, in collaboration with Norwegian partners, completed analysis of data and prepared two manuscripts describing experiments investigating the effects of increased CO<sub>2</sub>/lower pH on growth and development of nauplius and copepodid stages of *C. finmarchicus*. The experiments were conducted between April 15-June 15, 2013, at the Austevoll Research Station in Norway. The first paper (Fields et al. 2015) describes an unexpected finding of high infection rates of *C. finmarchicus* at the coastal fjord station where copepods were collected for experiments. The second paper (Runge et al., "Minimal direct impact of ocean acidification on vital rates of *Calanus finmarchicus*, an ecologically critical planktonic species in North Atlantic ecosystems") is in preparation for submission to a special issue of the ICES J Mar Sci on ocean acidification. This activity was supported by leveraging support from this NSF award with funding support from the Institute of Marine Research, Norway. It contributes to accomplishment of Objectives 1(b) and 1 (d) above.

3. J. Christensen analyzed water samples taken during the experiments at the Darling Marine Center and during the research survey of the Gulf of Maine conducted in fall, 2012 on the *R/V Cape Hatteras*. Titration alkalinity, total carbon dioxide, salinity, nitrate plus nitrite, ammonium, inorganic phosphate, and dissolved silicate were measured and used to calculate the real pH of seawater. The analysis was carried out at the Green Eyes LLC laboratory in Maryland. This activity contributes to completion of Objectives 1(a), 1(c) and (2).
4. J. Runge and research assistant, Cameron Thompson, in collaboration with Norwegian partners, assisted in experiments investigating effects of increased CO<sub>2</sub>/lower pH on growth and development of nauplius and copepodid stages of the copepod, *Calanus glacialis*. This species is predominant in the arctic zooplankton assemblages and an important component of arctic marine ecosystems. The experiments were conducted at the Austevoll Research Institute between March and June, 2014, and form part of the Ph.D. research of Allison Bailey, a graduate student at the Norwegian Polar Institute, Tromsø, Norway. This activity contributes to Objective 1(a).
5. A manuscript reviewing knowledge of the life history characteristics of *Calanus finmarchicus* across its North Atlantic range was published in *Prog. Oceanogr.* (Melle et al. 2014). The work represents a collaboration of zooplankton ecologists from North America and Europe. J. Runge, the second author, was supported during the writing phase by the NSF Ocean Acidification award. This activity contributes to objective 3.
6. A manuscript addressing the population dynamics of *Calanus finmarchicus* in the Gulf of Maine was prepared and published in 2014-15 (Runge et al. 2015. *Journal of Plankton Research*). The research paper puts forward a mechanism involving transport of late stage *Calanus* from Canadian waters into the Gulf of Maine, and subsequent high production and transport to the western Gulf of Maine in the food-rich Maine Coastal Current. This hypothesis resolves differences between life cycle model predictions and observations of *C. finmarchicus* dynamics in Wilkinson Basin, the overwintering repository of the species supplying the Georges Bank and southern New England ecosystem. A research proposal based on this analysis was submitted to NSF and recommended for funding. This activity contributes to Objective 3.
7. A manuscript reviewing advances in physical, biological and coupled ocean models was published in *Oceanography* in December, 2013 (Curchister et al. 2013). J. Runge was supported in the preparation of this manuscript by the present NSF award. This activity contributes to Objective 3.
8. During the review period researchers and students involved in this project presented research or prepared results for several national and international conferences: the ASLO/AGU Ocean Sciences Meeting in Honolulu in February, 2014; the Arctic Change Conference in Ottawa in December, 2014 and the ASLO Aquatic Sciences meetin in Granada in February, 2015. This activity contributes to Objectives 1 and 3.
9. Samples from the research survey of the Gulf of Maine conducted in fall, 2012 on the *R/V Cape Hatteras* have been analyzed and archived with BCO-DMO. Data include hydrographic data from the ship's CTD, pH of seawater, stage-structured abundance of *C. finmarchicus* and abundance of other zooplankton, dry weight and lipid levels of *C. finmarchicus* stage CV, egg production and molting rates, and chlorophyll a concentrations. These data have been prepared into a comprehensive report that will be filed in BCO-DMO as specified in our data management plan. This activity when the report is completed will accomplish Objective (2)

- Specific Objectives:
1. Preparation and publication of manuscripts based on Brian Preziosi's masters thesis research. This objective was achieved by activity (1) above.
  2. Preparation and publication of manuscripts reporting on laboratory experiments to investigate OA effects on nauplius and copepodid growth, development and other vital rate processes at the Austevoll Research Station. This objective was achieved by activity (2) above.
  3. Analysis of carbonate chemistry samples from laboratory experiments and Gulf of Maine survey. This objective was achieved by activity (3) above.
  4. Participation in experiments at the Austevoll Research Station to investigate ocean acidification effects on the arctic *Calanus* species, *C. glacialis*. This objective was achieved by activity (4) above.
  5. Preparation and publication of manuscripts describing the life history characteristics and population dynamics of *Calanus finmarchicus* in the Gulf of Maine. This objective was achieved by activities (5), (6) and (7) above.
  6. Completion of analysis of hydrographic and biological samples (CTD data, zooplankton abundance, chlorophyll a) from the Gulf of Maine survey and time series station and archiving of data with BCO-DMO. This objective was achieved by activity (9) above.
  7. Present results at national and international scientific meetings. This objective was achieved by activity (8) above.

Significant Results: Objective 1

Our experiments showed no significant effect of increased CO<sub>2</sub>/lower pH on *C. finmarchicus* hatching success or on growth rate, lipid accumulation, feeding rate or respiration rate of nauplius and copepodid stages through adult. Hatching success experiments investigating the multiple stress of high CO<sub>2</sub> and high temperatures indicate an effect at pH levels <7.5, lower than levels expected in the ocean over the next century (Preziosi 2012; Preziosi et al. in prep). A review of published studies of ocean acidification effects on planktonic copepods finds significant effects at levels predicted over the next 100-200 years in only three of the 19 species investigated (Runge et al. in prep.)

Objectives 2 and 3

The population structure, egg production and molting rates of *C. finmarchicus* measured during the fall research survey in the Gulf of Maine (Runge et al. 2015) were not consistent with our life history model (Maps et al. 2010. *J. Plankton Res.* 34:36-54), which had predicted that the population in Wilkinson Basin would be dominated by reproductive females due to early emergence of overwintering stage CV in the relatively warm deep water of the basin. In Runge et al. (2015), we put forward an alternative hypothesis that the overwintering population in Wilkinson Basin is supplied in late summer by stage CV that develop in the phytoplankton rich Maine Coastal Current during summer and are transported to the western Gulf of Maine, where they accumulate in Wilkinson Basin as they make their overwintering migration to deeper water. These newly diapausing stage CV do not emerge in the relatively warm water of the basin until later in winter or early spring, when adults may be able to take advantage of winter-spring phytoplankton blooms to reproduce and populate the waters of southern New England. Our data therefore do not indicate a significant role for high CO<sub>2</sub> combined with high temperatures during the fall bloom as important in the population dynamics of *C. finmarchicus* in the region. We therefore conclude that ocean acidification in the future is a second-order issue for *C. finmarchicus* in the Gulf of Maine.

Key outcomes or  
Other achievements:

1. Our results support an emerging general conclusion that key, non-calcifying zooplankton species may not be substantially impacted by predicted levels of increased CO<sub>2</sub>/lower pH over the next century.
2. We have contributed a review of OA impacts on zooplankton to the Arctic Monitoring and Assessment Programme (AMAP) in their 2013 report on Arctic Ocean Acidification
3. A major outcome is that rate processes parameterization of *C. finmarchicus* population dynamics models will not need to be performed to take into account predicted ocean acidification levels. This finding will be submitted for publication in a special ICES issue on ocean acidification effects.
4. This award contributed to the publication of a major review of *C. finmarchicus* life history characteristics found in research studies across the North Atlantic Ocean
5. The present award supported sample collection and analysis that led to the publication of a new hypothesis about mechanisms supporting persistence despite climate change of a major planktonic species in the Gulf of Maine ecosystem. It led to submission of a new NSF proposal to continue research toward development of predictive population models of *C. finmarchicus*. This proposal has been recommended for funding.

**\* What opportunities for training and professional development has the project provided?**

1. The project supported the training of a master's student (Brian Preziosi), who was awarded his Masters of Marine Science degree in 2012. It also partially supported the master's research, on *C. finmarchicus* mortality rates, of Camaron Thompson, who also was awarded his Masters of Marine Science degree in 2012.
2. The project supported the professional development of Cameron Thompson, who was hired as a technical Research Associate and is contributing to project related research activities. Mr. Thompson received mentoring in copepod culture and experimental methods while working on the project during two 4-8 week stays at the Austevoll Research Station in 2013-14.

**\* How have the results been disseminated to communities of interest?**

1. We have contributed a review of OA impacts on zooplankton to the Arctic Monitoring and Assessment Programme (AMAP) in their 2013 report on Arctic Ocean Acidification
2. To date, we have reported results at a number of regional, national and international scientific conferences: the 2012 Ocean Sciences Meeting (Salt Lake City); the 2012 OA PI meeting (Washington DC); regional RARGOM Gulf of Maine Theme sessions (Oct 2012-13); the Maine Fishermen's Forum (2013); the 2014 Ocean Sciences meeting (Honolulu); the Arctic Change Conference (2014: Ottawa); the 2015 ASLO Aquatic Sciences Meeting, and in several seminars to research and public audiences.
3. The results have been communicated in a number of research publications, detailed in the products section of this report. Three databases supported fully or in part by this award have been archived with BCO-DMO.

## Products

### Books

#### Book Chapters

Browman, H.I., S. Dupont, J. Havenhund, L. Robbins, M. Beman, J. Runge et al. (2013). Biological responses to ocean acidification. *Arctic Monitoring and Assessment Program (AMAP): Arctic Ocean Acidification* R. Shearer et al.. AMAP. Oslo. 37. Status = PUBLISHED; Acknowledgement of Federal Support = No ; Peer Reviewed = Yes ; ISBN: [ISBN-978-82-7971-082-0](https://doi.org/10.1007/978-82-7971-082-0).

## Conference Papers and Presentations

Runge, J. (2013). *Changing Ocean- What changes are we observing in the Gulf of Maine and what does it mean for the ecosystem?*. Maine Fishermen's Forum. Rockport, Maine. Status = OTHER; Acknowledgement of Federal Support = Yes

Runge, J.A. (2013). *Changing Ocean: What changes are we observing in the Gulf of Maine and what does it mean for the ecosystem supporting the coastal food system?*. Camden Conference Symposium: Food and Climate Change-Global Challenges and Maine Responses. Camden, Maine. Status = OTHER; Acknowledgement of Federal Support = Yes

Runge, J., Jones, R., Preziosi, B. and J. Christiansen (2011). *Effects of increased CO2/lower pH on reproductive success of Calanus finmarchicus.*. Joint Norway-US Workshop on Ocean Acidification.. Bergen, Norway. Status = OTHER; Acknowledgement of Federal Support = Yes

Runge, J. C. Thompson, R. Bjelland, H. Browman, C. Durif, D. Fields, S. Shema, A.B. Skiftesvik. (2013). *Effects of ocean acidification on growth and development of the planktonic copepod, Calanus finmarchicus.* Second U.S. Ocean Acidification Principal Investigators' Meeting.. Washington, DC. Status = OTHER; Acknowledgement of Federal Support = Yes

Preziosi, B., Jones, R., Runge, J. and J. Christiansen. (2012). *Effects of ocean acidification on reproductive processes of the marine planktonic copepod Calanus finmarchicus.*. Ocean Sciences Meeting. Salt Lake City, USA. Status = OTHER; Acknowledgement of Federal Support = Yes

Preziosi, B., Runge, J., Christensen, J. and Jones, R. (2013). *Effects of ocean acidification on reproductive processes of the marine planktonic copepod, Calanus finmarchicus.* Second U.S. Ocean Acidification Principal Investigators' Meeting.. Washington, DC. Status = OTHER; Acknowledgement of Federal Support = Yes

Runge, J. A., Maps, F., Pershing, A., Leising, A., Kimmel, D. and J. Pierson (2012). *Phenology and persistence of Calanus finmarchicus under climate forcing in the Gulf of Maine.* ASLO/AGU Ocean Sciences Meeting. Salt Lake City, USA. Status = OTHER; Acknowledgement of Federal Support = Yes

Runge, J, F. Maps, A. Leising, A. Pershing, J. Pierson and D. Kimmel (2011). *Scenarios of climate change impacts on local production of the subarctic copepod, Calanus finmarchicus, in the Gulf of Maine.* 5th International Zooplankton Production Symposium. Pucon, Chile. Status = OTHER; Acknowledgement of Federal Support = Yes

Runge, J.A., R. Ji, C. Thompson, N. Record, C. Chen, D. Vandemark, J. Salisbury and F. Maps (2014). *Sustained abundance of Calanus finmarchicus in the western Gulf of Maine despite record negative NAO and warm temperatures.* ASLO/AGU Ocean Science Meeting. Honolulu, USA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Runge, J. A., C.T. Thompson and R. J. Jones (2013). *Sustained abundance of Calanus finmarchicus in the western Gulf of Maine, despite record warm temperatures in 2012.* RARGOM (Regional Association for Research on the Gulf of Maine) Annual Science Meeting. Portsmouth, NH. Status = OTHER; Acknowledgement of Federal Support = Yes

Bailey, A., P. Thor, H. I. Browman, D. Fields, J. Runge, A. Vermont, R. Bjelland, C. Thompson, S. Shema, C. Durif. (2014). *The effects of projected ocean acidification on the early development of the key Arctic copepod, Calanus glacialis.*. Arctic Change Conference.. Ottawa, Canada. Status = OTHER; Acknowledgement of Federal Support = Yes

Bailey, A., P. Thor, H. I. Browman, D. Fields, J. Runge, A. Vermont, R. Bjelland, C. Thompson, S. Shema, C. Durif. (2015). *The effects of projected ocean acidification on the early development of the key Arctic copepod, Calanus glacialis.* ASLO Aquatic Sciences Meeting.. ASLO Aquatic Sciences Meeting. Granada, Spain. Status = OTHER; Acknowledgement of Federal Support = Yes

Runge, J.A. (2012). *What controls the abundance of Calanus finmarchicus in the Gulf of Maine?*. The Gulf of Maine in a Changing Climate. Bowdoin College, Brunswick Maine. Status = OTHER; Acknowledgement of Federal Support =

Yes

## Inventions

### Journals

Curchitser, E.N., H.P. Batchelder, D.B. Haidvogel, J. Fiechter, and J. Runge (2013). Advances in physical, biological, and coupled ocean models during the US GLOBEC program.. *Oceanography*. 26 (4), 52. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Fields, D. M., J. A. Runge, C. Thompson, S. Shema, R. Bjelland, A. B. Skiftesvik, and H. Browman (2015). Infection of the planktonic copepod *Calanus finmarchicus* by the parasitic dinoflagellate, *Blastodinium* spp.: effects on grazing, respiration, fecundity, and fecal pellet production.. *Journal of Plankton Research*. 37 (1), 211. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi:[10.1093/plankt/fbu084](https://doi.org/10.1093/plankt/fbu084)

Howard, J., E. Babij, R. Griffis, B. Helmuth, A. Himes-Cornell et al. (2013). Oceans and Marine Resources in a changing climate.. *Oceanography and Marine Biology: An Annual Review*. 51 71. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = Yes

Melle, W., J. Runge, E. Head, S. Plourde, C. Castellani, P. Licandro, J. Pierson, S. Jonasdottir, C. Johnson, G. Chust, C. Broms, H. Debes, T. Falkenhaus, E. Gaard, A. Gislason, M. Heath, B. Niehoff, T. Nielsen, P. Pepin and E. Stenevik (2014). The North Atlantic Ocean as habitat for *Calanus finmarchicus*: environmental factors and life history traits.. *Prog. Oceanogr.* 129 244. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: <http://dx.doi.org/10.1016/j.pocean.2014.04.026>

Preziosi, B. M. and J. A. Runge (2014). The effect of warm temperatures on hatching success of the marine planktonic copepod, *Calanus finmarchicus*. *Journal of Plankton Research*. 36 (5), 1381. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Preziosi, B. M., J.A. Runge and J. P. Christensen (2015). Effects of increased CO2 and temperature on hatching success of the marine planktonic copepod, *Calanus finmarchicus*.. *Mar. Biol.* . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Runge, J.A. , D.M. Fields, C. R. S. Thompson, S. D. Shema, R.M. Bjelland, C. M. F. Durif, A.B. Skiftesvik and H. I. Browman. (2015). Minimal direct impact of ocean acidification on vital rates of *Calanus finmarchicus*, an ecologically critical planktonic species in North Atlantic ecosystems.. *ICES Journal of Marine Science*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Runge, J.A., R. Ji, C. Thompson, N. Record, C. Chen, D. Vandemark, J. Salisbury and F. Maps (2015). Persistence of *Calanus finmarchicus* in the western Gulf of Maine during recent extreme warming. *Journal of Plankton Research*. 37 (1), 221. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: doi:[10.1093/plankt/fbu098](https://doi.org/10.1093/plankt/fbu098)

### Licenses

#### Other Products

##### Databases.

This database is registered in BCO-DMO. It contains data from experiments investigating effects of ocean acidification on *Calanus finmarchicus* hatching success, described in Preziosi (2012).

The link to the project is:

<http://www.bco-dmo.org/project/2184>

##### Databases.

This database resides in BCO-DMO. It contains biological and physical data collected during the R/V Cape Hatteras



cruise to the Gulf of Maine in the fall of 2012.

The project name is CH0712: Gulf of Maine Zooplankton and Ocean Acidification Cruise

The link to the database is:

<http://www.bco-dmo.org/project/544272>

### Databases.

This database resides in BCO-DMO.

It archives hydrographic (salinity, temperature, in some years fluorescence and light extinction) and biological data (zooplankton species abundances) collected at the Coastal Maine Time Series Station (CMTS) located in mid coast Maine near the Darling Marine Center. The series started in 2007 and will be updated periodically.

Support for sampling and analysis of samples collected at CMTS has been and will continue to be provided from multiple funding sources, including this award. At present, it is filed under the project, "CAMEO: Using interdecadal comparisons to understand trade-offs between abundance and condition in fishery ecosystems" but will eventually also be listed under the project title, CMTS: data of the Coastal Maine Time Series Station located off the Darling Marine Center in the Gulf of Maine". The CMTS project will be crosslisted as a database under other projects that have provided funding support.

The link to these data is:

<http://www.bco-dmo.org/project/544202>

### Other Publications

Melle, W., J. Runge, E. Head, S. Plourde, C. Castellani, P. Licandro, J. Pierson, S. Jonasdottir, C. Johnson, C. Broms, H. Debes, T. Falkenhaus, E. Gaard, A. Gislason, M. Heath, B. Niehoff, T. Nielsen, P. Pepin and E. Stenevik and G. Chust. (2014). *Biogeography of key mesozooplankton species in the North Atlantic, by manual counting methods, and egg production of Calanus finmarchicus.* Database published in Earth Syst. Sci. Data Discuss. 7: 225-242.. Status = PUBLISHED; Acknowledgement of Federal Support = No

### Patents

### Technologies or Techniques

### Thesis/Dissertations

Cameron R.S. Thompson. *Calanus finmarchicus Mortality and Population Dynamics in the Gulf of Maine.* (2012). University of Maine. Acknowledgement of Federal Support = Yes

Brian Preziosi. *The effects of ocean acidification and climate change on reproductive processes of the marine copepod, Calanus finmarchicus.* (2012). University of Maine. Acknowledgement of Federal Support = Yes

### Websites

## Participants/Organizations

### What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Runge, Jeffrey	PD/PI	3
Christensen, John	Co-Investigator	3

Kelly, Vincent	Other Professional	1
Thompson, Cameron	Technician	3
Preziosi, Brian	Graduate Student (research assistant)	1

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**Full details of individuals who have worked on the project:**

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**Jeffrey Albert Runge****Email:** jeffrey.runge@maine.edu**Most Senior Project Role:** PD/PI**Nearest Person Month Worked:** 3**Contribution to the Project:** Project oversight; participation in experiments at Austevoll Research Station; data analysis; writing of manuscripts; conference presentations**Funding Support:** This award University of Maine Austevoll Research Station**International Collaboration:** Yes, Norway**International Travel:** Yes, Norway - 0 years, 1 months, 0 days

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**John P. Christensen****Email:** jchristensen@gescience.com**Most Senior Project Role:** Co-Investigator**Nearest Person Month Worked:** 3**Contribution to the Project:** Expert on carbonate and pH chemistry Oversees and conducts analysis of carbonate chemistry and pH variables**Funding Support:** This award**International Collaboration:** No**International Travel:** No

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**Vincent Kelly****Email:** vince@gescience.com**Most Senior Project Role:** Other Professional**Nearest Person Month Worked:** 1**Contribution to the Project:** Participation in Fall, 2012 research cruise to the Gulf of Maine Assistance with analysis of carbonate and pH chemistry variables**Funding Support:** This award**International Collaboration:** No**International Travel:** No

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**Cameron R.S. Thompson****Email:** cameronrsthompson@gmail.com**Most Senior Project Role:** Technician**Nearest Person Month Worked:** 3

**Contribution to the Project:** Participation in execution, analysis and writeup of experiments conducted at the Austevoll Research Station Analysis of zooplankton samples collected at cruise survey and time series stations  
Compilation and submission of data to BCO-DMO for archiving

**Funding Support:** This award Austevoll Research Station, Institute of Marine Research, Norway

**International Collaboration:** Yes, Norway

**International Travel:** Yes, Norway - 0 years, 2 months, 0 days

**Brian M. Preziosi**

**Email:** brian.preziosi@maine.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Student thesis research on effects of ocean acidification on hatching success of *C. finmarchicus*  
Preparation of manuscripts based on thesis results

**Funding Support:** This award

**International Collaboration:** No

**International Travel:** No

**What other organizations have been involved as partners?**

Name	Type of Partner Organization	Location
Bigelow Laboratory for Ocean Sciences	Other Nonprofits	East Boothbay, Maine
Green Eyes Environmental Observing Systems	Industrial or Commercial Firms	28034 Holly Road Easton, MD 21601
Institute of Marine Research	Other Organizations (foreign or domestic)	Austevoll Research Station, Norway

**Full details of organizations that have been involved as partners:**

**Bigelow Laboratory for Ocean Sciences**

**Organization Type:** Other Nonprofits

**Organization Location:** East Boothbay, Maine

**Partner's Contribution to the Project:**

Collaborative Research

Personnel Exchanges

**More Detail on Partner and Contribution:** David M. Fields and technician

**Green Eyes Environmental Observing Systems**

**Organization Type:** Industrial or Commercial Firms

**Organization Location:** 28034 Holly Road Easton, MD 21601

**Partner's Contribution to the Project:**

Facilities

Collaborative Research

**More Detail on Partner and Contribution:** Partner in analysis of carbonate and pH chemistry variables

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**Institute of Marine Research****Organization Type:** Other Organizations (foreign or domestic)**Organization Location:** Austevoll Research Station, Norway**Partner's Contribution to the Project:**

Financial support

In-Kind Support

Collaborative Research

Personnel Exchanges

**More Detail on Partner and Contribution:** Collaboration with Howard Browman and staff at his research laboratory at the Austevoll Research Station on experiments to investigate OA effects on *C. finmarchicus* vital rates

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**What other collaborators or contacts have been involved?**

NO

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**Impacts****What is the impact on the development of the principal discipline(s) of the project?**

The results from this project fill a gap in our knowledge about the effects of ocean acidification on zooplankton. Because zooplankton are fundamental to coastal and oceanic food webs, information about OA impacts is needed in order to understand potential impacts on marine ecosystems. The results of this project will be used to develop robust models of effects of climate change on distribution of key planktonic species determining ecosystem productivity and structure supporting fisheries in coastal North Atlantic and Arctic ecosystems.

**What is the impact on other disciplines?**

The results will be used by U.S., Norwegian and other European government agencies, research institutions and non profit organizations to predict and adapt to climate change in North Atlantic and Arctic coastal communities and fisheries.

One specific application is the use of knowledge acquired in this award to the establishment of an Integrated Sentinel Monitoring Network (ISMN) on the Northeastern US Coastal Shelf (<http://www.neracoos.org/sentinelmonitoring>). The ISMN project is a joint venture of NROC (Northeast Regional Ocean Council) and NERACOOS (Northeast Regional Association of Coastal Ocean Observing Systems). The ISMN is presently involved in writing a Science and Implementation Plan that will be available to the public in late spring, 2015.

**What is the impact on the development of human resources?**

The project provided training for a master's level graduate student (B. Preziosi) and professional development of a technical research associate (C. Thompson)

**What is the impact on physical resources that form infrastructure?**

Project demonstrated capacity and protocols for ocean acidification experiments at the Darling Marine Center, University of Maine.

Project contributed facilities (SAMI pH sensor) to the University of Maine system.

**What is the impact on institutional resources that form infrastructure?**

This project has helped to establish the Darling Marine Center, University of Maine, as a regional center for ocean acidification research.

**What is the impact on information resources that form infrastructure?**

Nothing to report.

**What is the impact on technology transfer?**

Nothing to report.

**What is the impact on society beyond science and technology?**

The results are encouraging in that the effects of ocean acidification on marine life is not uniformly bad news. In talking about ocean acidification and our results in particular to the media and the general public, we find that there is a great interest and need to be informed. This information will contribute to the participatory democratic process determining decisions in the future related to management and adaptation strategies in the context of environmental change.

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## Changes/Problems

**Changes in approach and reason for change**

Nothing to report.

**Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

**Changes that have a significant impact on expenditures**

Nothing to report.

**Significant changes in use or care of human subjects**

Nothing to report.

**Significant changes in use or care of vertebrate animals**

Nothing to report.

**Significant changes in use or care of biohazards**

Nothing to report.