

Table 2: Carbonate data and nutrients measured during *Calanus finmarchicus* and *Meganyctiphanes norvegica* egg hatching success experiments, 2011-2012

Website: <https://www.bco-dmo.org/dataset/738494>

Data Type: experimental

Version: 1

Version Date: 2018-06-13

Project

» [Ocean Acidification-Category 1- Impact of ocean acidification on survival of early life stages of planktonic copepods in the genus *Calanus* in the northern](#) (OA *Calanus* Survival)

Programs

» [Science, Engineering and Education for Sustainability NSF-Wide Investment \(SEES\): Ocean Acidification \(formerly CRI-OA\)](#) (SEES-OA)

» [Ocean Carbon and Biogeochemistry](#) (OCB)

Contributors	Affiliation	Role
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Abstract

This dataset presents the carbonate system and nutrients measurements during *Calanus finmarchicus* and *Meganyctiphanes norvegica* egg hatching success experiments, 2011-2012. Results are published in Preziosi et al (2017), Table 2.

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Coverage

Spatial Extent: Lat:43.7474 Lon:-69.501

Temporal Extent: 2011-05-26 - 2012-08-01

Dataset Description

This dataset presents the carbonate system and nutrients measurements during *Calanus finmarchicus* and *Meganyctiphanes norvegica* egg hatching success experiments, 2011-2012. Results are published in Preziosi et al (2017), Table 2.

Acquisition Description

Total Alkalinity: Alkalinity was determined using an open cell titration with HCl (Dickson et al., 2007). The pH meter was a Corning model 109 which had been adapted so that the millivolt out was logged by computer through a 14 bit A to D converter. The electrode was an Orion Ross ultra semi-micro glass electrode model 8103-BNUWP. The pH electrode was standardized with accurate pH buffers. The tris buffer (2-amino-2-hydroxymethyl-1,3-propanediol) had a pH of about 8.09 depending on temperature. The AMP buffer (2-aminopyridine) had a pH of about 6.79 depending on temperature. Both were dissolved in artificial seawater at S = 35 (Dickson et al., 2007, SOP-6a). Samples and standards were titrated with a 0.15 M HCl solution in 0.45 M NaCl and the temperature was measured to the nearest 0.01C using a NIST calibrated platinum thermometer. The alkalinity standards generally were precise alkalinity/total carbon dioxide seawater standards from Scripps Institute of Oceanography (SIO), but early experiments also used a phosphate buffer standard comprised of an equal molar mixture of KH₂PO₄ and Na₂HPO₄ · 7 H₂O in 0.70 M NaCl. This phosphate standard was cross calibrated with the SIO standards. The procedure used generally gave the precision of several replicate standard titrations of 0.06% (standard error of the mean as percent of the mean value). Alkalinities were determined by the fitting procedure described in Dickson et al., 2007 (SOP-3b).

Total Carbon Dioxide: These concentrations were determined by acid stripping a 1.113 ml

volume of water sample or TCO₂ standard, trapping the expelled CO₂, and then injecting it into a Shimadzu Model GC-8A gas chromatograph with a thermal conductivity detector (Christensen, 2008). Two standards were employed, ones made from prebaked and freshly made Na₂CO₃, and the previously mentioned SIO total carbon dioxide seawater standards. This analytical system obtained a precision of about 0.06% (standard error of the mean as percent of the mean). However, in the results listed in this report, precision was less, averaging about 0.25% (standard error of the mean as percent of the mean) because sample analysis time was speeded up causing slightly less efficient trapping of the sample's CO₂.

Salinity and Nutrients: Salinity was determined using an Autosal 8400A conductivity salinometer with IAPSO standard seawater standards. Replicate determinations of a single sample were made until two consecutive readings of conductivity matched within +/- 0.002 ppt. Nutrients were determined by autoanalyzer using the methods for nitrate and nitrite of Armstrong et al. (1967) and Pavlou (1972), for ammonium of Koroleff (1970) and Slawyk and MacIsaac (1972), for dissolved inorganic phosphate (Drummond and Maher, 1995), and dissolved silicate (Armstrong et al., 1967). Concentrations were measured in mol L⁻¹ and converted to mol kg⁻¹ based on the sample's sigma-t value computed from the sample's salinity and the laboratory temperature during analysis.

Calculation of Carbonate System Parameters: Carbonate system parameters, include total pH, were calculated from the measured chemistry of the water samples using the carbonate equilibrium model, CO₂SYS (DOE, 1994; Lewis and Wallace, 1995). This program employs the equilibrium coefficients of Roy et al. (1993) for carbonate coefficients, K₁ and K₂, of Weiss (1974) for carbon dioxide, K₀, of Dickson (1990a) for borate, of Dickson and Riley (1979) for fluoride, of Dickson (1990b) for sulfate, and of Millero (1995) for phosphate (kp₁, kp₂, kp₃) and silicate. Seawater density at atmospheric pressure was that of UNESCO (1981).

Processing Description

BCO-DMO Processing Notes:

- added conventional header with dataset name, PI name, version date
- modified parameter names to conform with BCO-DMO naming conventions
- hid separator rows (all -99), and duplicate columns

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Related Publications

Armstrong, F. A. J., Stearns, C. R., & Strickland, J. D. H. (1967). The measurement of upwelling

and subsequent biological process by means of the Technicon Autoanalyzer® and associated equipment. *Deep Sea Research and Oceanographic Abstracts*, 14(3), 381–389.

doi:[10.1016/0011-7471\(67\)90082-4](https://doi.org/10.1016/0011-7471(67)90082-4)

Christensen, J. P. (2008). Sedimentary Carbon Oxidation and Denitrification on the Shelf Break of the Alaskan Beaufort and Chukchi Seas. *The Open Oceanography Journal*, 2(1), 6–17.

doi:[10.2174/1874252100802010006](https://doi.org/10.2174/1874252100802010006)

Dickson, A. ., & Riley, J. . (1979). The estimation of acid dissociation constants in seawater media from potentiometric titrations with strong base. I. The ionic product of water — Kw. *Marine Chemistry*, 7(2), 89–99. doi:[10.1016/0304-4203\(79\)90001-X](https://doi.org/10.1016/0304-4203(79)90001-X)

Dickson, A. G. (1990). Standard potential of the reaction: , and and the standard acidity constant of the ion HSO₄⁻ in synthetic sea water from 273.15 to 318.15 K. *The Journal of Chemical Thermodynamics*, 22(2), 113–127. doi:[10.1016/0021-9614\(90\)90074-Z](https://doi.org/10.1016/0021-9614(90)90074-Z)

Dickson, A. G. (1990). Thermodynamics of the dissociation of boric acid in synthetic seawater from 273.15 to 318.15 K. *Deep Sea Research Part A. Oceanographic Research Papers*, 37(5), 755–766. doi:[10.1016/0198-0149\(90\)90004-F](https://doi.org/10.1016/0198-0149(90)90004-F)

Dickson, A. G., & Goyet, C. eds. (1994). Handbook of methods for the analysis of the various parameters of the carbon dioxide system in sea water. Version 2 (No. ORNL/CDIAC--74). Oak Ridge National Lab., TN doi:[10.2172/10107773](https://doi.org/10.2172/10107773)

Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.) 2007. Guide to best practices for ocean CO₂ measurements. PICES Special Publication 3, 191 pp. ISBN: 1-897176-07-4. Handle: <http://hdl.handle.net/11329/249>. URL:

https://www.nodc.noaa.gov/ocads/oceans/Handbook_2007.html

Koroleff, F. (1970) Revised version of "Direct determination of ammonia in natural waters as indophenol blue, *Int. Con. Explor. Sea, C. M. 1969/C:9*". ICES Information on Techniques and Methods for Sea Water Analysis Interlab. Rep. No. 3, pp 19-22.

Lewis, E. R., Wallace, D. W. R. (1995) Basic programs for the CO₂ system in seawater. BNL-61827. Brookhaven National Laboratory, Upton, p 11973. OSTI Identifier: 81005

McLAREN, I. A., CORKETT, C. J., & ZILLIOUX, E. J. (1969). Temperature adaptations of the copepod eggs from the arctic to the tropics. *The Biological Bulletin*, 137(3), 486–493.

doi:[10.2307/1540170](https://doi.org/10.2307/1540170)

Millero, F. J. (1995). Thermodynamics of the carbon dioxide system in the oceans. *Geochimica et Cosmochimica Acta*, 59(4), 661–677. doi:[10.1016/0016-7037\(94\)00354-O](https://doi.org/10.1016/0016-7037(94)00354-O)

Pavlou, S. P. (1972) Phytoplankton growth dynamics. Technical series 1, chemostat methodology and chemical analyses. Special Report No 52, Dept. of Oceanography, University of Washington, Seattle, WA 98195, p. 130.

Preziosi, B. M., Runge, J. A., Christensen, J. P., & Jones, R. J. (2017). Effects of pH and

temperature on egg hatching success of the marine planktonic copepod, *Calanus finmarchicus*. *Marine Biology*, 164(11). doi:[10.1007/s00227-017-3243-5](https://doi.org/10.1007/s00227-017-3243-5)

Roy, R. N., Roy, L. N., Vogel, K. M., Porter-Moore, C., Pearson, T., Good, C. E., Millero, F. J., Campbell, D. M. (1993). The dissociation constants of carbonic acid in seawater at salinities 5 to 45 and temperatures 0 to 45 °C. *Marine Chemistry*, 44(2-4), 249-267. doi:[10.1016/0304-4203\(93\)90207-5](https://doi.org/10.1016/0304-4203(93)90207-5)

Slawyk, G., & MacIsaac, J. J. (1972). Comparison of two automated ammonium methods in a region of coastal upwelling. *Deep Sea Research and Oceanographic Abstracts*, 19(7), 521–524. doi:[10.1016/0011-7471\(72\)90019-8](https://doi.org/10.1016/0011-7471(72)90019-8)

UNESCO (1981) Background papers and supporting data on the international equation of state of seawater, 1980. UNESCO Tech Paper Mar. Sci. 38: 193.

Weiss, R. F. (1974). Carbon dioxide in water and seawater: the solubility of a non-ideal gas. *Marine Chemistry*, 2(3), 203–215. doi:[10.1016/0304-4203\(74\)90015-2](https://doi.org/10.1016/0304-4203(74)90015-2)

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Parameters

Parameter	Description	Units
SAMPLING_DATE	Date of sampling formatted as yymmdd	unitless
EXPERIMENT	Number of the experiment	unitless
EVENT	Number of the sampling event	unitless
TIME_elapsed	Time from internment of eggs	hours
TANK	Number of the tank	unitless
TEMP	Tank temperature	degrees Celsius
SAL	Salinity in the tank	parts per thousand (ppt)
ALKALIN	Total alkalinity in the tank	micromol/kilogram
TCO2	Total CO2 concentration in the tank	micromol/kilogram
NO3_NO2	Tank's nitrate + nitrite concentration	micromol/kilogram
NH4	Tank's dissolved ammonium concentration	micromol/kilogram
PO4	Tank's dissolved phosphate concentration	micromol/kilogram
SI	Tank's dissolved silicate concentration	micromol/kilogram
PHTTL	Total pH in the tank (calculated)	pH units
XCO2	CO2 gas concentration (calculated)	parts per million (ppm) in dry gas
OMCA	Degree of saturation for calcite	unitless
OMAR	Degree of saturation for aragonite	unitless

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Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Nutrient Autoanalyzer
Generic Instrument Description	Nutrient Autoanalyzer is a generic term used when specific type, make and model were not specified. In general, a Nutrient Autoanalyzer is an automated flow-thru system for doing nutrient analysis (nitrate, ammonium, orthophosphate, and silicate) on seawater samples.

Dataset-specific Instrument Name	Autosal 8400A conductivity salinometer
Generic Instrument Name	Autosal salinometer
Dataset-specific Description	Used to measure salinity, with IAPSO seawater standards.
Generic Instrument Description	The salinometer is an instrument for measuring the salinity of a water sample.

Dataset-specific Instrument Name	Shimadzu Model GC-8A gas chromatograph
Generic Instrument Name	Gas Chromatograph
Dataset-specific Description	Used to measure Total CO ₂ , determined by acid stripping a 1.113 ml volume of water sample or TCO ₂ standard, trapping the expelled CO ₂ , and then injecting it into the chromatograph had a thermal conductivity detector.
Generic Instrument Description	Instrument separating gases, volatile substances, or substances dissolved in a volatile solvent by transporting an inert gas through a column packed with a sorbent to a detector for assay. (from SeaDataNet, BODC)

Dataset-specific Instrument Name	Corning model 109
Generic Instrument Name	Benchtop pH Meter
Dataset-specific Description	Adapted so that the millivolt out was logged by computer through a 14 bit A to D converter. The electrode was an Orion Ross ultra semi-micro glass electrode model 8103-BNUWP.
Generic Instrument Description	An instrument consisting of an electronic voltmeter and pH-responsive electrode that gives a direct conversion of voltage differences to differences of pH at the measurement temperature. (McGraw-Hill Dictionary of Scientific and Technical Terms) This instrument does not map to the NERC instrument vocabulary term for 'pH Sensor' which measures values in the water column. Benchtop models are typically employed for stationary lab applications.

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Project Information

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

Coverage: Gulf of Maine

The project description is a modification of the original NSF award abstract. This research project is part of the larger NSF funded CRI-OA collaborative research initiative and was funded as an Ocean Acidification-Category 1, 2010 award. While attention concerning impacts of predicted acidification of the world's oceans has focused on calcifying organisms, non-calcifying plankton may also be vulnerable. In this project, the investigator will evaluate the potential for impacts of ocean acidification on the reproductive success of three species of planktonic copepods in the genus *Calanus* that are prominent in high latitude oceans. *C. finmarchicus* dominates the mesozooplankton biomass across much of the coastal and deep North Atlantic Ocean. *C. glacialis* and the larger *C. hyperboreus* are among the most abundant planktonic copepods in the Arctic Ocean. Previous research showed that hatching success of

C. finmarchicus eggs was severely inhibited by increased CO₂ and lower pH in seawater, but only tested at an extreme level. Preliminary results in the investigator's laboratory indicate that hatching success of *C. finmarchicus* is substantially reduced at increased seawater CO₂ concentrations corresponding to pH levels between 7.9 and 7.5. Predictions of likely decline of surface pH levels to 7.7-7.8 over the next century raise questions about impacts on *Calanus* population dynamics if these preliminary results are confirmed. *C. finmarchicus*, for example, is presently at the southern edge of its range in the Gulf of Maine. The combination of higher surface layer temperature and lower pH may inhibit reproductive success during the late summer/fall bloom, which the PI hypothesize is critical to sustain the overwintering stock in this region. The investigators will collect *C. finmarchicus* females from the Gulf of Maine and, with the assistance of Canadian colleagues, *C. glacialis* and *C. hyperboreus* females from the deep lower St. Lawrence Estuary. They will conduct laboratory experiments in which hatching success, development and growth of *Calanus* nauplius stages are measured in controls of natural seawater and at a series of treatments in which CO₂ concentrations, pH and temperature are rigorously controlled to represent possible future states of the northern ocean. The investigators will measure present surface and deep pCO₂ and pH across the Gulf of Maine, including its deep basins, during a research cruise. The study will evaluate the hypothesis that predicted levels of CO₂ increase in the northern ocean will impact population dynamics of the *Calanus* species. Using the results from the research cruise and a recently developed 1-D, Individual-Based life cycle model, the PI will explore in detail scenarios of impact of higher temperature and lower surface and deep pH on population dynamics of *C. finmarchicus* in the Gulf of Maine. The lipid-rich *Calanus* species are considered key intermediary links between primary production and higher trophic levels in North Atlantic and Arctic Ocean food webs. Impacts of higher surface temperature and lower pH on reproductive success may potentially lead to profound changes in energy transfer and structure of pelagic ecosystems in the northern oceans. In the Gulf of Maine, *C. finmarchicus* serves as primary prey for herring, sand lance, and mackerel, as well as the endangered northern right whale, warranting thorough evaluation of ocean acidification effects on its population dynamics.

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Program Information

**Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES):
Ocean Acidification (formerly CRI-OA) (SEES-OA)**

Website: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503477

Coverage: global

NSF Climate Research Investment (CRI) activities that were initiated in 2010 are now included under Science, Engineering and Education for Sustainability NSF-Wide Investment (SEES). SEES is a portfolio of activities that highlights NSF's unique role in helping society address the challenge(s) of achieving sustainability. Detailed information about the SEES program is available from NSF (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504707). In recognition of the need for basic research concerning the nature, extent and impact of ocean acidification on oceanic environments in the past, present and future, the goal of the SEES: OA program is to understand (a) the chemistry and physical chemistry of ocean acidification; (b) how ocean acidification interacts with processes at the organismal level; and (c) how the earth system history informs our understanding of the effects of ocean acidification on the present day and future ocean. Solicitations issued under this program: NSF 10-530, FY 2010- FY2011 NSF 12-500, FY 2012 NSF 12-600, FY 2013 NSF 13-586, FY 2014 NSF 13-586 was the final solicitation that will be released for this program. PI Meetings: 1st U.S. Ocean Acidification PI Meeting (March 22-24, 2011, Woods Hole, MA) 2nd U.S. Ocean Acidification PI Meeting (Sept. 18-20, 2013, Washington, DC) 3rd U.S. Ocean Acidification PI Meeting (June 9-11, 2015, Woods Hole, MA – Tentative) NSF media releases for the Ocean Acidification Program: Press Release 10-186 NSF Awards Grants to Study Effects of Ocean Acidification Discovery Blue Mussels "Hang On" Along Rocky Shores: For How Long? Discovery [nsf.gov](http://www.nsf.gov) - National Science Foundation (NSF) Discoveries - Trouble in Paradise: Ocean Acidification This Way Comes - US National Science Foundation (NSF) Press Release 12-179 [nsf.gov](http://www.nsf.gov) - National Science Foundation (NSF) News - Ocean Acidification: Finding New Answers Through National Science Foundation Research Grants - US National Science Foundation (NSF) Press Release 13-102 World Oceans Month Brings Mixed News for Oysters Press Release 13-108 [nsf.gov](http://www.nsf.gov) - National Science Foundation (NSF) News - Natural Underwater Springs Show How Coral Reefs Respond to Ocean Acidification - US National Science Foundation (NSF) Press Release 13-148 Ocean acidification: Making new discoveries through National Science Foundation research grants Press Release 13-148 - Video [nsf.gov](http://www.nsf.gov) - News - Video - NSF Ocean Sciences Division Director David Conover answers questions about ocean acidification. - US National Science Foundation (NSF) Press Release 14-010 [nsf.gov](http://www.nsf.gov) - National Science Foundation (NSF) News - Palau's coral reefs surprisingly resistant to ocean acidification - US National Science Foundation (NSF) Press Release 14-116 [nsf.gov](http://www.nsf.gov) - National Science Foundation (NSF) News - Ocean Acidification: NSF awards \$11.4 million in new grants to study effects on marine ecosystems - US National Science Foundation (NSF)

Ocean Carbon and Biogeochemistry (OCB)

Website: <http://us-ocb.org/>

Coverage: Global

The Ocean Carbon and Biogeochemistry (OCB) program focuses on the ocean's role as a component of the global Earth system, bringing together research in geochemistry, ocean physics, and ecology that inform on and advance our understanding of ocean biogeochemistry. The overall program goals are to promote, plan, and coordinate collaborative, multidisciplinary research opportunities within the U.S. research community and with international partners. Important OCB-related activities currently include: the Ocean Carbon and Climate Change (OCCC) and the North American Carbon Program (NACP); U.S. contributions to IMBER, SOLAS, CARBOOCEAN; and numerous U.S. single-investigator and medium-size research projects funded by U.S. federal agencies including NASA, NOAA, and NSF. The scientific mission of OCB is to study the evolving role of the ocean in the global carbon cycle, in the face of environmental variability and change through studies of marine biogeochemical cycles and associated ecosystems. The overarching OCB science themes include improved understanding and prediction of: 1) oceanic uptake and release of atmospheric CO₂ and other greenhouse gases and 2) environmental sensitivities of biogeochemical cycles, marine ecosystems, and interactions between the two. The OCB Research Priorities (updated January 2012) include: ocean acidification; terrestrial/coastal carbon fluxes and exchanges; climate sensitivities of and change in ecosystem structure and associated impacts on biogeochemical cycles; mesopelagic ecological and biogeochemical interactions; benthic-pelagic feedbacks on biogeochemical cycles; ocean carbon uptake and storage; and expanding low-oxygen conditions in the coastal and open oceans.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1041081

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