Environmental Studies Program: Ongoing Study

Field	Study Information
Title	Zooplankton Ecology of the western Gulf of Maine: trends in abundance and diversity (NT-23-x13)
Administered by	Office of Environmental Programs
BOEM Contact(s)	Desray Reeb (desray.reeb@boem.gov)
Procurement Type(s)	Cooperative Agreement
Conducting Organization(s)	University of Maine
Total BOEM Cost	$199,970
Performance Period	FY 2023-2025
Final Report Due	May 2025
Date Revised	February 1, 2024
Problem	There are stakeholder concerns that offshore renewable energy development a will put additional pressures on the highly endangered North Atlantic right whale population by potentially affecting the distribution and or availability of their prey in the Gulf of Maine and the NW Atlantic.
Intervention	Sustained long term monitoring at 2 sampling stations in the Gulf of Maine.
Comparison	This study will build upon the multiple years of baseline data collected previously by the Canadian Atlantic Zone Monitoring Program and the University of Maine/University of New Hampshire.
Outcome	To understand the long-term variability of *Calanus finmarchicus* in the Gulf of Maine and how that influences the NARW feeding grounds in the Gulf and the NW Atlantic.
Context	Gulf of Maine

BOEM Information Need(s): Offshore renewable energy development is currently underway in the NE Atlantic, and in the planning stages in the Gulf of Maine (GoMe). BOEM must evaluate the cumulative effects of offshore wind on marine species including the highly endangered North Atlantic right whale (NARW). As part of this analysis, variation in food availability is one stressor that must be taken into consideration, particularly in a rapidly changing environment. The Gulf of Maine is currently designated as critical habitat to support NARW feeding.

Background: Elevated NARW mortalities beginning in 2017 resulted in NOAA declaring an Unusual Mortality Event.[1] From 2017-early 2023 98 NARW deaths have been recorded. Of those that were

[1] https://www.fisheries.noaa.gov/national/marine-life-distress/2017-2018-north-atlantic-right-whale-unusual-mortality-event

necropsied, entanglement in fishing gear or vessel strikes were determined to be the cause of mortality. The NARW population is currently declining (Pace et al., 2017) with approximately 340 individuals left.[2]

Like all mammals, NARWs need sufficient food available in order to fulfil the energetic requirements of gestation and lactation. NARWs feed primarily on copepods, specifically, *Calanus finmarchicus* (Baumgartner and Mate, 2003). Concerns about the effects of fixed-bottom offshore wind structures on oceanographic, atmospheric, and hydrodynamic processes have been raised by the public and cooperating agencies. These concerns include the alteration of currents locally resulting in changes in oceanographic processes such as the dispersion of larvae and related spillover effects on surrounding ecosystems (van Berkel et al., 2020; Galparsoro et al., 2022). Specifically, it is postulated that changes in oceanographic conditions caused by offshore wind could result in the dispersion of zooplankton, via disruption of flow-field mechanisms acting to aggregate prey (White and Veit, 2020) thus reducing their concentration, thereby, limiting the food source for North Atlantic right whales, and possibly causing increased energetic expenditure to find enhanced concentrations of prey.

A workshop co-hosted by the Massachusetts Clean Energy Center and BOEM in May 2018 determined that impacts to zooplankton communities are currently not possible to detect in the short term and that long-term sampling efforts should be supported (Kraus et al., 2019).

Calanus finmarchicus has key functional significance in the GoMe ecosystem (Bigelow, 1924; Johnson et al., 2011). The lipid-rich stage CV are a primary prey for planktivorous fish, such as herring and sand lance (e.g., Payne et al., 1990; Collette and Klein-MacPhee, 2002) that are fundamental trophic links in regional fisheries. Since there is no apparent functional redundancy for *C. finmarchicus* in the GoMe ecosystem, significant shifts in abundance of *C. finmarchicus* may have substantial impacts on the region's metazoan energy budget and consequently affect local distribution and abundance of planktivores and higher trophic-level predators (Johnson et al., 2011). Wilkinson Basin plays a particularly important role in the western GoMe because it serves as a primary source of supply of *C. finmarchicus* to fishing and NARW feeding grounds in waters off southern New England, including the Great South Channel and Georges Bank (Wishner et al., 1995; Miller et al., 1998; Pendleton et al., 2009).

The GoMe lies at the epicenter of the most rapid warming trend in U.S. coastal waters. Recent warming has placed the habitat for *C. finmarchicus* in the GoMe at risk. Statistical studies of *C. finmarchicus* habitat suggest that the species will disappear or dramatically decline from the GoMe over the next several decades (Reygondeau and Beaugrand 2011; Grieve et al. 2017). Recent research indicates that the abundance patterns of *C. finmarchicus* in the GoMe have shifted over the past decade (Meyer-Gutbrod et al., 2021) . The abundance of older, lipid rich stages of *C. finmarchicus* has declined by approximately 30% in summer and fall in the western Gulf of Maine and even more dramatically, by an order of magnitude, in the eastern Gulf of Maine (Record et al. 2019). The recent changes are linked to a shift in ocean circulation patterns that transport seawater into the Gulf (Meyer-Gutbrod et al., 2021). One ecosystem consequence of this oceanographic change is that North Atlantic right whales have shifted their foraging distributions away from traditional feeding grounds in the Gulf of Maine in summer and fall, affecting their reproduction and mortality rates.

Through long term monitoring by the Canadian Atlantic Zone Monitoring Program and the University of Maine/University of New Hampshire, time series data within the Gulf of St Lawrence and the GoMe

[2] https://www.narwc.org/uploads/1/1/6/6/116623219/2022reportcardfinal.pdf

have resulted in data showing *C. finmarchicus* persistence in the GoMe during recent extreme warming events (Runge et al., 2015), and more recently showed interdecadal variability of *C. finmarchicus* in the eastern and western GoMe in relation to NARW distribution (Record et al., 2019). This same time series has provided insight on the mechanisms controlling *C. finmarchicus* abundance in the GoMe and in turn how it influences the NARW feeding grounds in southern New England (Ji et al., 2017). Due to a lack of funding, the US data collection stations in Wilkinson Bay and in the Maine Coastal Current ended in 2017. BOEM Cooperative Agreement M19AC00022 supported collection and analysis of samples from the Wilkinson Basin Time Series (WBTS) and Coastal Maine Time Series (CMTS) stations as part of the NERACOOS Integrated Sentinel Monitoring Network (ISMN) Gulf of Maine MBON project from 2020-2022.

The WBTS and CMTS stations are strategically located in the western Gulf of Maine to monitor planktonic ecosystem characteristics in the Maine Coastal Current, a regional production driver, and in Wilkinson Basin, the primary overwintering habitat for the energy-rich foundation species, the planktonic copepod *C. finmarchicus*, that supports the Gulf of Maine subarctic food web and its ecosystem services. Observations of summer abundance of *C. finmarchicus* late stages at the CMTS station show approximately a 30% decline from 2008 to 2021, consistent with the WBTS CI. Data collected in 2022 at both the CMTS and WBTS stations, however, indicate a rebound in *Calanus* abundance. This rebound suggest a recent change in oceanographic conditions affecting supply of *Calanus* into the GoMe; whether this is a singular annual event or the start of a longer-term increase in *Calanus* abundance awaits future observations (Runge et al., 2023). Funding for 2023 sampling was provided through the MBON but this funding ends in January 2024.

Moving forward it is imperative to continue this long-term data collection in order to detect any climatological or other effects on this ecosystem that may be happening with or without the influence of BOEM-related activities in this area identified as NARW critical feed habitat.

Objectives: To understand the long-term variability of *C. finmarchicus* in the GoMe and how that influences the NARW feeding grounds in the Gulf of Maine and the NW Atlantic.

Methods: The plankton data will be collected following standard protocols used during previous sampling efforts conducted at these stations. Sampling at approximately monthly intervals (10-12 times per year) in WBTS provide an estimate of success of spring production and overwintering abundance in the western Gulf of Maine. For the CMTS, late spring and summer sampling will be conducted (approx. 8 times per year), providing an index of supply of zooplankton to the western GoMe . Data are analyzed using appropriate, established analytical techniques. Zooplankton net samples are analyzed for total zooplankton dry weight (per m^2) and abundance of *Calanus finmarchicus* life stages (the Calanus Index) as well as other zooplankton taxa. Changes in biomass, *Calanus* abundance and zooplankton community composition are reported. Comparative analysis of DNA metabarcoding of metazoan and single celled zooplankton will be compared with results from microscopy. Supporting hydrographic, phytoplankton and microzooplankton data, measured with a CTD, flow cytometer, microscopy (for phytoplankton species composition) and FlowCam, will also be collected.

Specific Research Question(s):

1. Is the abundance of Calanus finmarchicus changing in the western Gulf of Maine? This question is addressed by the Calanus Index, which measures abundance of spring, summer, and fall-winter abundance of later *Calanus* copepodid stages in Wilkinson Basin.

2. Is the zooplankton community composition changing in the western Gulf of Maine? This question is addressed by microscopic analysis of net-captured zooplankton samples in combination with DNA metabarcoding.
3. If there are any changes in species distribution, can they be attributed to any specific environmental factors? This question is addressed by analysis of trends in indicators of water mass temperature and salinity, primary productivity (chlorophyll a, bacteria, phytoplankton species composition), microzooplankton abundance and zooplankton supply in the Maine Coastal Current.

Current Status: Post award meeting was held on October 16, 2023.

Publications Completed:

Runge J, Karp Boss L, Dullaert E, Ji, R, Motyka J, Young-Morse R, Pugh, D, Shellito S, Vandemark D. 2023. Sustained monitoring of zooplankton populations at the Coastal Maine Time Series (CMTS) and Wilkinson Basin Time Series (WBTS) stations in the western Gulf of Maine: Results from 2005-2022. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 40 p. Report No.: OCS Study BOEM 2023-015.

Affiliated WWW Sites: None

References:

Baumgartner MF, Mate BR. 2003. Summertime foraging ecology of North Atlantic right whales. Mar. Ecol. Prog. Ser. 264:123–135.

Bigelow HB. 1924 Plankton of the offshore waters of the Gulf of Maine. Bull. Bur. Fish., XI, 1–486.

Chust G, Castellani C, Licandro P, Ibaibarriaga L, Sagarminaga Y, Irigoien X. 2014. Are Calanus spp. shifting poleward in the North Atlantic? A habitat modelling approach. ICES Journal of Marine Science. 71:241–253.

Collette BB, Klein-MacPhee G, editors. 2002. Bigelow and Schroeder's fishes of the Gulf of Maine, 3rd edition. Smithsonian Institution Press, Washington.

Galparsoro I, Menchaca I, Garmendia J, Borja A, Maldonado AD, Iglesias G, Bald J. 2022. Reviewing the ecological impacts of offshore wind farms. npj Ocean Sustainability. 1:1. doi:10.1038/s44183-022-00003-5.

Grieve BD, Hare JA, Saba VS. 2017. Projecting the effects of climate change on *Calanus finmarchicus* distribution within the US Northeast Continental Shelf. Scientific Reports. 7(1):1–12.

Ji R, Feng Z, Jones BT, Thompson C, Chen C, Record NR, Runge JA. 2017. Coastal amplification of supply and transport (CAST): a new hypothesis about the persistence of *Calanus finmarchicus* in the Gulf of Maine. ICES Journal of Marine Science. 74(7)1865–1874. doi:10.1093/icesjms/fsw253.

Johnson C, Runge J, Bucklin A, et al. 2011. Biodiversity and ecosystem function in the Gulf of Maine: pattern and role of zooplankton and pelagic nekton. PLOS One. 6:1–18.

Kraus SD, Kenney RD, Thomas L. 2019. A framework for studying the effects of offshore wind development on marine mammals and turtles. Report prepared for the Massachusetts Clean Energy Center, Boston, MA 02110, and the Bureau of Ocean Energy Management. May 2019.

Miller CB, Lynch DR, Carlotti F, Gentleman W, Lewis CVW. 1998. Coupling of an individual-based population dynamic model of Calanus finmarchicus to a circulation model for the Georges Bank region. Fisheries Oceanography. 7:219–234.

Pace RM, Corkeron PJ, Kraus SD. 2017. State–space mark–recapture estimates reveal a recent decline in abundance of North Atlantic right whales. Ecology and Evolution. 2017(7):8730–8741. doi: 10.1002/ece3.3406.

Payne PM, Wiley DN, Young SB, Pittman S, Clapham PJ, Jossi JW. 1990. Recent fluctuations in the abundance of baleen whales in the southern Gulf of Maine in relation to changes in selected prey. Fishery Bulletin. 88(4):687–696.

Pendleton DE, Pershing AJ, Brown MW, Mayo CA, Kenney RD, Record NR, Cole TVN. 2009. Regional-scale mean copepod concentration indicates relative abundance of North Atlantic right whales. Marine Ecology Press Series. 378:211–225.

Record NR, Runge JA, Pendleton DE, Balch WM, Davies KTA, Pershing AJ, Johnson CL, Stamieszkin K, Ji R, Feng Z, et al. 2019. Rapid climate-driven circulation changes threaten conservation of endangered North Atlantic right whales. Oceanography 32(2):162–169.

Reygondeau G, Beaugrand G. 2011. Future climate-driven shifts in distribution of *Calanus finmarchicus*. Global Change Biology. 17:756 –766.

Runge JA, Ji R, Thompson CRS, Record NR, Chen C, Vandemark DC, Salisbury JE, Maps FJ. 2015. Persistence of *Calanus finmarchicus* in the western Gulf of Maine during recent extreme warming. Journal of Plankton Research. 37(1):221–232.

Runge J, Karp Boss L, Dullaert E, Ji, R, Motyka J, Young-Morse R, Pugh, D, Shellito S, Vandemark D. 2023. Sustained monitoring of zooplankton populations at the Coastal Maine Time Series (CMTS) and Wilkinson Basin Time Series (WBTS) stations in the western Gulf of Maine: Results from 2005-2022. Sterling (VA): U.S. Department of the Interior, Bureau of Ocean Energy Management. 40 p. Report No.: OCS Study BOEM 2023-015.

van Berkel J, Burchard H, Christensen A, Mortensen LO, Svenstrup Petersen O, and Thomsen F. 2020. The effects of offshore wind farms on hydrodynamics and implications for fishes. Oceanography. 33(4):108–117. doi:10.5670/oceanog.2020.410.

Wishner KF, Schoenherr JR, Beardsley R, Chen C. 1995. Abundance, distribution, and population structure of the copepod *Calanus finmarchicus* in a springtime right whale feeding area in the southwestern Gulf of Maine. Continental Shelf Research. 15(4–):475–507.