The planktonic lipidscape: Does a shift in foraging distribution of the North Atlantic right whale indicate a change in the structure of the offshore ecosystem in the eastern Gulf of Maine?

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*Rapid climate-driven circulation changes threaten conservation of endangered North Atlantic right whales.*

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In waters deeper than 100m in the Gulf of Maine, *C. finmarchicus* makes up 75-90% of the total copepod biomass.

*Characteristic subarctic pelagic species:*
- *Calanus* spp.
- Herring, Capelin, Sand lance
- Cod
- Large whales

**Simplified North Atlantic subarctic food web**

- **Planktivorous fish**
- **Fish larvae**
- **Planktonic predators**
- **Small copepods**
- **Calanus spp.**
- **Large phytoplankton**
- **Small phytoplankton**
- **Microzooplankton**
- **Heterotrophic flagellates**
- **Bacteria**
- **Dissolved organic matter**
- **Inorganic nutrients**
Change in advective supply to the eastern Gulf of Maine

From the *Calanus*-rich Scotian Shelf as the primary source to transport through the Northeast Channel of Atlantic slope water off the North Atlantic Temperate Water.

Recent evidence for a weakening of AMOC and northward shift of Gulf Stream (Ceasar et al. 2018: Nature 556:191)
Right Whale population decline in the Gulf of Maine

Since 2010, calving rates have decreased by 40%.

No calves were born in the winter of 2017.

Number that can be accounted for in the GoM

Calanus finmarchicus in the eastern Gulf of Maine

Dramatic declines in abundance in Jordan Basin since 2010 from available EcoMON data

N. Record et al. 2019
Sightings of right whales (SPUE) in the Bay of Fundy way down since 2010, correlated with eGoM C. finmarchicus abundance.
NERACOOS and the Northeast Regional Ocean Council (NROC) have jointly developed a plan for an Integrated Sentinel Monitoring Network for U.S. Northeastern waters, including the Gulf of Maine.

Regional facilitation of integrated, sustained observing across pelagic, benthic and nearshore and estuarine ecosystems.
**ISMN functions**

- Identifies observing activities and provides access to data sets
- Identifies and provides support to fill observing gaps
- Promotes standardization and quality assurance across observing activities
- Facilitates analysis and interpretation of ecosystem change across data sets
- Provides information to stakeholders and the broader community to inform ecosystem-based decision making
Canadian Atlantic Zone Monitoring Program (AZMP) since 1999

ISMN supports two AZMP-type Gulf of Maine fixed stations: Coastal Maine Time Series (CMTS) and Wilkinson Basin Time series (WBTS)
Challenges and opportunities


Food web compartments in the eastern Gulf of Maine?

Offshore: North Atlantic subarctic food web at the southern margin: Calanus-Herring-Cod-BFT-Large whales. CHANGING WITH LIMITED MANAGEMENT OPTIONS

Menhaden as a possible replacement for *C. finmarchicus*

Nearshore: phytoplankton-benthic invertebrates-small copepods-diadromous fish. FEASIBLE MEASURES TO CONSERVE THIS FOR LOCALLY-BASED SUSTAINABLE FISHERIES

*C. finmarchicus* is not abundant in coastal waters shallower than

![Graph showing abundance (ten thousands/m²) versus depth (m) with data points and trend line.](chart)

(Runge et al. unpubl. Coastal Maine survey) 2009 data
• Calanus-based subarctic offshore food web under pressure in eGoM
• There is no lipid rich planktonic replacement for C. finmarchicus
• Without Calanus, more primary production sinking to bottom fueling benthic production
• Menhaden, which feed directly on phytoplankton and store lipids, are a possible substitute
Calanus finmarchicus egg production rate: Functional relationship for the Gulf of Maine in February.

At chlorophyll a concentration of 1 - 2 µg Chl a/liter, strong potential for amplification of C. finmarchicus abundance.

Durbin et al. 2003
Abundance of smaller copepods at the WBTS station has also shifted

J. Runge unpubl.
Summary: Gulf of Maine C. *finmarchicus*

- Despite recent surface warming, *C. finmarchicus* persists in high abundance in the western Gulf of Maine, maintaining the subarctic character of the pelagic ecosystem.
- The persistence mechanism involves a combination of advective transport of *Calanus* into the eastern GoM, transport and amplification in the food-rich Maine Coastal Current, and favorable timing of emergence from diapause and winter spring food availability in Wilkinson Basin.
- The recent warming in the eastern Gulf of Maine, lower *Calanus* abundance and absence of northern right whales are consistent with changes in currents entering the Gulf of Maine. The change in currents is associated with warming in the North Atlantic basin. The recent lower reproductive rates of northern right whales and a shift in their distribution may be an indicator of change in the Gulf of Maine ecosystem.
Implementation of the Integrated Sentinel Monitoring Network (ISMN)
“Life is change: how it differs from the rocks”
- Jefferson Airplane, Crown of Creation. 1968

“'Cause time rolls by like hurricanes/
Runnin' after the subway train”
- Allman Brothers Band, Ain’t wastin’ time no more. 1972.
What sustains the remarkable abundance of *C. finmarchicus* in the Gulf of Maine?

Coastal Amplification of Supply and Transport

Ji et al. 2017. ICES Mar Sci
Two primary production regimes in the Gulf of Maine:

- The coastal shelf, where phytoplankton biomass is high from late winter to fall.
- The central GoM, following the more classic temperate seasonal pattern.
Mike Sargent, FV Tina Marie II
Offshore: Actors