**ACKNOWLEDGEMENTS**

a coastal ocean ecosystem.

Phytoplankton play critical roles in biogeochemical cycles, including transforming atmospheric CO2 into particulate matter that eventually sinks to the deep ocean (the biological carbon pump).

The fate of carbon (C) within the oceans is controlled by individual interactions in a highly complex and interconnected marine food web.

Independent analyses of global datasets revealed a strong positive link between viruses and C flux to the deep ocean1,2.

Mechanisms underlying virus-enhanced C transfer to particulate organic matter (POM) are unknown.

**OBJECTIVES**

Quantify viral impacts on trophic transfer of carbon (C) and nitrogen (N) using a combination of stable isotope labeling (13C, 15N), fluorescence activated cell sorting (FACS) and isotope ratio mass spectrometry (IRMS) in a model plankton community and a coastal ocean ecosystem.

**METHODS:**

1. **SIMPLIFIED MARINE PLANKTON FOOD WEB**

   - The picophytoplankton, *Ostreococcus tauri* (CCAC3221) was grown with 13C-labeled sodium bicarbonate and 15N-labeled sodium nitrate for 48 h.
   - The cells were then washed and resuspended in stable-isotope free seawater, enabling us to trace the flow of C and N from picophytoplankton to other members of the plankton community.
   - One treatment contained the lytic virus *OIV*, that infects only the *Ostreococcus tauri* picophytoplankton; one treatment contained no OIV.
   - Five biological replicates per treatment.
   - Other models included: the non-phageangus *Ostracodermic galea* (CCMP1232), the microeukaryotic *Ostracodermic galea* (CCMP1232), and the calcified copepod *Acartia tonsa*.
   - Heterotrophic bacteria in the model community were derived from the copepods and non-selective plankton cultures.
   - Samples were collected at 0, 6, 12, 24, 48 h for virus and organism abundance, 13C-DOC, 13C-PIC, 13N-POM, and copepod 13C and 15N.

2. **COASTAL ATLANTIC OCEAN FIELD EXPERIMENT**

   - Field experiments conducted in July 2016, Boothbay, Maine, during a phytoplankton bloom.
   - Whole seawater was incubated in situ for 36 h with NaH13CO3 and Na15NO3.
   - 13C, 15N-labeled phytoplankton and ambient seawater were used for the experiments.
   - One treatment received 40% more viruses (isolated and concentrated from field site).
   - Both treatments received adult, female *Acartia tonsa*, isolated from field site, as the apex predator in the food web.
   - Samples were collected at 0, 6, 12, 24, 48 h for virus and organism abundance, 13C-DOC, 13C-PIC, 15N-POM, and copepod 13C and 15N.

**RESULTS**

1. **VIRUSES ENHANCE C AND N FLUX TO ZOOPLANKTON**

   - In both a culture-based simplified plankton food web and a natural community, addition of viruses infecting picophytoplankton leads to increased C and N flux from picophytoplankton to copepods.

   - Viruses enhance C and N flux to zooplankton, leading to increased C and N flux from picophytoplankton to copepods.

   - Field experiments revealed that enrichment of a natural virus community resulted in reduced Synechococcus growth, increased bacterial growth, and increased growth of heterotrophic protists feeding on Synechococcus.

2. **VIRUSES ENHANCE COPEPOD FECAL PELLET PRODUCTION**

   - Acartia tonsa fecal pellet production was >2x higher in the presence of viruses infecting the picophytoplankton *Ostreococcus tauri*.

3. **VIRUSES FACILITATE GROWTH OF BACTERIA AND HETEROTROPHIC PROTISTS**

   - Field experiments confirmed that viral enrichment of a natural virus community resulted in decreased Synechococcus growth, increased bacterial growth, and increased growth of heterotrophic protists feeding on Synechococcus.

**CONCLUSIONS**

- Marine viruses enhance C transfer from picophytoplankton to higher trophic levels (copepods).
- Marine viruses also stimulate DOC release and bacterial growth (C transfer to lower trophic levels).

- Picophytoplankton viruses stimulate zooplankton feeding and fecal pellet formation, thereby potentially facilitating C export to the deep sea.

**FUTURE DIRECTIONS**

- Intact, virus-infected cells release a range of dissolved organic substances, including chemoattractants, but little is known about the composition and impact of viral-derived organic compounds on microbial interaction dynamics.

Current work includes use of:

- Microfluidics to quantify the chemotactic response of various marine microbes to dissolved organic matter (DOM) released from intact, virus-infected picophytoplankton.
- Chip-based microbial food webs to characterize viral impacts on microscale predator-prey interactions.
- Untargeted stable isotope enabled mass spectrometry to identify novel viral-derived chemoattractants.

We observed virus-stimulated formation of aggregates >500 μm.

- Quantifying viral impacts on marine aggregate formation is essential to understanding C export.