# Abundances of mixotrophic, phototrophic, and heterotrophic nanoflagellates, and associated environmental data, synthesized from the scientific literature.

**Website**: https://www.bco-dmo.org/dataset/807195
**Data Type**: Other Field Results
**Version**: 1
**Version Date**: 2020-03-30

**Project**
» Eating themselves sick? Ecological interactions among a mixotrophic flagellate, its prokaryotic prey, and an ingestible giant virus. (Giant virus ecology)



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|---|---|---|
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**Abstract**
Abundances of mixotrophic, phototrophic, and heterotrophic nanoflagellates, and associated environmental data, synthesized from the scientific literature.

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## Coverage

**Spatial Extent**: **N**:81 **E**:25 **S**:-36.4 **W**:-125
**Temporal Extent**: 1990-10-04 - 2018-02-01

### Methods & Sampling

Data were compiled from 130 experiments in 11 publications that use fluorescently labeled bacteria or beads to estimate the abundance of bacterivorous mixotrophic nanoflagellates (MNF), defined as nanoflagellates with both ingested labeled prey and chlorophyll autofluorescence.These experiments simultaneously counted heterotrophic nanoflagellates (nanoflagellates with no chlorophyll autofluorescence, HNF) and total phototrophic nanoflagellates (all nanoflagellates with chlorophyll autofluorescence, PNF). In some cases researchers also estimated bulk ingestion rate by MNF and HNF, and these data were also extracted.

To ask whether MNF, HNF, and PNF shift in relative abundance across environmental gradients, data on environmental conditions were extracted from the same studies: temperature, chlorophyll-a concentration, nitrate concentration, and bacterial abundance. Although some samples were taken from below the mixed layer, mixed layer Chl-a and nitrate were used as predictors for all analyses, intended as proxies of total productivity or nutrient supply at that location. For two studies Chl-a was not reported and climatological values were used. To capture the light environment, climatological photosynthetically active radiation data (PAR) were used, because *in situ* PAR data were reported in few studies. Monthly climatological mean PAR from the SeaWiFS mission for each location was extracted from the NASA Giovanni portal (https://giovanni.gsfc.nasa.gov/giovanni/).

For samples taken within the mixed layer the light environment was characterized as the median mixed layer PAR, defined as PARin * e^(−(0.121*Chlmix^0.428)*MLD/2), where PARin is incident PAR (mole photons per square meter per day), Chlmix is mixed layer Chl-a (micrograms per liter), and MLD is mixed layer depth (meters). For samples taken below the mixed layer the light environment was characterized as PAR at the sample depth, defined as PARin * e^(-(0.121*Chlmix^0.428)*MLD)

For four studies mixed layer depth could not be estimated from data in the study and was taken from a climatology (http://www.ifremer.fr/cerweb/deboyer/mld/Surface_Mixed_Layer_Depth.php).

### Data Processing Description

These data were published in: Edwards, K.F., 2019. Mixotrophy in nanoflagellates across environmental gradients in the ocean. *Proceedings of the National Academy of Sciences*, *116*(13), pp.6211-6220. Dataset S1.

BCO-DMO processing notes:

- Changed column headers to comply with database requirements
- Removed reference number variable
- Reformatted the data column to iso format: yyyy-mm-dd
- Rounded the columns Nitrate, Chl_a, HNF, MNF, PNF, Bacteria, HNF_ingest, MNF_infest, MLD, PAR are rounded to 0 decimals
- Rounded the columns HNF, MNF, PNF, Bacteria, HNF_ingest, MNF_infest, MLD are rounded to 0 decimals
- The chl_a, longitude and latitude columns are rounded to 2 decimals
- Rounded PAR to 1 decimal

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## Data Files

| File |
|---|
| **mixotrophic_nanoflagellate.csv** (Comma Separated Values (.csv), 12.81 KB) MD5:9bd95ce716a974bb4476e66733fefcf8<br>Primary data file for dataset ID 807195 |

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## Related Publications

Anderson, R., Jürgens, K., & Hansen, P. J. (2017). Mixotrophic Phytoflagellate Bacterivory Field Measurements Strongly Biased by Standard Approaches: A Case Study. Frontiers in Microbiology, 8. doi:10.3389/fmicb.2017.01398
*Related Research*

Arenovski, A. L., Lim, E. L., & Caron, D. A. (1995). Mixotrophic nanoplankton in oligotrophic surface waters of the Sargasso Sea may employ phagotrophy to obtain major nutrients. Journal of Plankton Research, 17(4), 801–820. doi:10.1093/plankt/17.4.801
*Related Research*

Christaki, U., Van Wambeke, F., & Dolan, J. (1999). Nanoflagellates (mixotrophs, heterotrophs and autotrophs) in the oligotrophic eastern Mediterranean:standing stocks, bacterivory and relationships with bacterial production. Marine Ecology Progress Series, 181, 297–307. doi:10.3354/meps181297
*Related Research*

Czypionka, T., Vargas, C. A., Silva, N., Daneri, G., González, H. E., & Iriarte, J. L. (2011). Importance of mixotrophic nanoplankton in Aysén Fjord (Southern Chile) during austral winter. Continental Shelf Research,

31(3-4), 216–224. doi:10.1016/j.csr.2010.06.014
*Related Research*

Edwards, K. F. (2019). Mixotrophy in nanoflagellates across environmental gradients in the ocean. Proceedings of the National Academy of Sciences, 116(13), 6211–6220. doi:10.1073/pnas.1814860116
*Results*

Gast, R. J., Fay, S. A., & Sanders, R. W. (2018). Mixotrophic Activity and Diversity of Antarctic Marine Protists in Austral Summer. Frontiers in Marine Science, 5. doi:10.3389/fmars.2018.00013
*Related Research*

Moorthi, S., Caron, D., Gast, R., & Sanders, R. (2009). Mixotrophy: a widespread and important ecological strategy for planktonic and sea-ice nanoflagellates in the Ross Sea, Antarctica. Aquatic Microbial Ecology, 54, 269–277. doi:10.3354/ame01276
*Related Research*

Safi, K., & Hall, J. (1999). Mixotrophic and heterotrophic nanoflagellate grazing in the convergence zone east of New Zealand. Aquatic Microbial Ecology, 20, 83–93. doi:10.3354/ame020083
*Related Research*

Sanders, R. W., & Gast, R. J. (2011). Bacterivory by phototrophic picoplankton and nanoplankton in Arctic waters. FEMS Microbiology Ecology, 82(2), 242–253. doi:10.1111/j.1574-6941.2011.01253.x
*Related Research*

Sanders, R., Berninger, U., Lim, E., Kemp, P., & Caron, D. (2000). Heterotrophic and mixotrophic nanoplankton predation on picoplankton in the Sargasso Sea and on Georges Bank. Marine Ecology Progress Series, 192, 103–118. doi:10.3354/meps192103
*Related Research*

Sato, M., Shiozaki, T., & Hashihama, F. (2016). Distribution of mixotrophic nanoflagellates along the latitudinal transect of the central North Pacific. Journal of Oceanography, 73(2), 159–168. doi:10.1007/s10872-016-0393-x
*Related Research*

Vargas, C., Contreras, P., & Iriarte, J. (2012). Relative importance of phototrophic, heterotrophic, and mixotrophic nanoflagellates in the microbial food web of a river-influenced coastal upwelling area. Aquatic Microbial Ecology, 65(3), 233–248. doi:10.3354/ame01551
*Related Research*

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## Parameters

| Parameter | Description | Units |
|---|---|---|
| Method | fluorescently labeled bacteria (FLB) or fluorescently labeled beads (beads) | unitless |
| Group | grouping variable for within-study spatial/temporal structure | unitless |
| Environment | coastal or open ocean (defined by eye) | unitless |
| Latitude | latitude, negative is south | decimal degrees |
| Longitude | longitude, negative is west | decimal degrees |
| Position | mixed layer (ML) or below the mixed layer | unitless |

| | | |
|---|---|---|
| Nitrate | nitrate concentration | micromoles per liter (umol/L) |
| Chl_a | mixed layer Chlorophyl a | micrograms per liter (ug/L) |
| HNF | heterotrophic nanoflagellates | cells per milliliter (cells/mL) |
| MNF | mixotrophic nanoflagellates | cells per milliliter (cells/mL) |
| PNF | phototrophic nanoflagellates | cells per milliliter (cells/mL) |
| Bacteria | bacteria | cells per milliliter (cells/mL) |
| HNF_ingest | total bacteria ingested by heterotrophic nanoflagellates | cells ingested per hour |
| MNF_ingest | total bacteria ingested by mixotrophic nanoflagellates | cells ingested per hour |
| MLD | mixed layer depth | meter (m) |
| PAR | climatological photosynthetically active radiation data (PAR) - either median mixed layer PAR or PAR at sample depth, as defined in Methods | mol photons per m^2 per day |
| Study | publication data are compiled from - full reference can be found in "publications" section of the BCO-DMO dataset landing page | unitless |
| Date | Date in format YYYY-MM-DD | unitless |
| Depth | Depth from the surface. | meters (m) |
| Temperature | Water temperature at sample depth | degrees Celsius (°C) |

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## Project Information

**Eating themselves sick? Ecological interactions among a mixotrophic flagellate, its prokaryotic prey, and an ingestible giant virus. (Giant virus ecology)**

**Coverage**: North Pacific Subtropical Gyre - Station ALOHA; and North Pacific tropical embayment, Oahu, HI - Kaneohe Bay

*NSF Award Abstract:*
Phytoplankton support the biological bounty of our seas, so understanding what controls their growth and

death is one of the central issues in oceanography. In much of the nutrient-depleted surface waters of the open ocean, the most successful phytoplankton are tiny photosynthetic bacteria known as Prochlorococcus. These bacteria are highly successful competitors for the ocean's limited nutrients and commonly outcompete larger phytoplankton. Yet, many larger types of phytoplankton persist in the ocean. One reason why this coexistence may occur is that some of the weaker competitors called mixotrophs have evolved a clever alternative strategy best summed up as "If you can't beat them, eat them". In addition to directly competing for nutrients dissolved in the water, these larger phytoplankton can acquire nutrients by consuming and digesting their smaller rivals. The dual ability to photosynthesize and eat competitors has clear advantages, but there can be hidden costs of this intraguild predation strategy. While feeding on Procholorococcus, mixotrophs may also inadvertently ingest giant viruses that are so large they are mistaken for food. Infection is often fatal. Mixotrophy and viral infection are ubiquitous in the ocean; however these processes are often understudied and missing from traditional models of marine food webs that generally consider photosynthesis and predation independently. In this project, the interactions among a common mixotroph (Florenciella), its prey (Prochlorococcus), and a virus that infects the mixotroph (FloV1) will be studied in the lab and field. This research will also help guide the development of a cohesive mixotroph-virus-prey trophic model. Improving these trophic models to account for more complex processes could fundamentally change our understanding of marine trophic dynamics. The project will directly support the training of a post-doc, graduate and undergraduate student in inter-disciplinary science that includes field, lab, and modeling activities. The project will support a major component of the graduate student's dissertation and the progressive training of an undergraduate student, culminating in an independent project. The concepts of mixotrophy and viral ecology investigated here will be translated into a public display seen by hundreds of children and members of the public. The PIs will engage a K-12 teacher in the fieldwork at sea through a "Science Teachers Aboard Research Ships (STARS)" program and will recruit an undergraduate researcher through the CMORE Scholars program at the University of Hawaii.

The advantages and drawbacks of a mixotrophic strategy will depend on the availability of resources and competitors and the likelihood of viral infection. The timing of grazing will be tested to determine whether Florenciella grazes continuously or separates it grazing and photosynthetic activities by only feeding at night. Prey preferences of Florenciella will be tested in competitive grazing experiments offering Prochlorococcus as prey in the presence of varying amounts of other bacteria and cyanobacteria. Electron microscopy will be used to determine whether prey and virus enter Florenciella by the same pathway and whether the presence of prey competitively interferes with viral infection. The kinetics of grazing by Florenciella and infection of Florenciella by FloV1 will be quantified. The results from these lab experiments will be used to parameterize a numerical model. The model will be used to answer questions and make predictions about the dynamics of the mixotroph-virus-prey system and those predictions will be compared to field data. Collectivity, these observational, experimental and quantitative analyses will provide a detailed exploration of the ecological complexity hidden at the base of the marine food web.

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## Funding


| Funding Source | Award |
| --- | --- |
| NSF Division of Ocean Sciences (NSF OCE) | OCE-1559356 |


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