Mixotrophy in the Gulf of Alaska:
Abundant plant-animal cells have major implications for ecology and biogeochemistry

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Mixotrophy: multiple modes of nutrition in a single organism

Photosynthesis + Feeding:

Venus fly trap:
a plant that eats

Stony corals:
an animal – algal association

Many marine protists are mixotrophs:

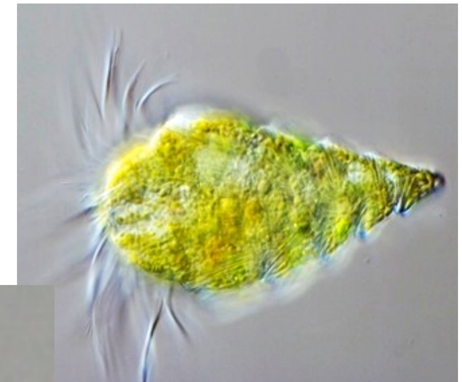
“phytoplankton” & “microzooplankton”

Two main strategies:

Steal and retain chloroplasts from prey:

ciliates, a few dinoflagellates

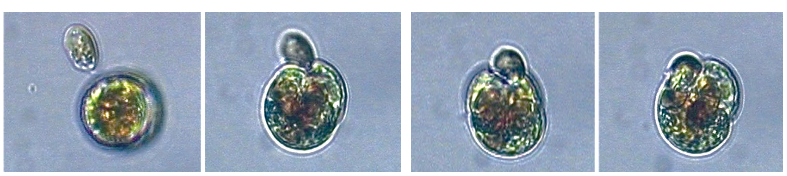
C subsidy

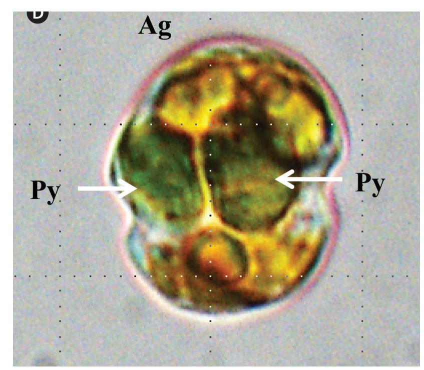


Supplement constitutive photosynthesis with feeding:

many flagellate ‘phytoplankton’ incl. dinoflagellates

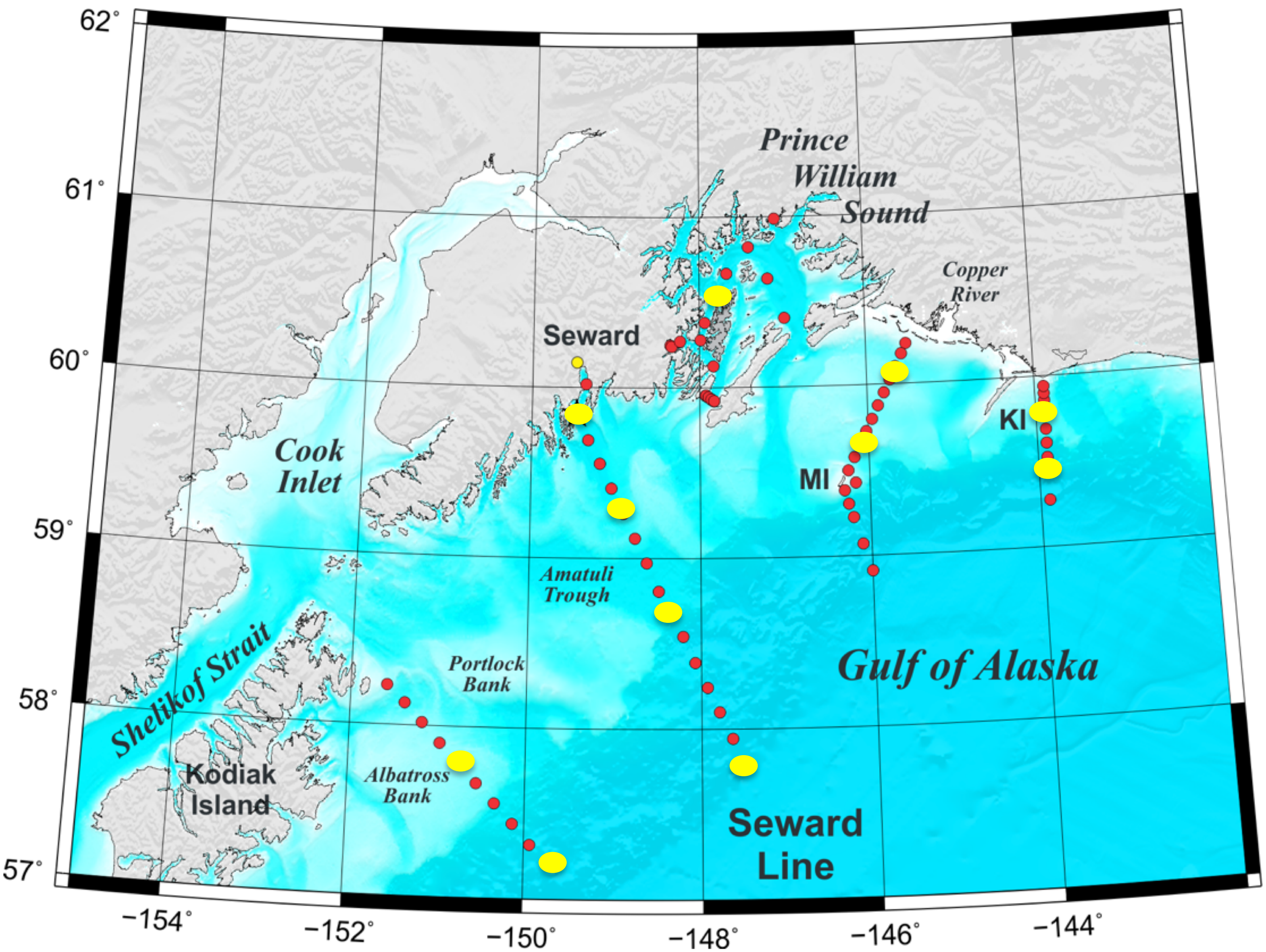
nutrient subsidy





Questions:

1. How common and abundant are NGA mixotrophs?
2. What is their potential impact on the ecosystem?



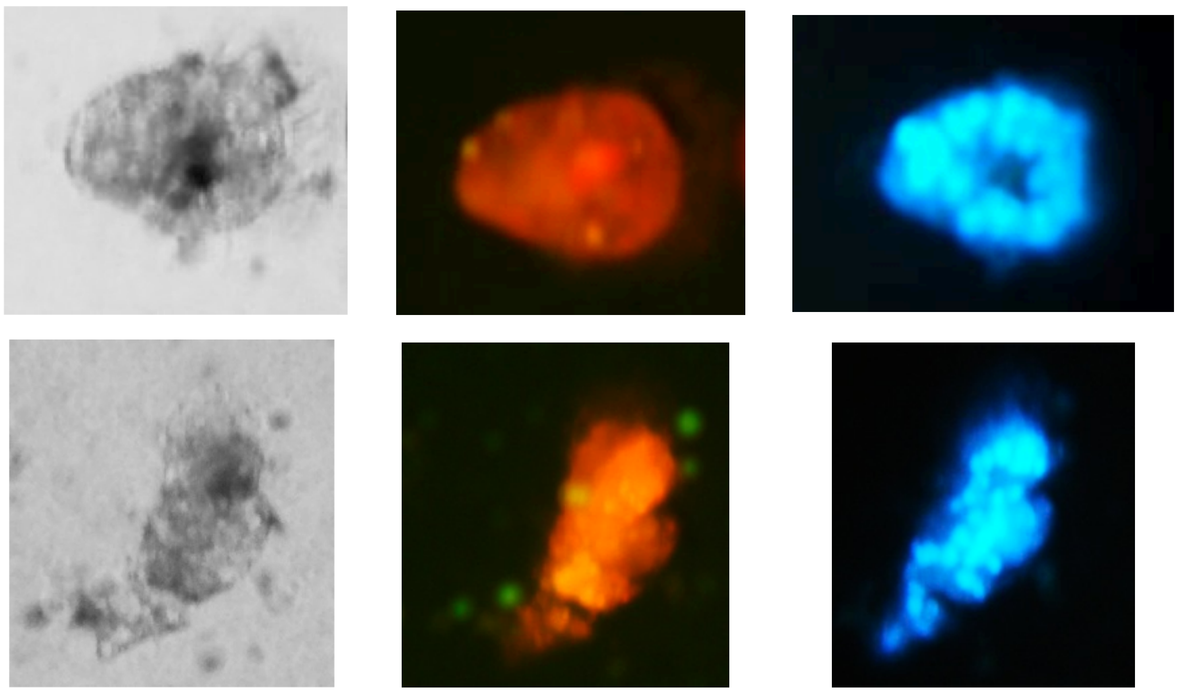
Sampling in spring, summer, fall

Mixotrophy stations

Identifying mixotrophs:

Chloroplast-retaining ciliates

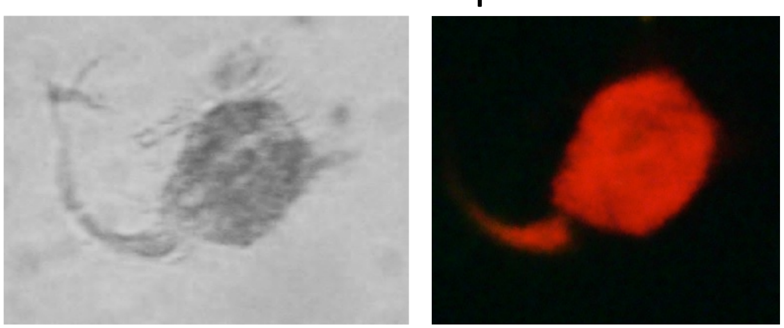
Light | Blue ex: chl | UV ex: nuclei



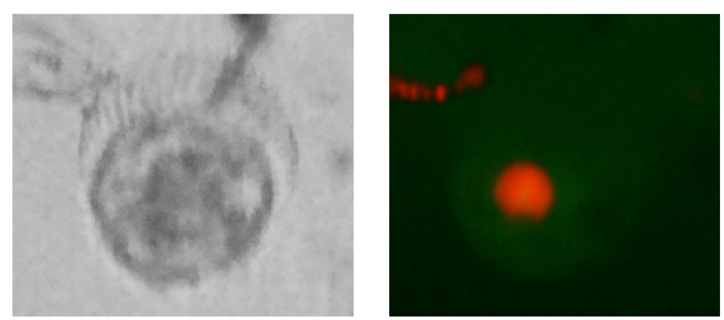
Strombidium lynni

Laboea strobila

Tontonia sp.



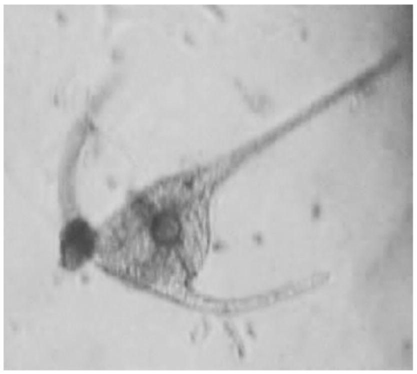
Strobilidium sp. NOT A MIXOTROPH



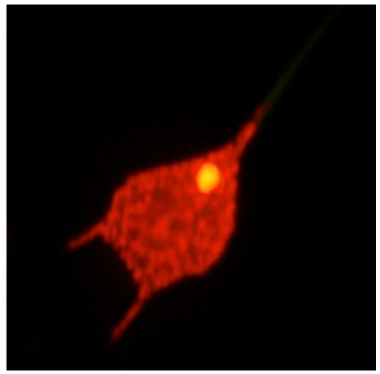
Identifying mixotrophs:

Photosynthetic dinoflagellates that eat

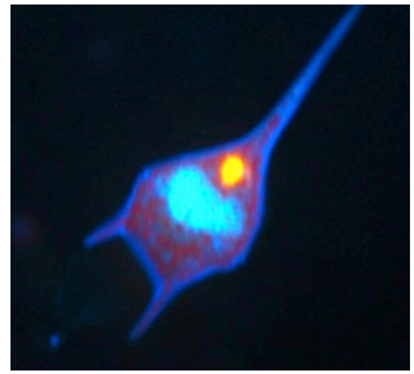
Light



Blue ex: chl

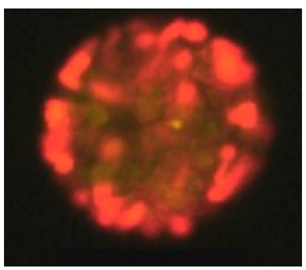


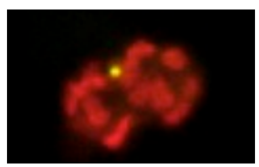
UV ex: nuclei

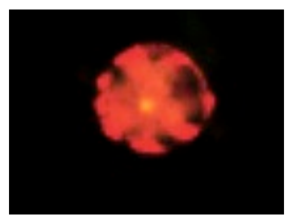


Ceratium spp.

Blue ex: chl

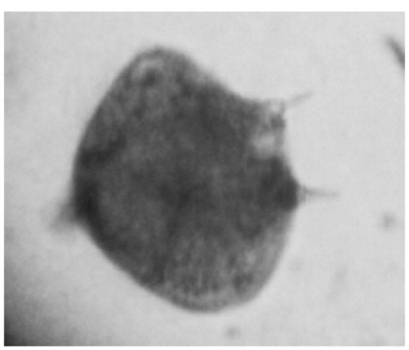


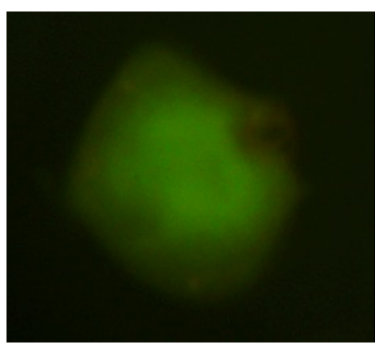




Misc autotrophic dinos
with ingested cyanobacteria

We know that nearly all photo
dinos can eat (Jeong et al.)

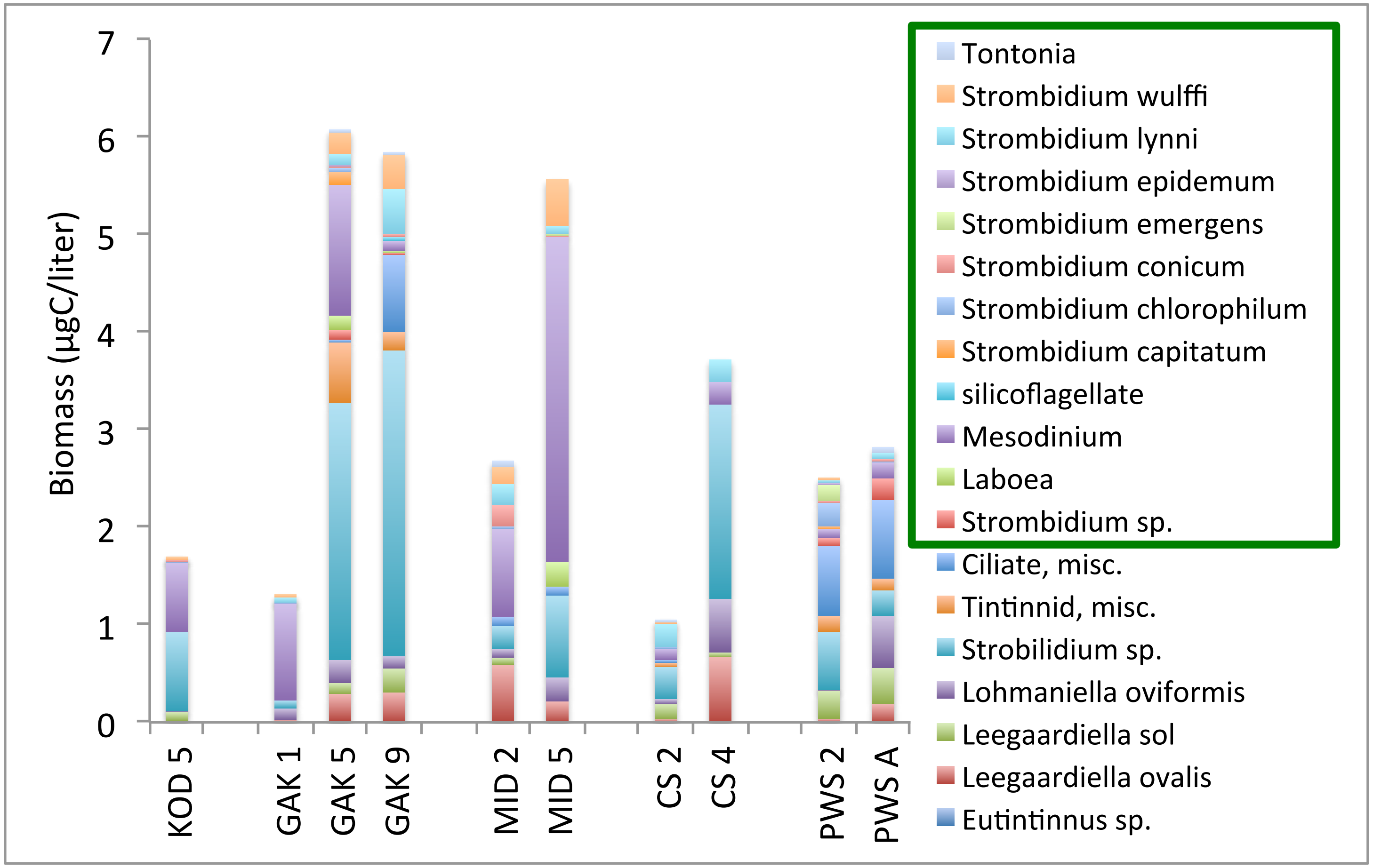




Protoperidinium sp. NOT A MIXOTROPH

Seasonal mixotroph community:

SPRING 2018 Ciliate community composition

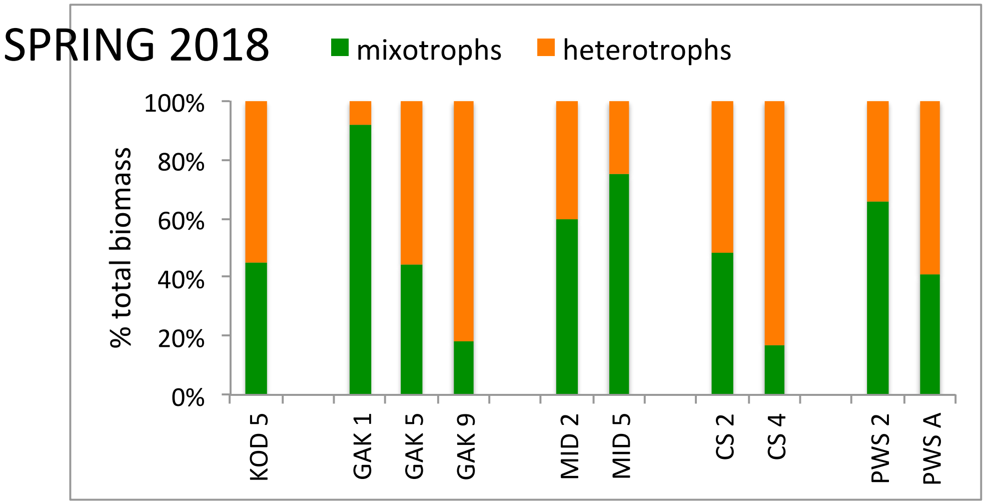


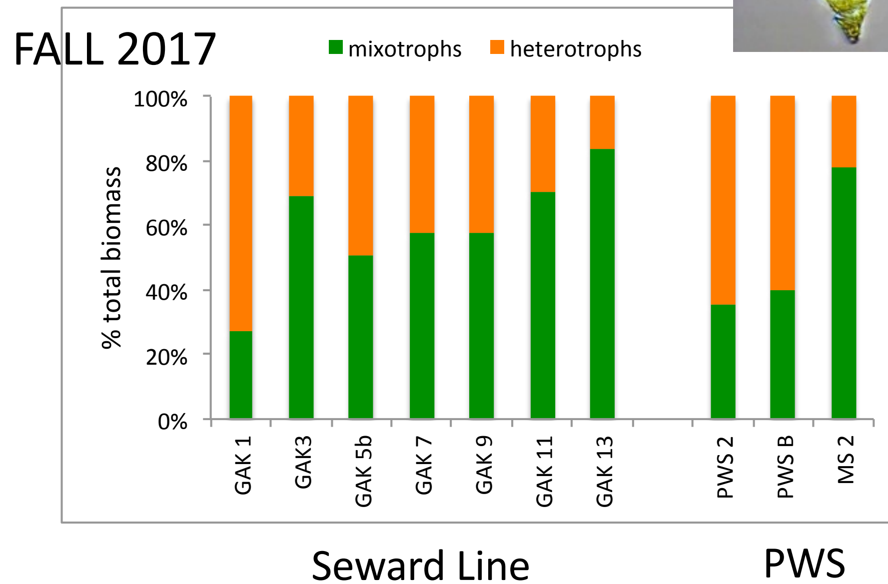
west east PWS

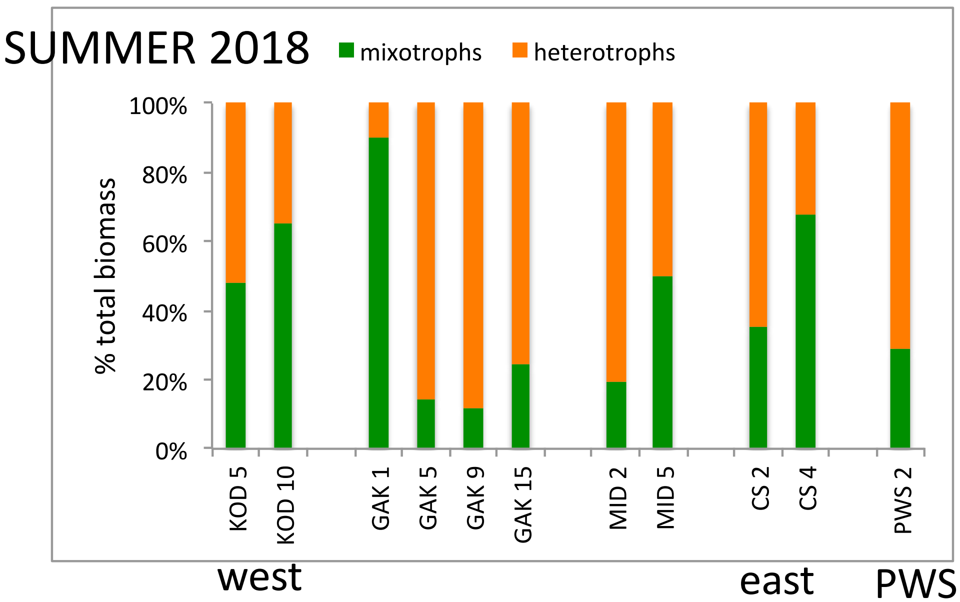
Mixotrophs
(chloroplast-retaining ciliates)

Seasonal mixotroph community:

Ciliate community composition



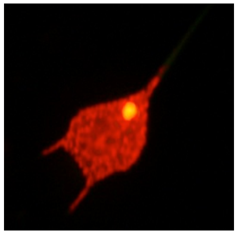




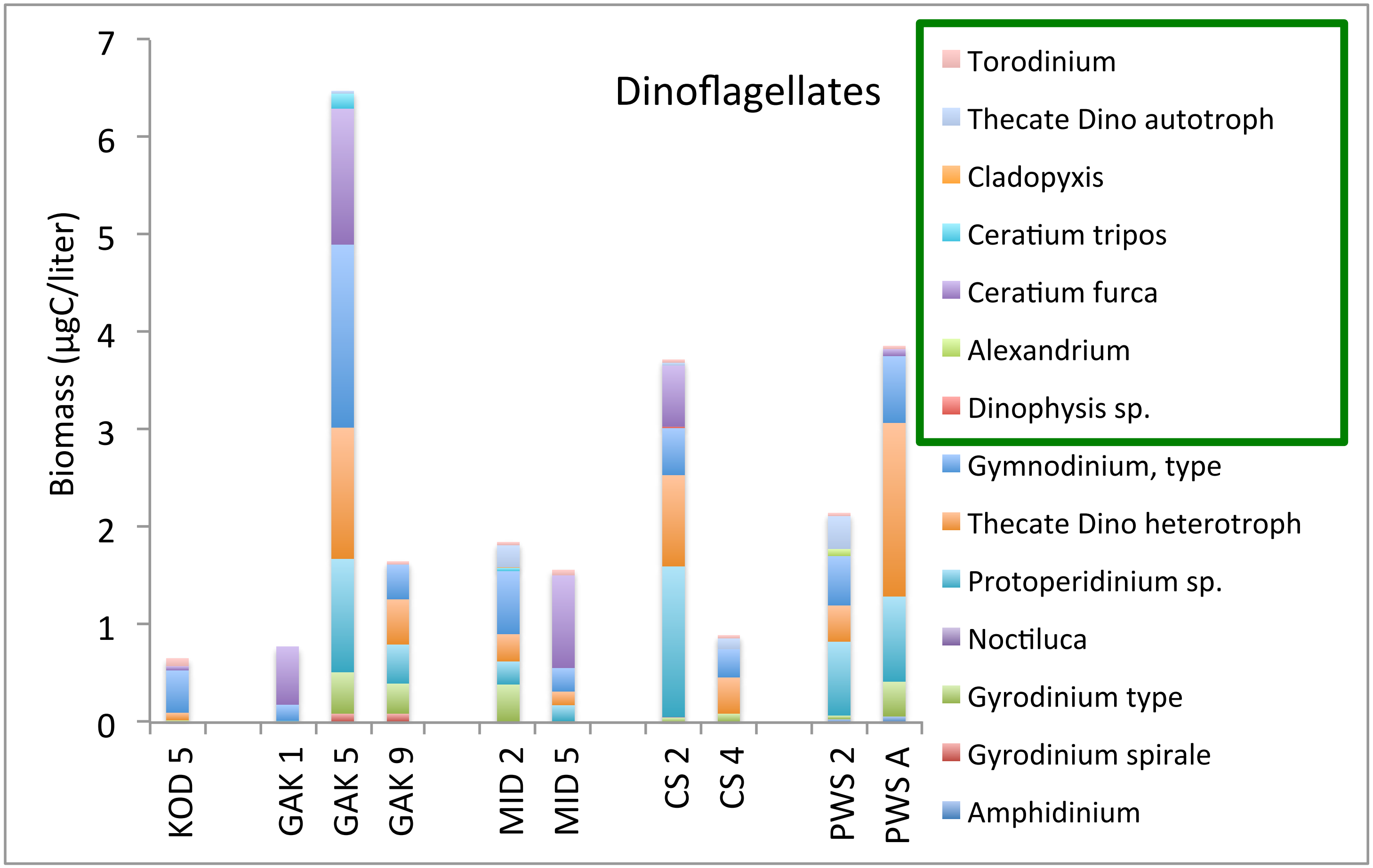
Median % mixotrophs:

Spring	47
Summer	35
Fall	58

Seasonal mixotroph community:



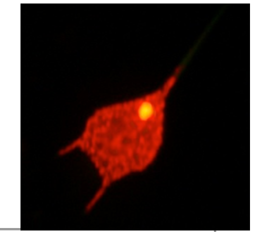
SPRING 2018 DInoflagellate community composition



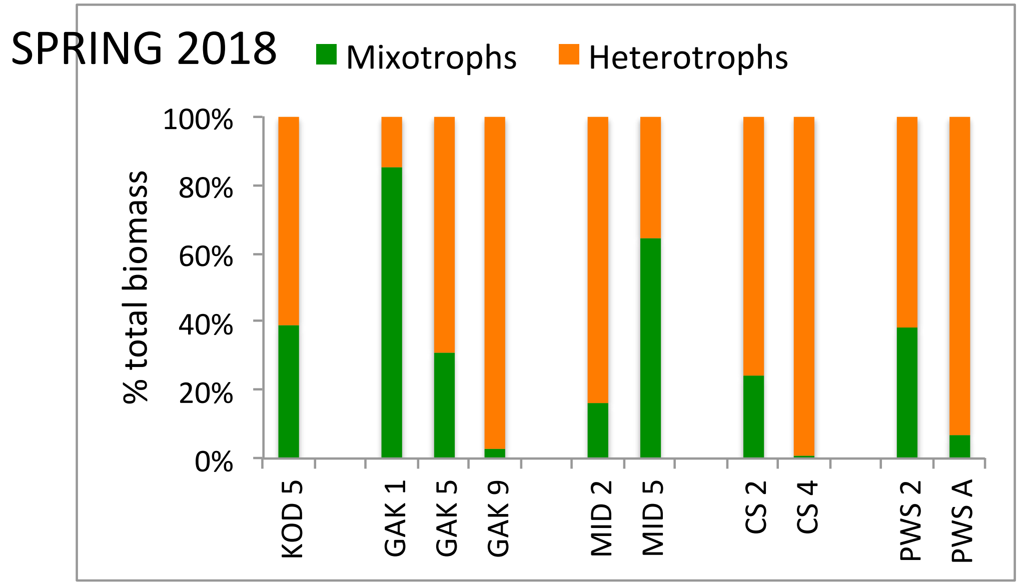
west east PWS

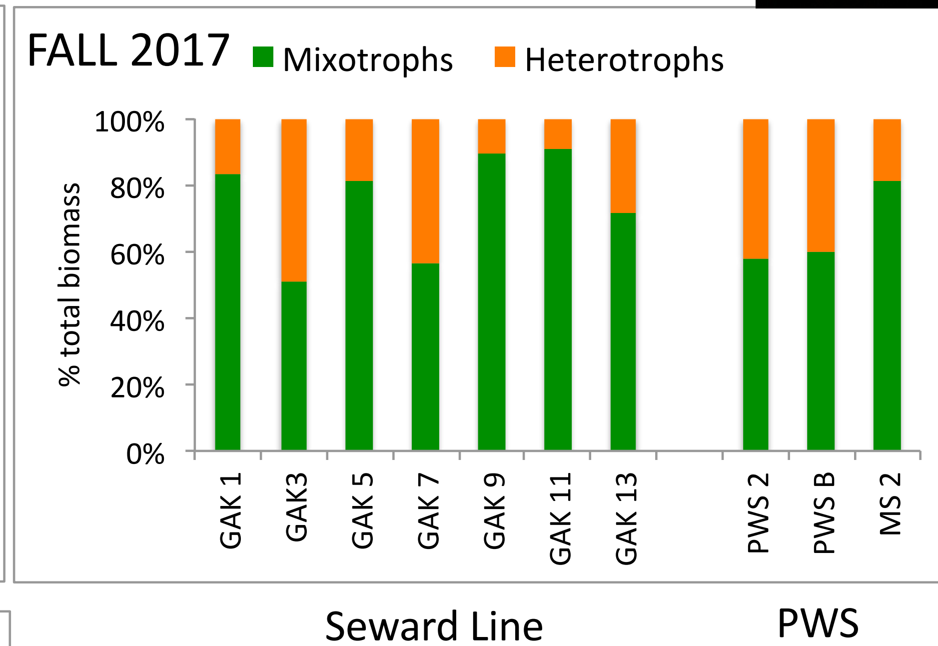
Mixotrophs (photosynthetic dinoflagellates)

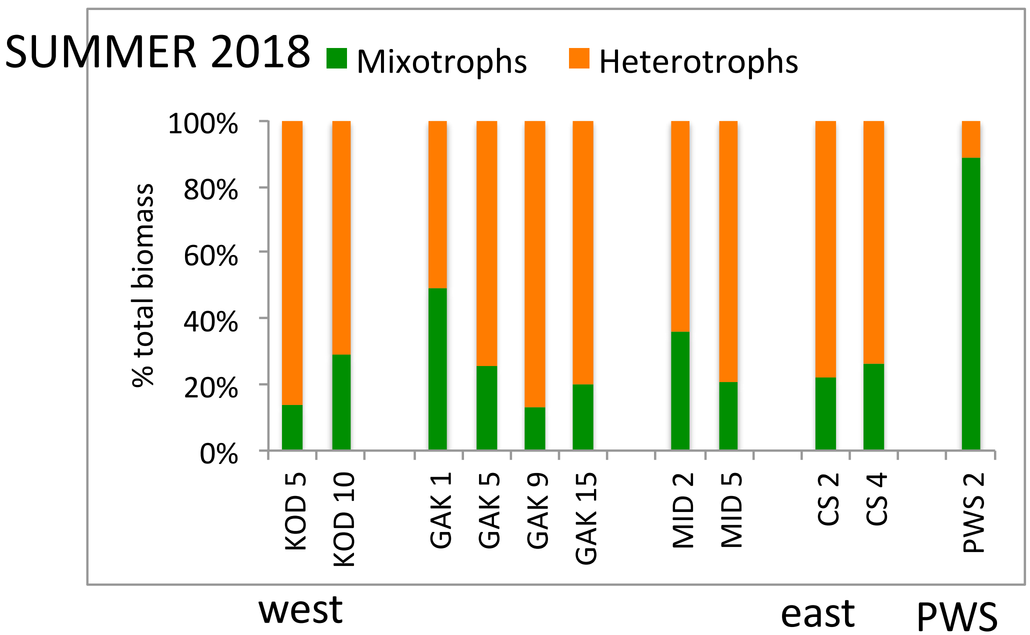
Seasonal mixotroph community:



Dinflagellate community composition







Median % mixotrophs:

Spring	28
Summer	25
Fall	76

Contribution to Chlorophyll-a:

Chloroplast-retaining ciliates:

C per cell from cell volume & conversion factors

Chl-a per cell from direct measurements

Median ciliate C:chl = 118 (Spring 2018)

Ciliate contribution to >20 µm Chl-a:

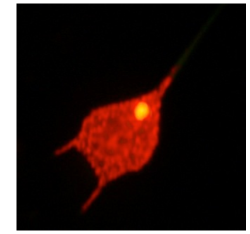
	Median	Min	Max
Spring	1%	0%	24%
Summer	42%	4%	85%
Fall	2%	0%	11%

In summer, chloroplast-retaining ciliates could be half or more of the large “phytoplankton”

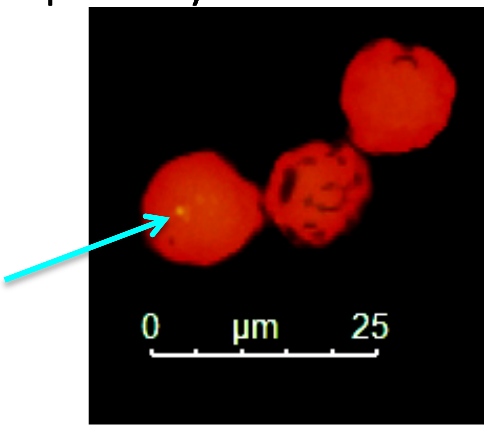
Feeding potential

Photosynthetic dinoflagellates:

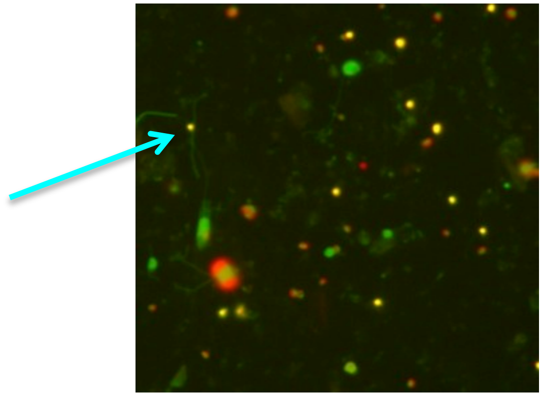
Summer 2018 Prince William Sound



Abundant 12 µm thecate photosyn dino



Abundant naturally occurring *Synechococcus*



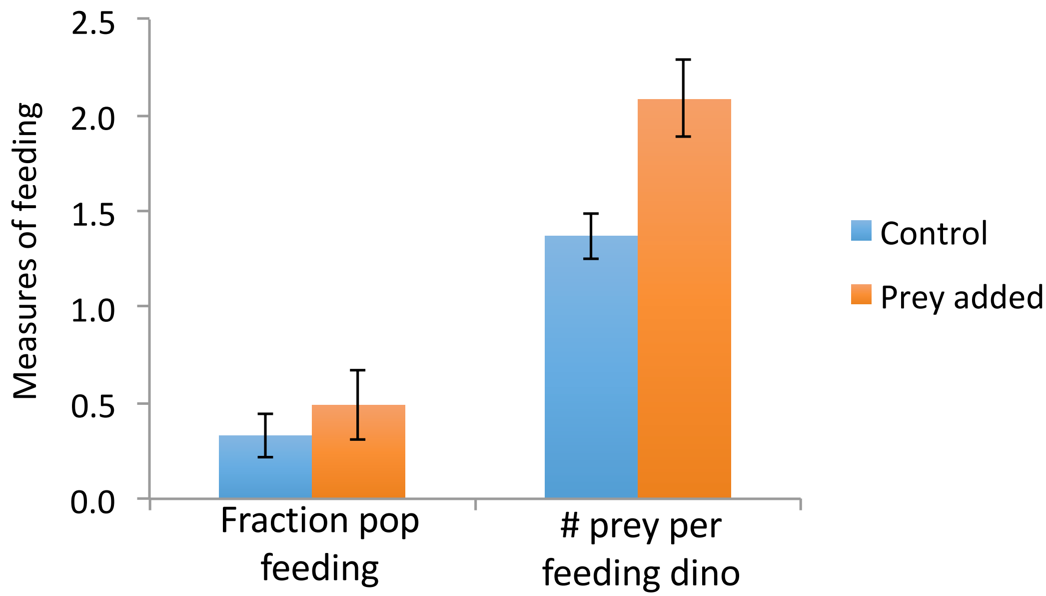
CONTROL (3x)

Cultured high-latitude *Synechococcus*

PREY ADDED (3x)

Incubate on deck 24 h; fix; assess 100 dinos per rep

Feeding increased in response to *Synechococcus* addition:



Control: 2.0×10^4 Syn ml^{-1}

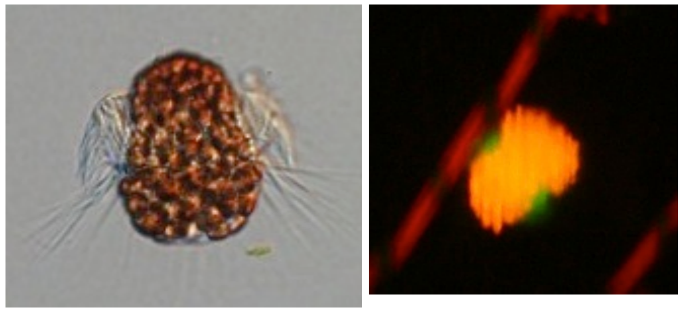
Prey added: 1.4×10^5 Syn ml^{-1}

Potential for experiments assessing environmental effects on predation by mixotrophs

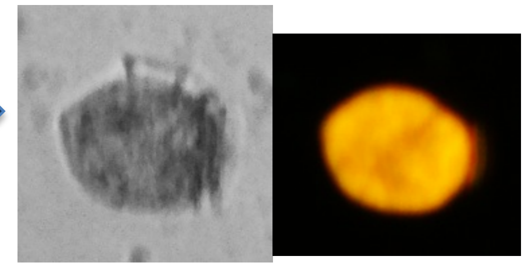
Fascinating species

Mesodinium rubrum: a mixotrophic ciliate

Cryptophyte algae: obligate prey



Ciliate *Mesodinium rubrum*: long-term retention of cryptophyte chloroplasts



Dinoflagellate *Dinophysis* sp.: must feed on *M. rubrum*, retains chloroplasts from ciliate

Mesodinium as % of mixotrophic ciliate biomass:

	Median	Min	Max
Spring	43%	6%	93%
Summer	37%	3%	86%
Fall	18%	0%	56%

PERSISTENT and IMPORTANT

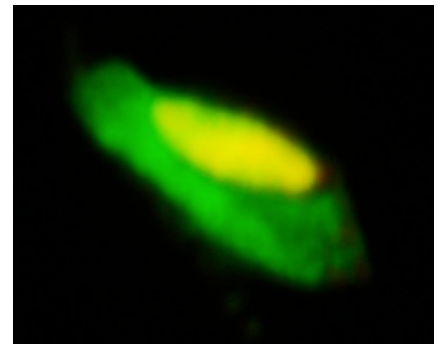
Fascinating species

***Torodinium* sp.:** a ?? dinoflagellate

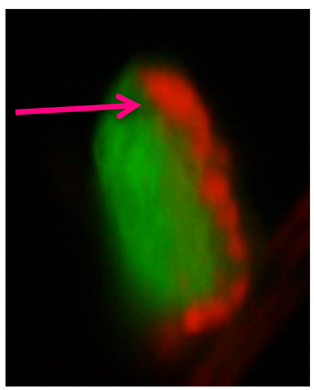
Light micrograph

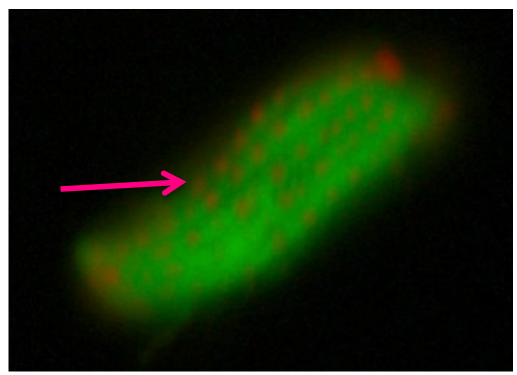
blue ex: chloroplasts

UV ex: nucleus



With food vacuole full of *Synechococcus*

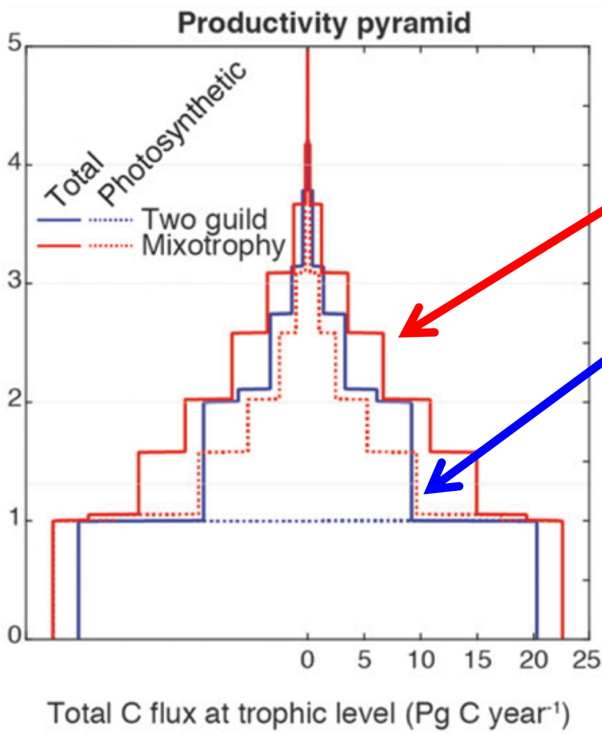




WHAT IS GOING ON?

Nothing in the literature about *Torodinium* having or acquiring chloroplasts

Consequences of mixotrophy for planktonic ecosystem:



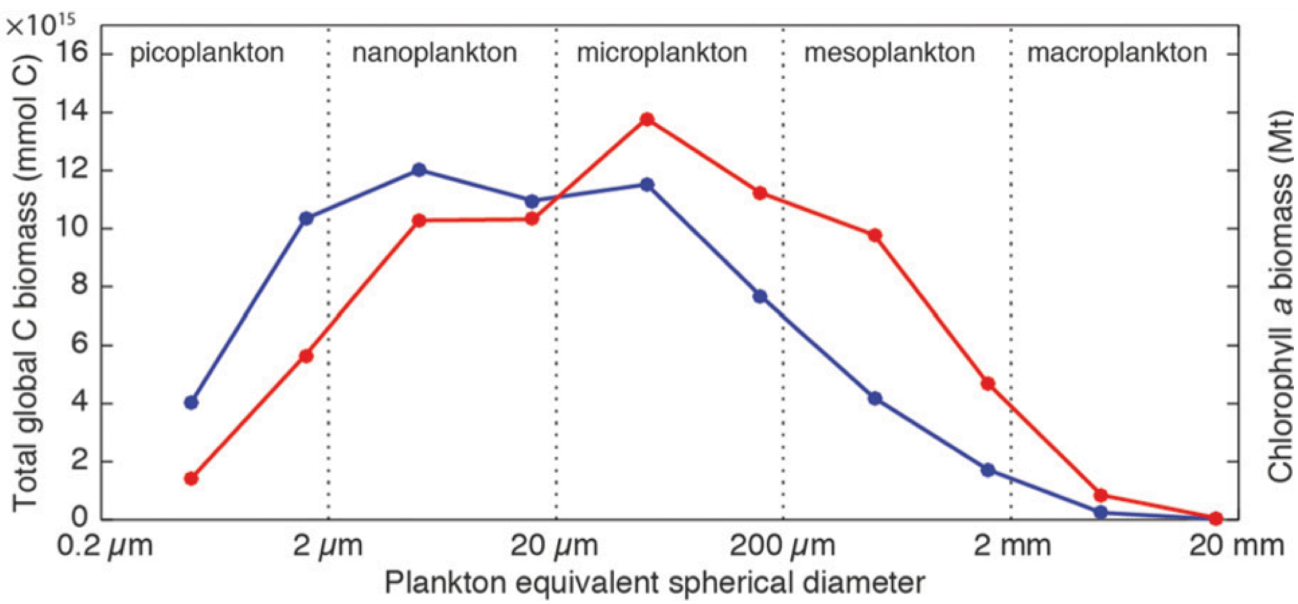
Model of Ward and Follows 2016 PNAS 113

With mixotrophy

With phytoplankton vs zooplankton

Mixotrophy increases

- primary production
- trophic transfer efficiency



Mixotrophy increases

- average particle size
- export flux

Conclusions (preliminary!)

- Mixotrophic dinoflagellates and ciliates are common and often abundant in the northern Gulf of Alaska

- They can contribute substantially (25 – 75%, on average) to "microzooplankton" biomass

- In summer, chloroplast-retaining ciliates comprised ~half of the large "phytoplankton"

- Through efficient C and nutrient acquisition and retention, mixotrophs can alter fundamental ecosystem properties

Thank you for your attention!

Photo credits

https://animals.sandiegozoo.org/plants/venus-flytrap

https://www.tripadvisor.ca/LocationPhotoDirectLink-g147395-d547336-i71787293-Smith_s_Reef-Turks_and_Caicos.html

Mesodinium light micrograph: Dierssen et al. 2015 PNAS 112

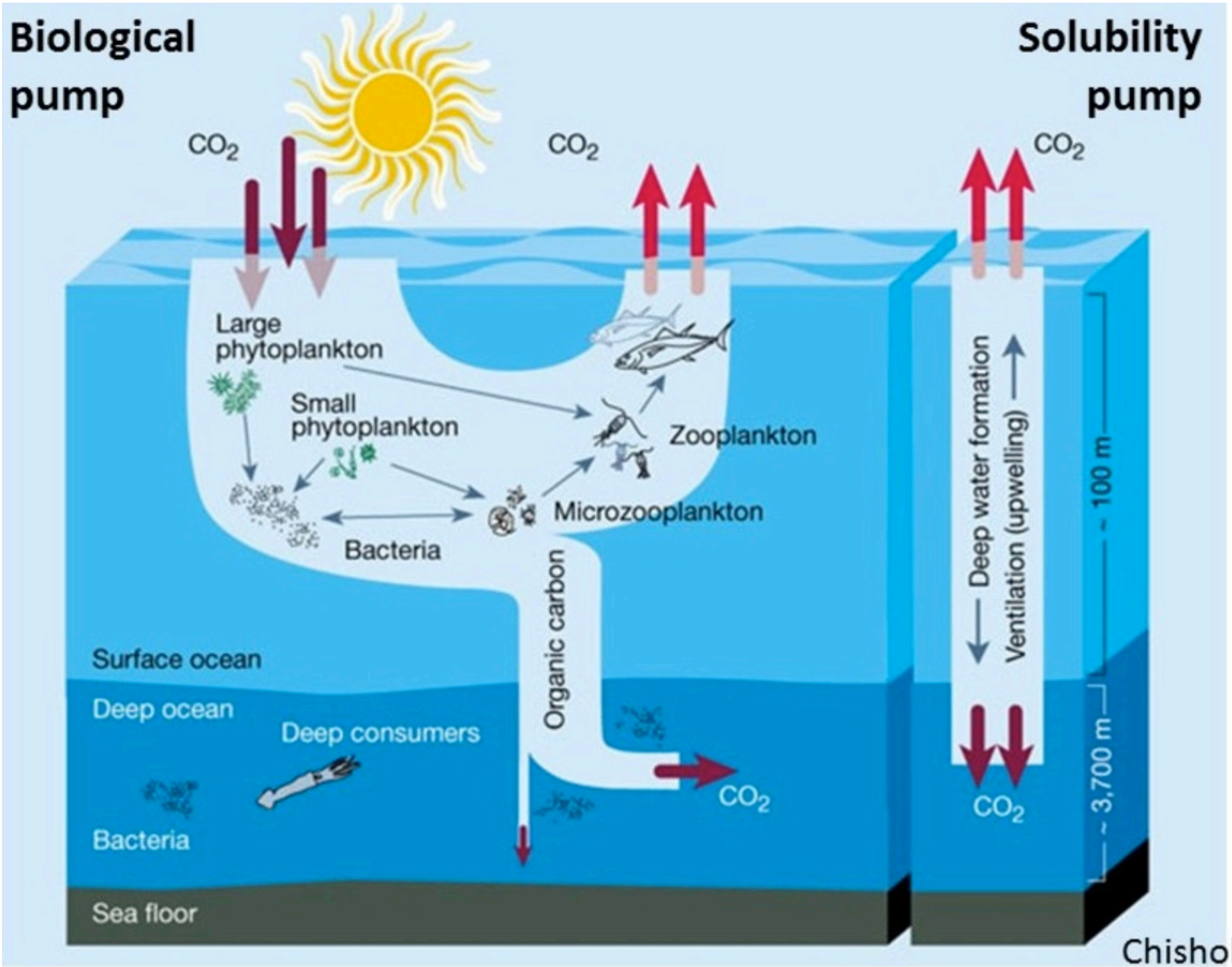
Green Laboea: Franz Neidl, Glacier Bay National Park

Karlodinium feeding: Berge et al. 2008 Aquat Microb Ecol 50

Ansanella granifera feeding: Lee et al. 2014 Algae 29

Cryptophytes under light microscope: https://en.wikipedia.org/wiki/Cryptomonad

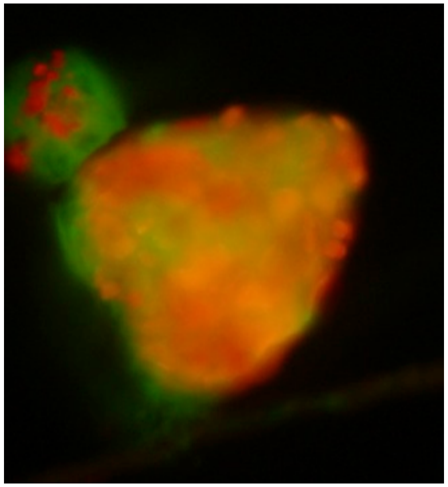
What’s wrong with this food web?

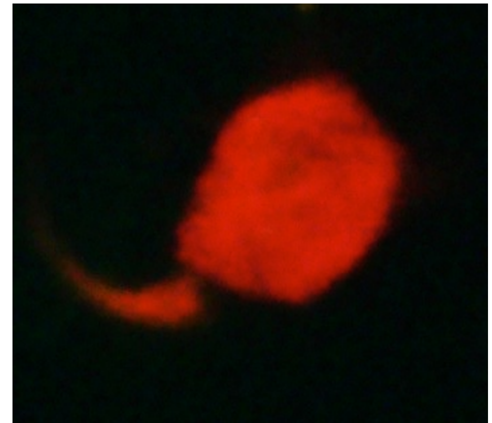


Chisholm, 2000

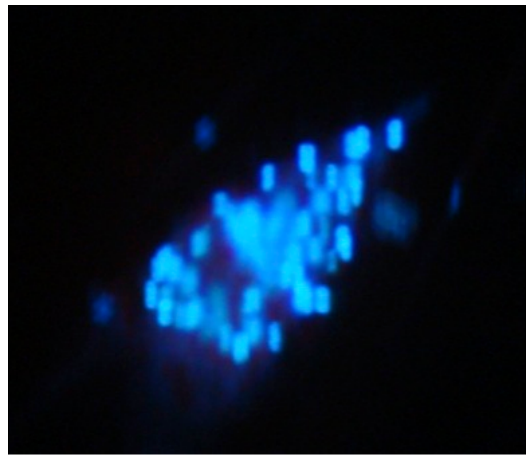
Mixotrophs from NGA:

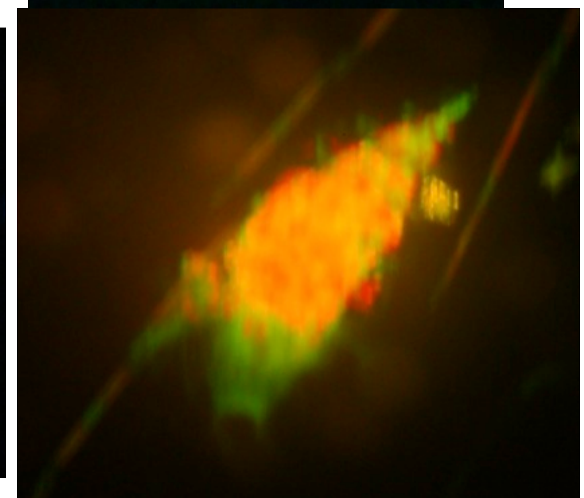
Chloroplast-retaining ciliates

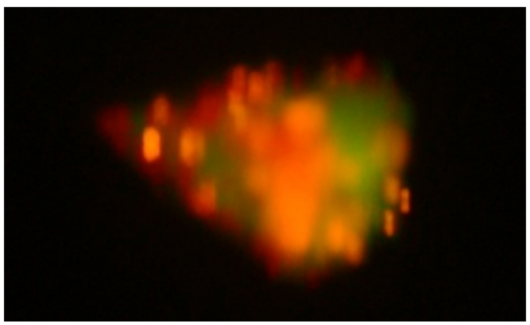


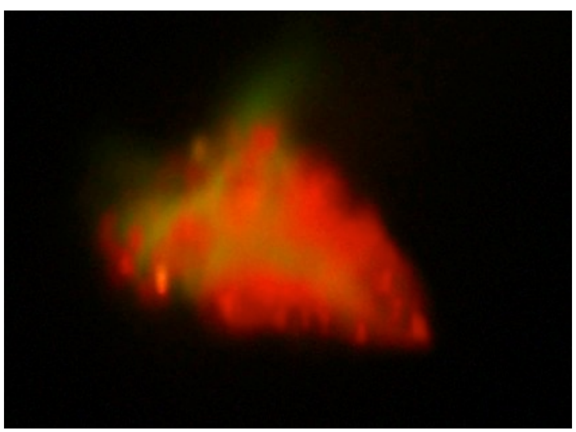


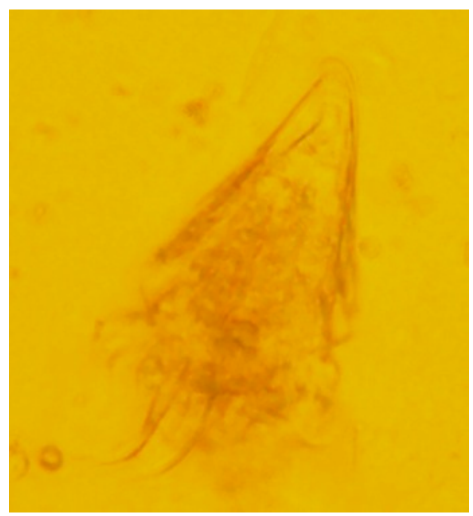
Fall
2017

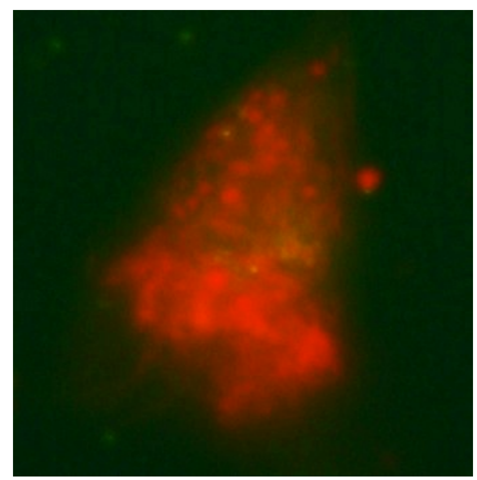




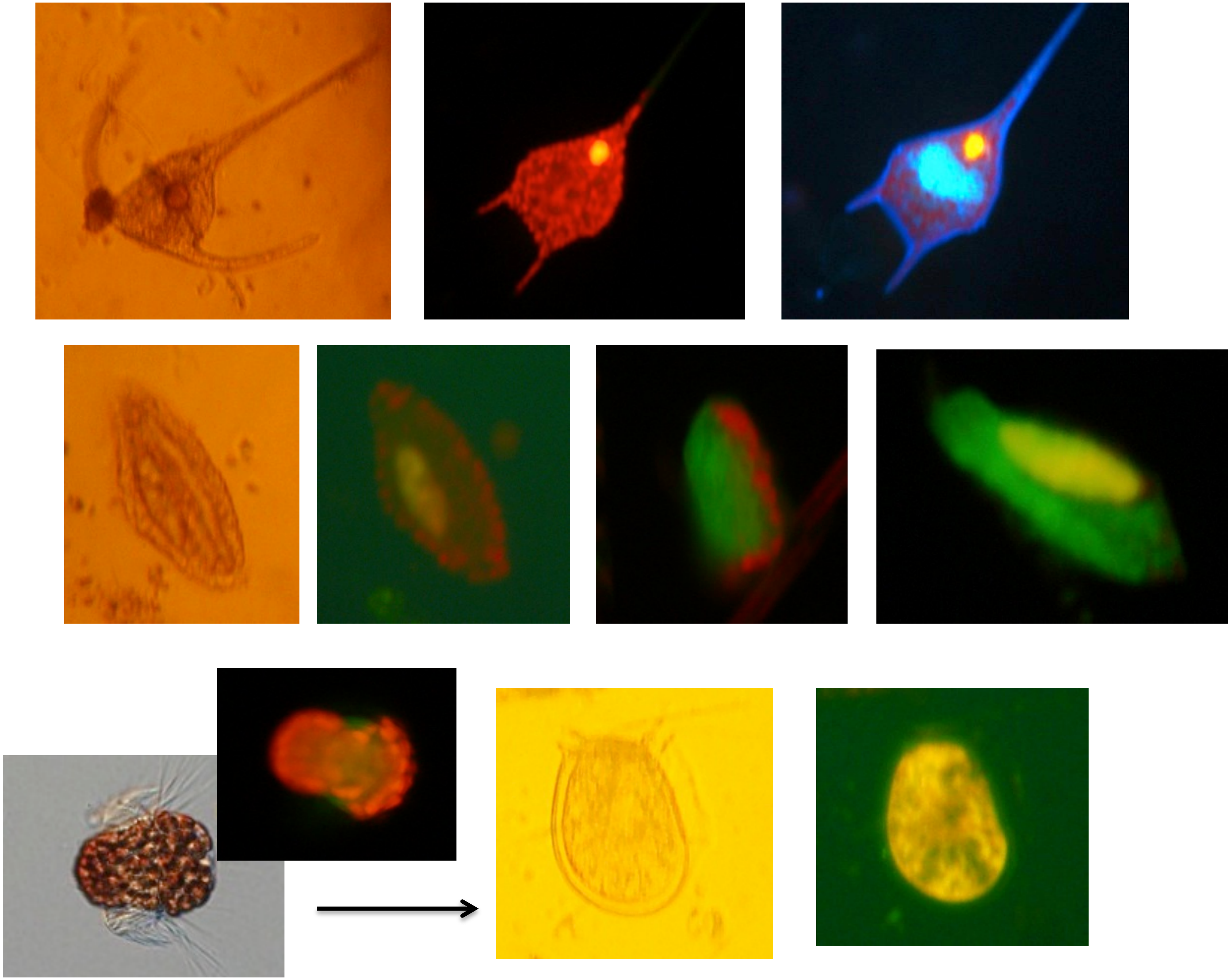








Mixotrophs from NGA: Photosynthetic dinoflagellates that feed



Fall
2017