

# Novel Insights from Multiscale Plankton Time Series at the Martha's Vineyard Coastal Observatory

Heidi M. Sosik



# Phytoplankton Diversity and Dynamics

What factors control phytoplankton diversity and dynamics?  
How are they changing through time?

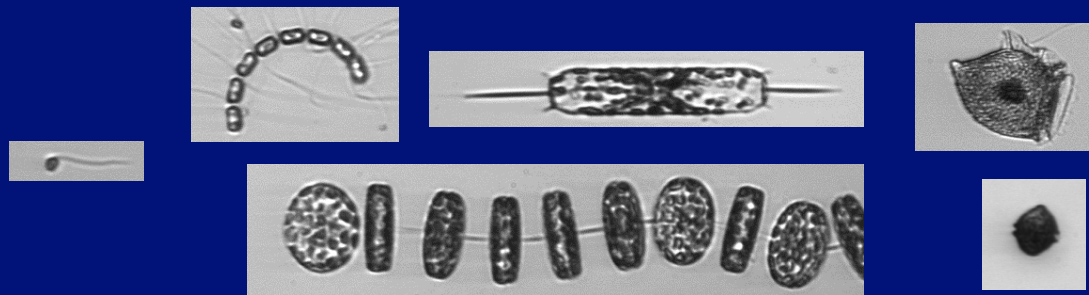
Approach: time series observations

with high resolution & long duration

cabled observatory facilities

new in situ sampling and analysis systems

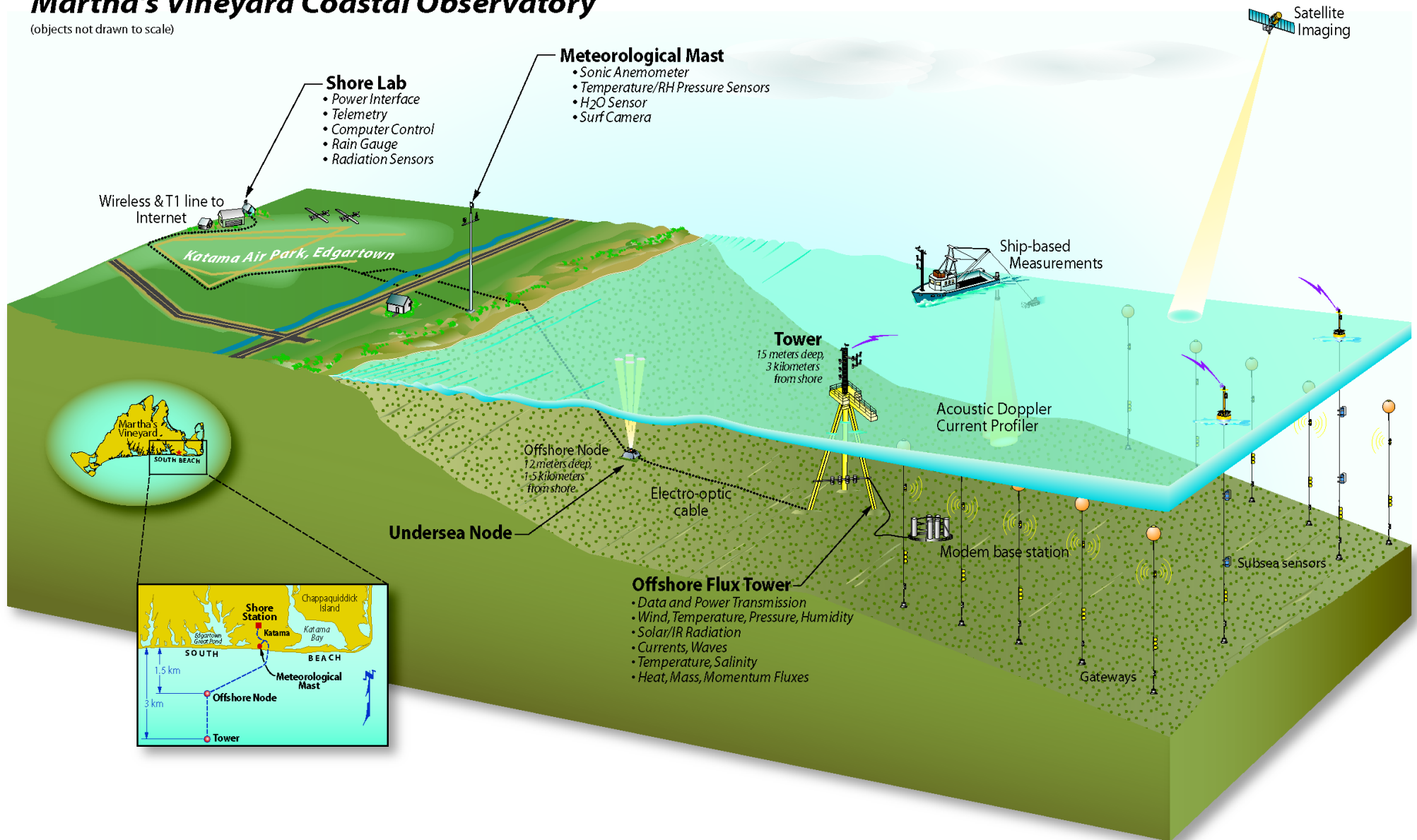
individual cells → taxa → communities



# Martha's Vineyard Coastal Observatory (MVCO)

## Martha's Vineyard Coastal Observatory

(objects not drawn to scale)



# Martha's Vineyard Coastal Observatory (MVCO)

Cabled to shore since 2001  
 Continuous power & Ethernet into the ocean  
 Open to new users - research and industry  
 Web-based data access – realtime & archived

## Long term data records:

temperature, salinity,  
 currents, wind,  
 waves, tides,  
 pressure, radiation,  
 rainfall, humidity



### Martha's Vineyard Coastal Observatory

EDGARTOWN, MASSACHUSETTS

[MVCO home](#) | [WHOI home](#) | [Coastal Ocean Institute](#) | [Related Links](#) | [Site Map](#) | [Contact](#)

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▶ [Description](#)
▶ [Data](#)
▶ [Projects](#)
▶ [Other Data Links](#)
▶ [MVCO News](#)
▶ [Plugging In](#)

12 Mar 2010 20:04 GMT

The MVCO is a research observatory located at South Beach and in the ocean a mile off the south shore of Martha's Vineyard. It provides real time and archived coastal oceanographic and meteorological data for researchers, students and the general public.

Current GMT time: Mar 12, 2010 20:11  
 Current local time: Mar 12, 2010 15:11

[Switch to Metric Units](#)   [Update Data](#)

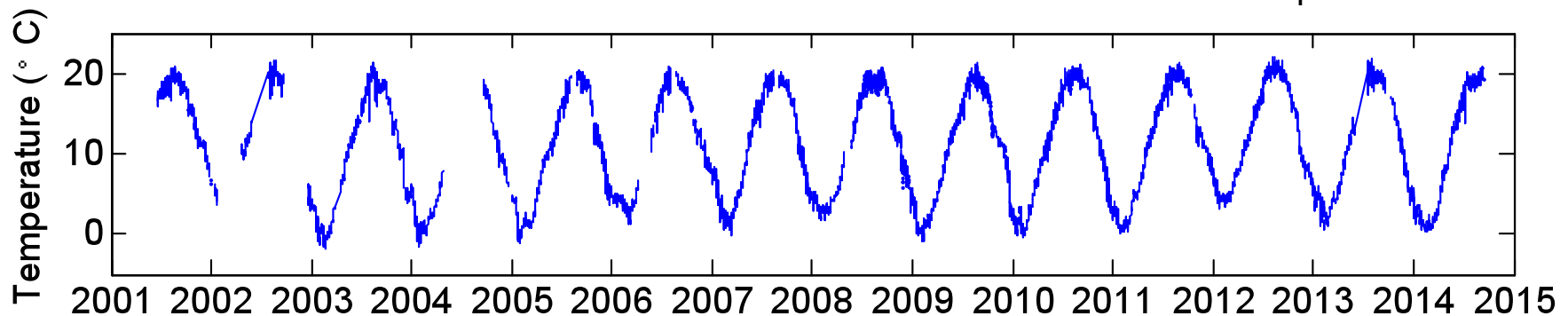
Edgartown, MA

Funded by:

Mar 12, 2010 19:40 GMT Meteorological Observations South Beach	
<a href="#">Wind Speed</a>	13.1 knots
<a href="#">Wind Direction from</a>	66 ° (ENE)
<a href="#">Air Temperature</a>	41.4 ° F
<a href="#">Relative Humidity</a>	75 %
<a href="#">Pressure</a>	1023 mb
<a href="#">Solar Radiation</a>	158 Wm <sup>-2</sup>
<a href="#">Infrared Radiation</a>	334 Wm <sup>-2</sup>
<a href="#">Precipitation (20 min burst)</a>	0.00 in
<a href="#">Time Series Plots - Composite</a>	

Mar 12, 2010 19:40 GMT Oceanographic Observations 1 mile offshore in the Atlantic	
<a href="#">Wave height</a>	2.6 feet
<a href="#">Dominant wave period</a>	4.0 seconds
<a href="#">Wave direction from</a>	142 °
<a href="#">Wave spectra (mks)</a>	
<a href="#">Near bottom water temperature</a>	39.4 ° F
<a href="#">Near bottom current</a>	0.32 knots
<a href="#">Near bottom current direction toward</a>	292 °
<a href="#">Near surface current</a>	0.46 knots
<a href="#">Near surface current direction toward</a>	279 °
<a href="#">Tide</a>	-0.1 feet
<a href="#">Salinity</a>	31.9 ppt
<a href="#">Time Series Plots - Composite</a>	

<http://www.whoi.edu/mvco>





# The FlowCytobot Instruments

## FlowCytobot

Principles from conventional flow cytometry  
(but automated and submersible)

Optimized for “small” cells ( $\sim 1\text{-}15\ \mu\text{m}$ )

Olson et al. 2003, Sosik et al. 2003



## Imaging FlowCytobot



Derived from FlowCytobot design

Optimized for large cells ( $\sim 10\text{-}200\ \mu\text{m}$ )

Olson and Sosik 2007, Sosik and Olson 2007

→ Automated features for extended deployment

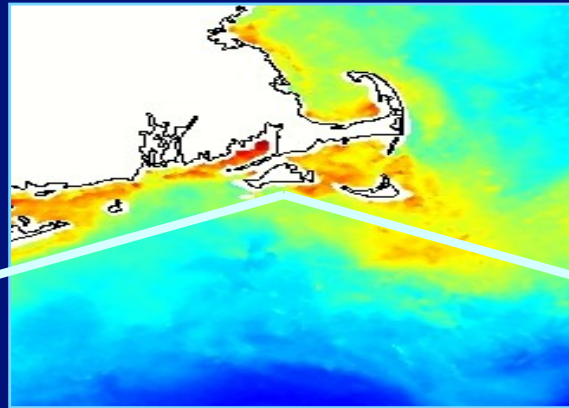
Standard analysis, biofouling control, real time  
humidity sensing & intake valve control

→ Observational capabilities

Enumeration, identification, and cell sizing  
Thousands of individual phytoplankton

# Phytoplankton Time Series at MVCO

Martha's Vineyard Coastal Observatory (MVCO)  
Cabled site with power and two-way communications



Picoplankton



FlowCytobot

Microplankton



Imaging FlowCytobot

# Phytoplankton Time Series at MVCO

Many species  
at MVCO  
~600 million images  
since 2006

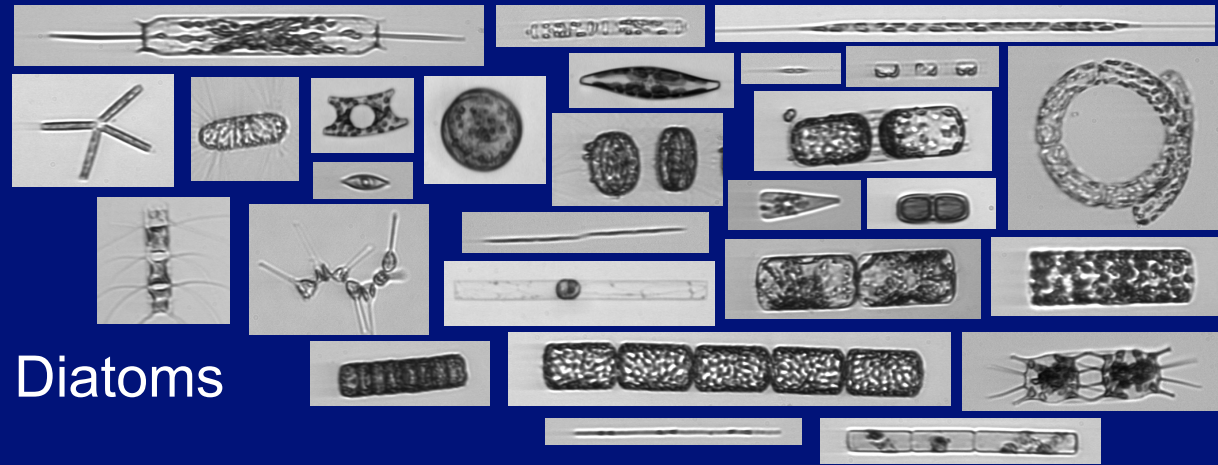
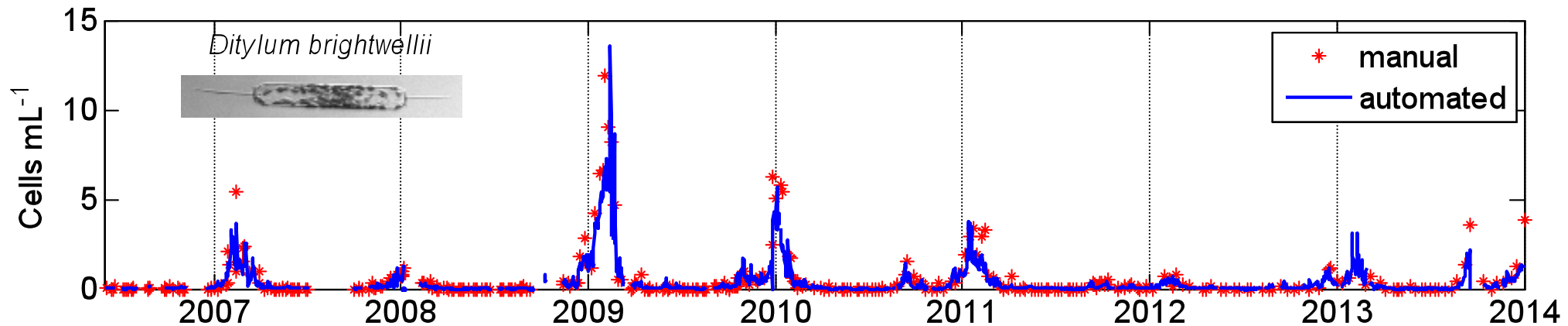


Image processing

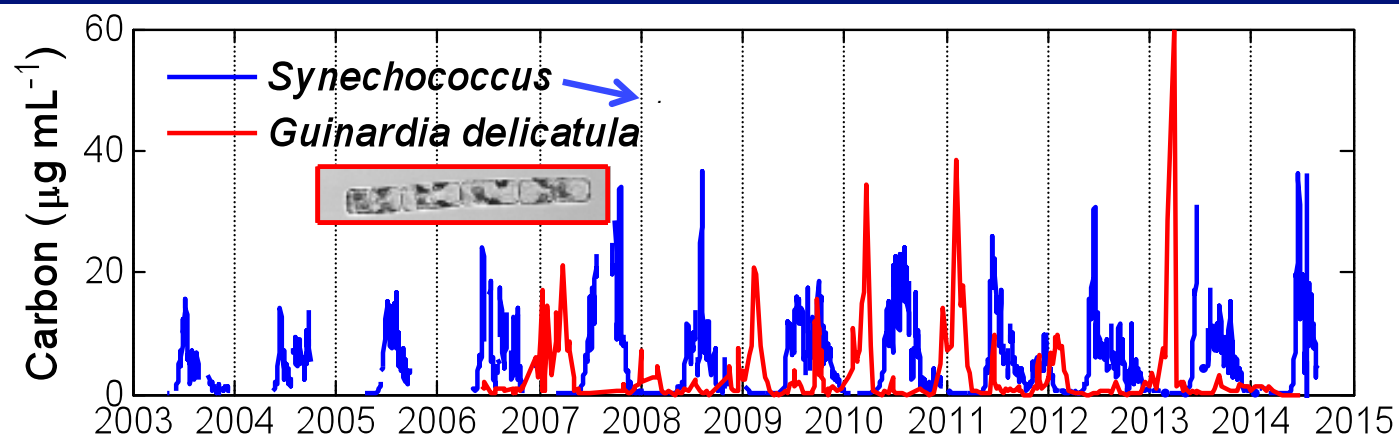
Feature extraction

Supervised machine learning

Sosik and Olson 2007

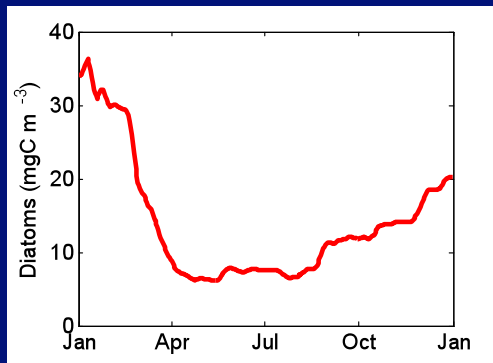


# Seasonal variability & diversity

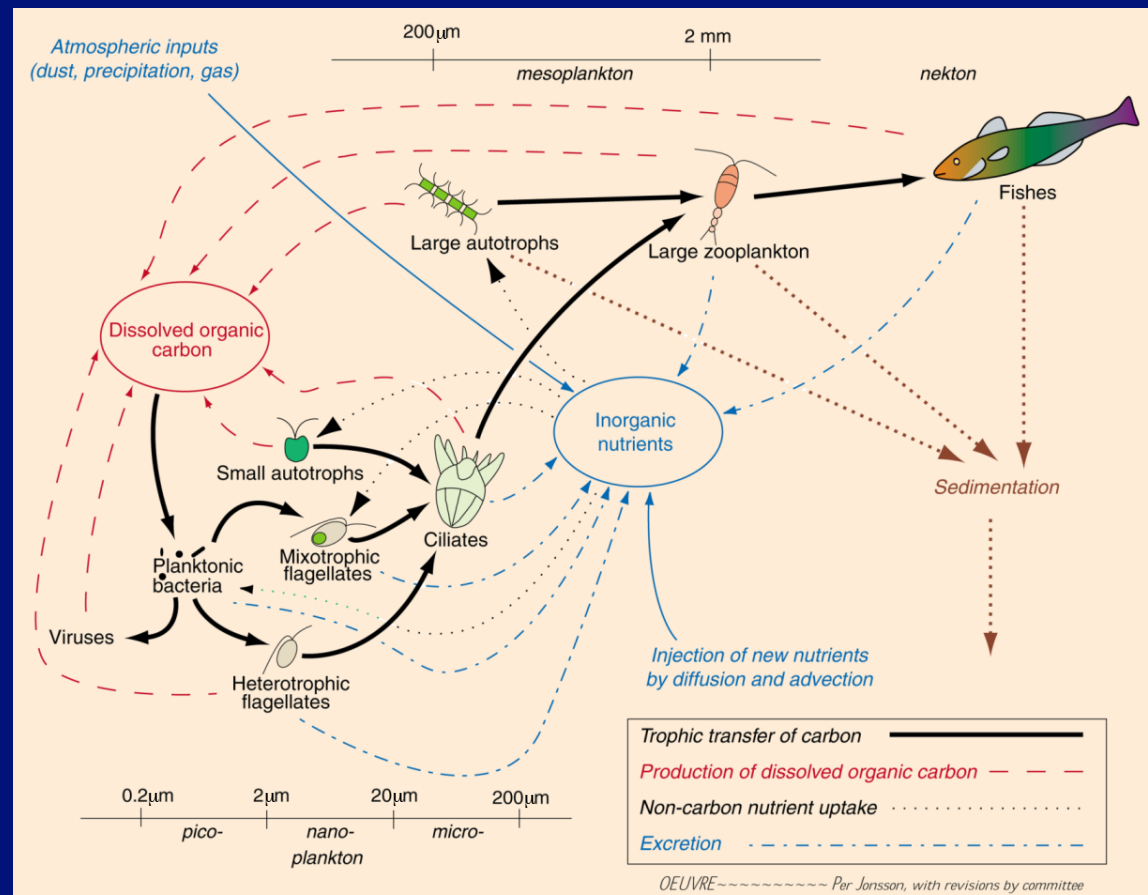
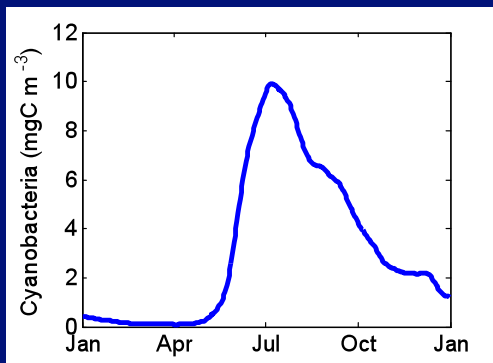


Dominant pico- and micro-phytoplankton species

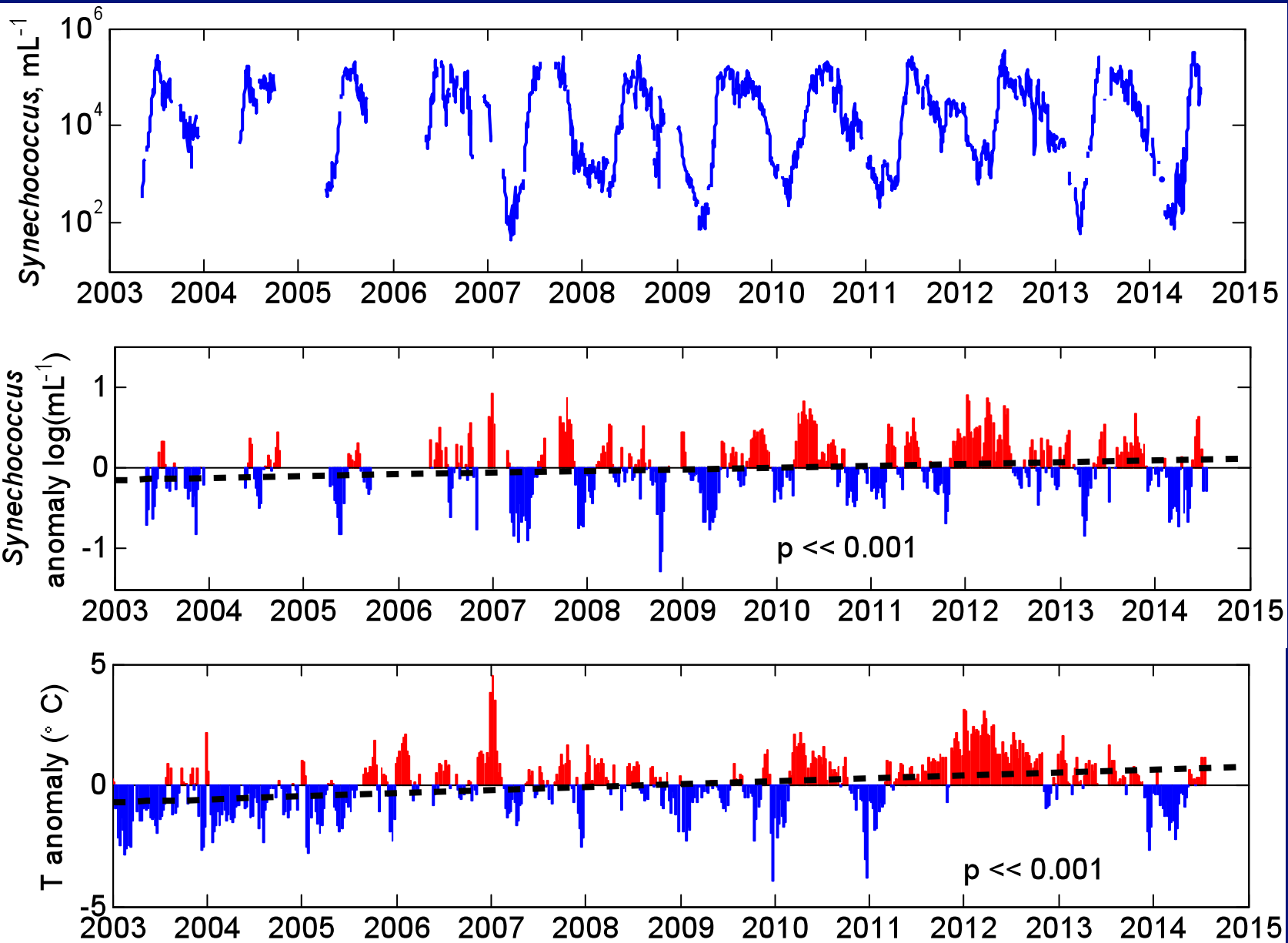
## Diatoms



## Cyanobacteria



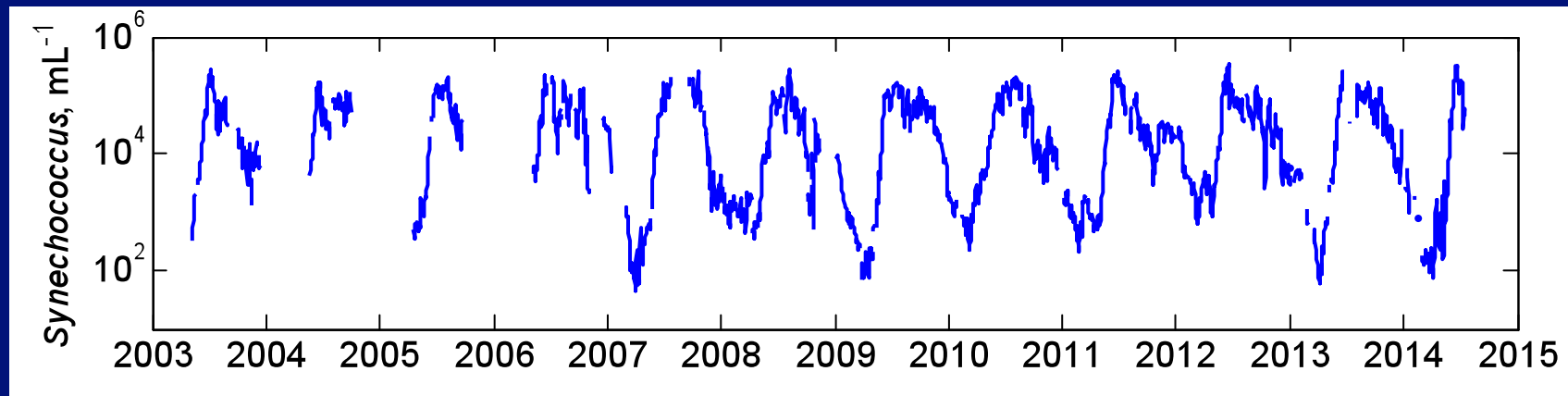
# Multi-year trends in picoplankton



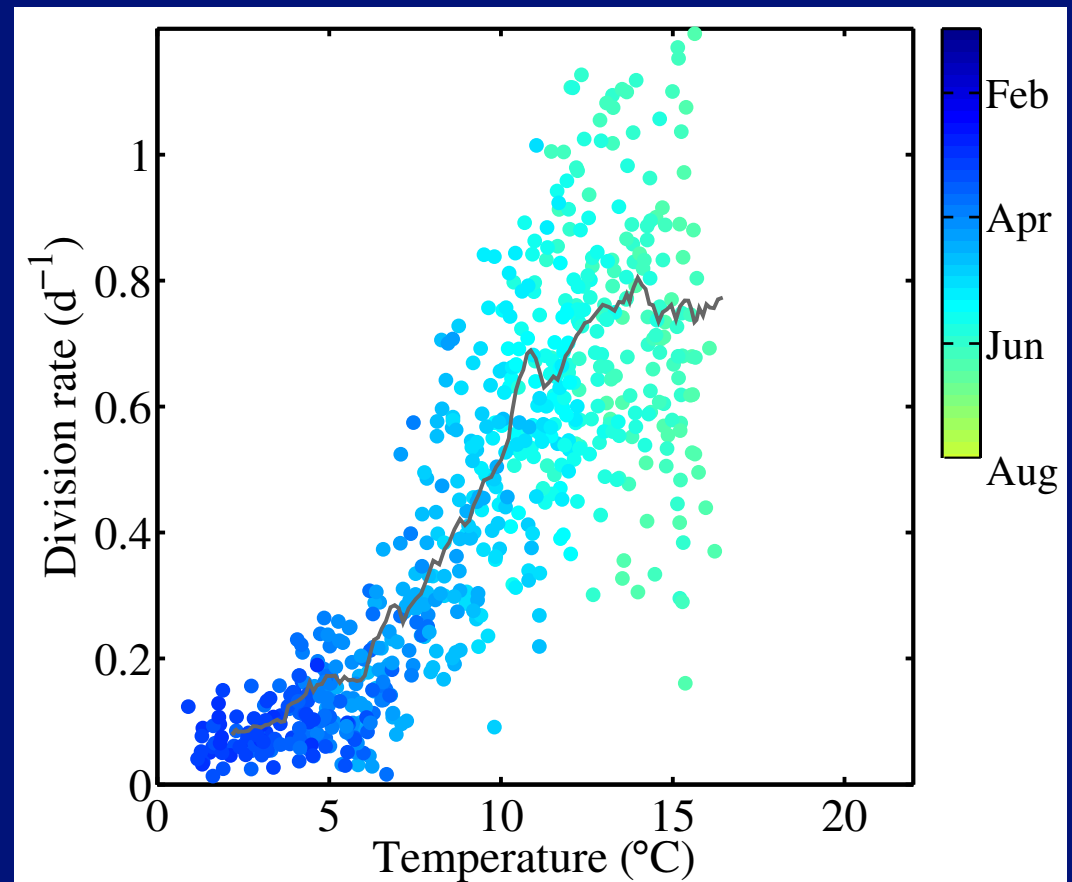
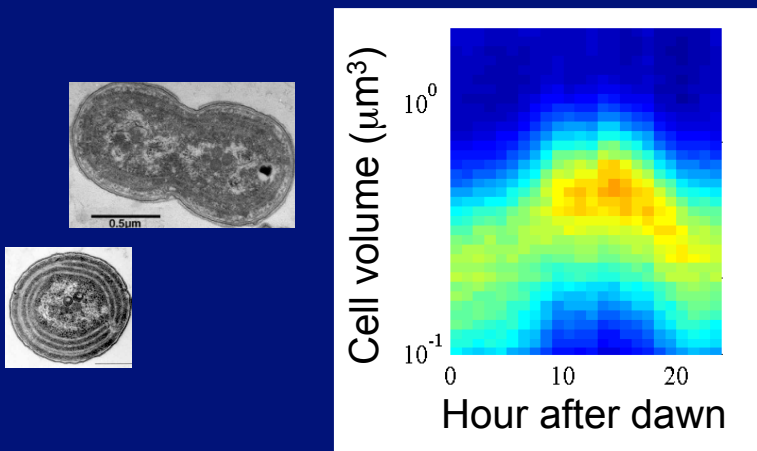
Decadal-scale increase in pico-cyanobacteria at MVCO



# Seasonal variability in picoplankton

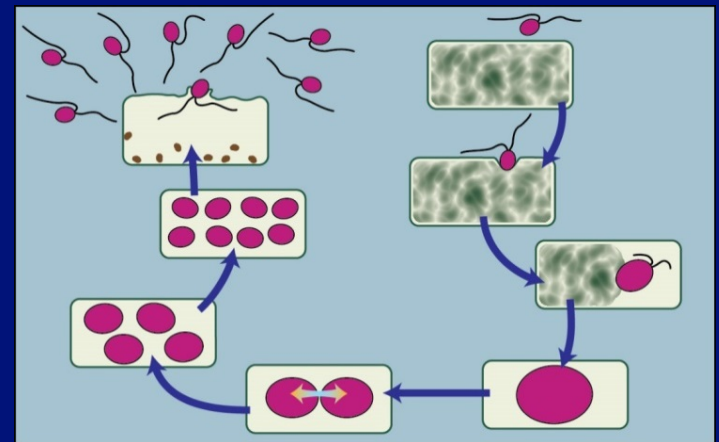
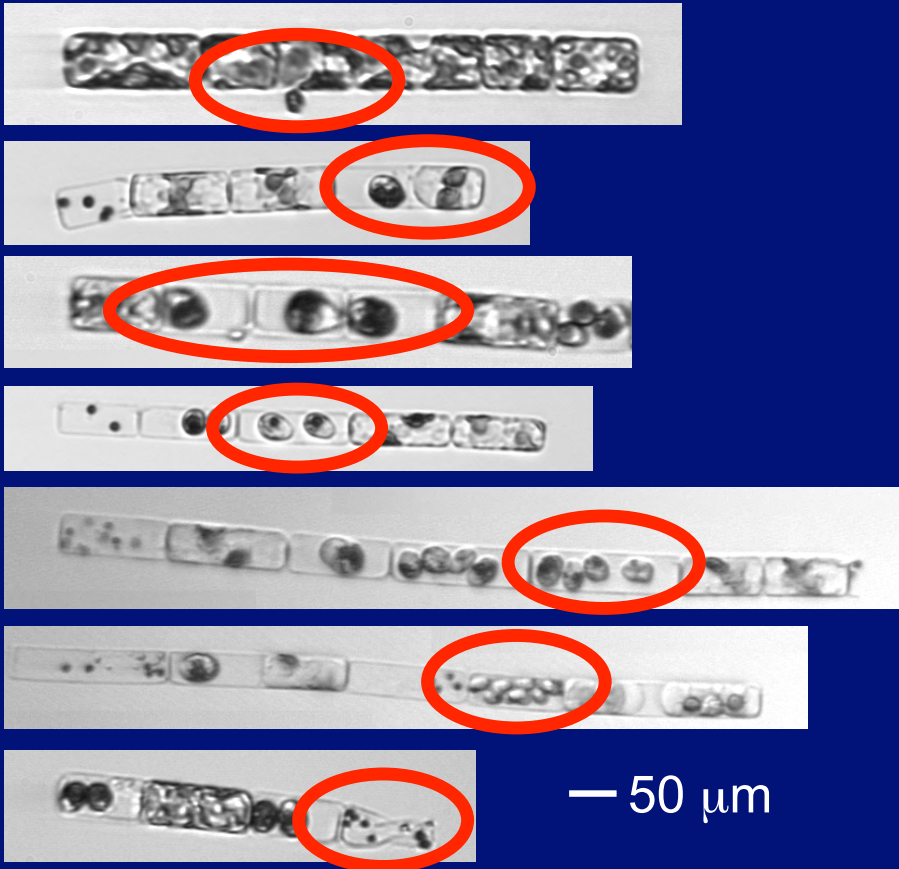
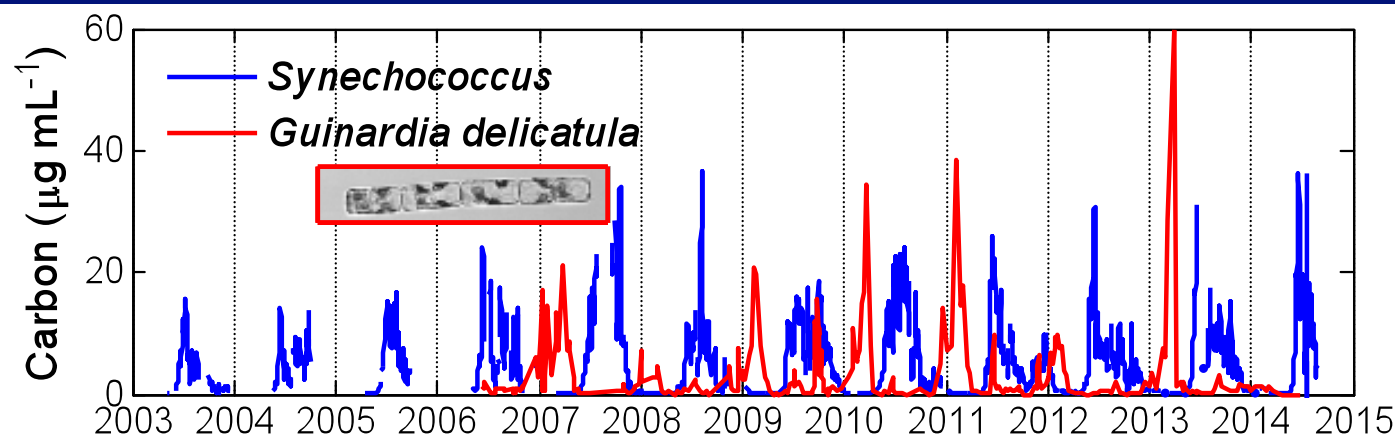


Diel changes in cell size distribution from  
FlowCytobot time series  
size-structured matrix population model



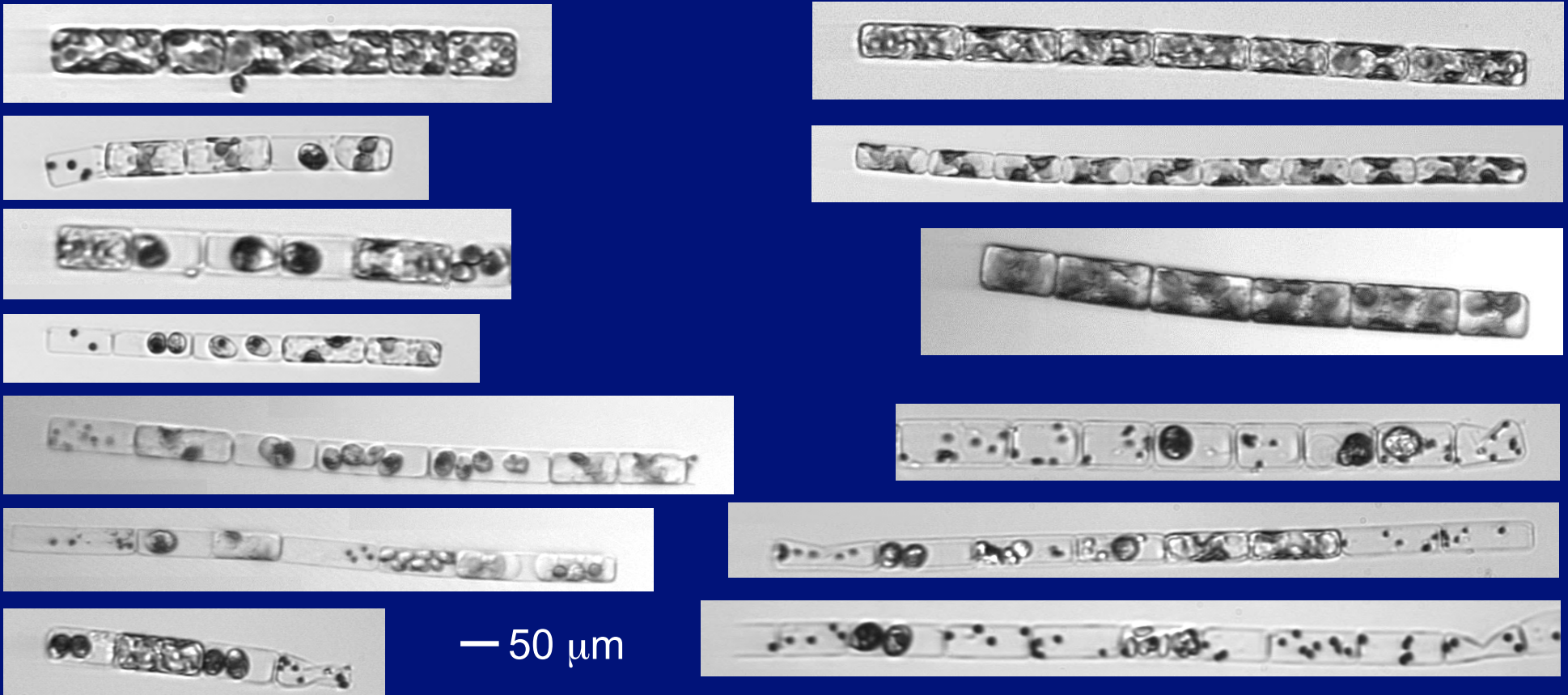
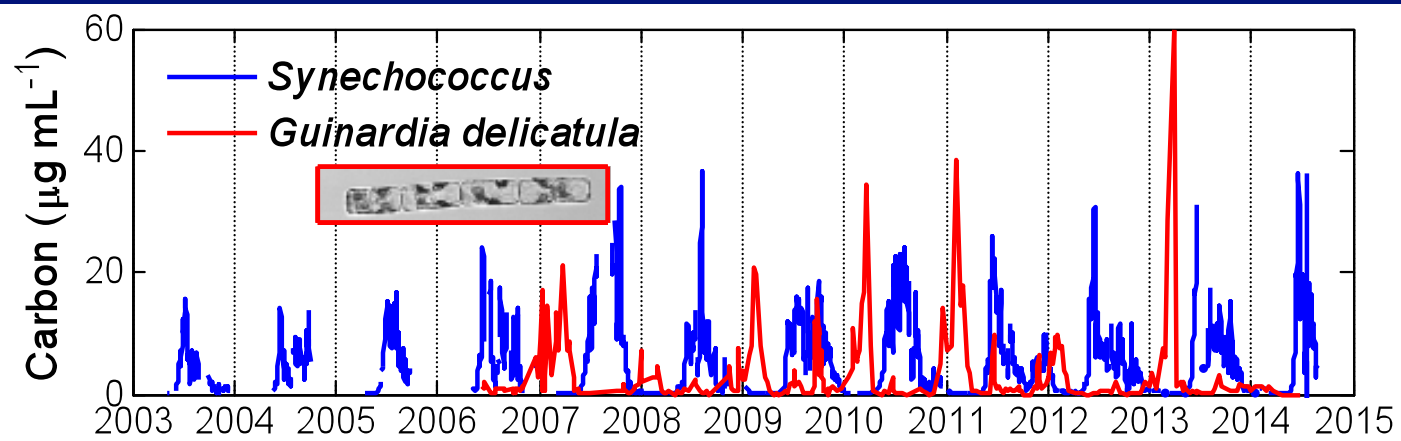
Hunter-Cevera et al. 2014

# Interannual variability in diatoms

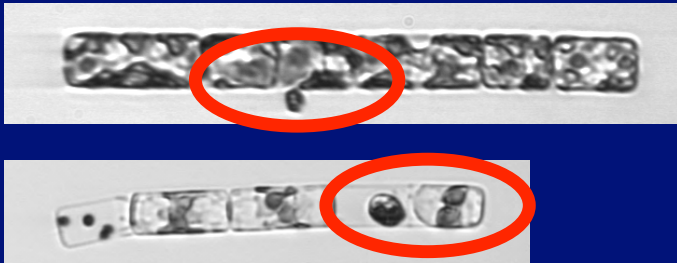


**Nanoflagellate parasites consume cytoplasm and reproduce inside diatom host cells**

# Interannual variability in diatoms

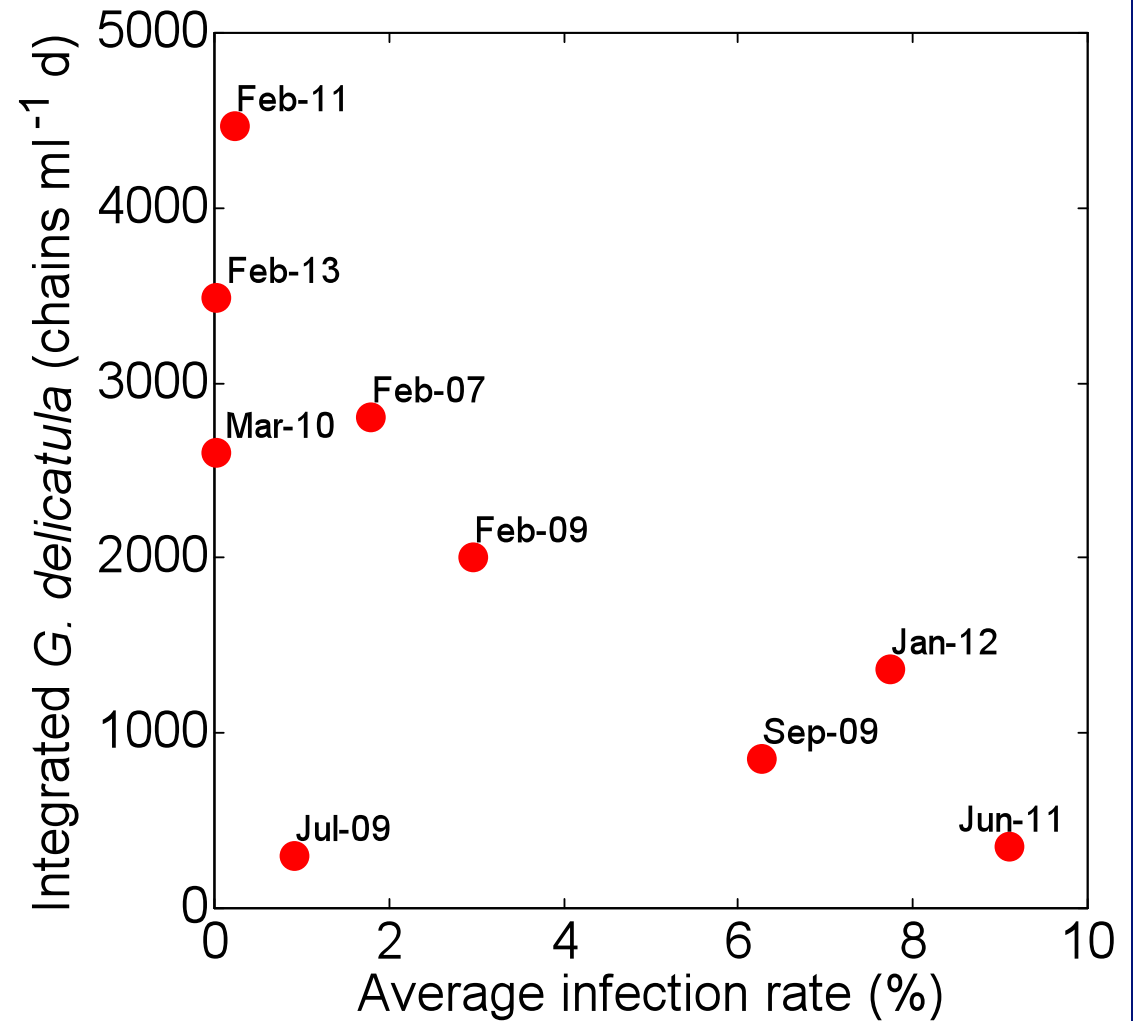


# Interannual variability in diatoms



Infection rate  
explains bloom  
magnitude

Peacock et al. 2014



# Summary

Submersible flow cytometry provides unprecedented capability for long term phytoplankton community analysis at observatories

Who's there? How are they changing?

## Picophytoplankton on the New England shelf

- extreme seasonality, strongly temperature-dependent
- pattern of long term increase

## Diatoms on the New England shelf

- same taxa recur year after year
- seasonality in taxon-specific blooms is typical, but with high interannual variability in bloom amplitude
- novel ecological interactions, such as parasitic infection, are important in seasonality and potential long term change





# Acknowledgments

Rob Olson

<http://ifcb-data.whoi.edu/>

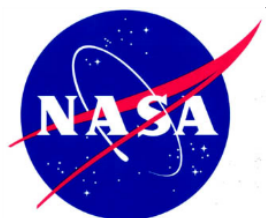
Joe Futrelle

MVCO Operations Team

Ocean Image Informatics Team

*Thank You!*

Kristen Hunter-Cevera, Emily Peacock, Taylor Crockford, Alexi Shalapyonok, Sam Laney, Emily Brownlee, Emily Moberg, Ben Lambert





# Image Informatics

<http://ifcb-data.whoi.edu/>

Open data  
access

Standard  
formats

Processing  
pipelines

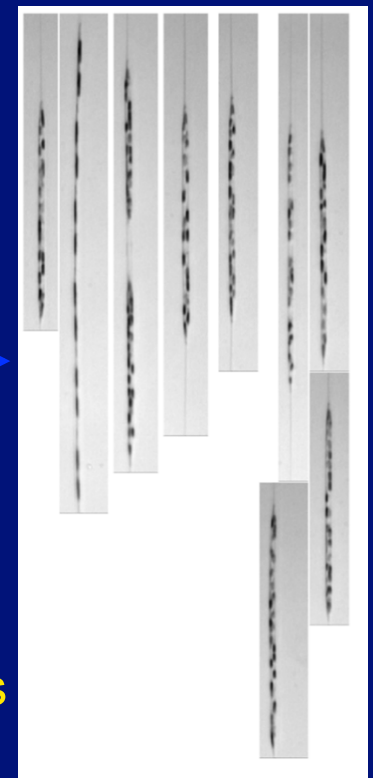
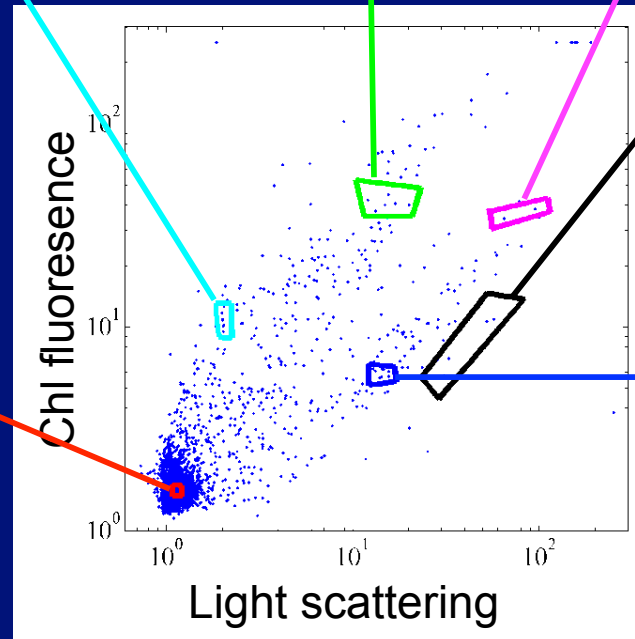
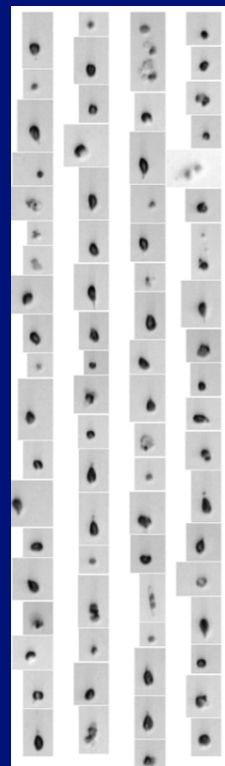
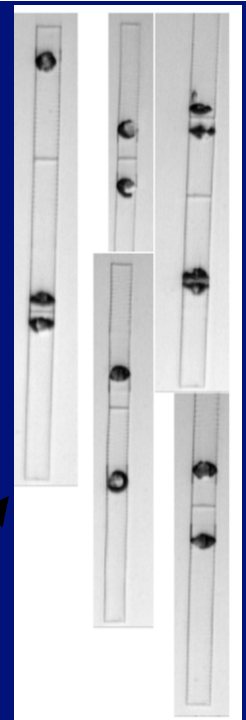
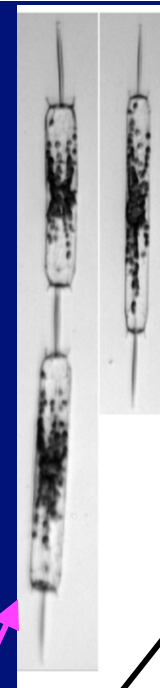
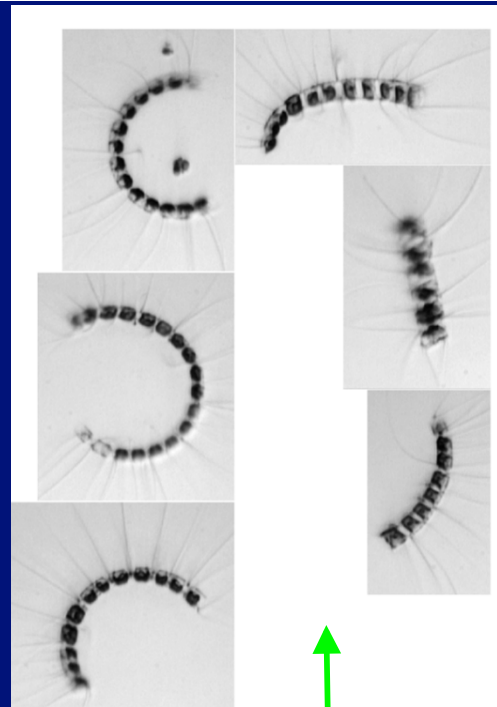
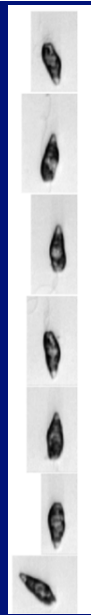
End-to-end  
provenance



# Imaging FlowCytobot Data example

Nano/microplankton

-Associated images  
(all same scale)



Individual particle measurements

# Future Directions

Imaging FlowCytobot redesign complete

→ Commercially available

## New Technology

Image-based cell sorting

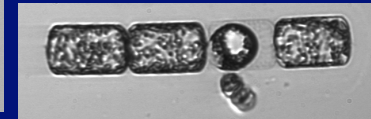
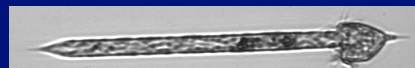
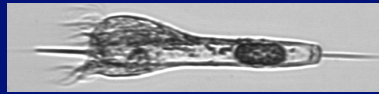
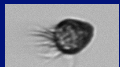
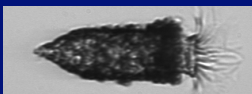
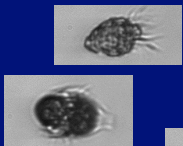
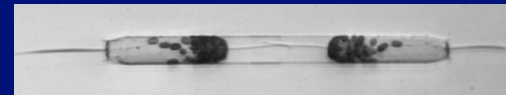
Imaging with stains, etc.

Acoustic focusing

## New Applications

Diatom growth rates?

Protozoan grazing?



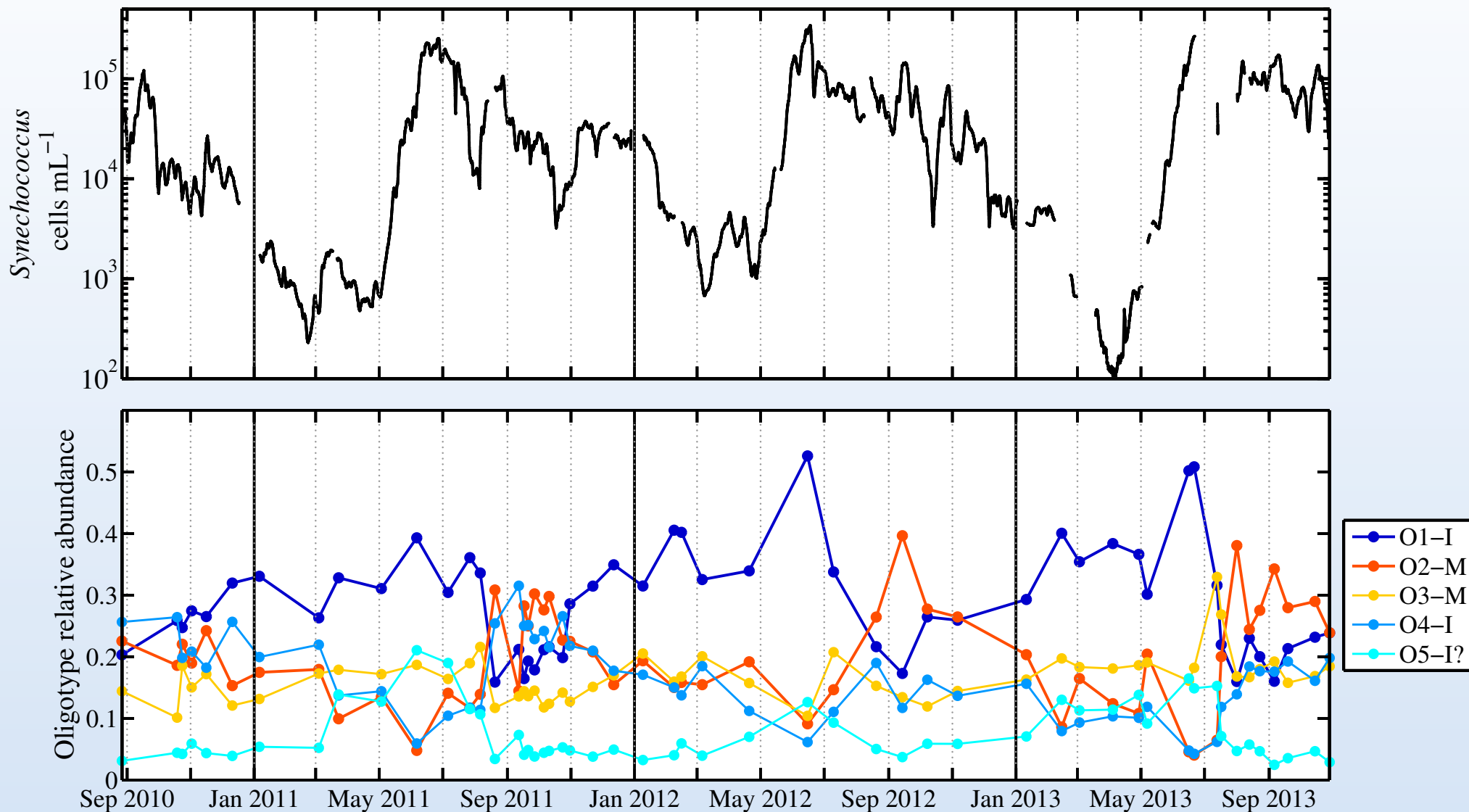


# *Synechococcus* population at MVCO is diverse

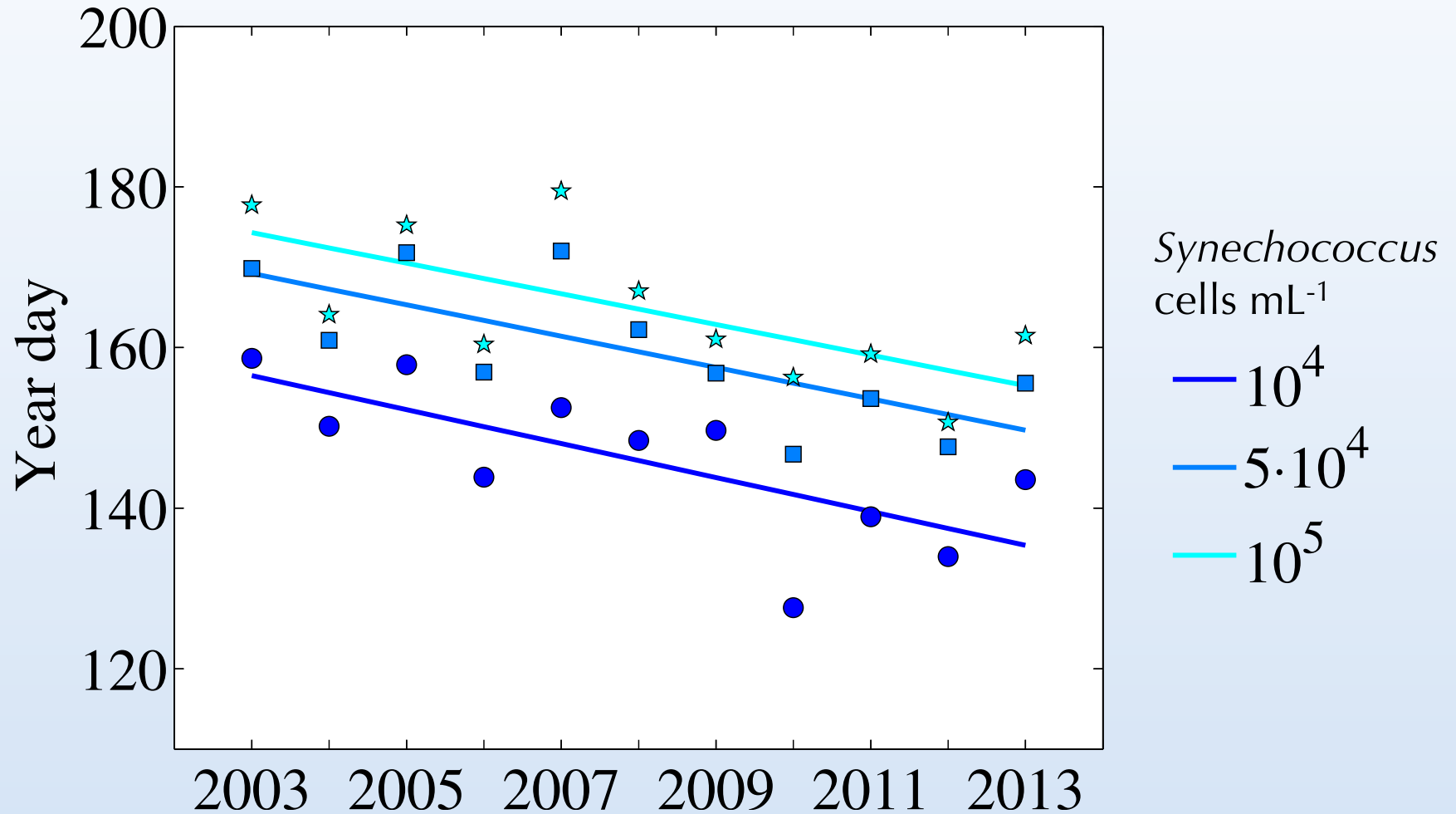
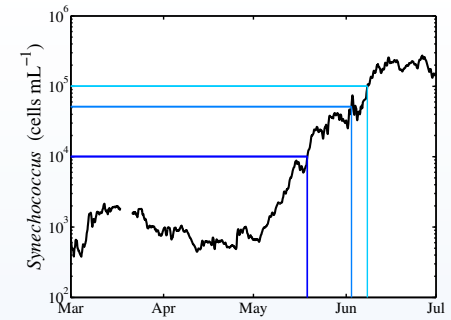


Clade I

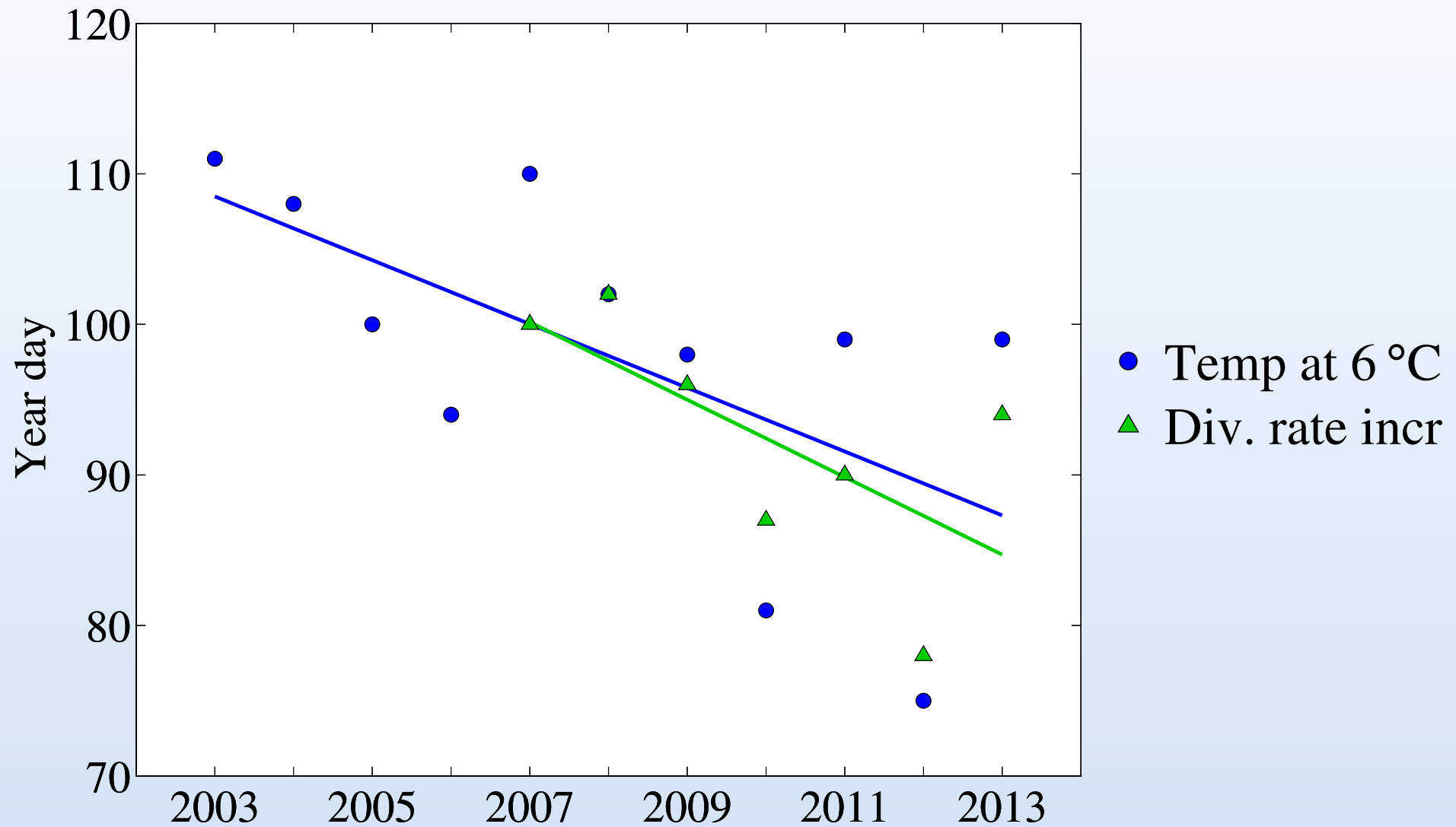
# Actual and relative abundance patterns



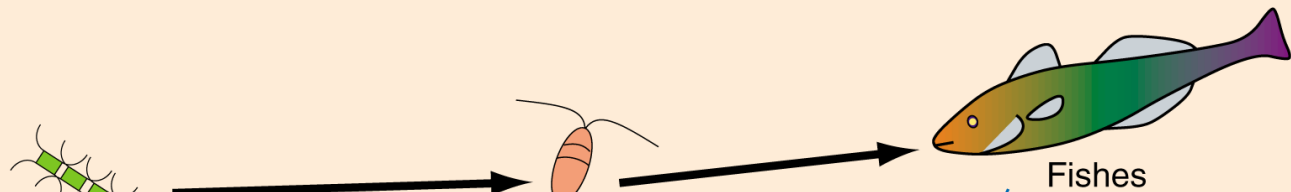
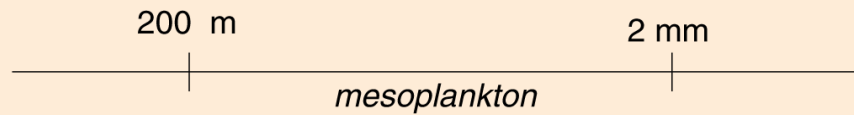
# Warming temperatures and the spring bloom



# Warming temperatures and the spring bloom



Atmospheric inputs  
(dust, precipitation, gas)

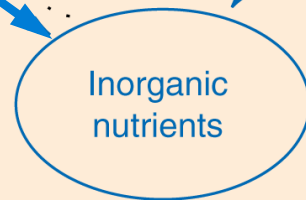


# Phytoplankton

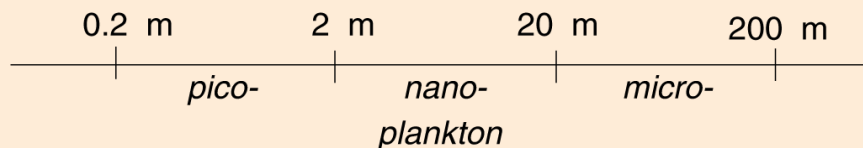
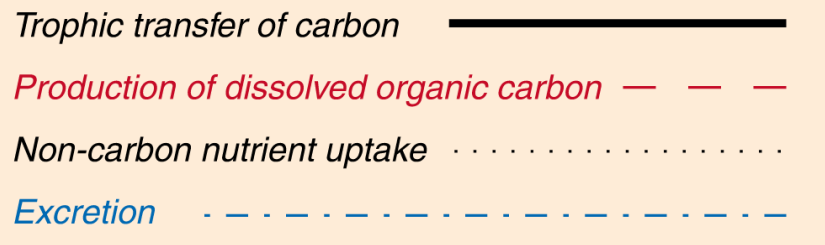
**Primary producers**

**Essential roles in  
marine ecosystems and  
biogeochemical cycles**

**Enormous Diversity**



Sedimentation





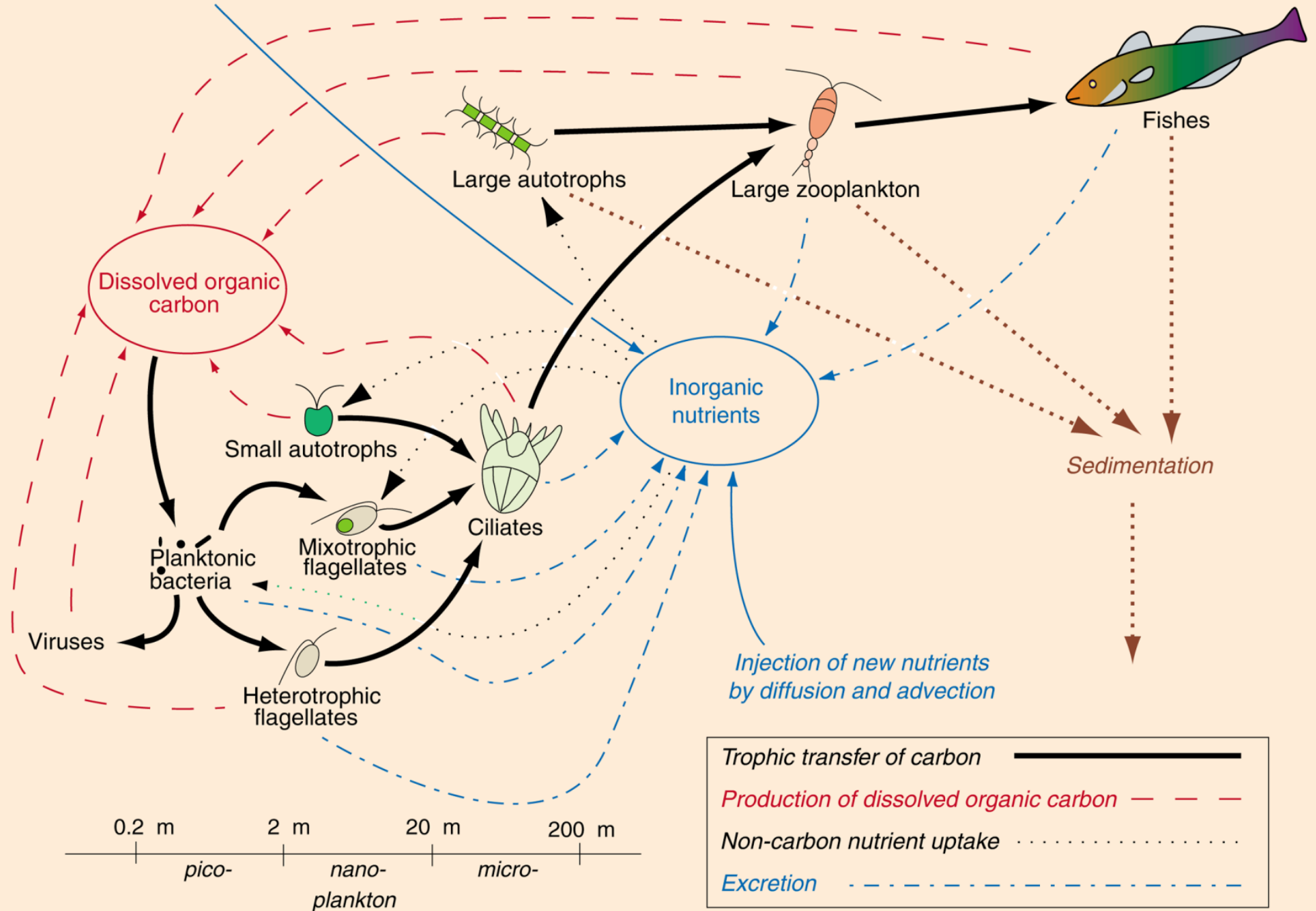
Atmospheric inputs  
(dust, precipitation, gas)

200 m

2 mm

mesoplankton

nekton



Fishes

Large autotrophs

Large zooplankton

Dissolved organic carbon

Inorganic nutrients

Small autotrophs

Sedimentation

Planktonic bacteria

Mixotrophic flagellates

Ciliates

Injection of new nutrients  
by diffusion and advection

Viruses

Heterotrophic flagellates

0.2 m

2 m

20 m

200 m

pico-

nano-  
plankton

micro-

Trophic transfer of carbon

Production of dissolved organic carbon

Non-carbon nutrient uptake

Excretion