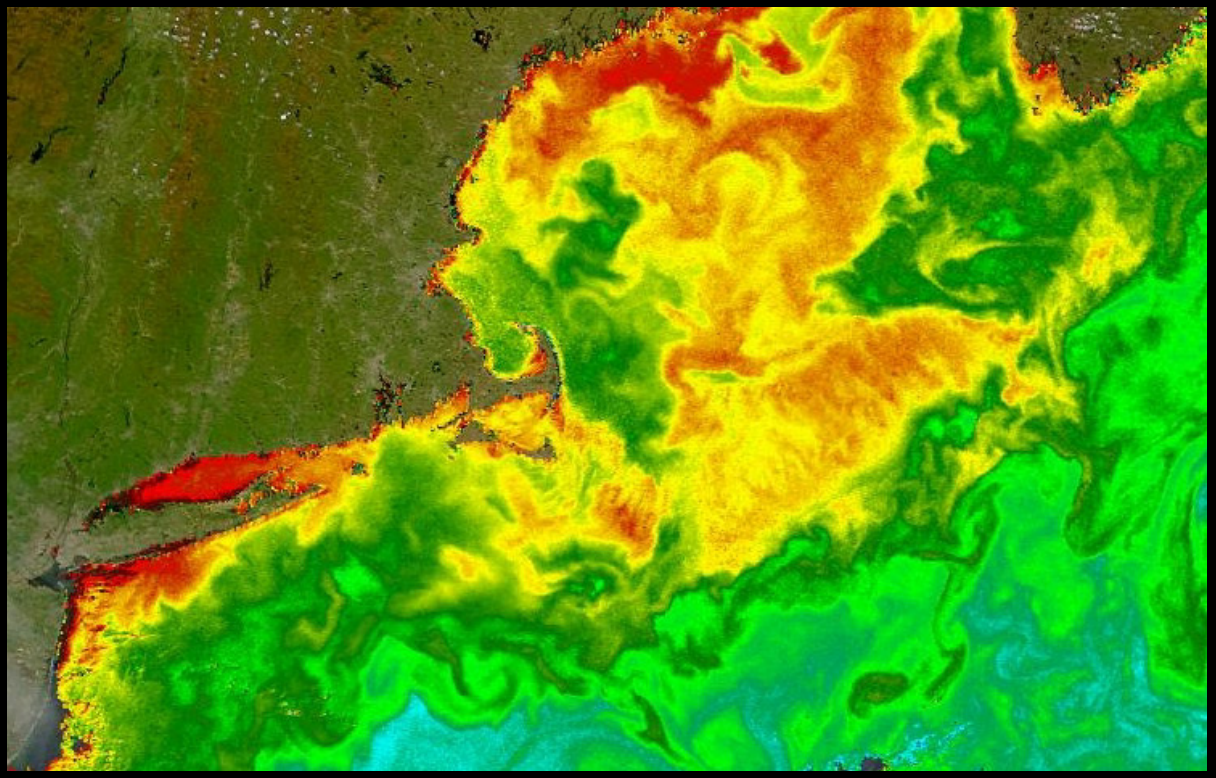
Plankton Biogeography:
Using Population Genetics Tools to Examine the Interplay of Biotic Structure and Biogeochemical Cycles

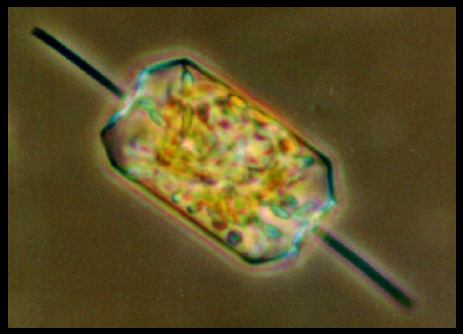


Tatiana Rynearson

University of Rhode Island, Graduate School of Oceanography

Biological hierarchy

Individuals

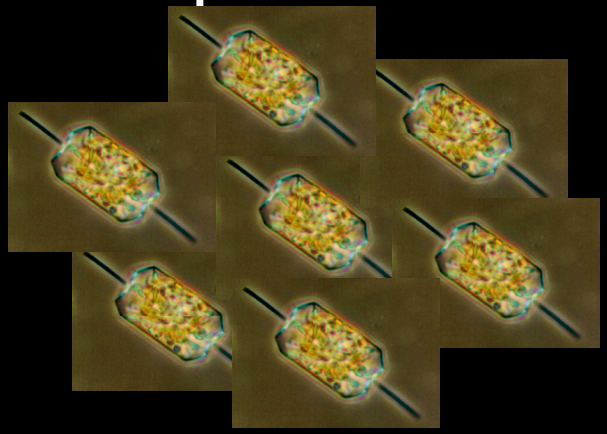


Mutation

Selection

Migration

Populations



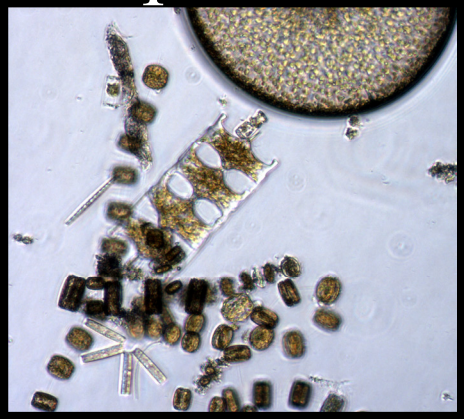
Diversity

Adaptation

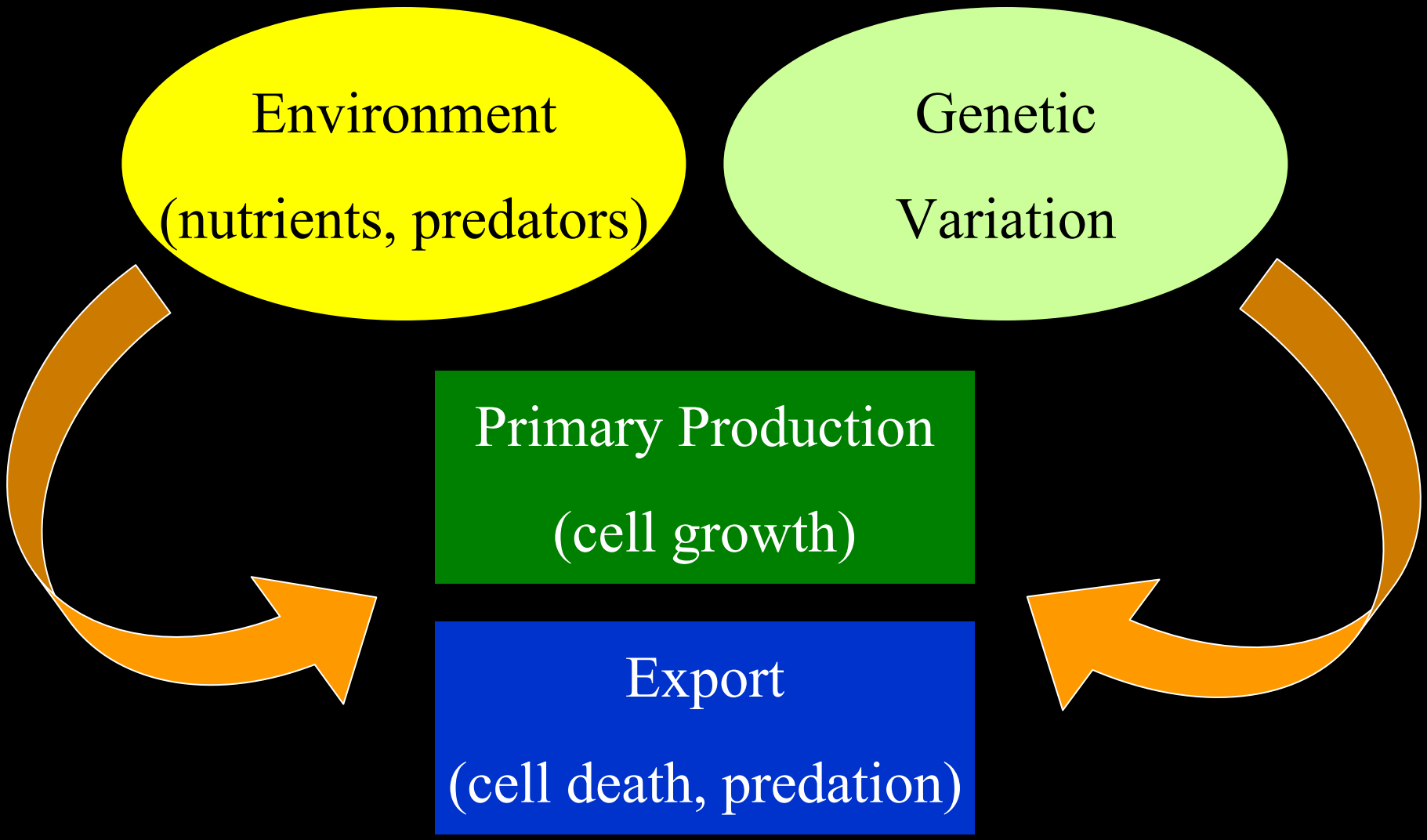
Biogeography

Speciation

Species

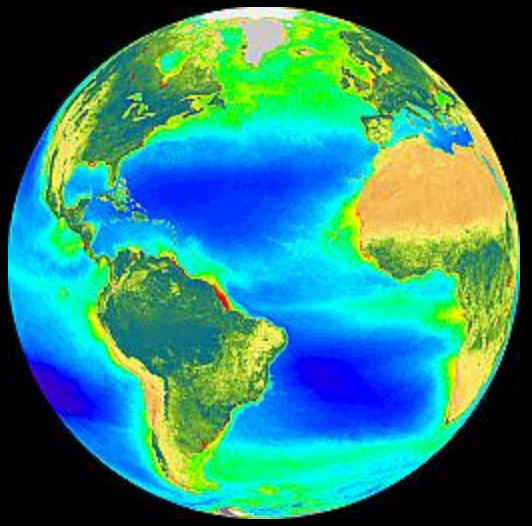


Persistence


Environment
(nutrients, predators)
Genetic
Variation
Primary Production
(cell growth)
Export
(cell death, predation)

Measuring genetic variation

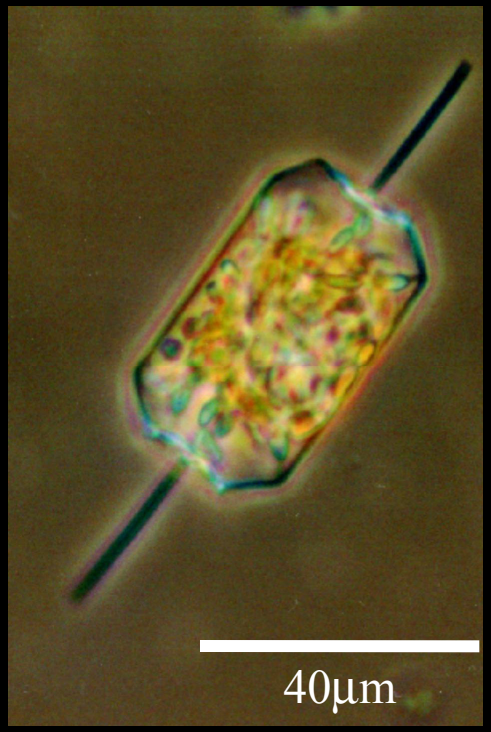
- Challenges
  - Planktonic
  - Unicellular
  - Individuals from multiple species can be morphologically identical

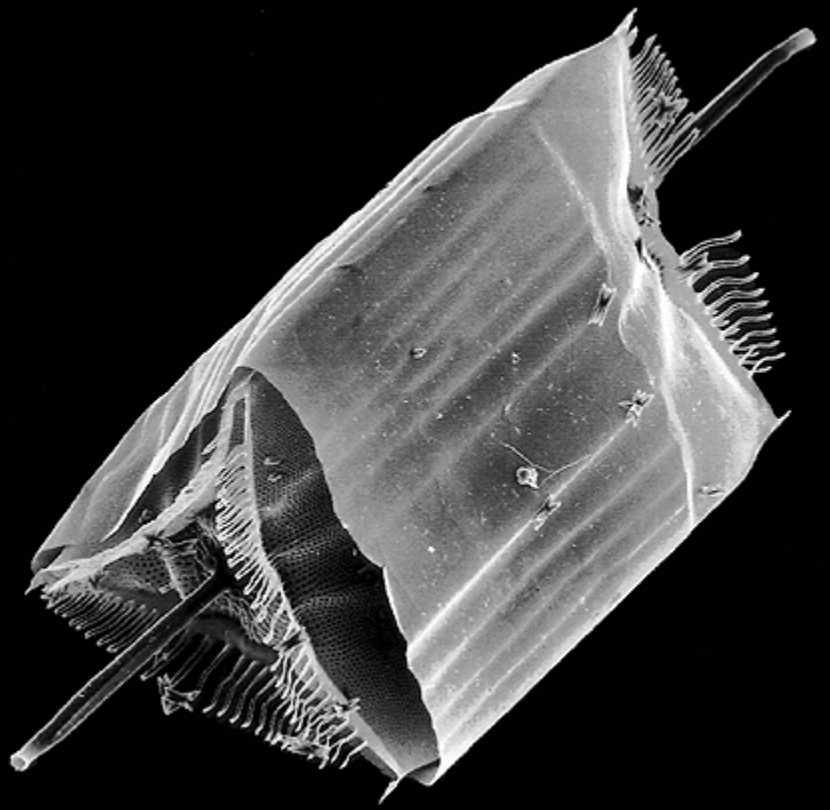


"One can **imagine** tracking all the individuals in a population…..and evaluating which ones succeed in leaving progeny and for what reasons."

Jumars, 1993

Ditylum brightwellii - Model Diatom

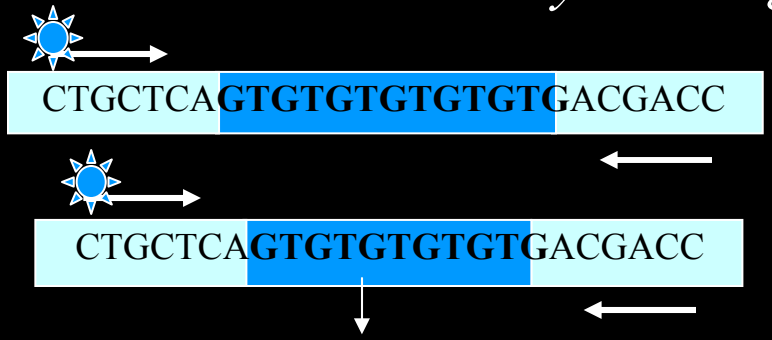




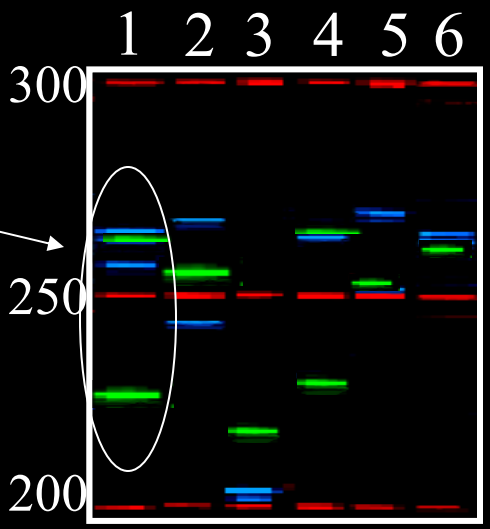
T. Nagumo, Nippon Dental Univ.

Tracking diatoms over space and time

Microsatellite Markers in *Ditylum brightwellii*



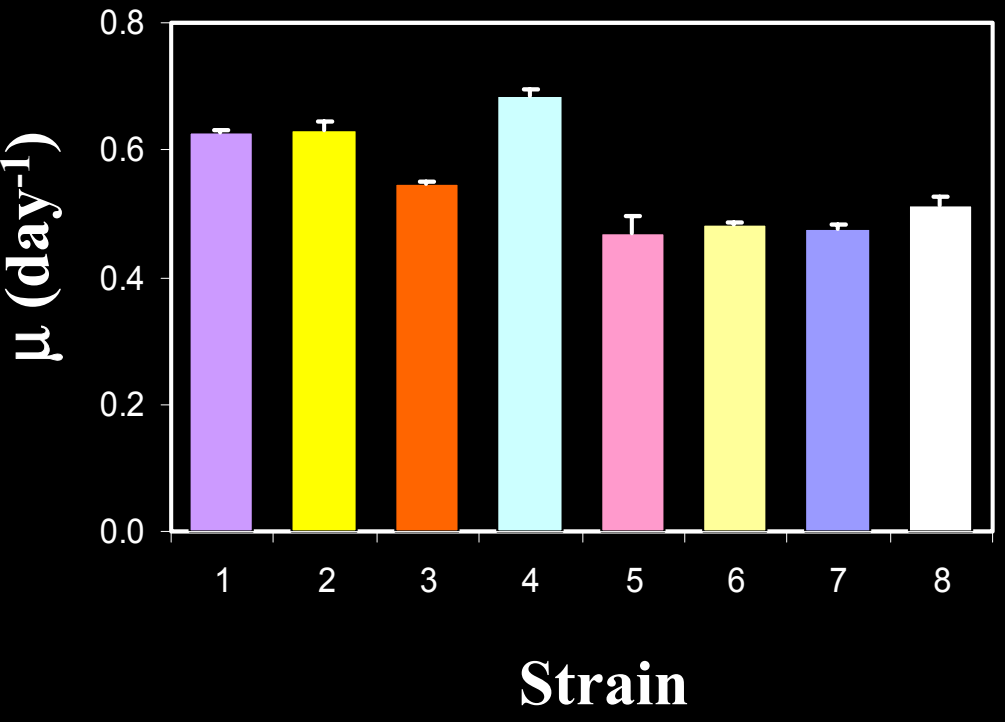
DNA fingerprint



1. Identify genotypes

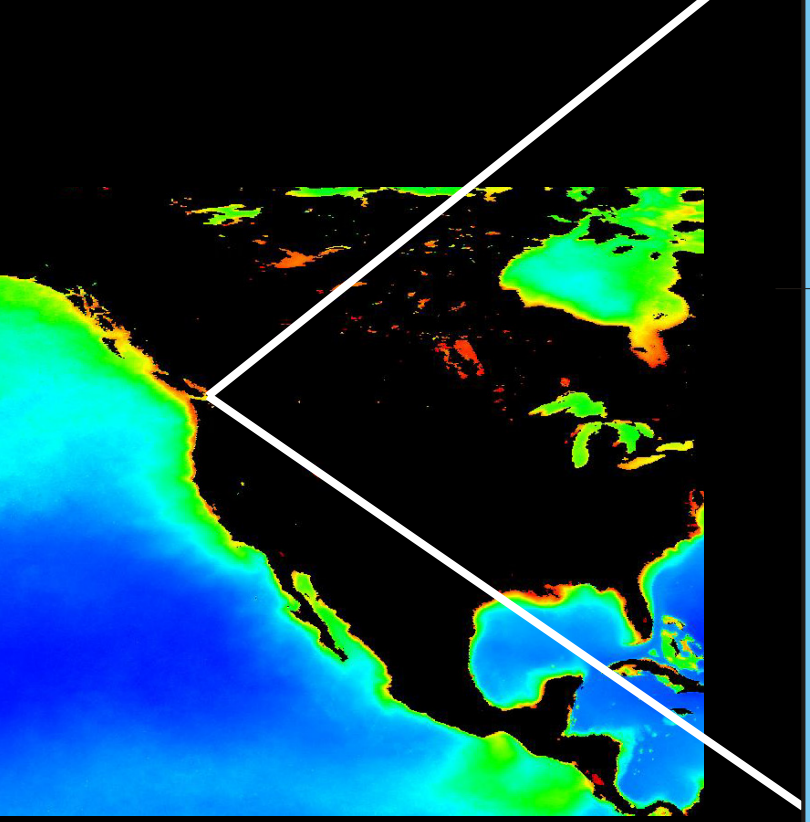
2. Identify genetically distinct populations

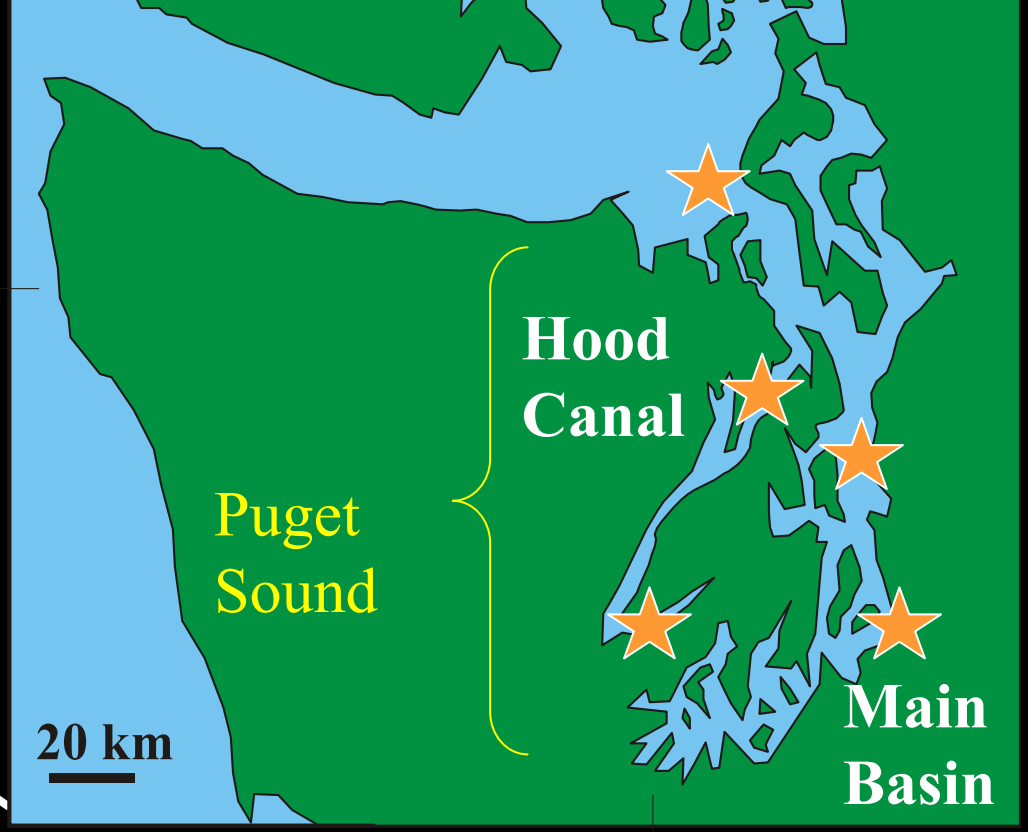
Physiological variation within the diatom species *Ditylum brightwellii*



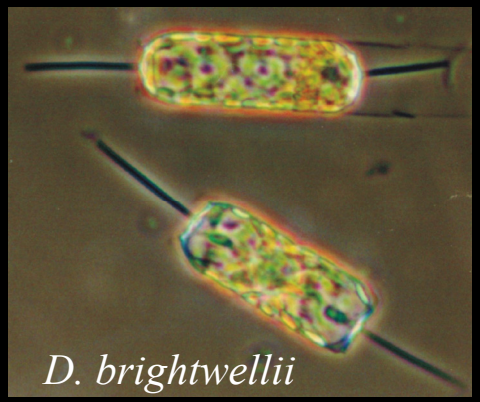
- Remove environmental variation to examine genetic variation
- Genetically distinct populations are physiologically distinct

Rynearson and Armbrust, 2000, 2004

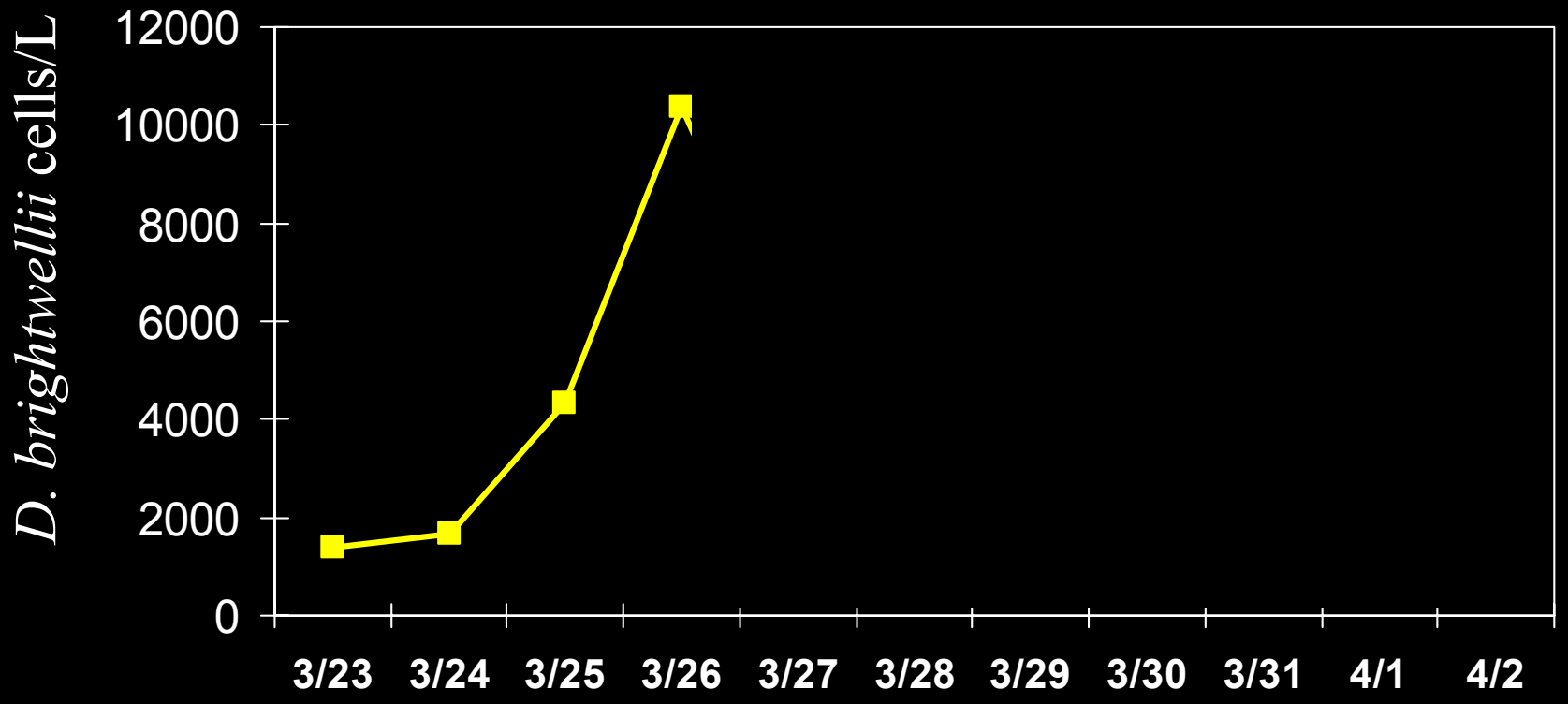




- Daily surface samples during course of a bloom (March)
- Monthly surface water samples collected Feb – June

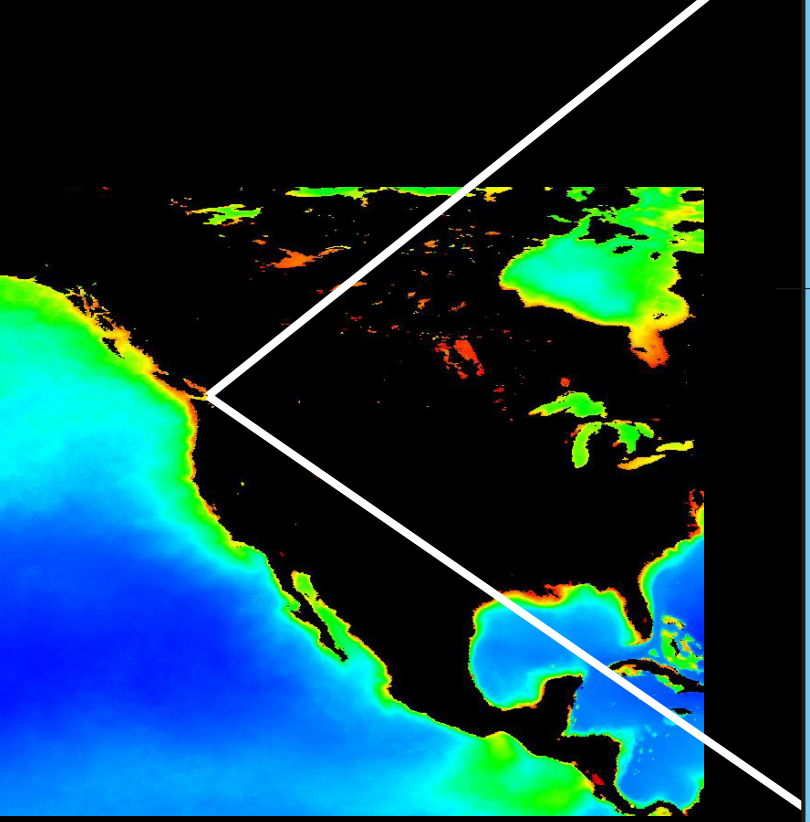


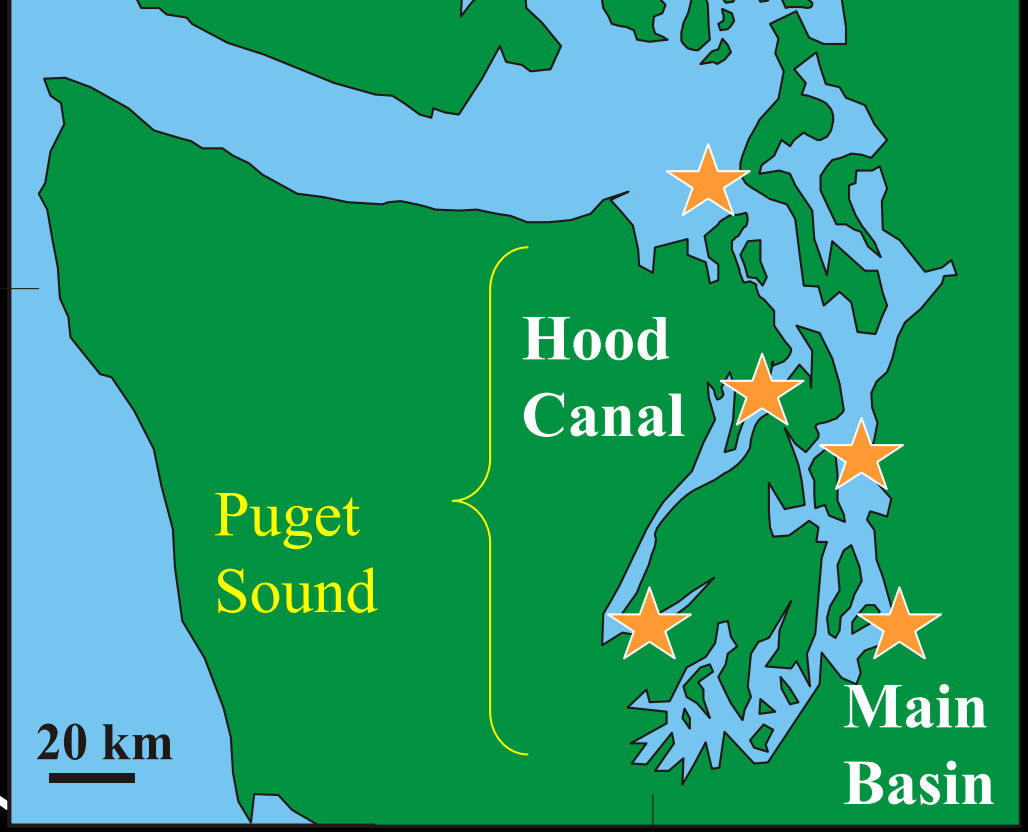
Spring bloom in Dabob Bay



- Analyzed **607** single cells, observed **497** different genotypes
- Predict at least **2400** clonal lineages composed the bloom (based on capture-recapture statistics)
- Blooms do not represent genetic bottlenecks

Rynearson and Armbrust, 2005





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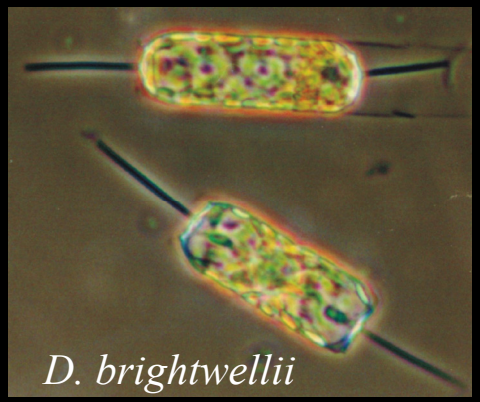
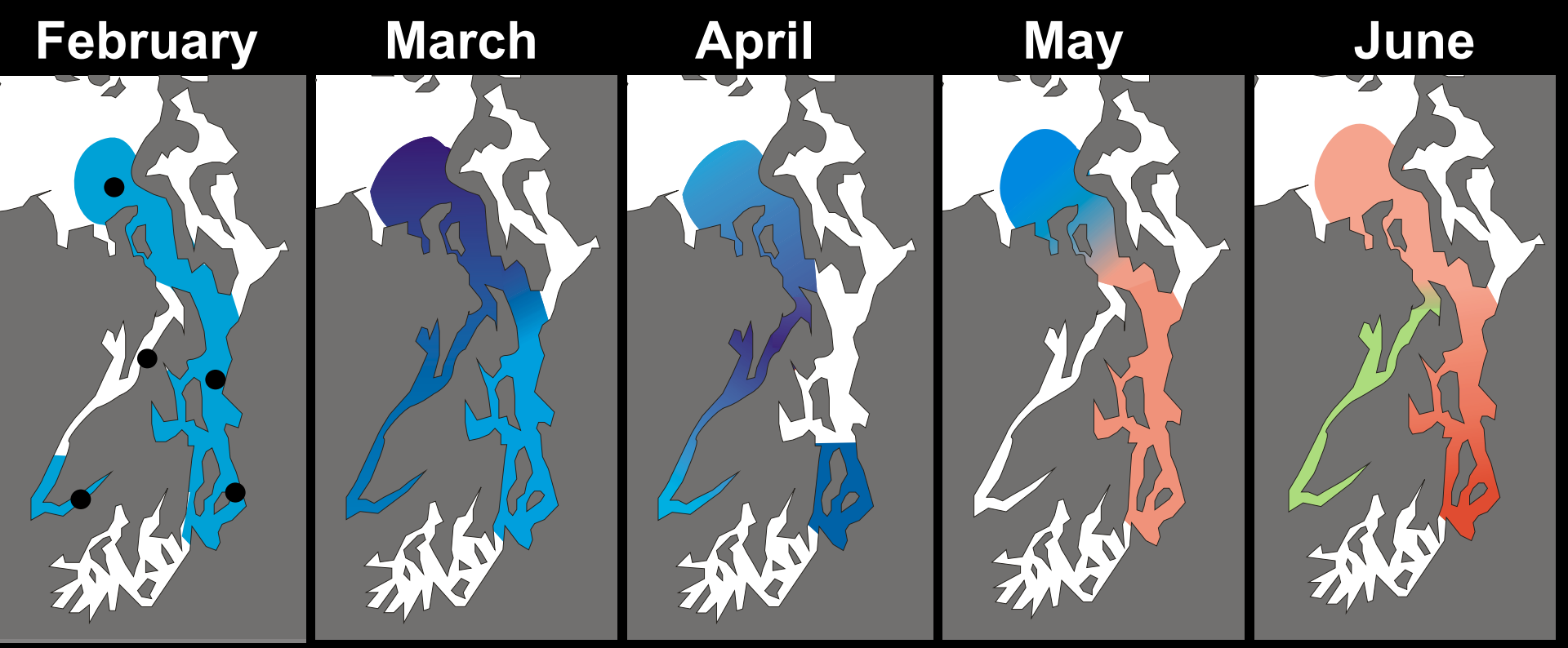




Cells·l^{-1}

10 3000

Population 1

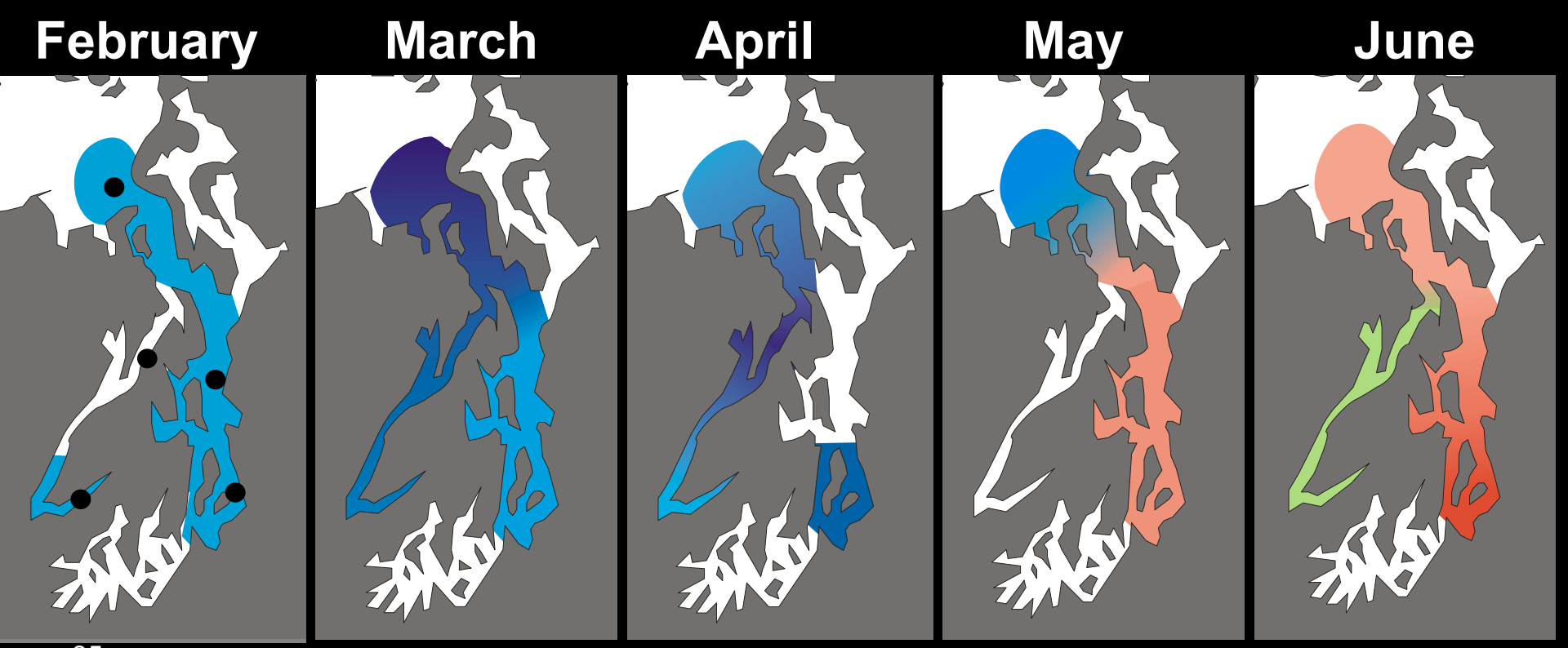
Population 2

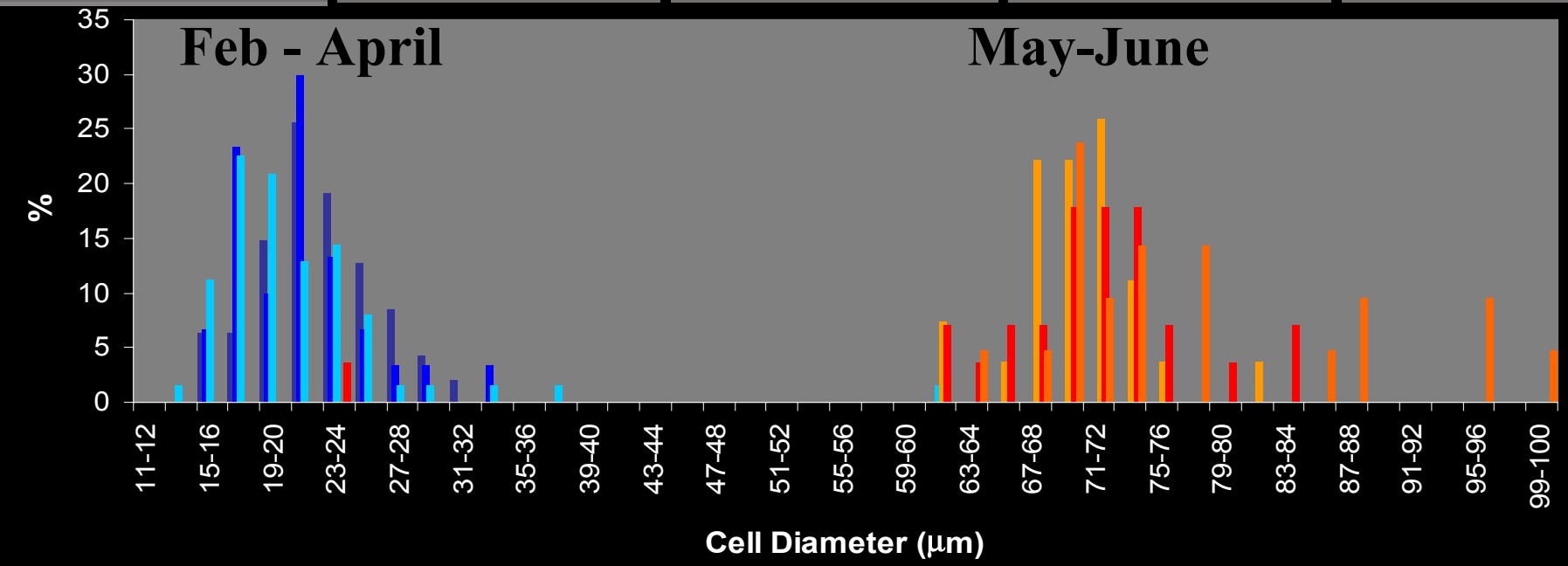
No sample

Below detection

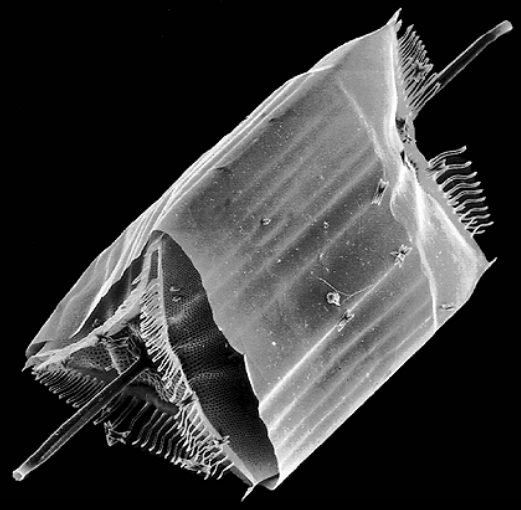
Successive blooms comprised of genetically distinct populations (F_{ST}= 0.2) associated with distinct environmental conditions

Rynearson et al. ‘06


February
March
April
May
June


Feb - April
May-June
%
35
30
25
20
15
10
5
0
11-12
15-16
19-20
23-24
27-28
31-32
35-36
39-40
43-44
47-48
51-52
55-56
59-60
63-64
67-68
71-72
75-76
79-80
83-84
87-88
91-92
95-96
99-100
Cell Diameter (µm)

Genetic variation in *D. brightwellii*

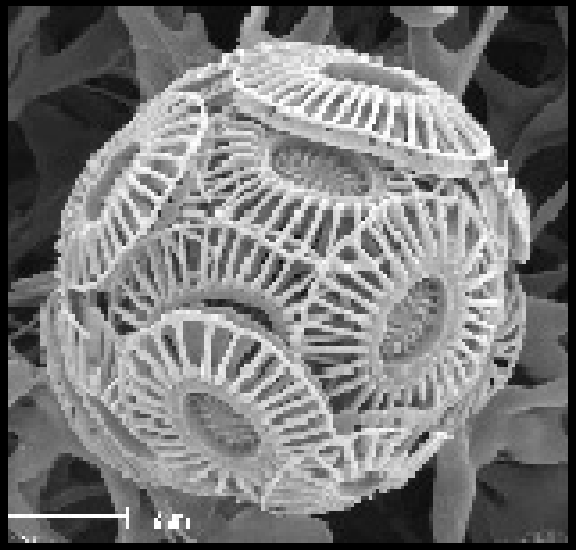


- Genetically distinct populations exist in planktonic organisms
  - Each population has own ‘gene pool’
  - 1000’s of distinct clonal lineages per population
  - Adaptive potential is high
- Production is influenced by a combination of environmental conditions and genetic composition
- Export could be affected by differential sinking rates and grazing susceptibility

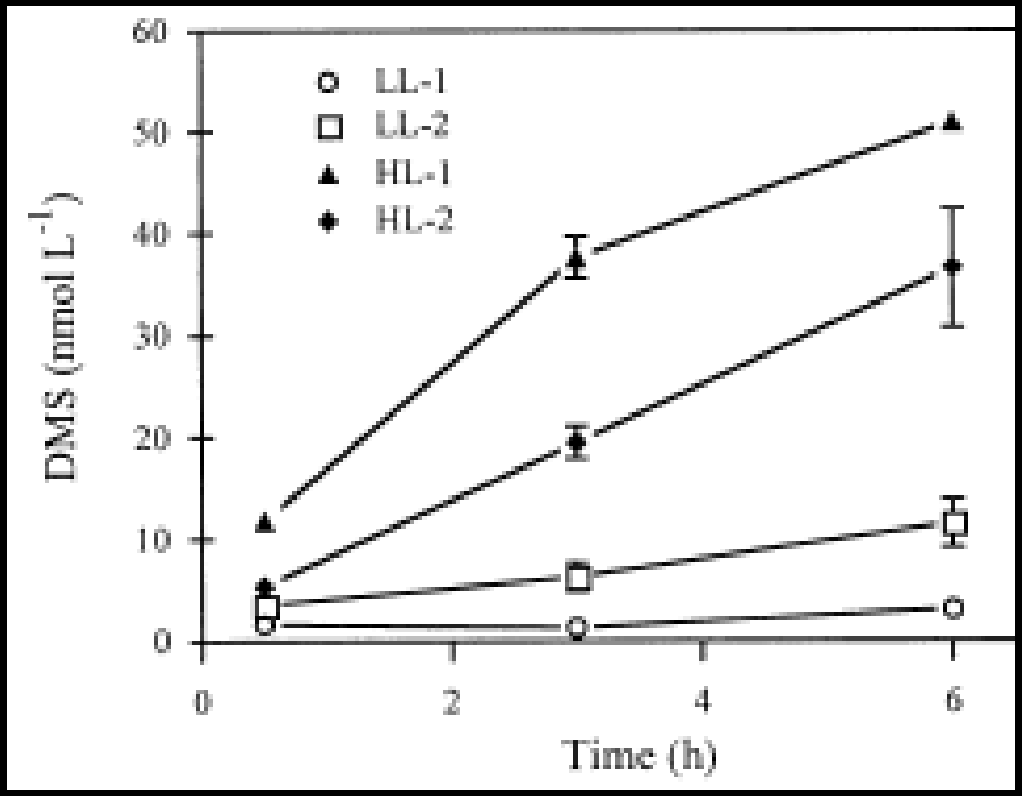
- Are high levels of genetic diversity a general characteristic of phytoplankton?
  - Dinoflagellates, Coccolithophorids, Raphidophytes
- How are grazing and disease impacted by genetic diversity?

Genetic variation & Grazing

Emiliania huxleyi



J. Young, Nat. Hist. Museum, London

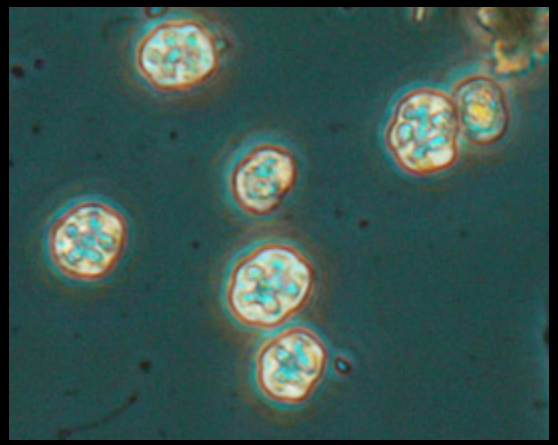


(Strom et al, '03)

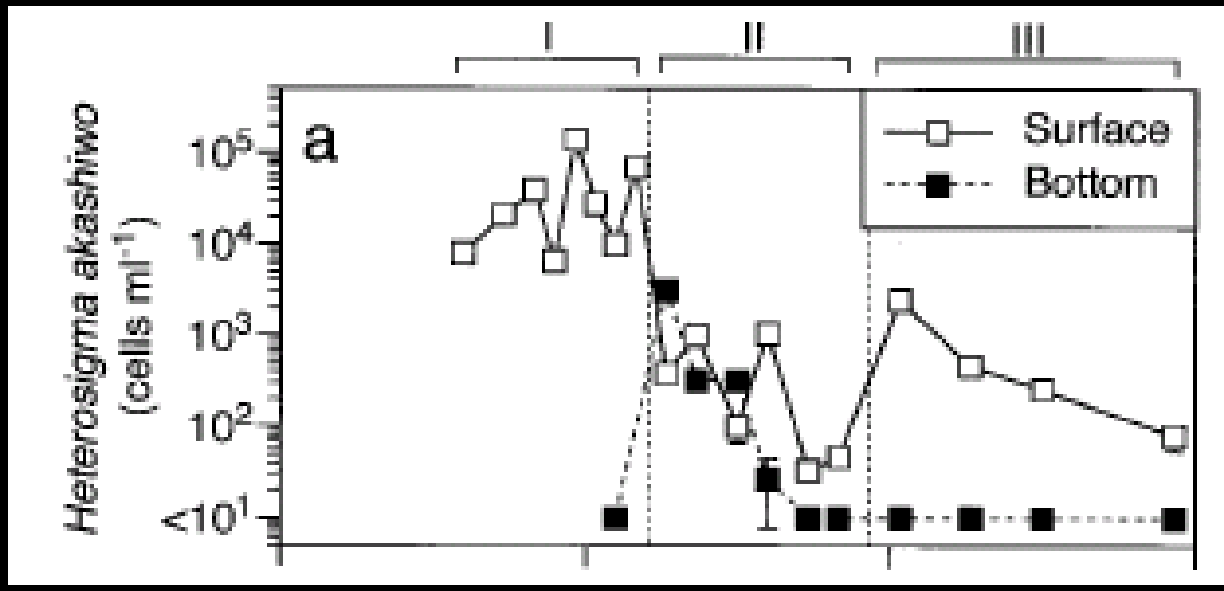
- Differential grazing on *E. huxleyi* strains by 5 protist predators
- Genetically distinct populations sampled in NE Atlantic and a Norwegian fjord (Iglesias-Rodriguez et al, '06)

Genetic variation & Disease

Heterosigma akashiwo



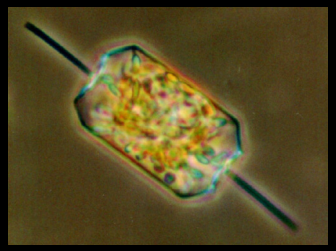
Smithsonian Envir.
Research Center



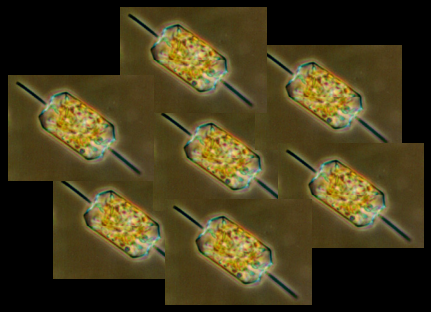
(Tarutani et al '00)

- Differential viral infection on *H. akashiwo* isolates
- High gene diversities observed in Hiroshima Bay (Nagai et al '06)

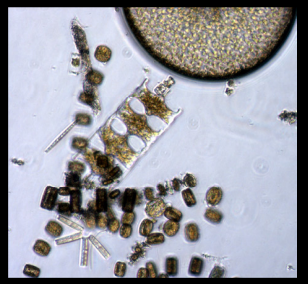
Individuals



Populations



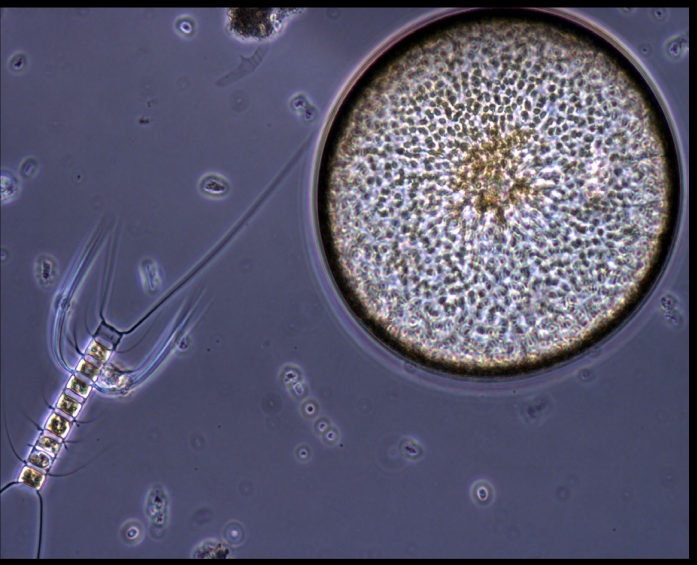
Species



- Species structure (individuals, populations) can influence production and export
  - Growth rate variation
  - Selective predation
  - Disease resistance

- Close coupling of populations with the environment
  - Bloom dynamics regulated by environment and genetics
  - Adaptation to environmental change

Future directions

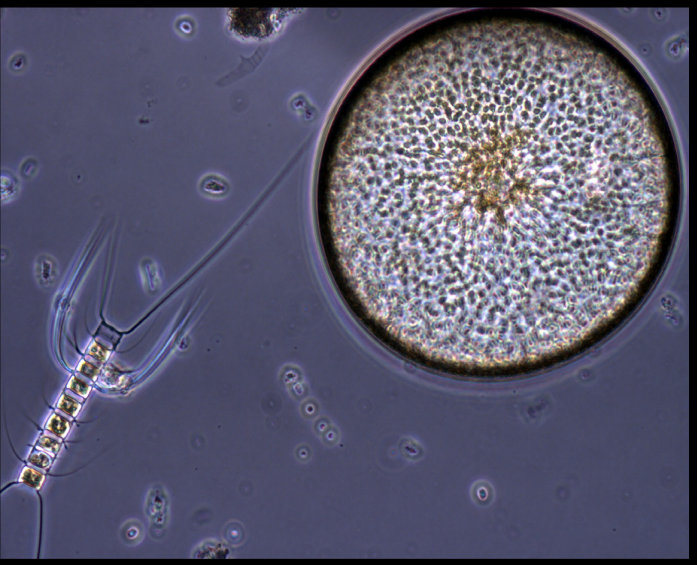


- How are species connected at local, regional and global scales?
  - Connectivity, gene flow and migration
- What kinds of adaptations characterize different populations?
  - What is the genetic basis of those adaptations?
  - Response to nutrients, grazing, disease
- How does genetic variation impact ecosystem structure and function?
  - Biogeochemical impacts of diversity
  - Food web dynamics
- Can we predict how environmental changes will drive natural selection and set evolutionary trajectories?
  - Impact on biogeochemical cycles

Acknowledgements

E.V. Armbrust, UW
R. Horner, UW
J. Newton, UW
J. Peckham, URI
Office of Naval Research
NSF ADVANCE

Future directions



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