What goes around comes around: Connectivity and microevolution in the plankton

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NSF

GORDON AND BETTY MOORE FOUNDATION

BGC and plankton

- Inter-specific physiological variation
- Intra-specific variation in the *lab*
  - Light
  - Nutrients
  - Temperature
  - Salinity
  - Composition (silica, POC)
  - Uptake rates
- Needed: high-throughput phenotypic screening 'phenomics'

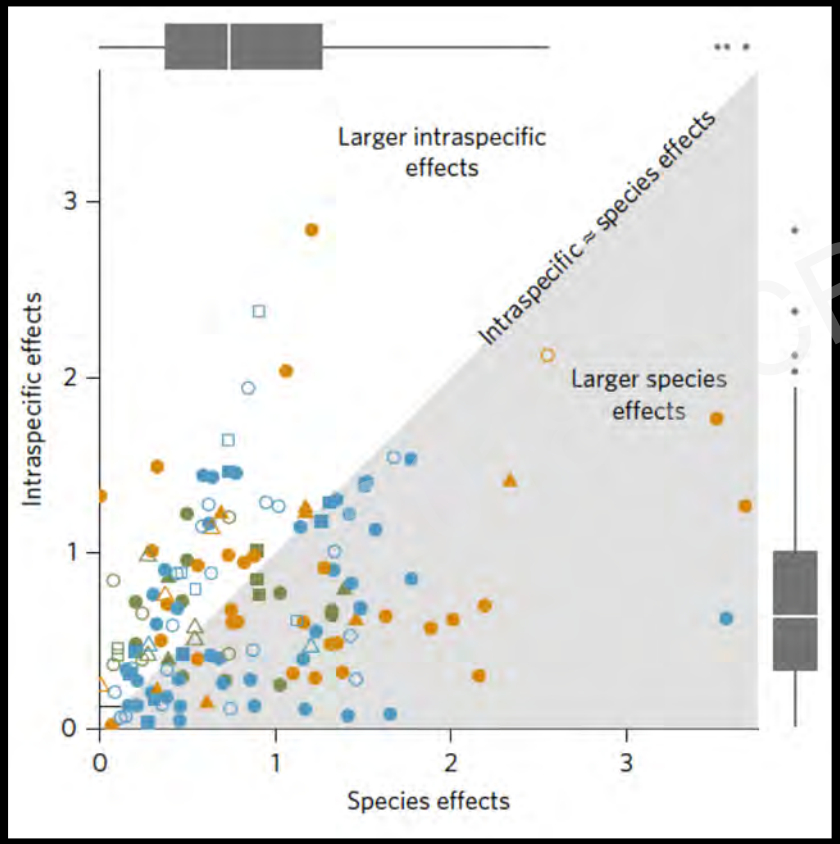
BGC

BGC

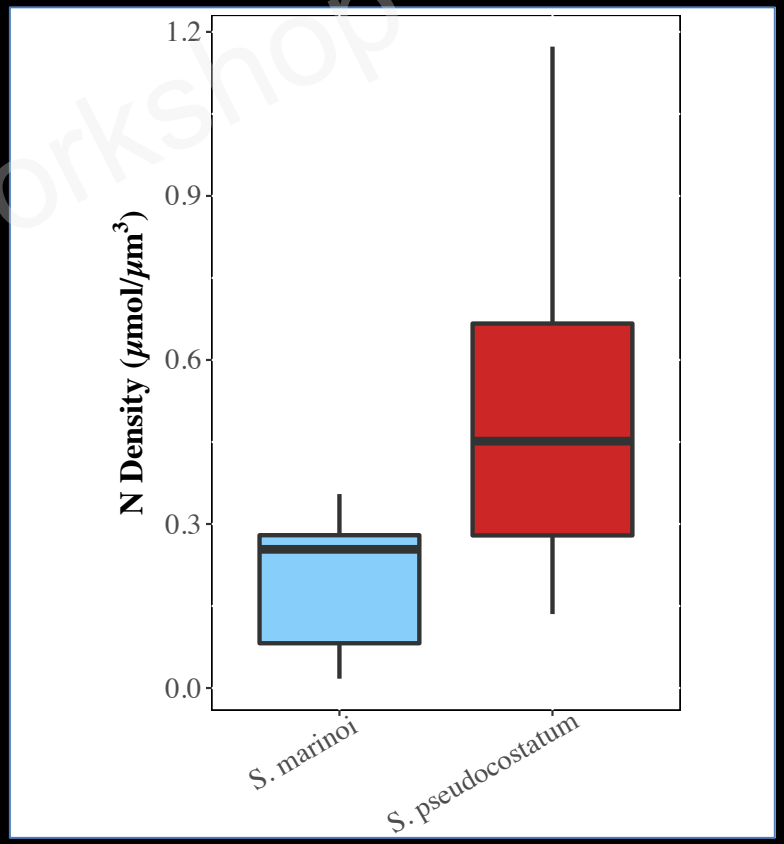
Reviewed in Godhe and Rynearson, 2107

BGC and Plankton

- Ecological effects of inter- vs intra-specific variation?



Des Roches et al. 2017, Nature Ecol & Evol



Anderson et al. in prep

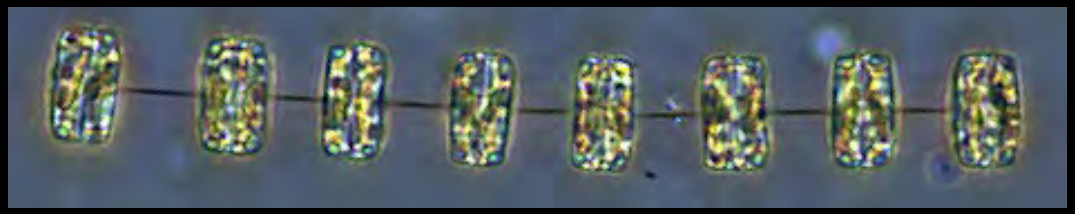
What's going on in the field?

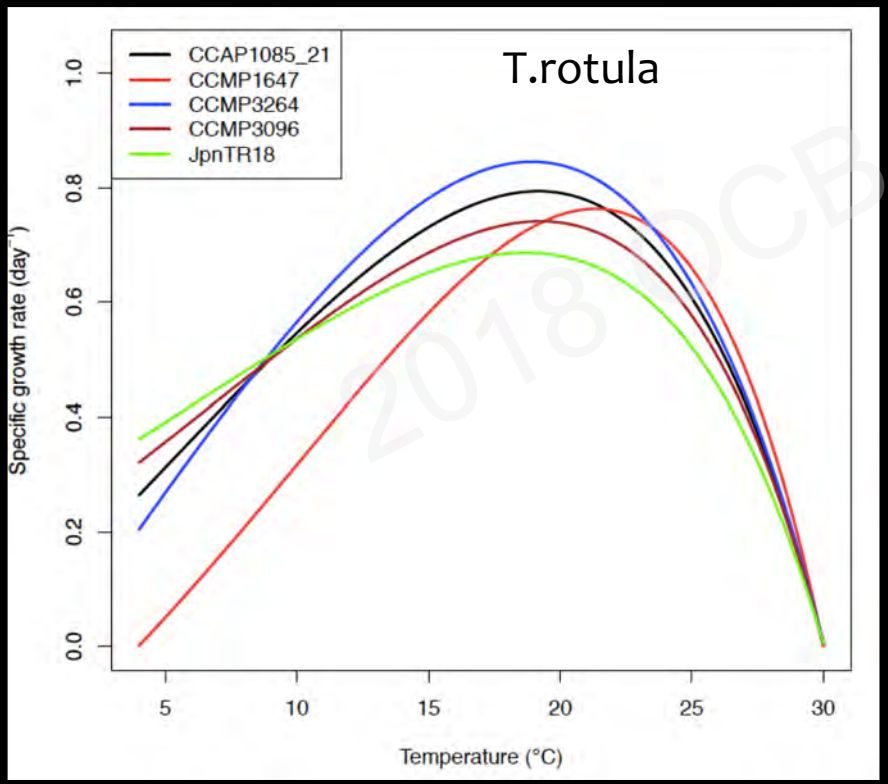
- Evolutionary "potential"?
- Mechanisms? (drift, selection, sex, mutation, migration?)
- Rates of change?
- How does water circulation influence these processes?
- What does the planktonic seascape look like?

Today's themes

- Ocean forensics:
  - How much raw material is out there for evolution to act on and how is it subdivided?
  - Temporal and spatial patterns of genetic variation
  - Tells us about evolutionary "potential"
- Diatoms and their friends
  - "You can tell a lot about a diatom by who it associates with"
  - Not only in test tubes. Potential for microbial co-evolution?

Ocean forensics: Temporal and spatial patterns of genetic variation





Whittaker & Rynearson 2012

Kerry Whittaker

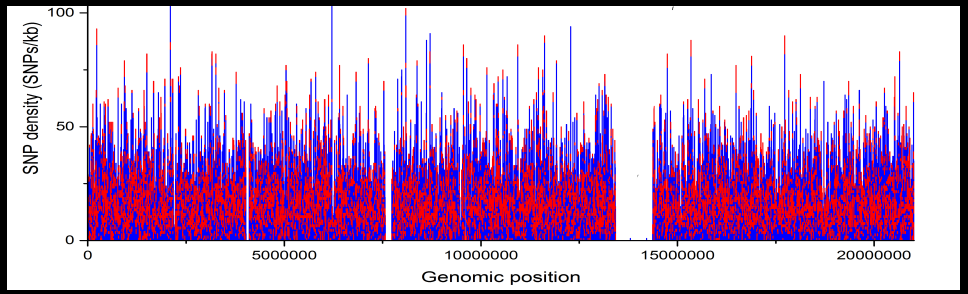
- Focus on diatom *T. rotula*
  - Phenotypic variation

How to ID genetic variation

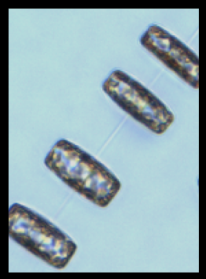
Microsatellite markers- Repeat region varies in length (Mutation)

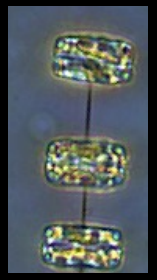
CTGCTCAGTGTGTGTGTGTGACGACC

Whole genome scans (Mutation)

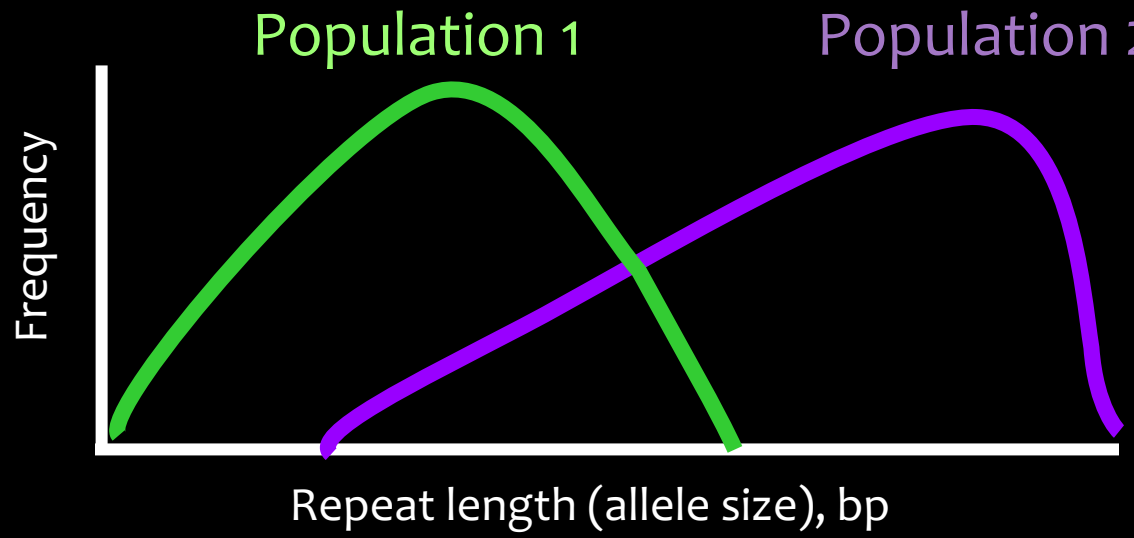


DNA fingerprints identify individuals





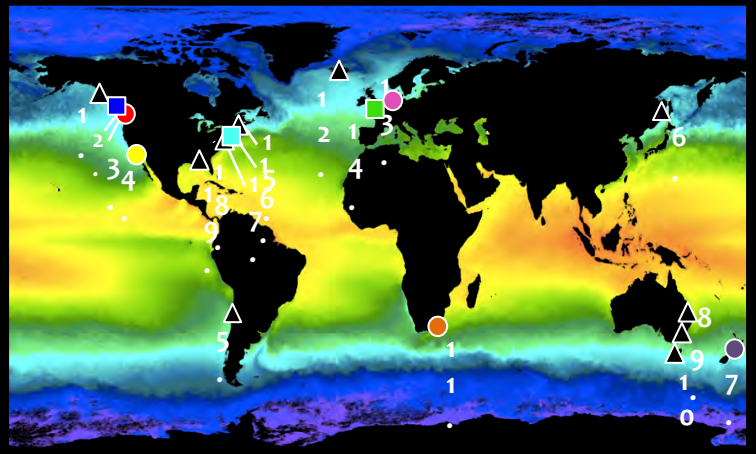
- Tells us how much genetic variation is out there



Gene pools identify genetically distinct populations

How variation is subdivided into distinct units (Selection, Migration, Recombination & Genetic Drift)

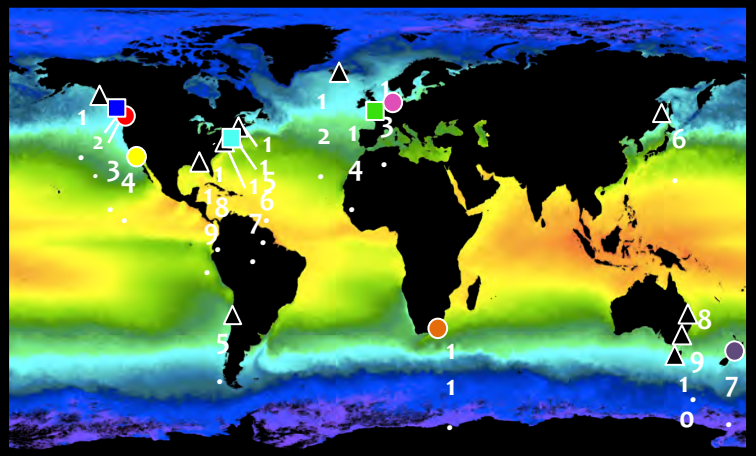
Global Diversity in T. rotula?



- Sampled 20 global locations simultaneously
- Isolated ~50 single cells from each location at multiple timepoints
- Extract DNA and amplify microsatellites

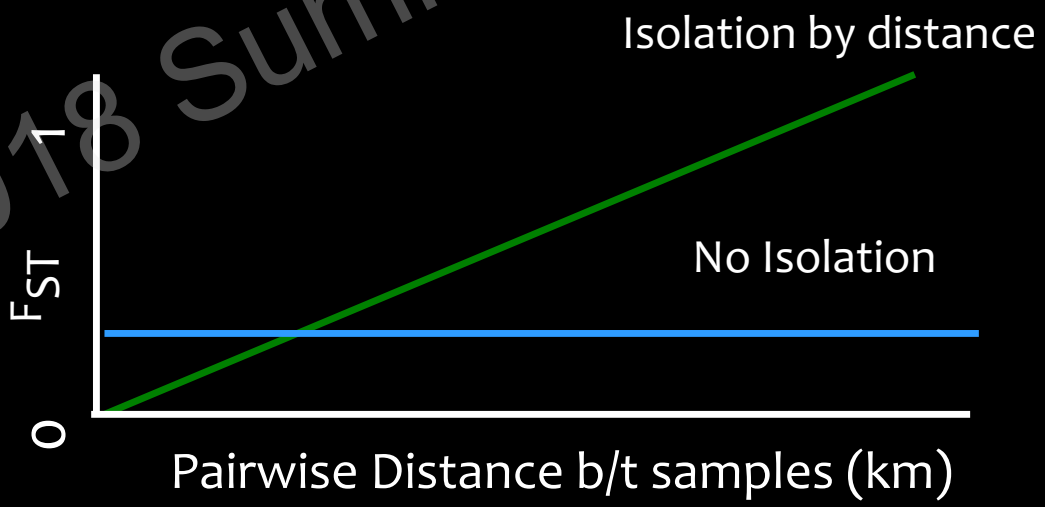
- 449 individuals genotyped
- 447 different genotypes
- Lots of raw material for contemporary evolution!
- Large population sizes (1000's of clonal lineages)
- Genetic Drift not as important as other mechanisms

High diversity but how is it subdivided?



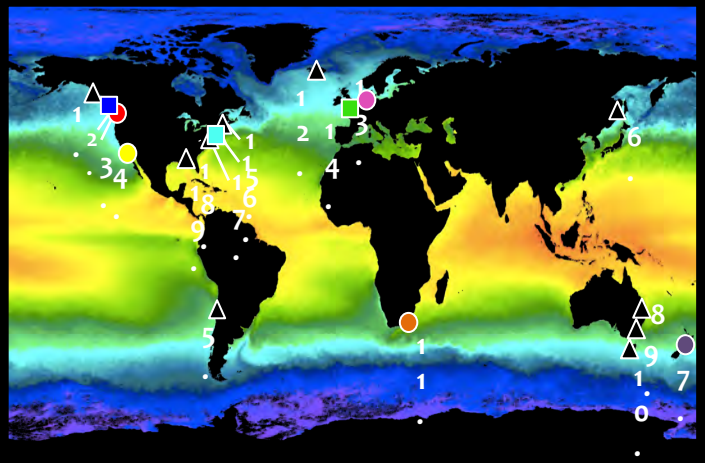
Quantify genetic divergence between water samples (F_{ST})

Test for isolation by distance

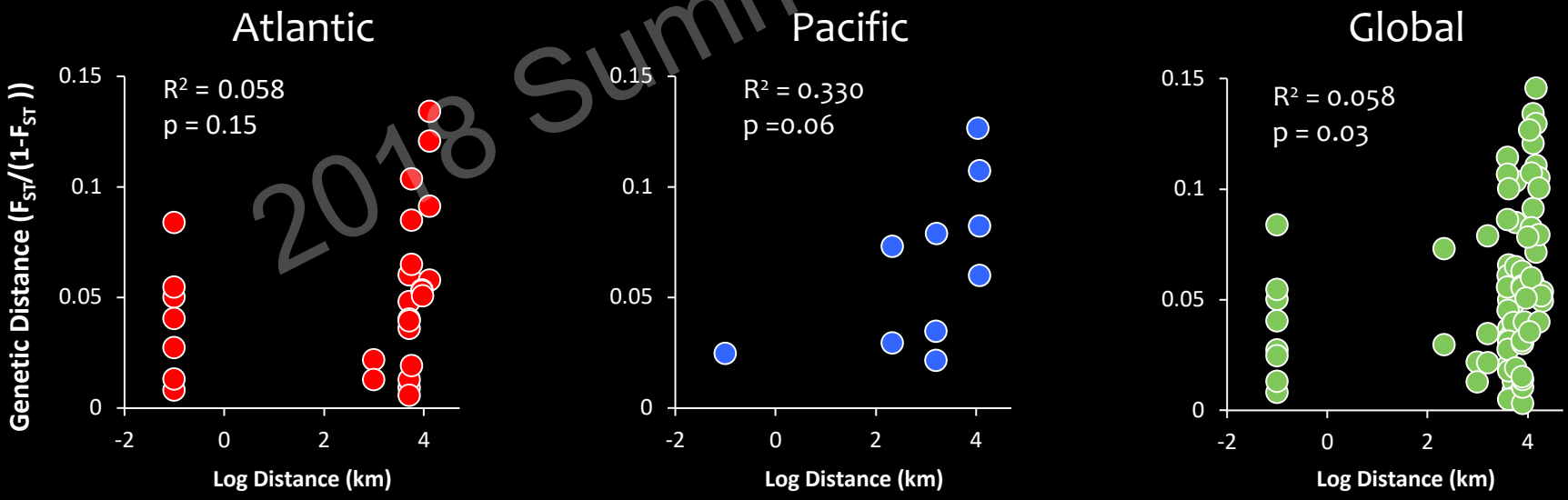


e.g. Wright, 1931

Isolation by distance in T. rotula?

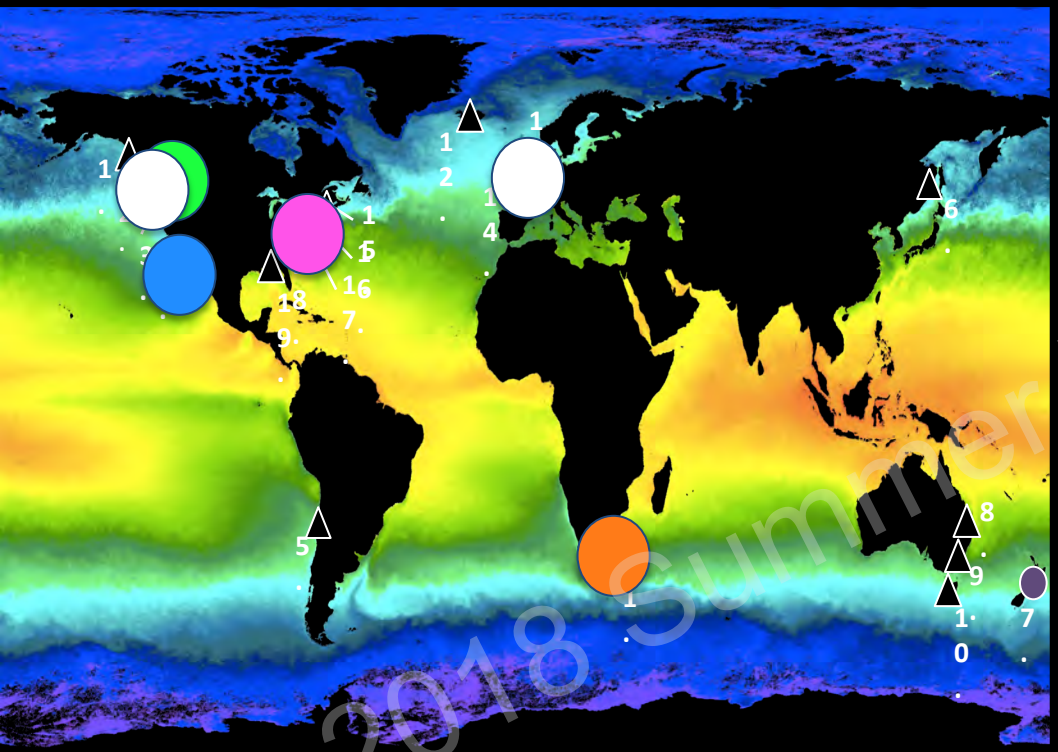


No substantive isolation by distance on global scale.



Whittaker & Rynearson, 2017, PNAS

How are diatom species subdivided over global scales?



- 6 genetically distinct populations, some sampled repeatedly
- Same population in different ocean basins

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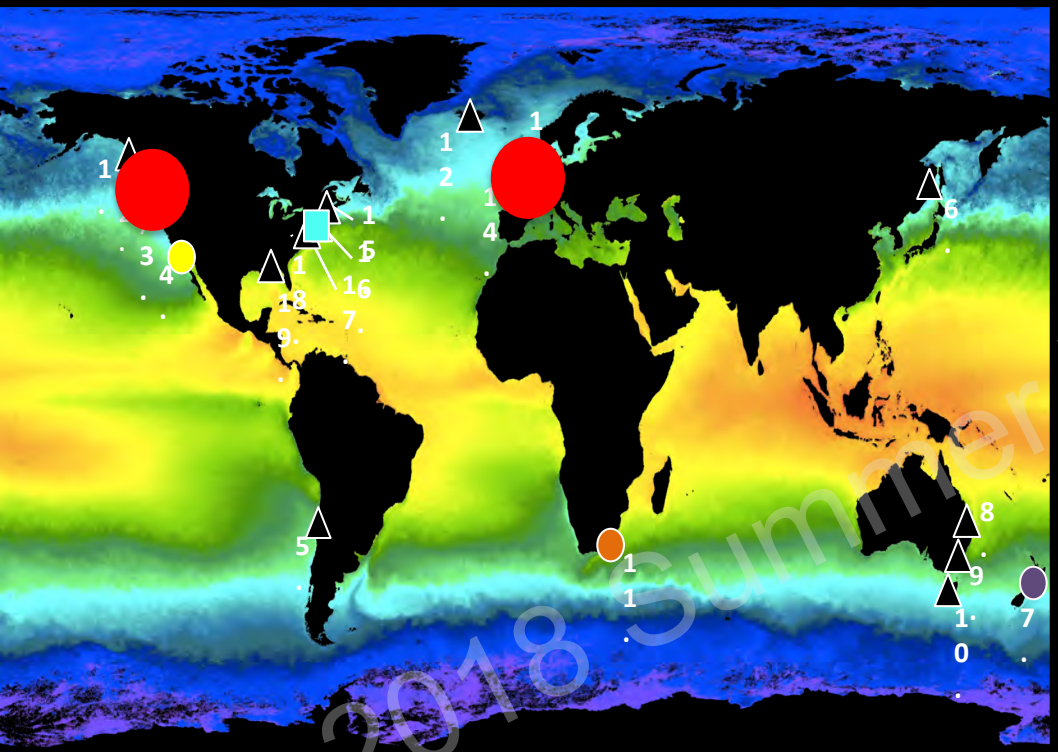
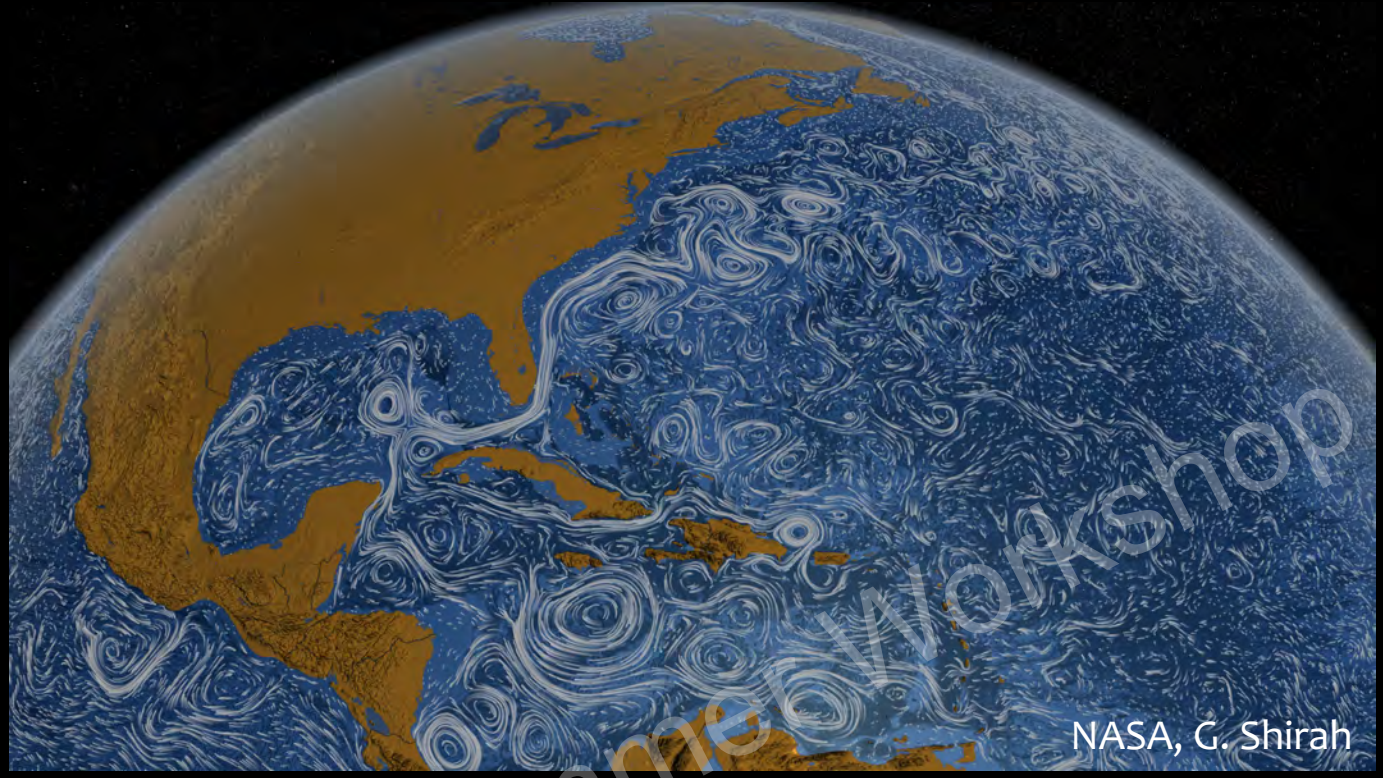


- 6 genetically distinct populations, some sampled repeatedly
- Same population in different ocean basins
- Same population succession in two ocean basins

- So… there is population variation but
  - Not static
  - Not dispersal limited

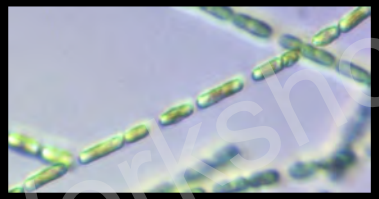
Whittaker & Rynearson, 2017, PNAS

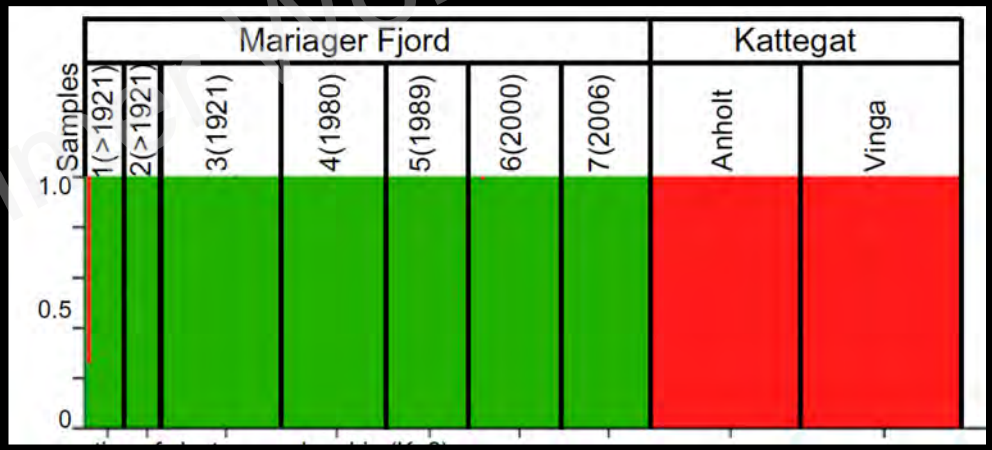


- *T. rotula* populations evolving more slowly than connectivity of surface ocean
  - Microbial evolution in a circulating ocean- see Hellweger et al. 2014
- Divergence maintained by <u>selection</u>
  - *T. rotula* populations associated with temperature and Chl. a
  - Selection reduces gene flow among populations

What else do we know about the diversity and divergence of diatoms?

Space Time Taxa





- Long-lived populations. >100yrs
  - LOTS of time for evolutionary adaptation
- Fjords harbor unique populations in *T. rotula* and *D. brightwellii*
  - Recirculating nature of fjords? (Rynearson et al. 2006)

Harnstrom, Ellegaard, Andersen, Godhe 2011

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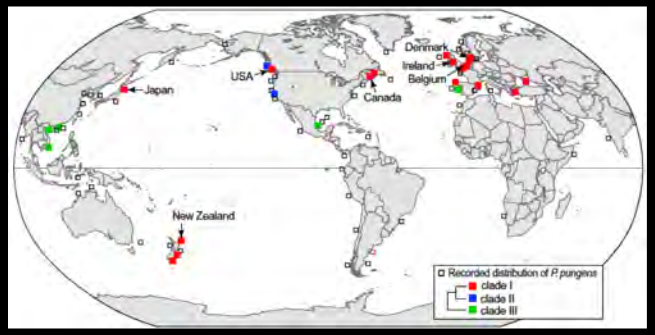
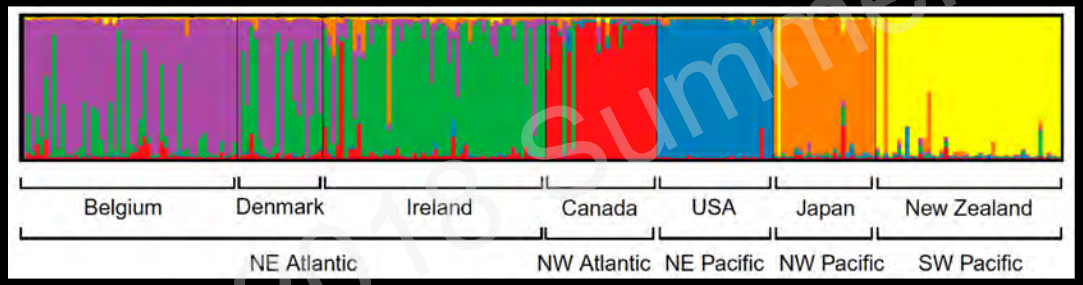
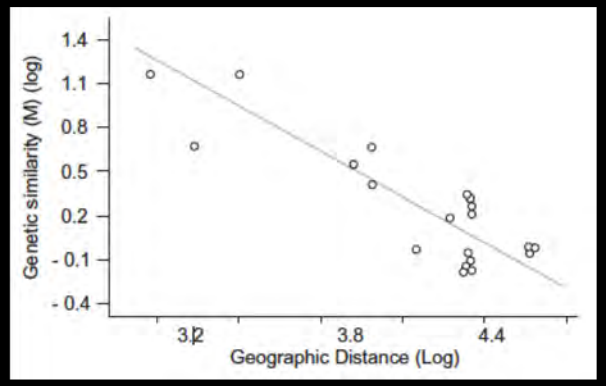


Phytopedia, EOAS, UBC





- Distinct Populations & Increasing divergence with increasing distance
  - Barriers to dispersal?
- Different than T. rotula!
  - Pennate : Centric signal? Different evolutionary potentials?

Casteleyn et al. 2010

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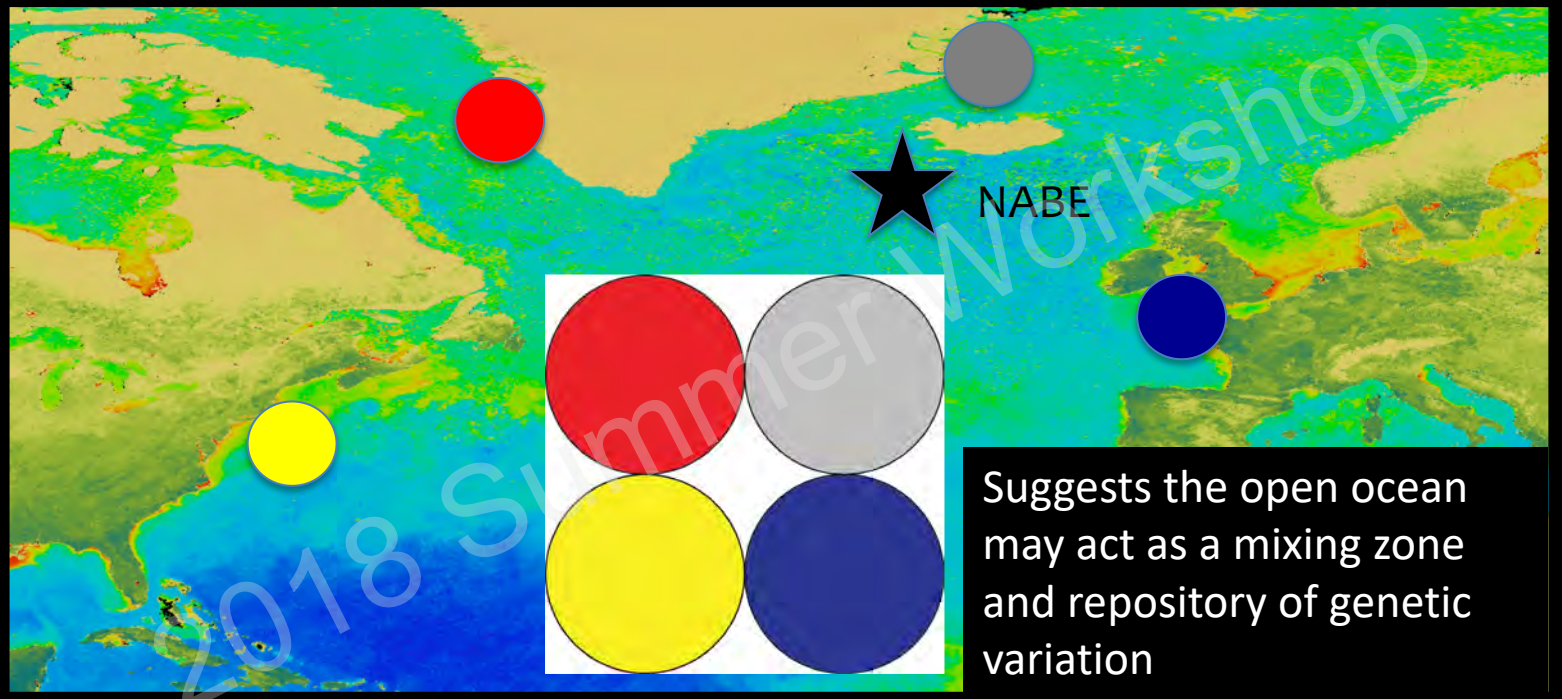
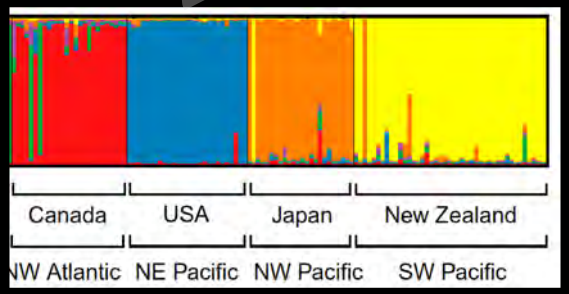
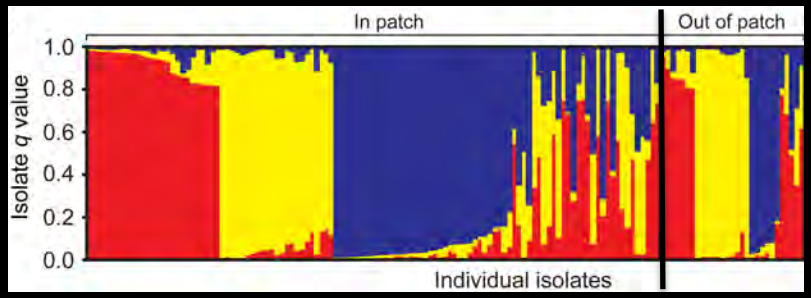


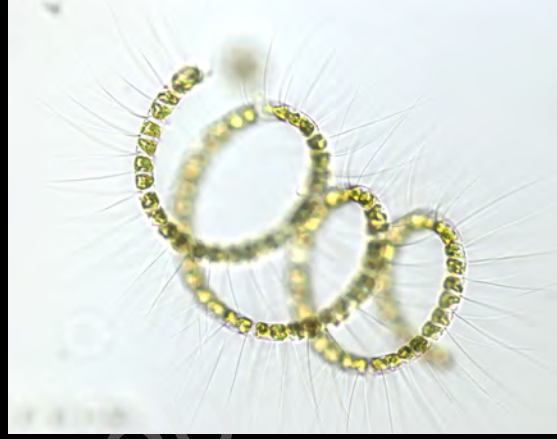
Suggests the open ocean may act as a mixing zone and repository of genetic variation





Chen and Rynearson, 2016

Today's themes



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- Diatoms and their friends
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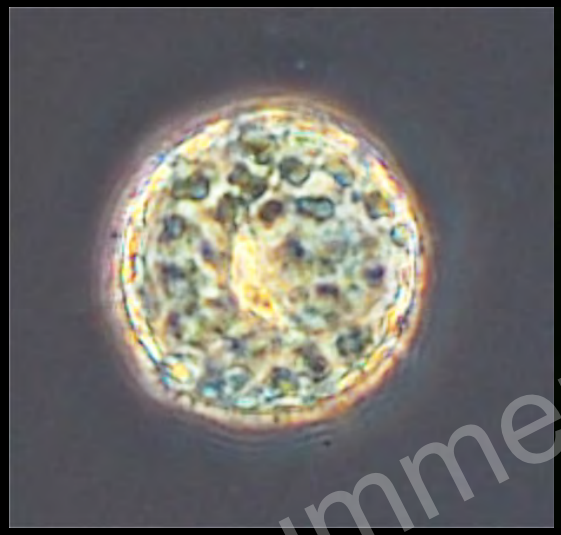
Olivia Ahern

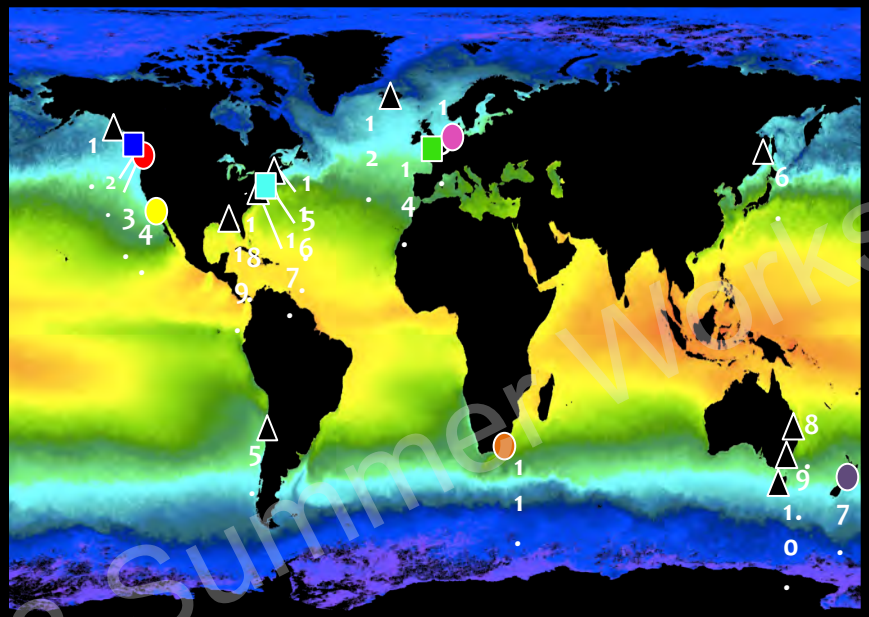


Organism interactions and significance for BGC

- Exchange of molecules, vitamins, and nutrients.
- Bacteria impact diatom host physiology

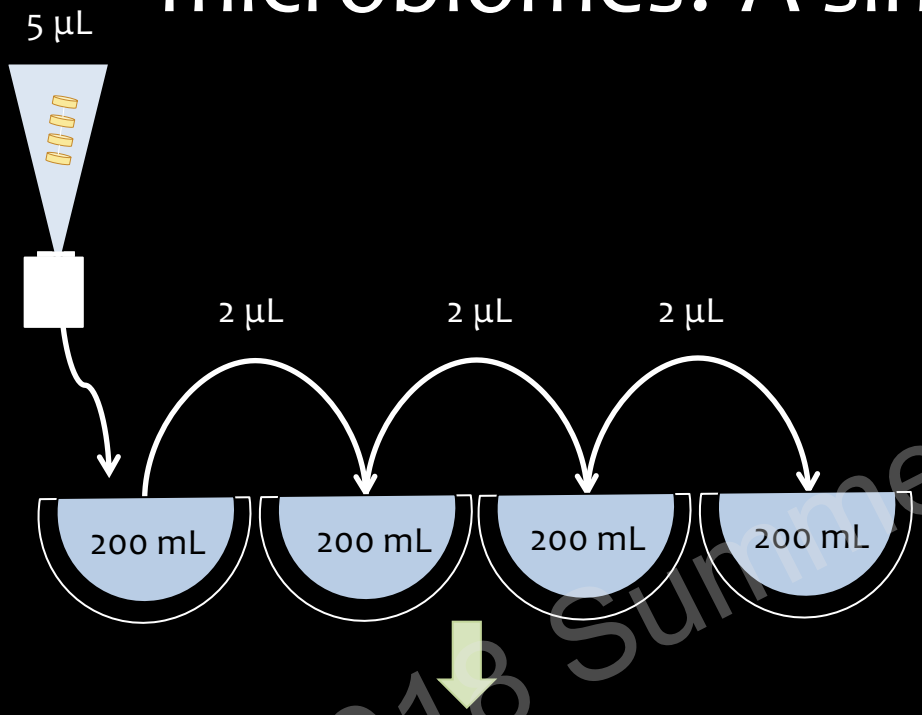
Species-specific associations

Do distinct diatom populations harbor distinct microbiomes?

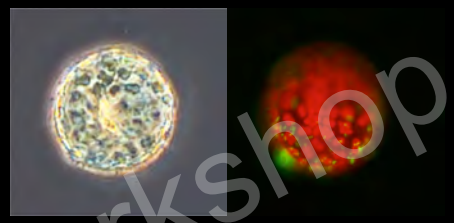


- Hints of intraspecific variation in diatom genus *Pseudonitzschia* (Sison-Mangus et al. ISMEJ 2014)
- Hypothesized there would be a single core microbiome with shifts in composition between populations

Do distinct diatom populations harbor distinct microbiomes? A single cell approach.



88 single cell diatom isolates + whole seawater samples

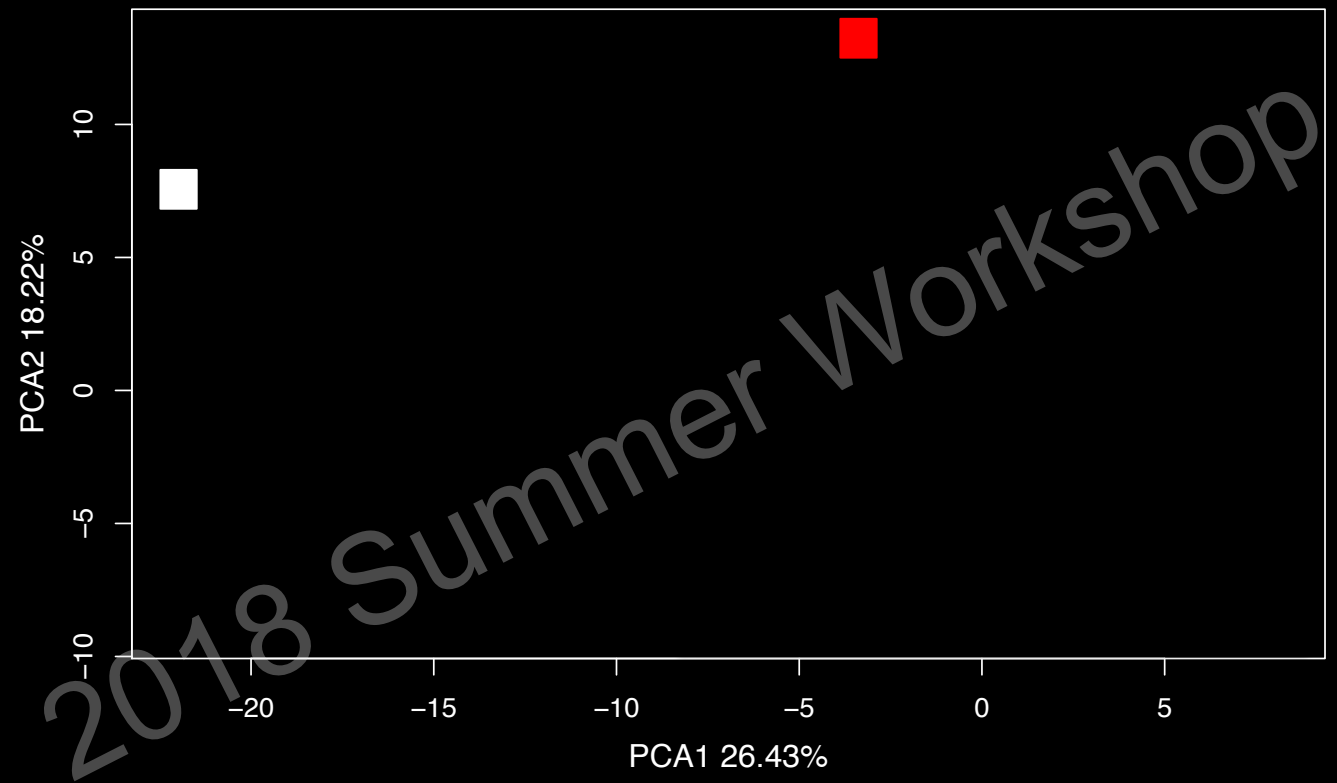


- Isolates washed 3x in sterile seawater. Transfer of << 1 free-floating bacteria into culture well.

- Isolates cultured for 2 wks
- DNA extraction
- Sequencing to determine taxonomic composition

Ahern et al. in prep

Diatom associated bacterial communities differ from whole seawater communities



T. rotula Narragansett Bay 1

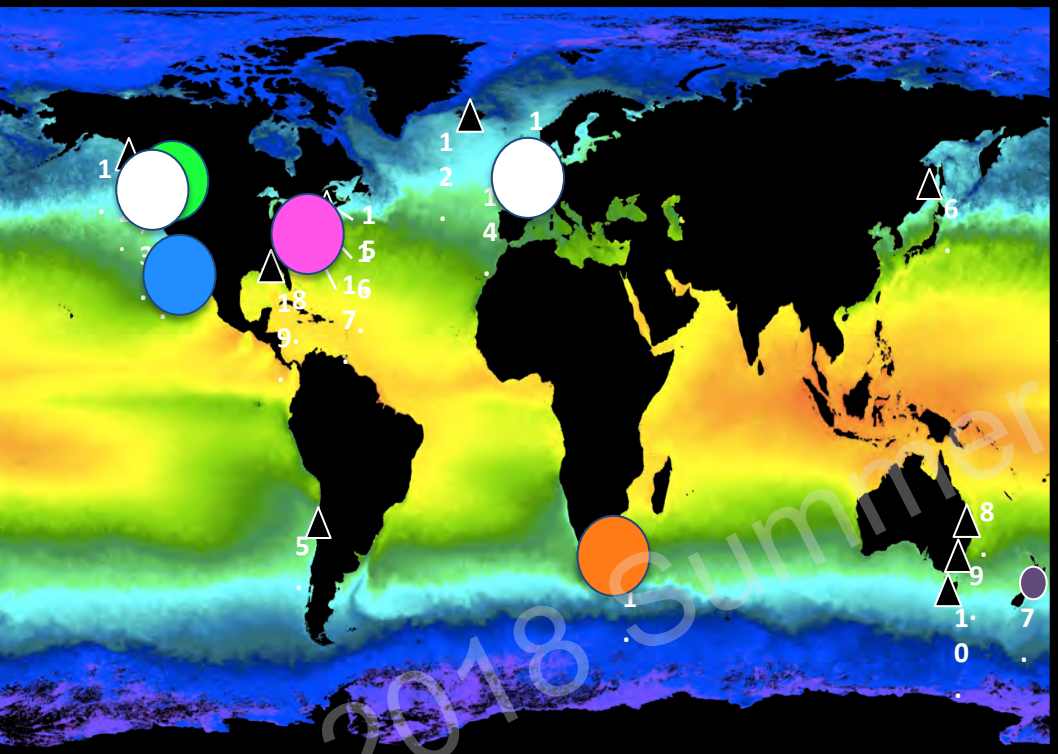
Whole Seawater Narragansett Bay 1

T. rotula Narragansett Bay 2

Whole Seawater Narragansett Bay 2

Ahern et al. in prep

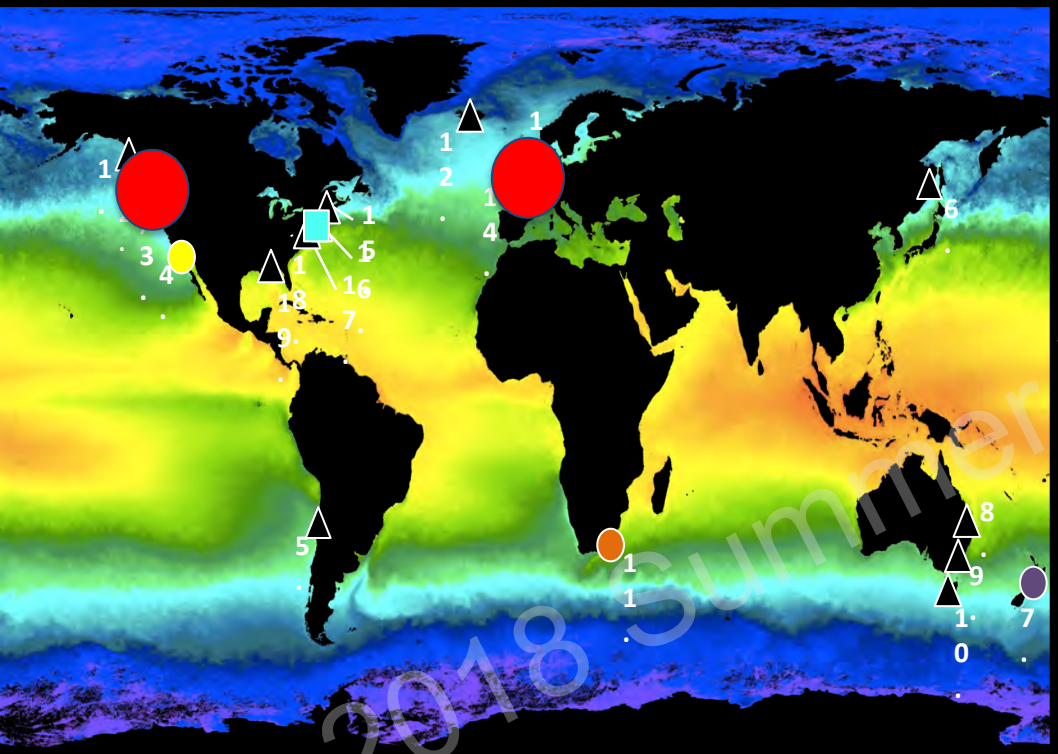
Different bacterial communities associated with genetically distinct diatom populations



- Bacterial community composition maps directly to diatom populations

Ahern et al. in prep

Different bacterial communities associated with genetically distinct diatom populations



- Suggests long-term associations between bacteria and diatoms
- Potential for co-evolutionary dynamics and significant impact on function, survival, and biogeochemical cycling

Ahern et al. in prep

What's going on in the field?

- Evolutionary potential is high! (Diatoms, Dinoflagellates, Prymnesiophytes)
- Mechanisms
  - Selection influenced by both environment & ecology
  - Genetic Drift not so important (large populations)
  - Open questions: frequency of sex (recombination)? Rates of mutation in the field?
- Persistent populations
  - Lifetimes exceed global connectivity of surface waters (>100 yrs)
  - Sufficient duration to acquire unique microbiomes
- Seascape: Barriers to dispersal?
  - No in Centrics. Yes in Pennate Diatoms.
    - High probability of immigration, emigration and niche occupation
    - Potential for local adaptation, reduced immigration and gene flow
  - Open ocean as a genetic "mixing" zone

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