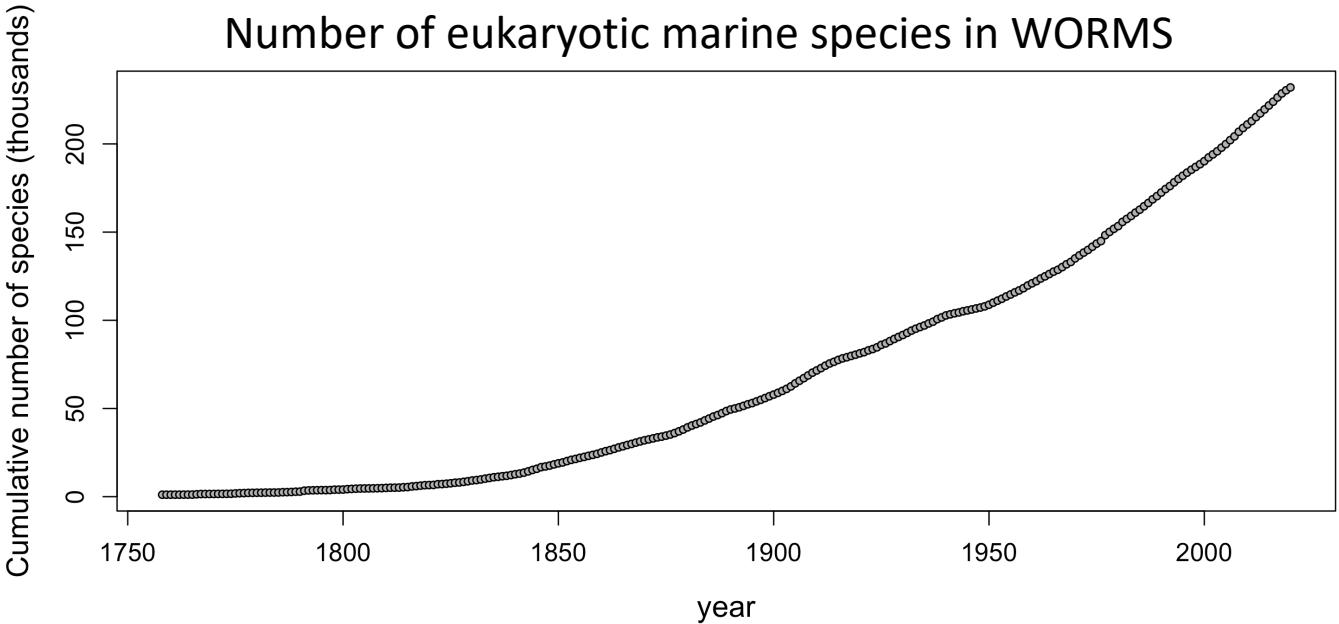


Marine Speciation

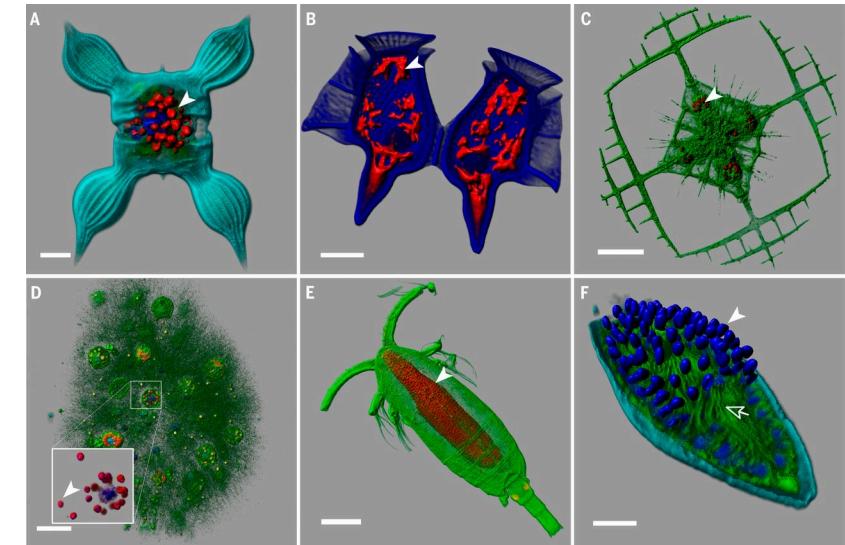


We're only beginning to identify marine species



How many species?

- Between 1 and 10 million
 - Appeltans et al., 2012; Mora et al., 2011; Leray and Knowlton 2016
- ~75-97% of marine eukaryotic species are not described
 - Majority of these are small (less than 1 mm) and cryptic



Why study speciation?

- Fundamentally important to understanding diversity on earth
- What is the role of geography, gene flow, selection...
- How do genomes diverge?
- Find genes/mechanisms driving speciation

- What is a species?
- How does speciation occur?
- Why is speciation different in the oceans?

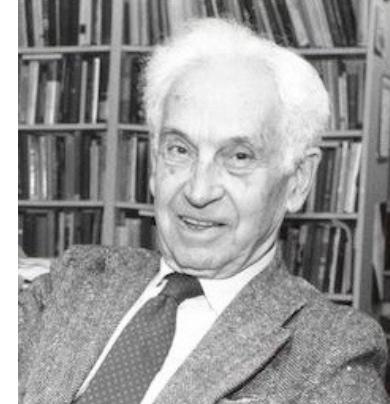
What are species?



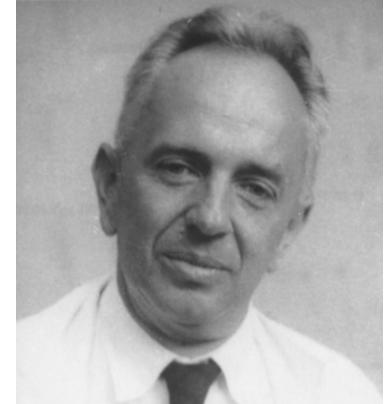
Andrews et al., 2016

What are species?

- Biological species concept
 - “as groups of interbreeding populations in nature, unable to exchange genes with other such groups living in the same area”
- 25% of plant species and 10% of animal species hybridize with other species (Mallet 2005)
- Evolutionary species concept
 - A lineage evolving separately from others and with its own evolutionary role and tendencies- de Queiroz 1998
- Speciation is about population differentiation



Mayr



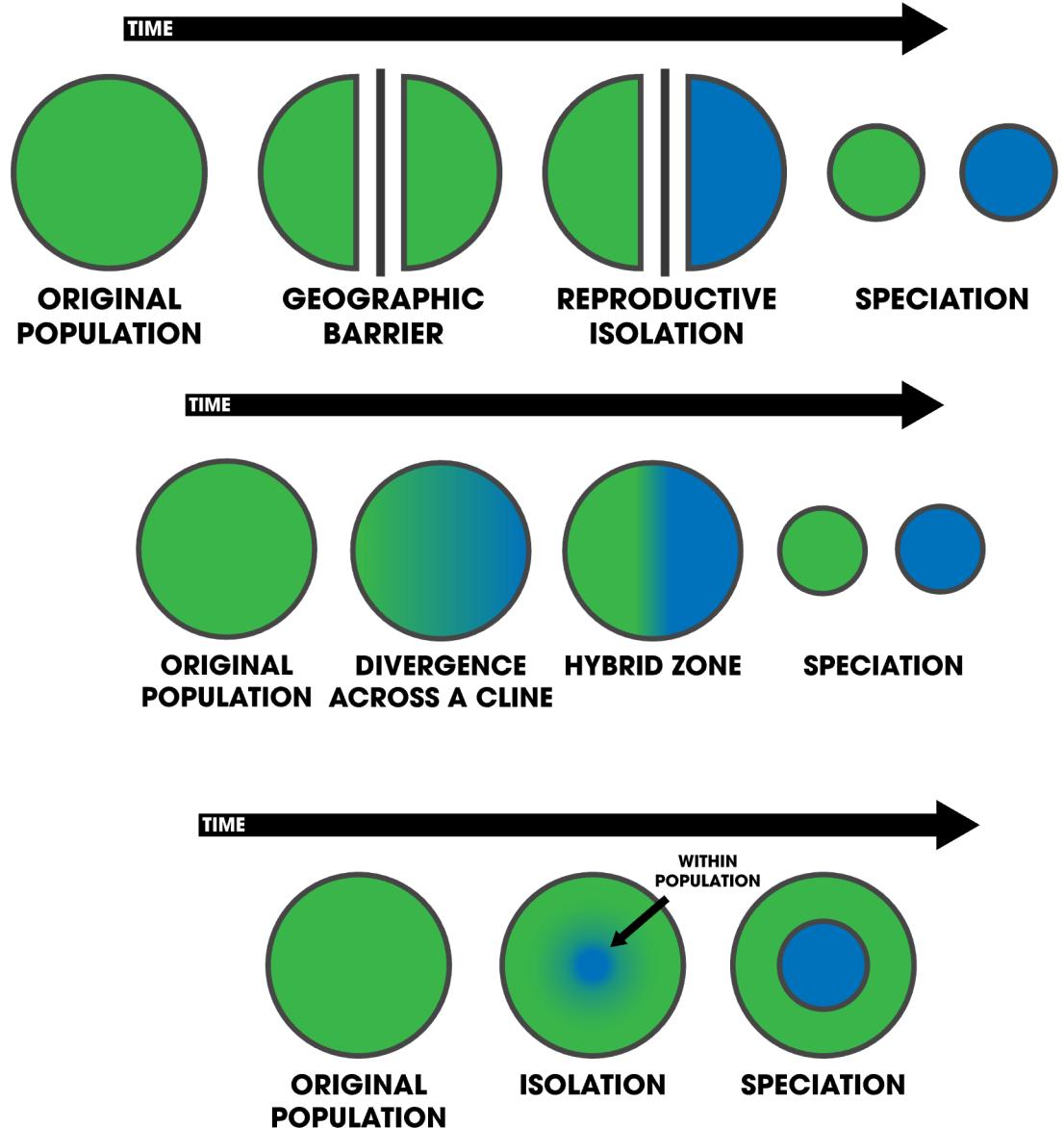
Dobzhansky

Forms of reproductive isolation

- Prezygotic
 - Before the formation of the zygote
 - No mating
 - Prevents formation of zygote
 - Temporal, ecological, behavioral, mechanical
- Postzygotic
 - After zygote formed
 - Genetic incompatibilities
 - Reduced hybrid fitness

How are species formed?

- Allopatric speciation
 - Geographic separation
- parapatric speciation
 - Adjacent populations
- Sympatric speciation
 - NO geographic separation



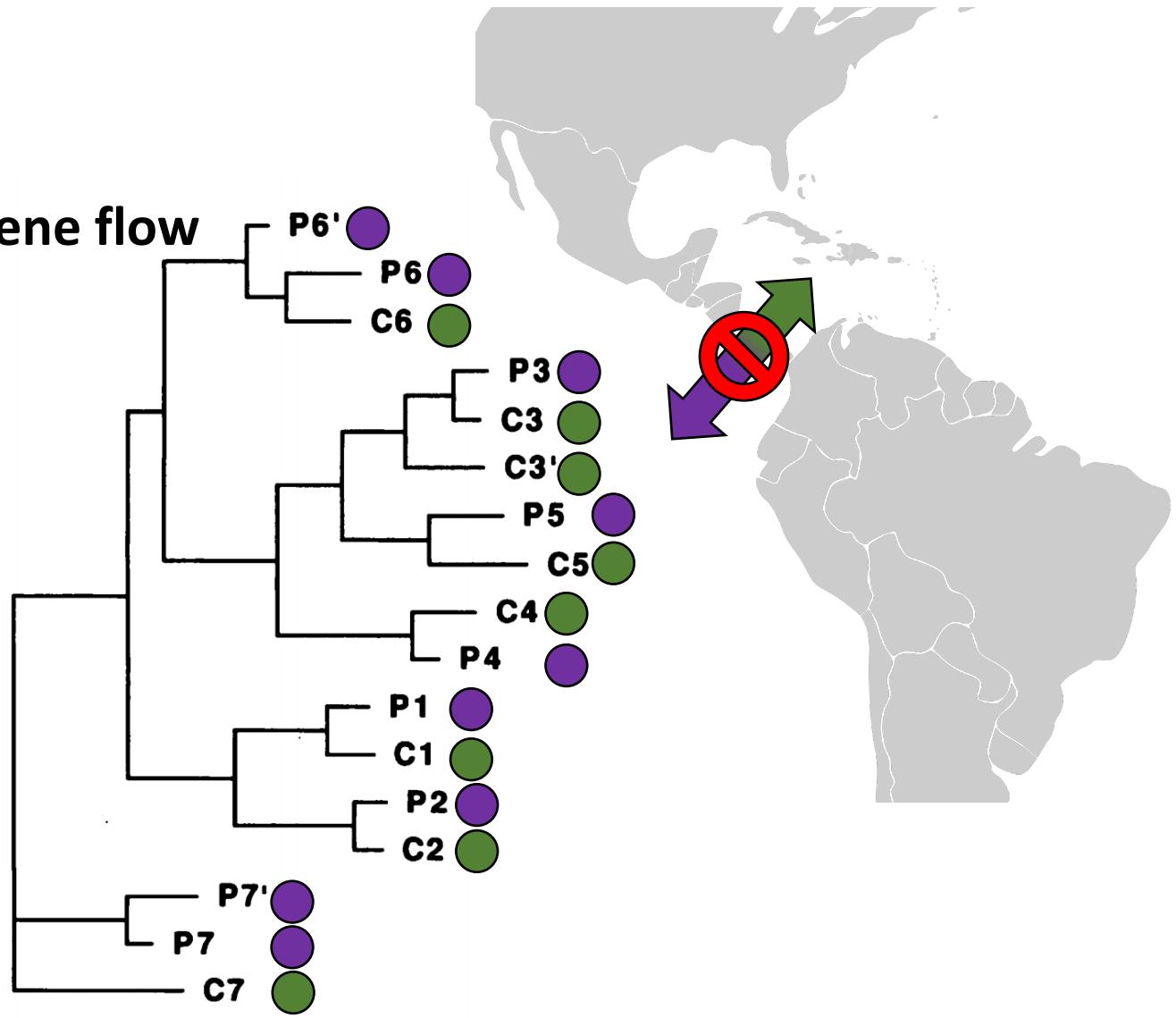
How are species formed?

- Allopatric speciation
 - Geographic separation
 - **Reduction/elimination of gene flow**
- Isthmus of Panama



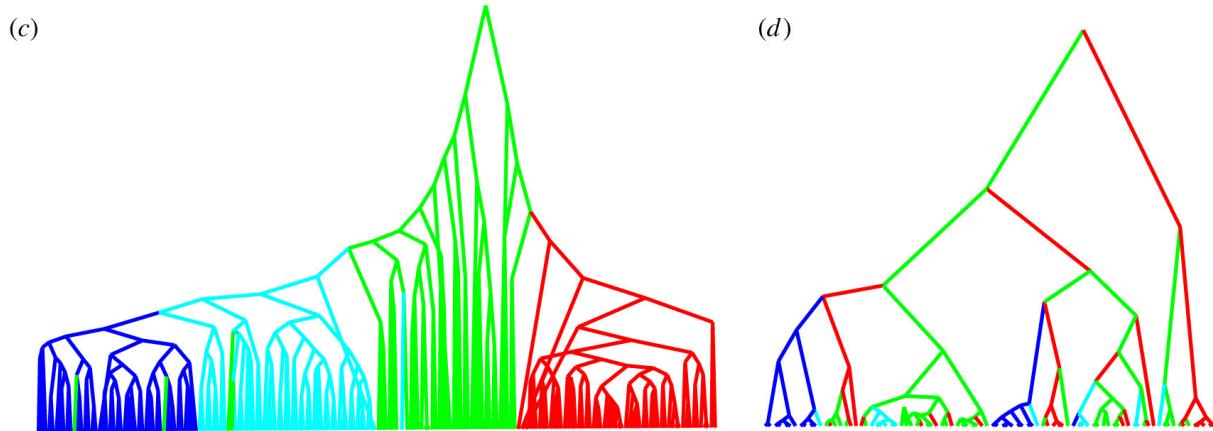
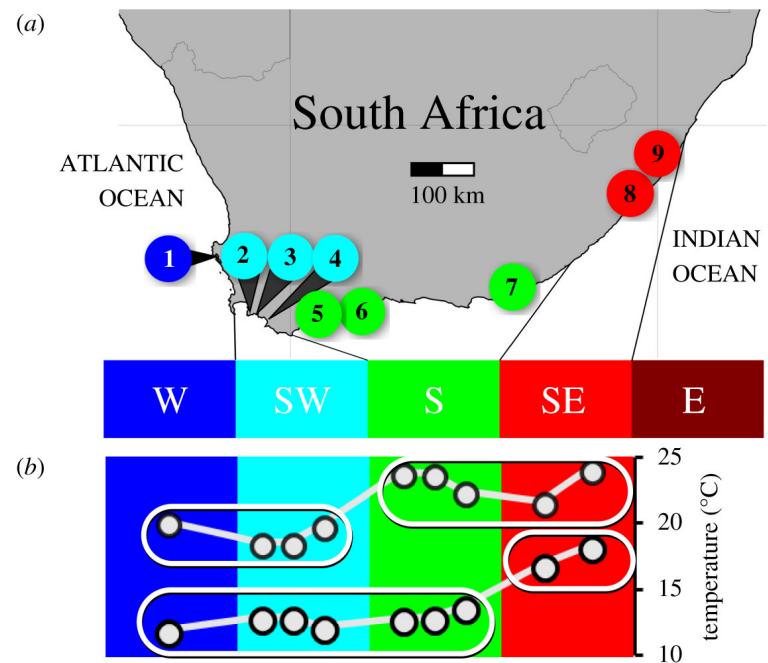
How are species formed?

- Allopatric speciation
 - Geographic separation
 - **Reduction/elimination of gene flow**
- Isthmus of Panama
- Snapping shrimp
 - Knowlton, 1993



Parapatric speciation

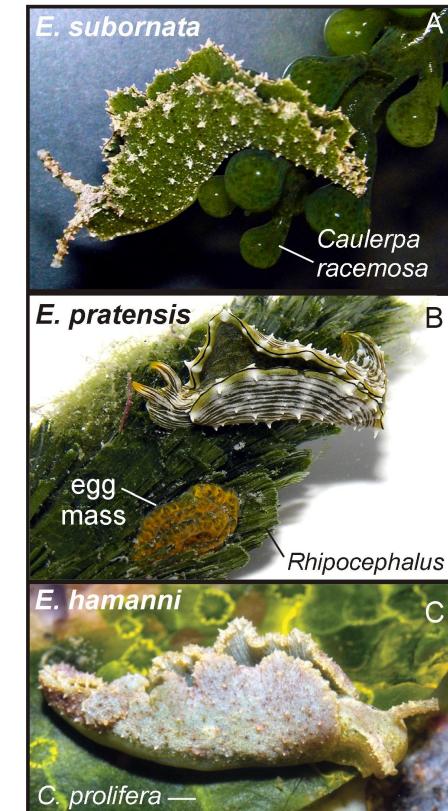
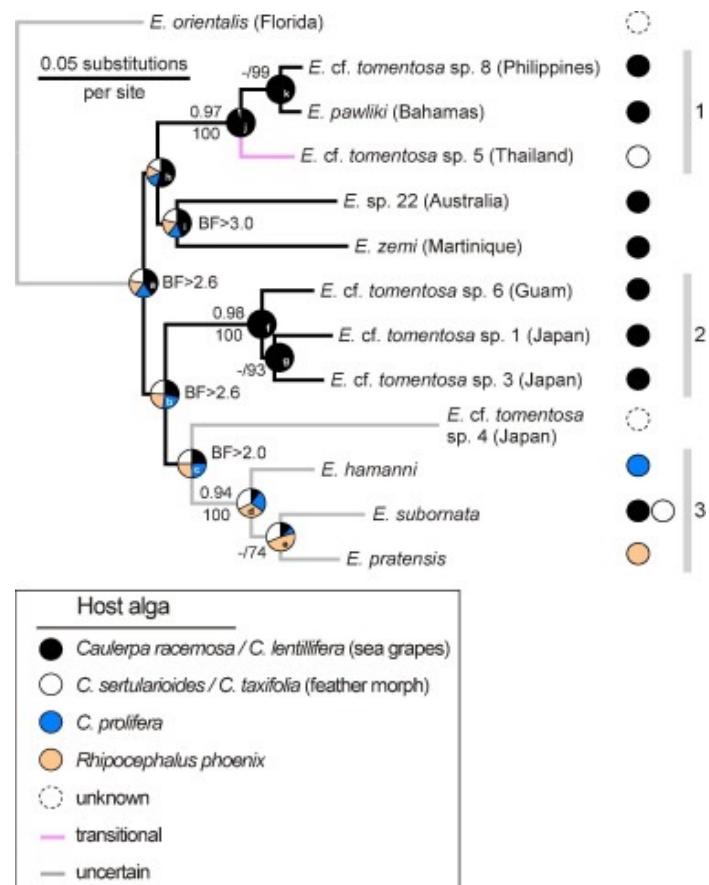
- Think environmental clines
- Knysna sandgoby, *Psammogobius knysnaensis*



● W
● SW
● S
● SE

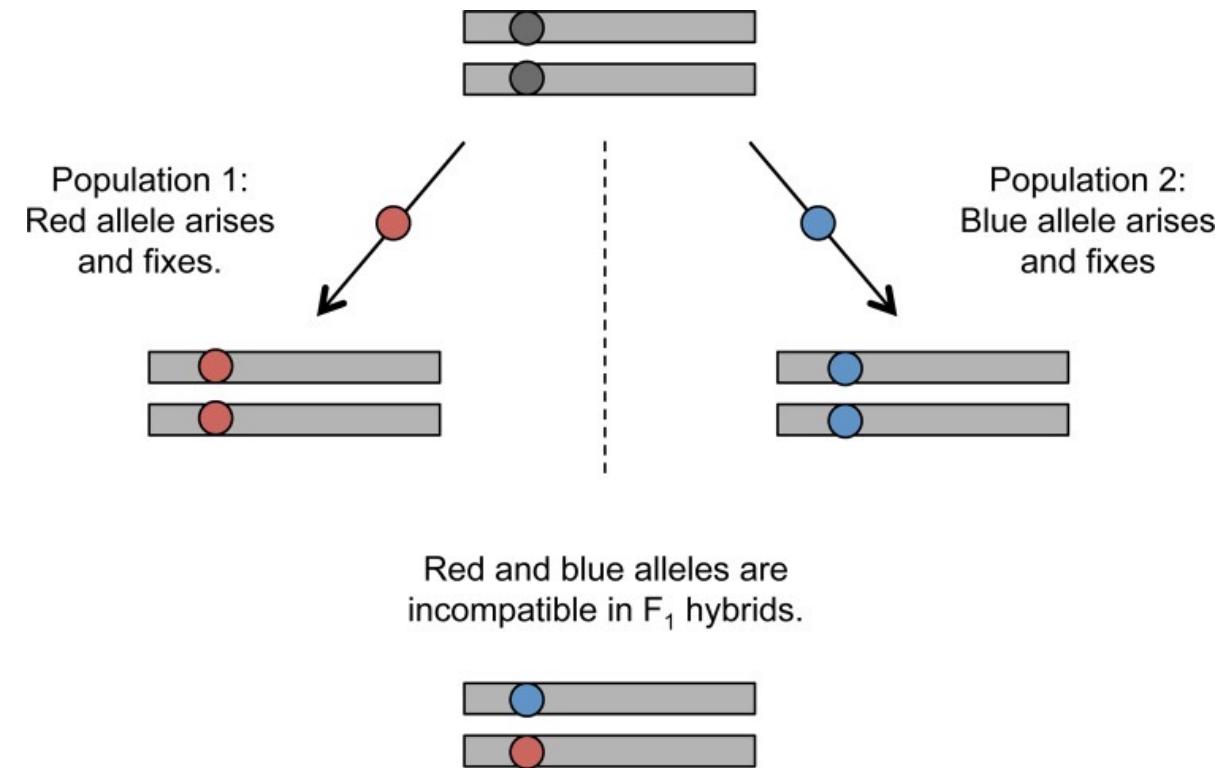
Sympatric speciation

- Sea slugs, *Caulerpa*
- Speciation driven by host shift

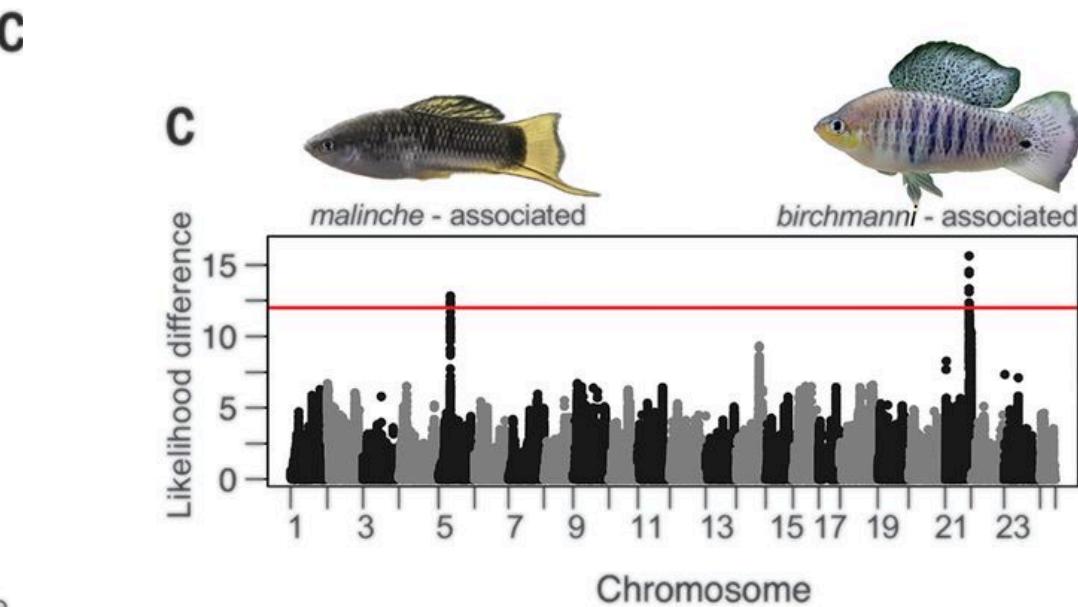
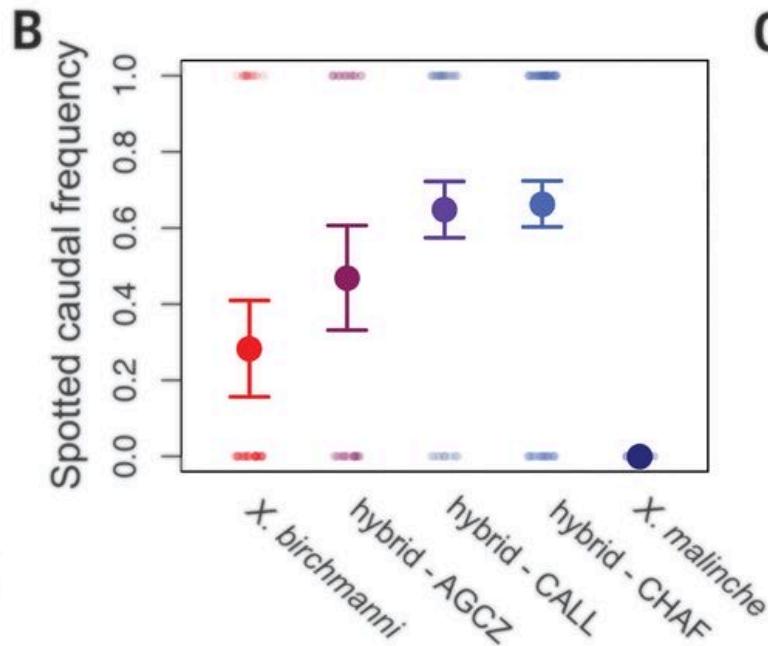


Genetic basis of reproductive isolation

- DMI- Dobzhansky Mueller Incompatibilities



Incompatibilities in swordtails



Incompatibilities in swordtails

C

Fin degradation phenotype

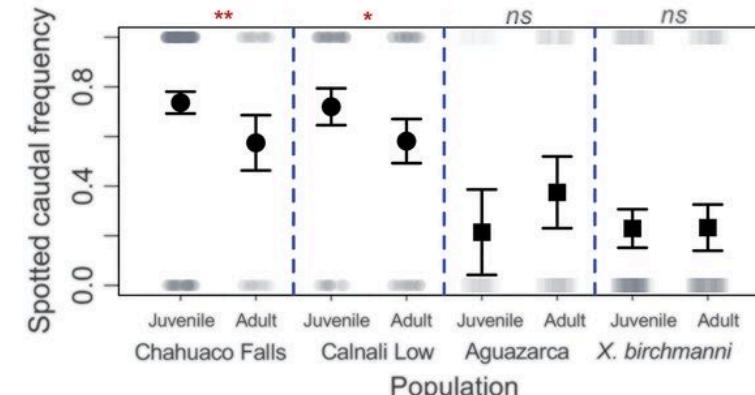


Tumor overgrowth phenotype

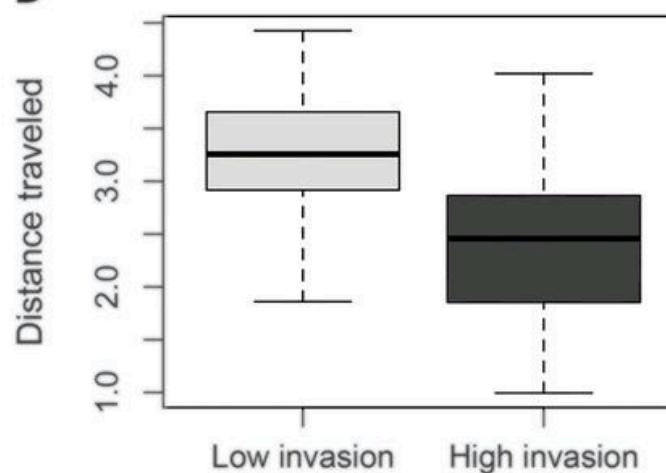


A

- High melanoma population
- Low melanoma population



□



But barriers like the Isthmus of Panama aren't that common in the ocean

What makes marine systems unique?

What makes marine systems unique?

- ↑ fecundity ↑ dispersal ↑ population sizes

- ↓ genetic drift ↓ barriers

- Generally, low genetic differentiation

How do populations diverge and speciate?

Mediterranean scallop dispersal

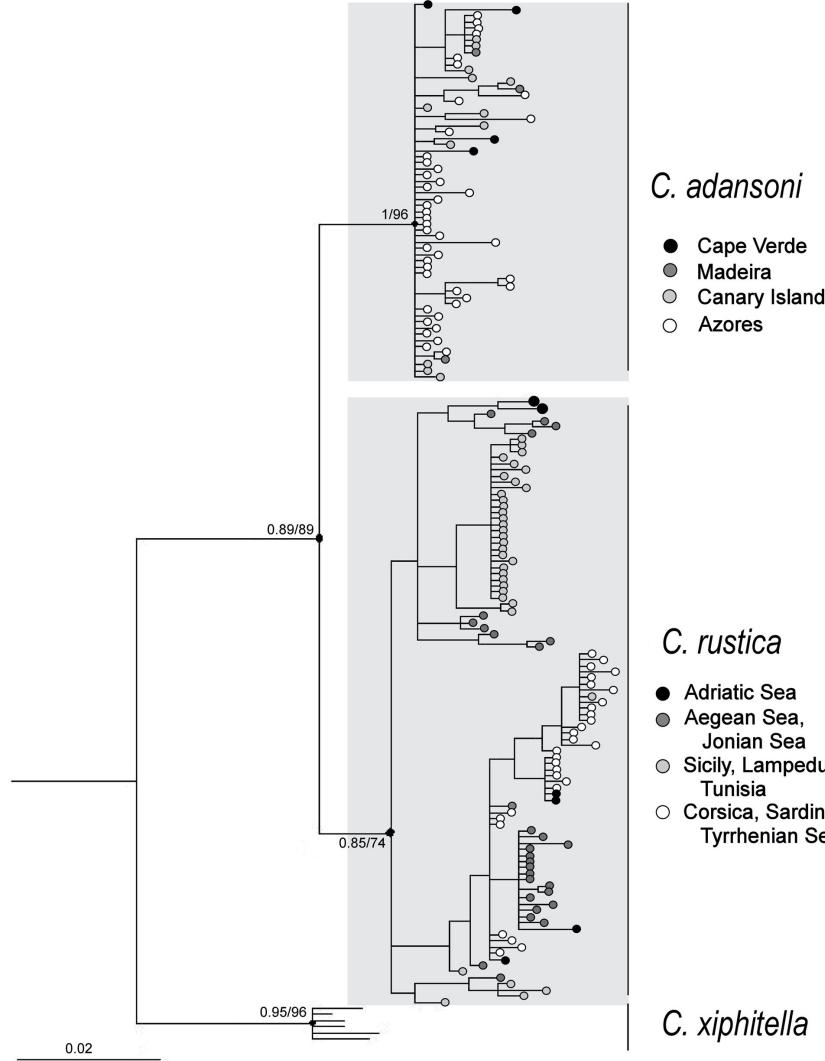
Drifters released 0.0 days ago, years=2007 to 2017, months 4 to 6, data from data/JebIBD_1m_YEAR_2D.nc
Pecten jacobaeus



Courtesy of Jamie Pringle

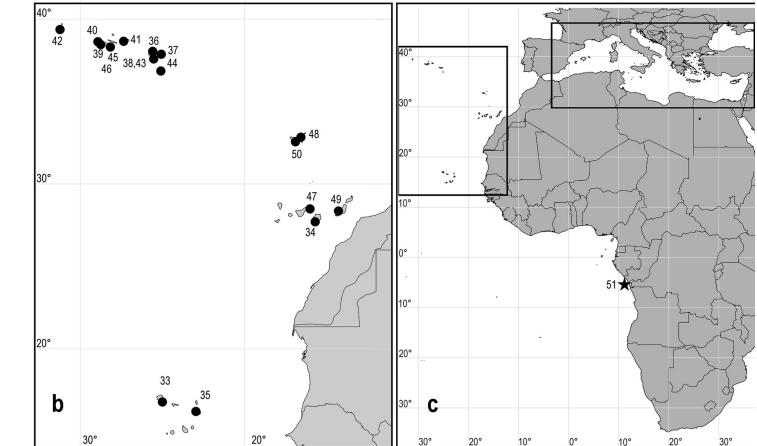
How does speciation occur in the ocean?

- Life history



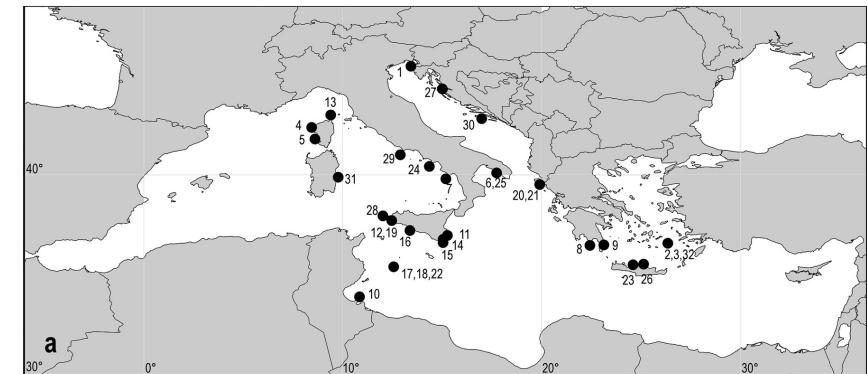
Columbella adansoni

Pelagic larvae



Columbella rustica

No pelagic larvae

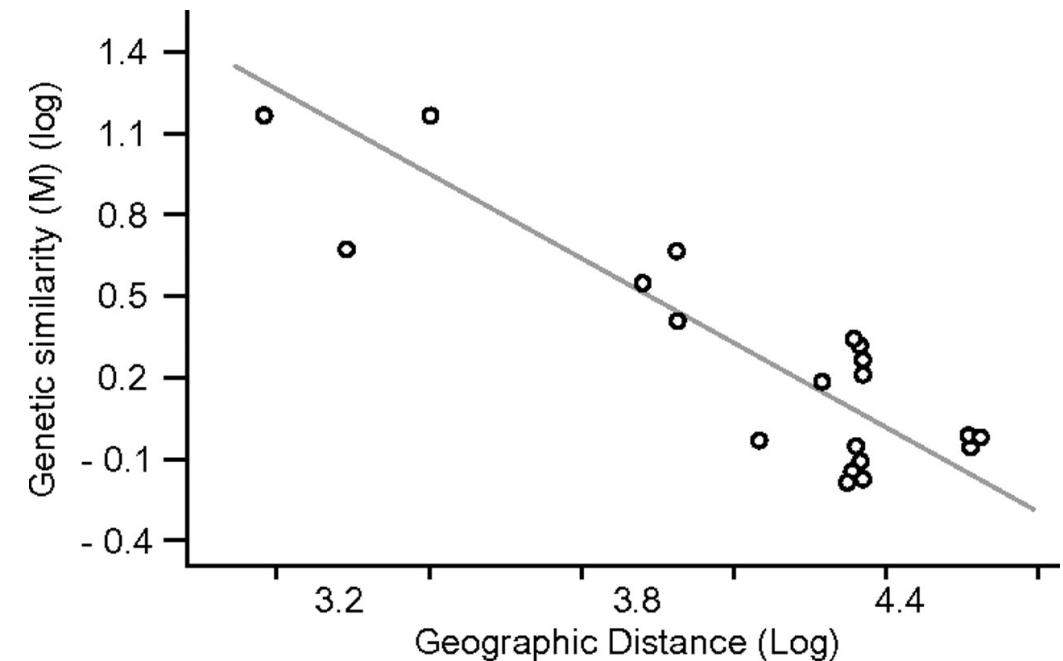
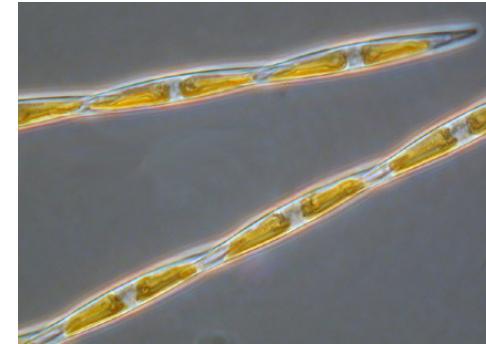
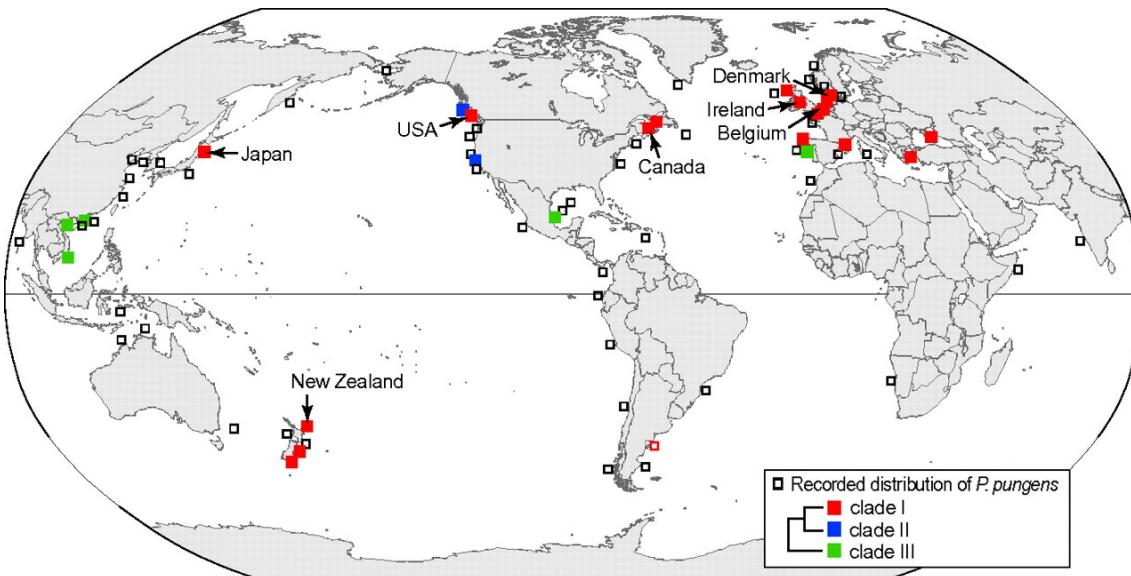


Modica et al., 2017

How does speciation occur in the ocean?

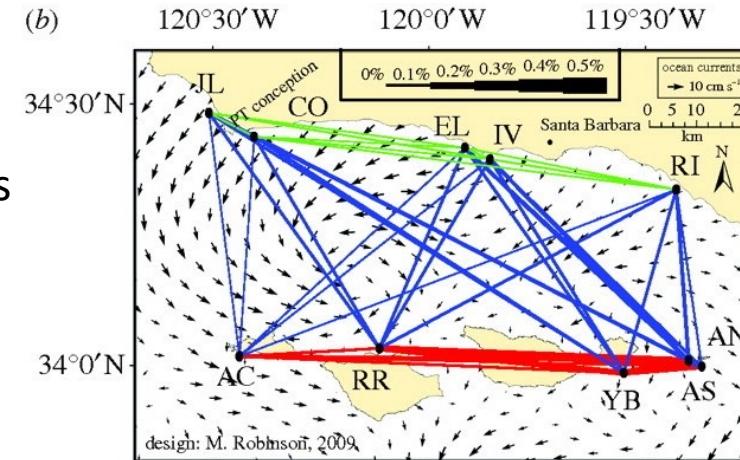
- Isolation by distance
 - differentiation over large distances

Marine diatom: *Pseudo-nitzschia pungens*

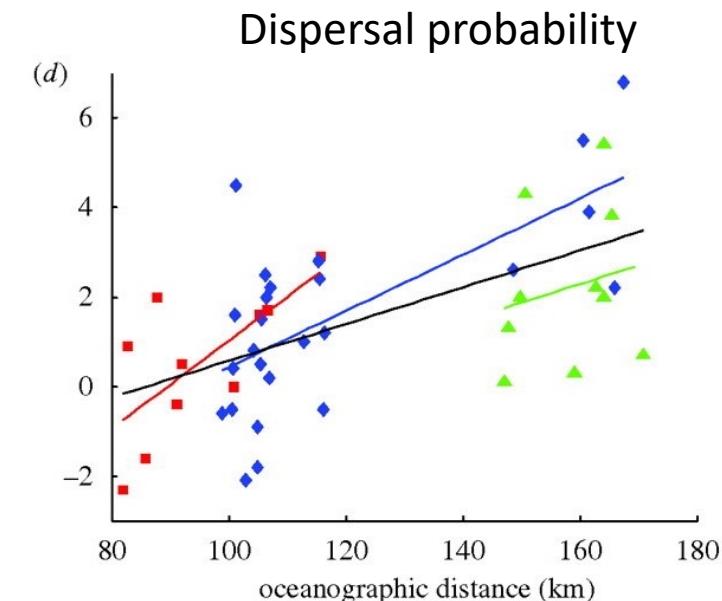
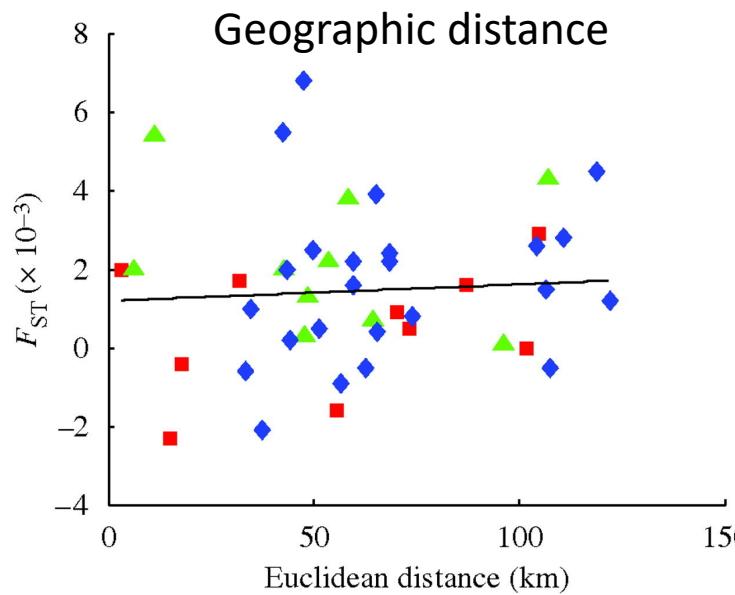


How does speciation occur in the ocean?

- Potential for gene flow may be high, in reality it is likely much lower.
 - Invisible barriers
 - Ocean currents
 - Less obvious geographic features
 - Tectonic plates, small scale currents



Kellet's whelk

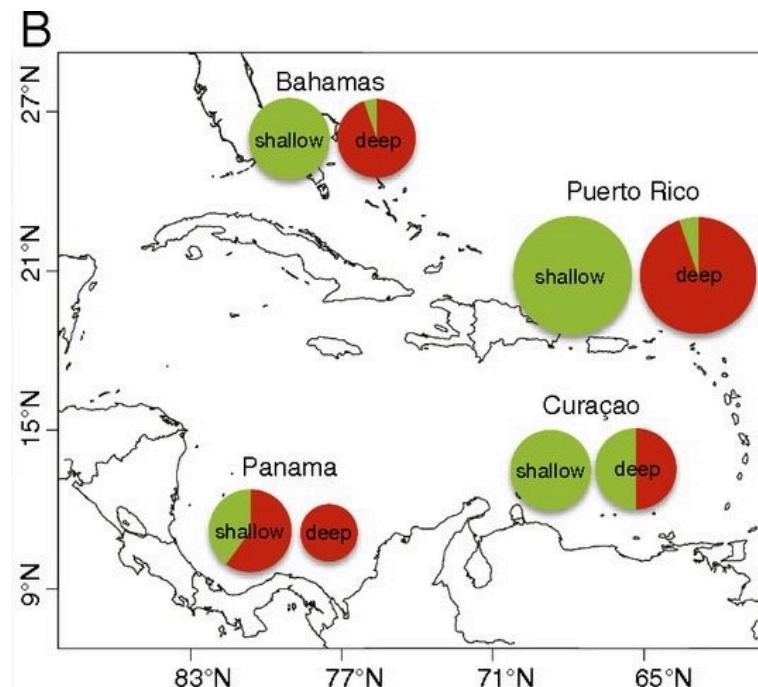
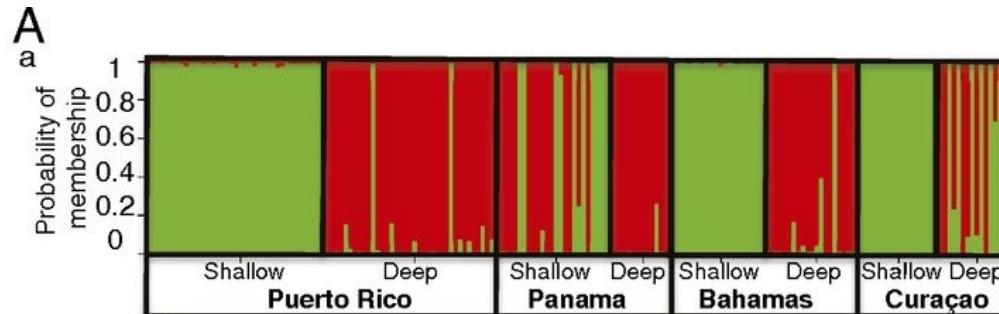
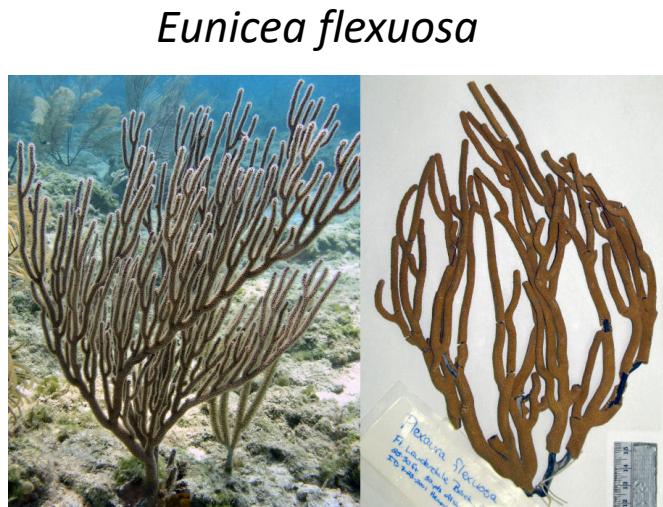


Ecological speciation

- Ecological factors reduce or limit gene flow
- adaptation to different environments or ecological niches leads to speciation

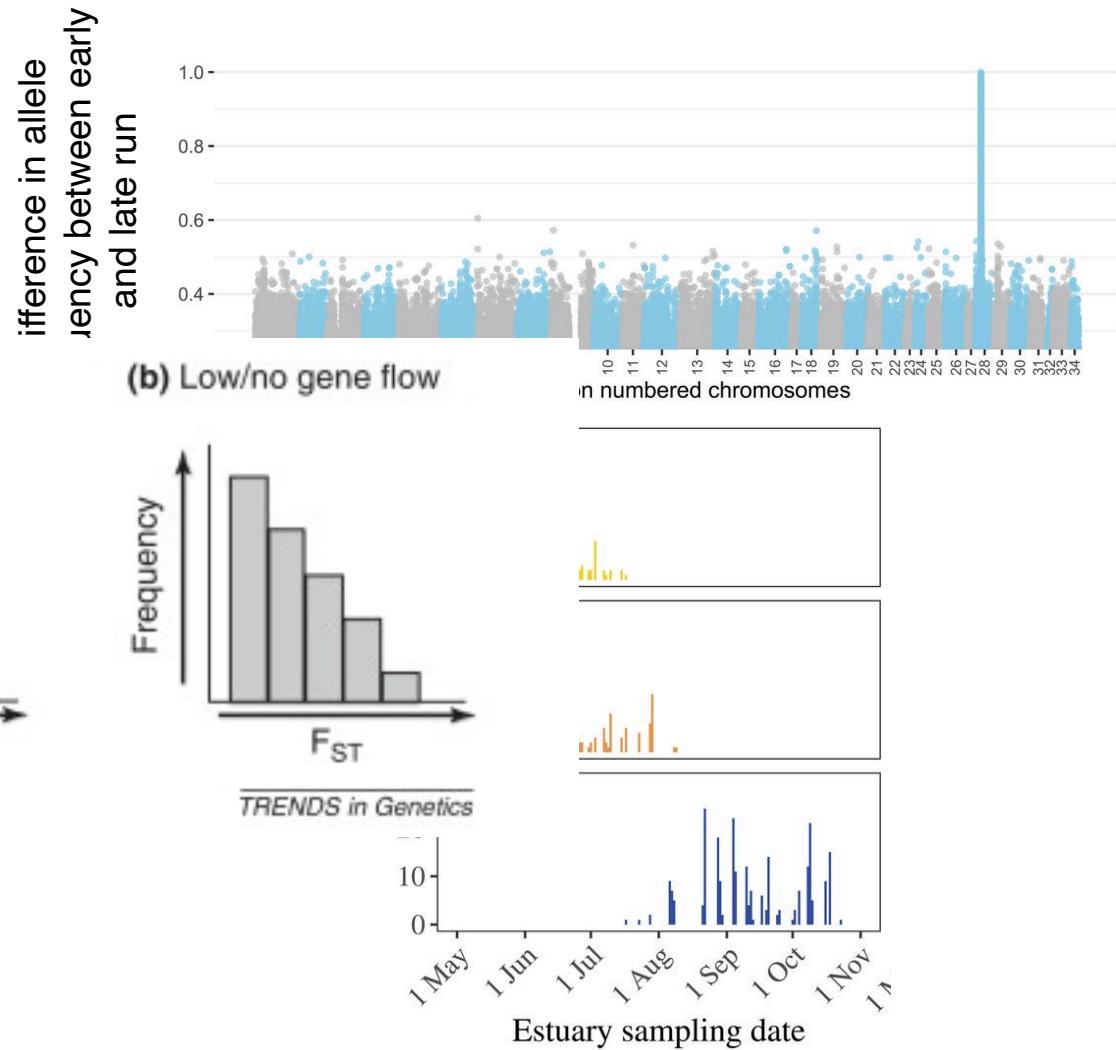
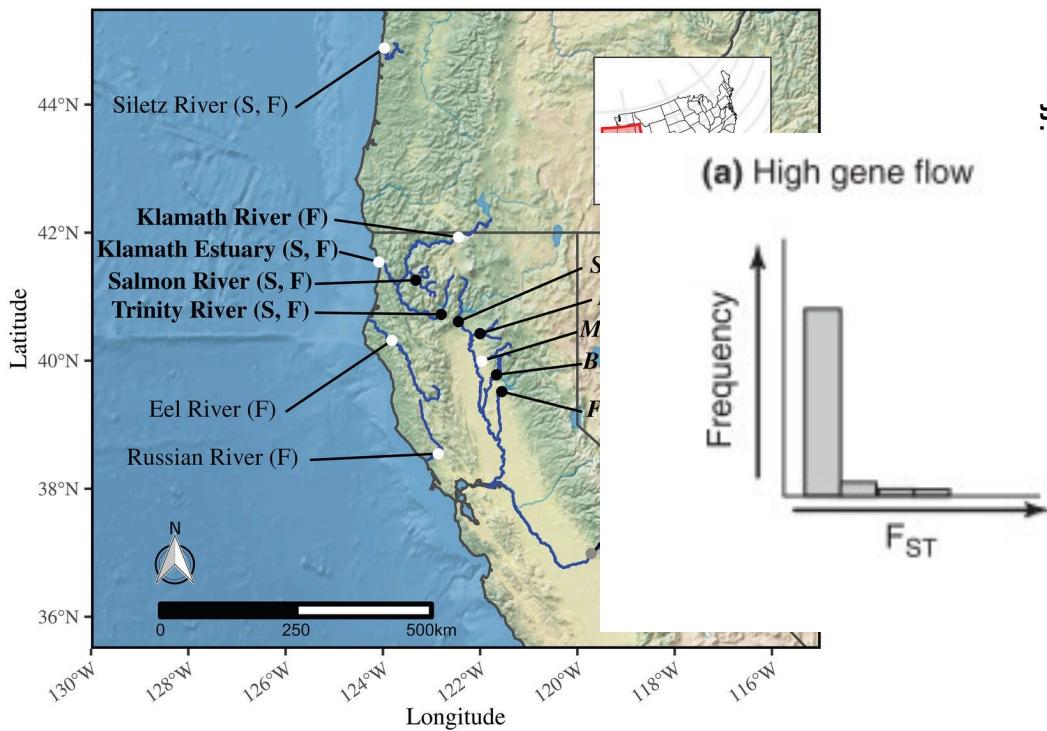
How does speciation occur in the ocean?

- Potential for gene flow may be high, in reality it is likely much lower.
 - Behavioral Limits to dispersal
 - Abiotic limits to dispersal



How does speciation occur in the ocean?

- Speciation with gene flow
 - Genetic differentiation only at specific genomic regions

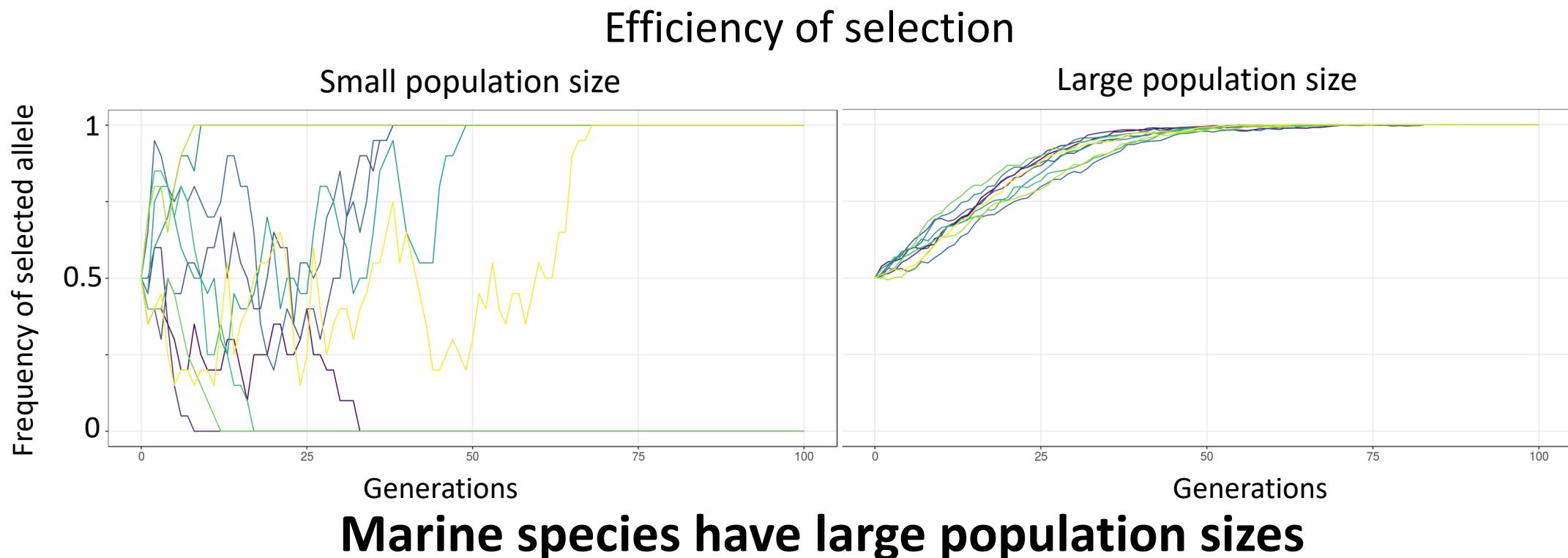


genotype EE EL LL

Thompson et al., 2020

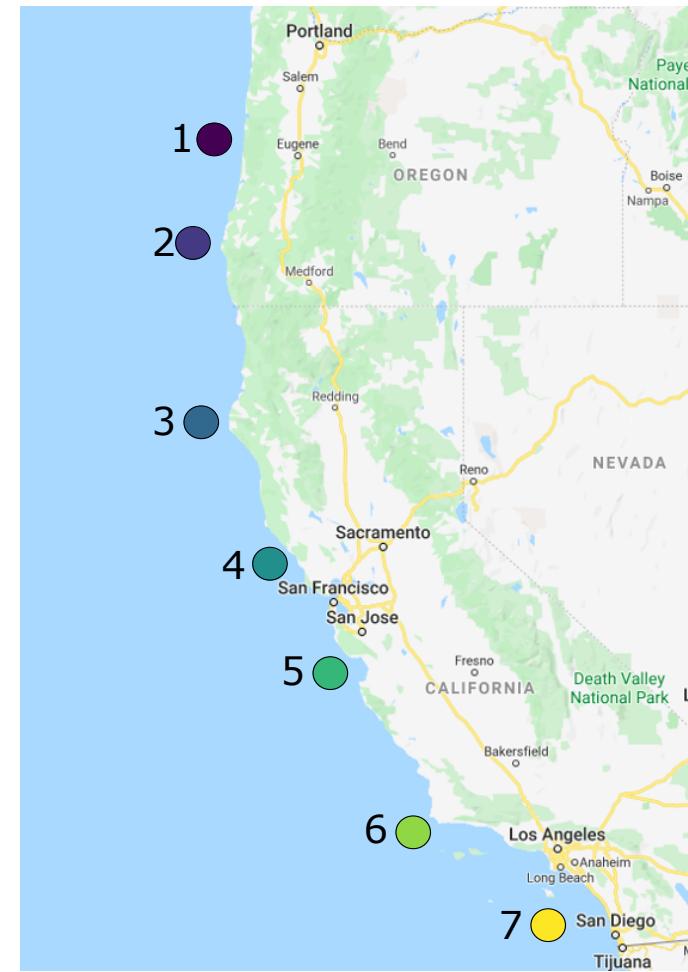
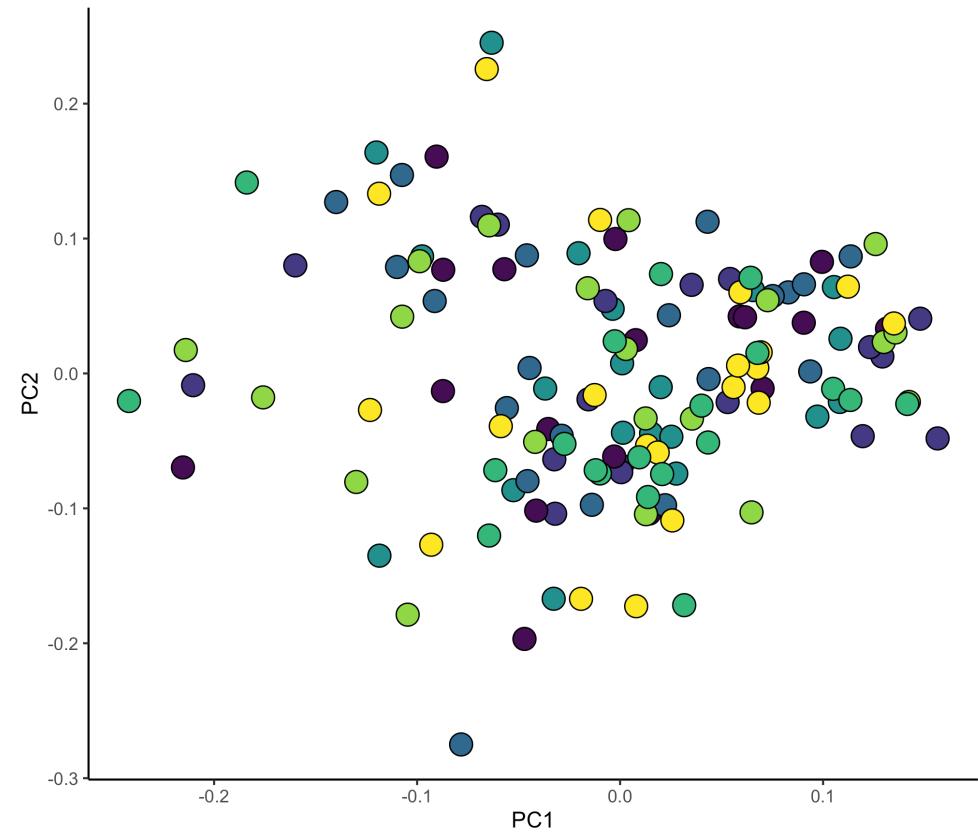
How does speciation occur in the ocean?

- Is speciation with gene flow more common in marine species?
 - Probably....
- Genomic resistance to gene flow
 - Strong selection



How does speciation occur in the ocean?

- There are a diversity of mechanisms of speciation in the sea
- Unique biology of marine organisms pose a challenge to principles that have been developed in terrestrial systems.
 - High gene flow, high population sizes
- Speciation with gene flow is likely common



How does speciation occur in the ocean?

- Speciation with gene flow
 - Development of reproductive isolation

Reproductive isolation due to divergence of gamete recognition proteins.

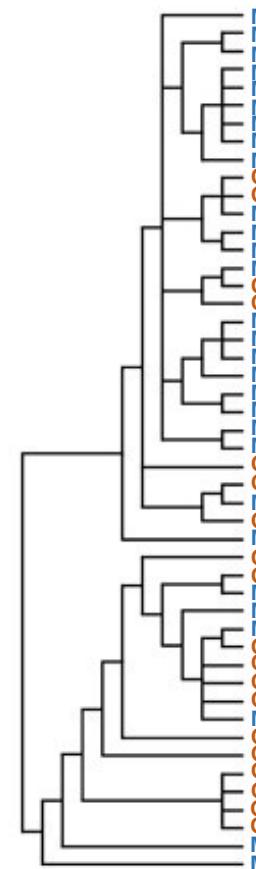


Echinometra mathaei

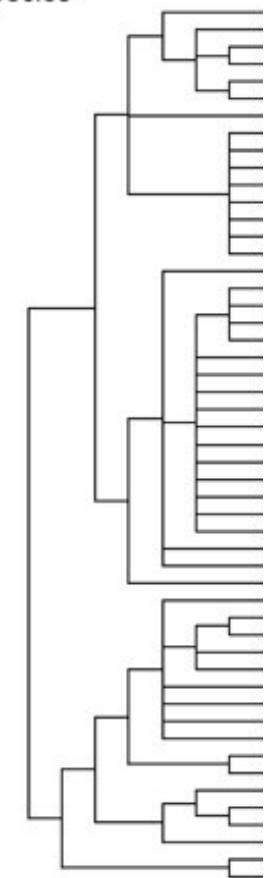


Echinometra oblonga

tRNA-deacylase
highly polyphyletic



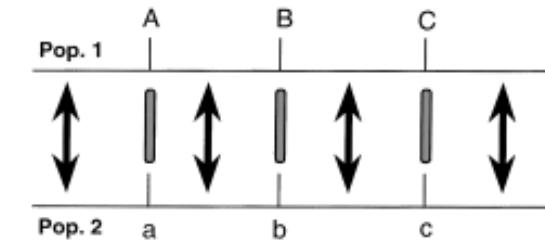
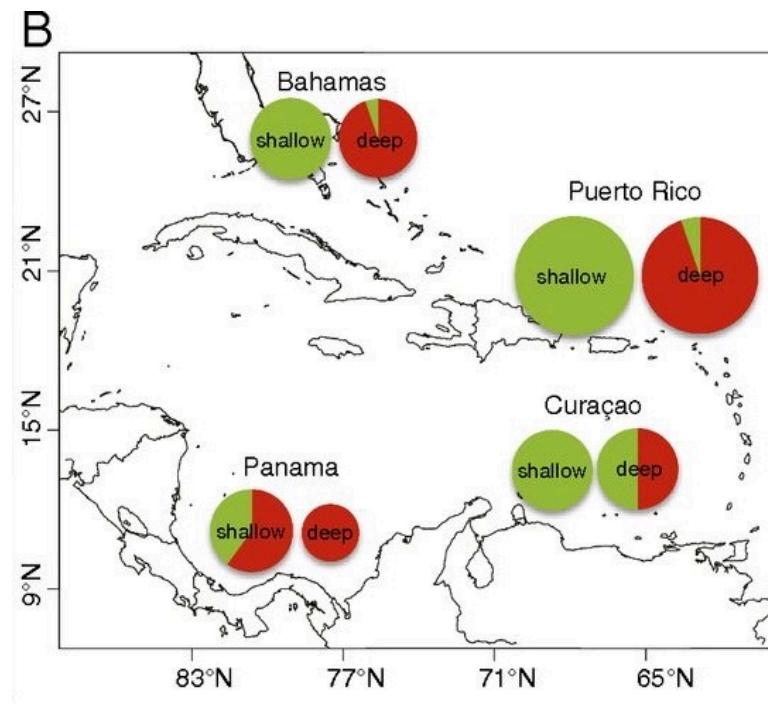
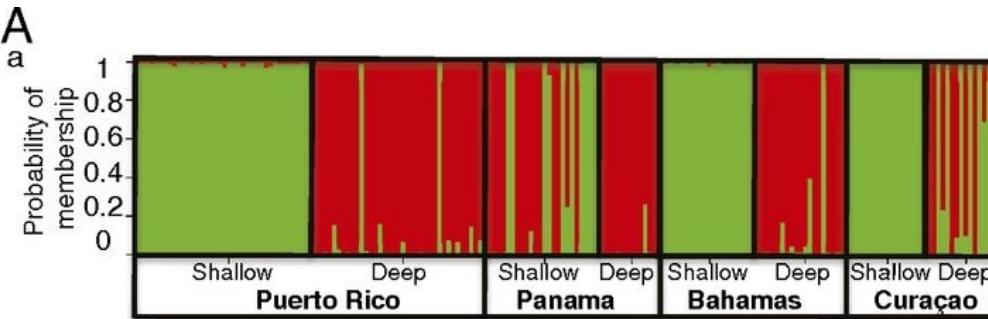
Bindin is reciprocally
monophyletic between
species



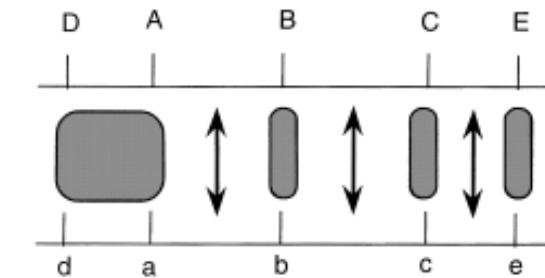
Palumbi 2008

Genomic divergence during speciation: Islands

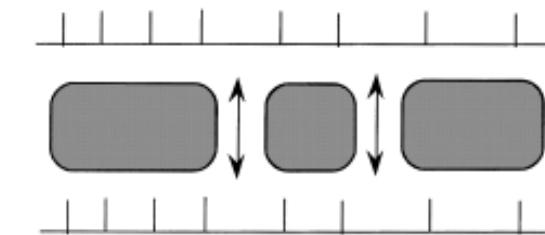
- Geneflow must be inhibited



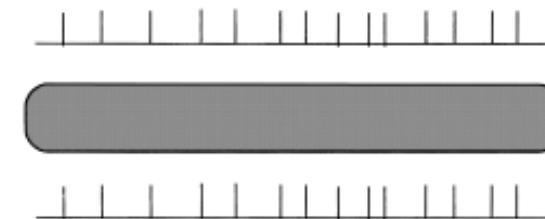
Stage I –
Populations/races with
differential adaptation;
RI not apparent.
3 divergent loci shown
here.



Stage II –
Transition between race and
species with some degree of RI;
populations may fuse or diverge.



Stage III –
Divergent populations beyond
the point of fusion but still share
a portion of their genomes via
gene flow; good species.



Stage IV –
Species with complete RI.

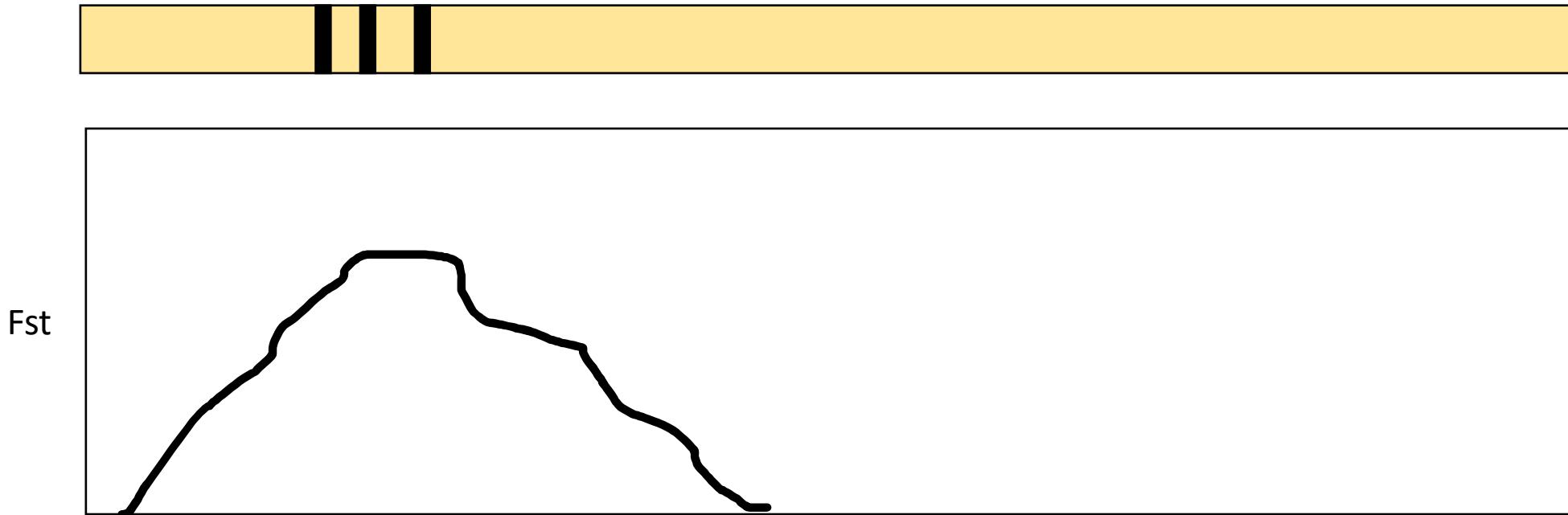
Phase 1: Adaptive divergence at a subset of the genome

Gene underlying adaptation



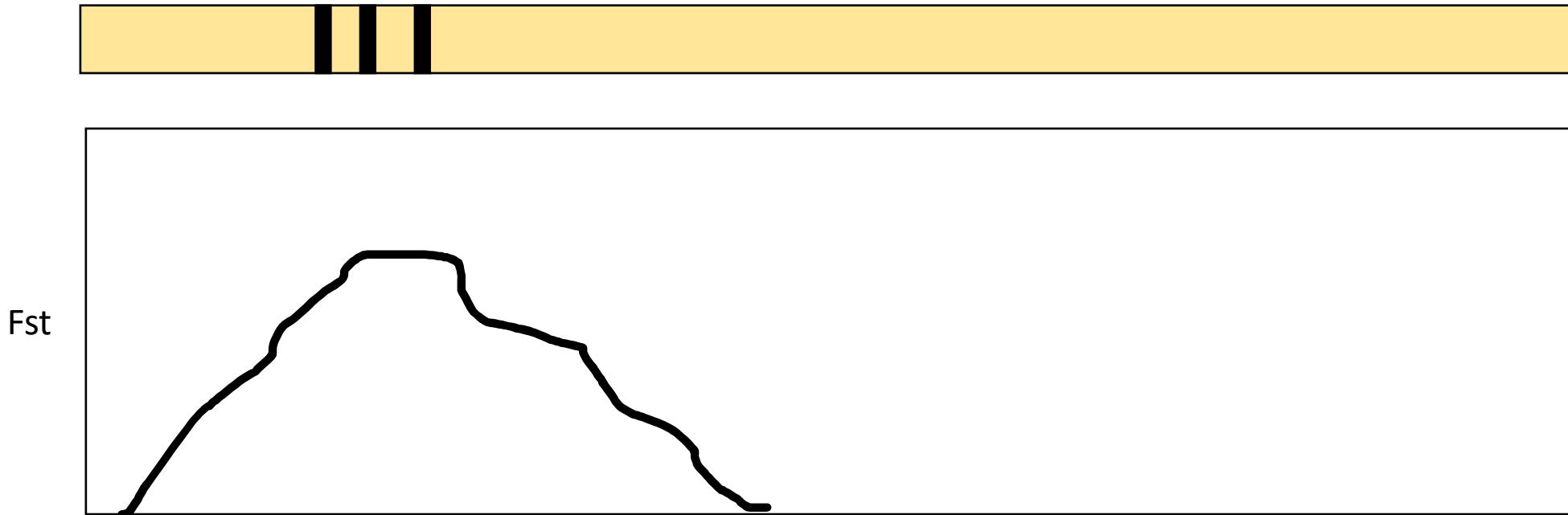
Phase 2: Divergence hitchhiking

Gene underlying adaptation

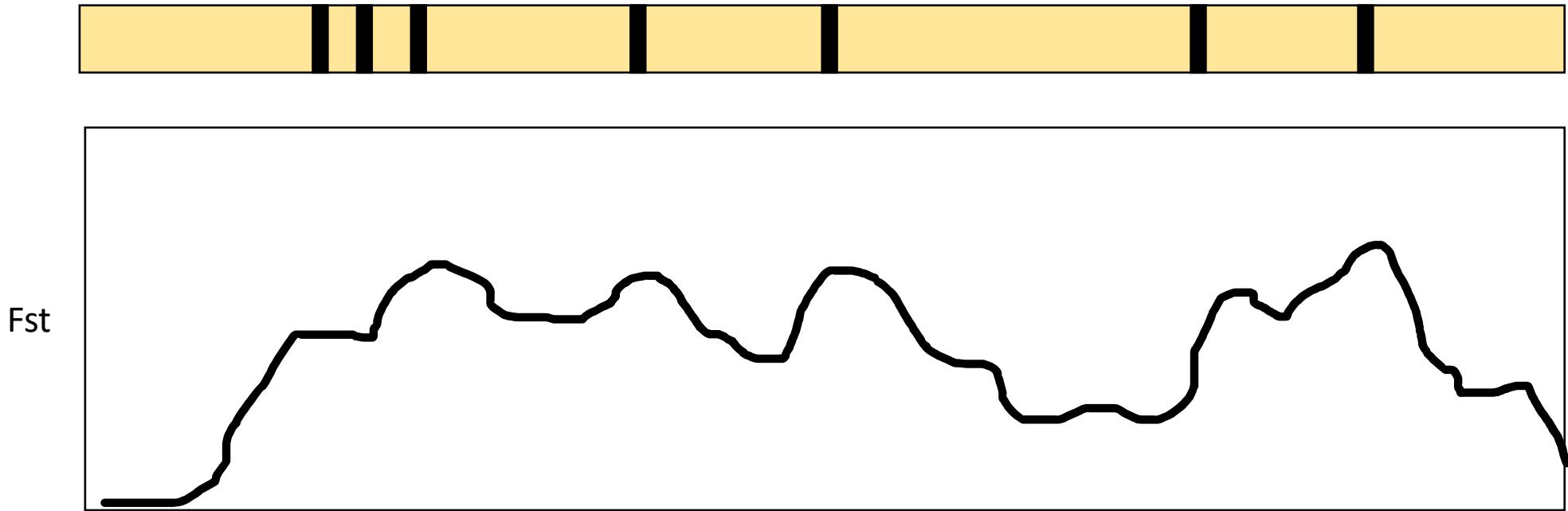


Phase 2: Divergence hitchhiking → inversions

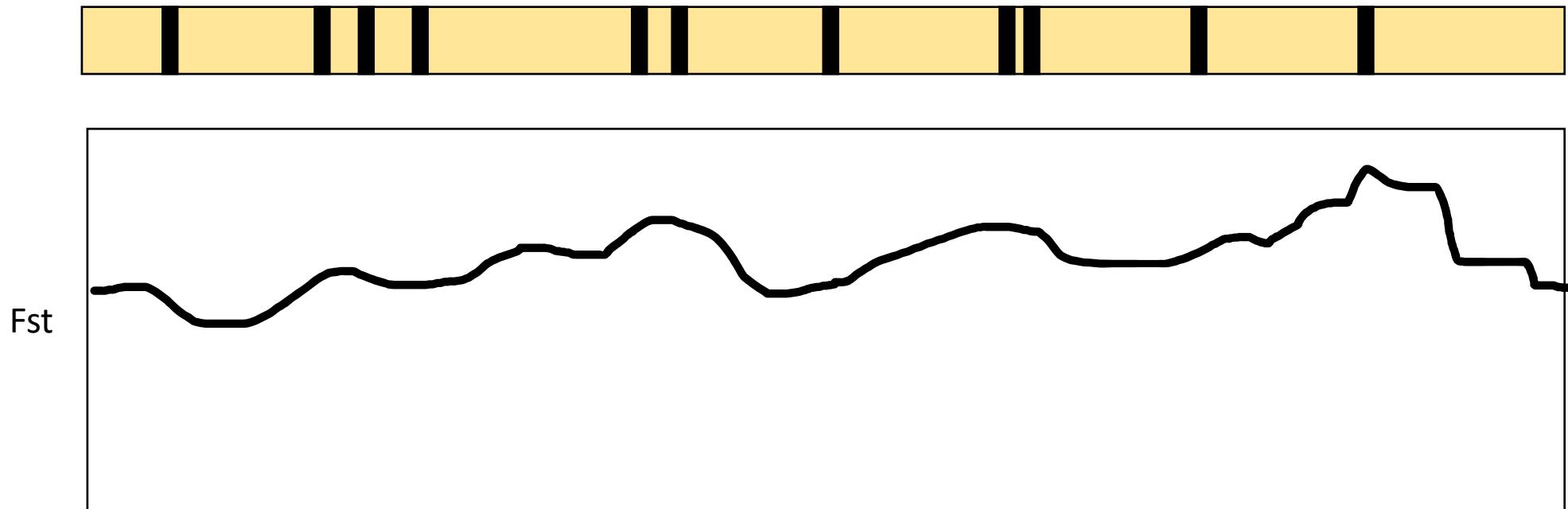
Inversions link multiple adaptive alleles



Phase 3: Genome hitchhiking

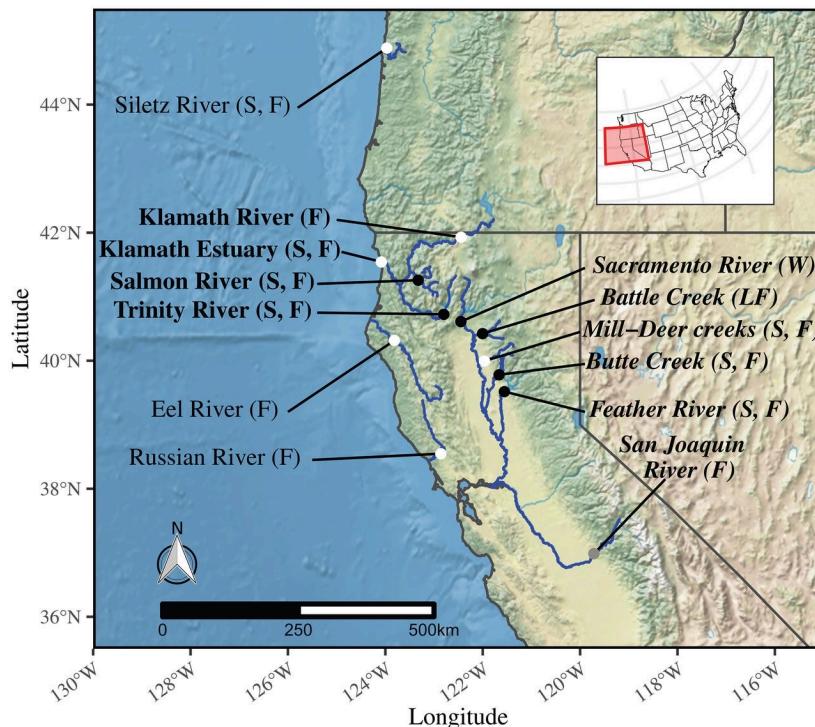


Phase 4: Speciation and genome-wide divergence

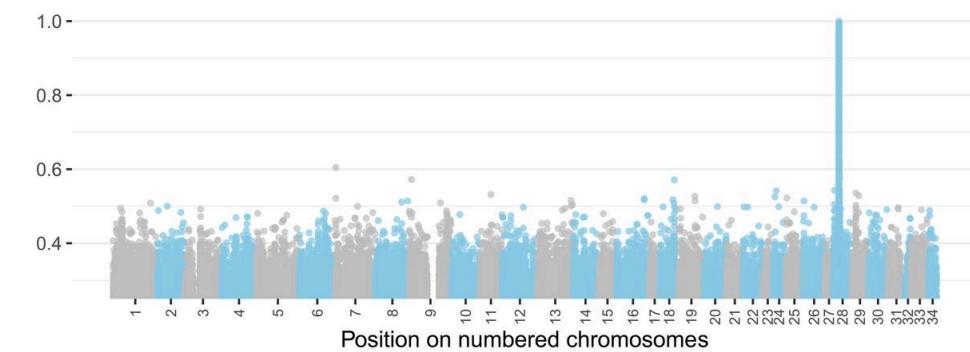


Phase 1:

Gene underlying adaptation



Difference in allele frequency between early and late run

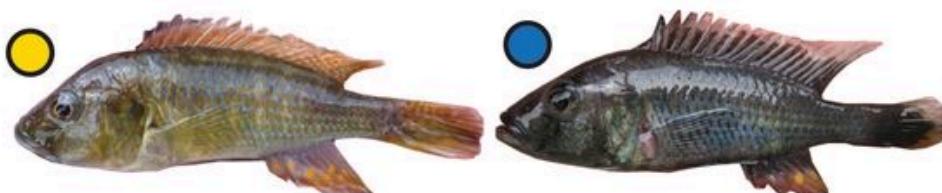


Phase 1:

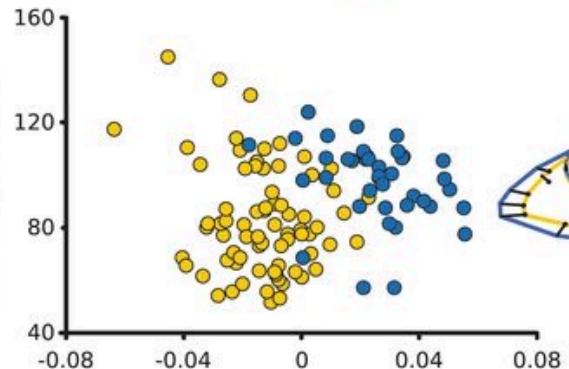
Gene underlying adaptation



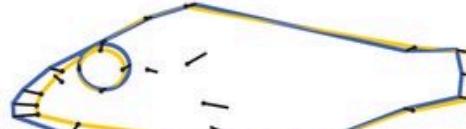
B



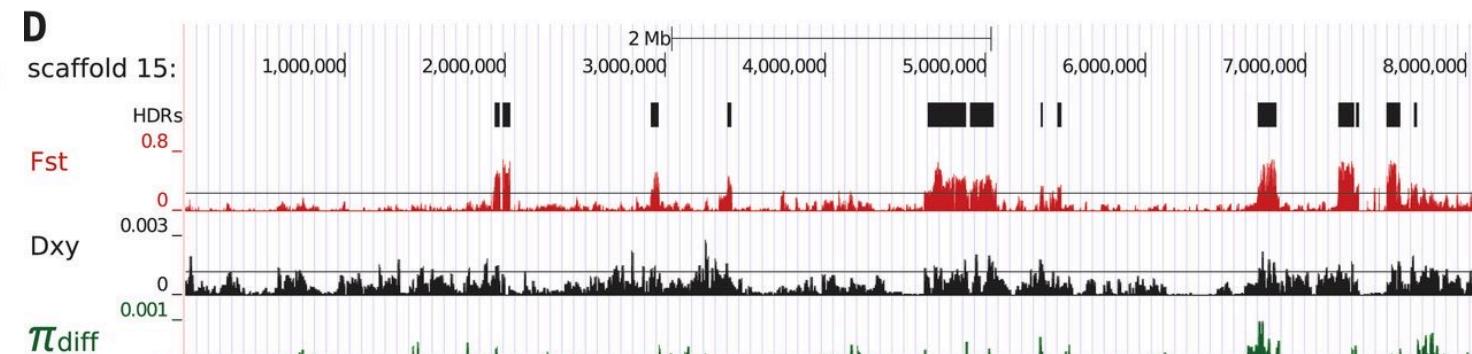
C Total length (mm)



Principal component axis 1 (29.7% of shape variation)

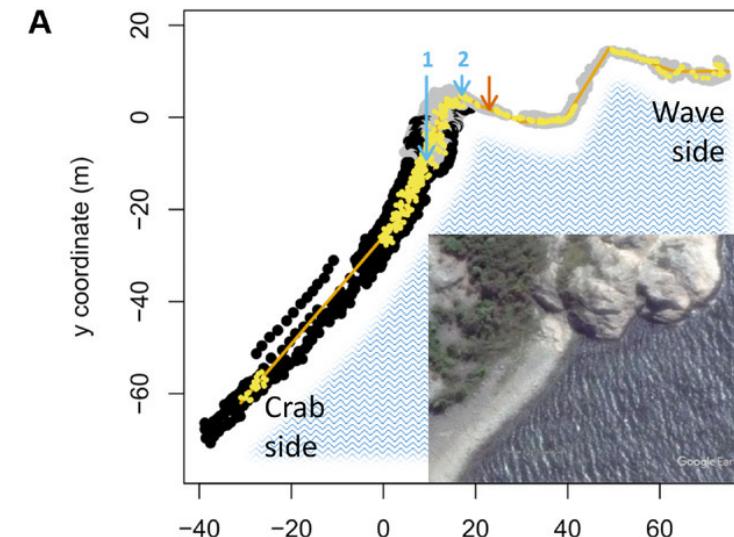
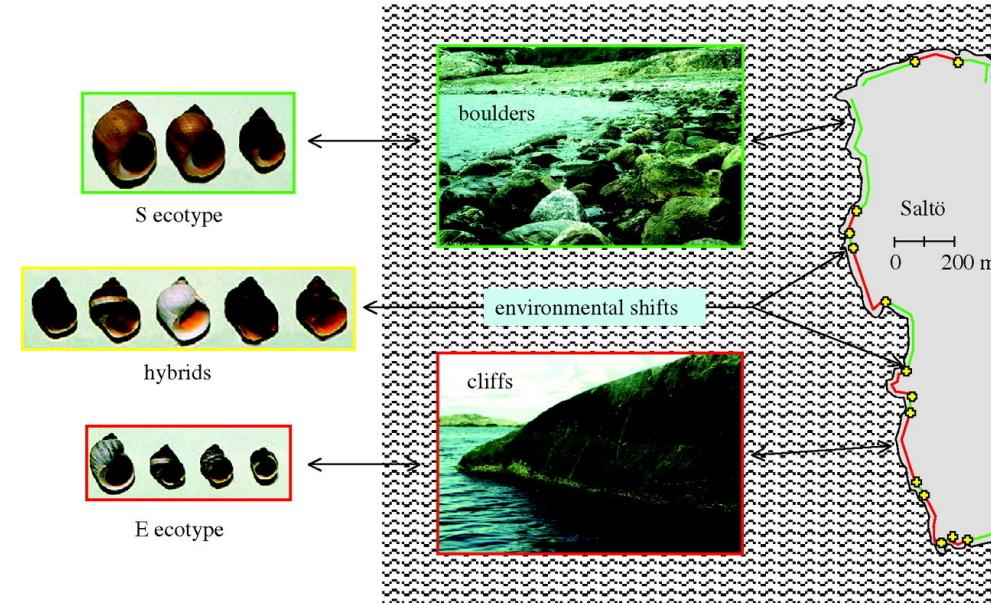
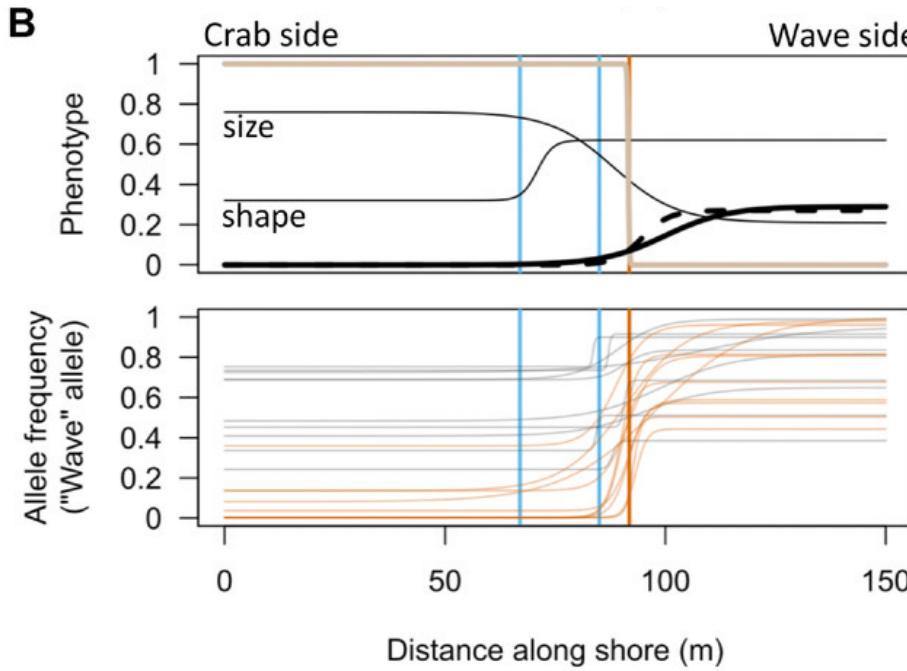


D



Hybridization as natural experiments

- *Littorina saxatilis*



Paper for next week

RESEARCH ARTICLE | BIOLOGICAL SCIENCES | 



Extraordinarily rapid speciation in a marine fish

Paolo Momigliano , Henri Jokinen, Antoine Fraimout,  , and Juha Merilä [Authors Info & Affiliations](#)