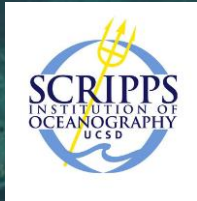


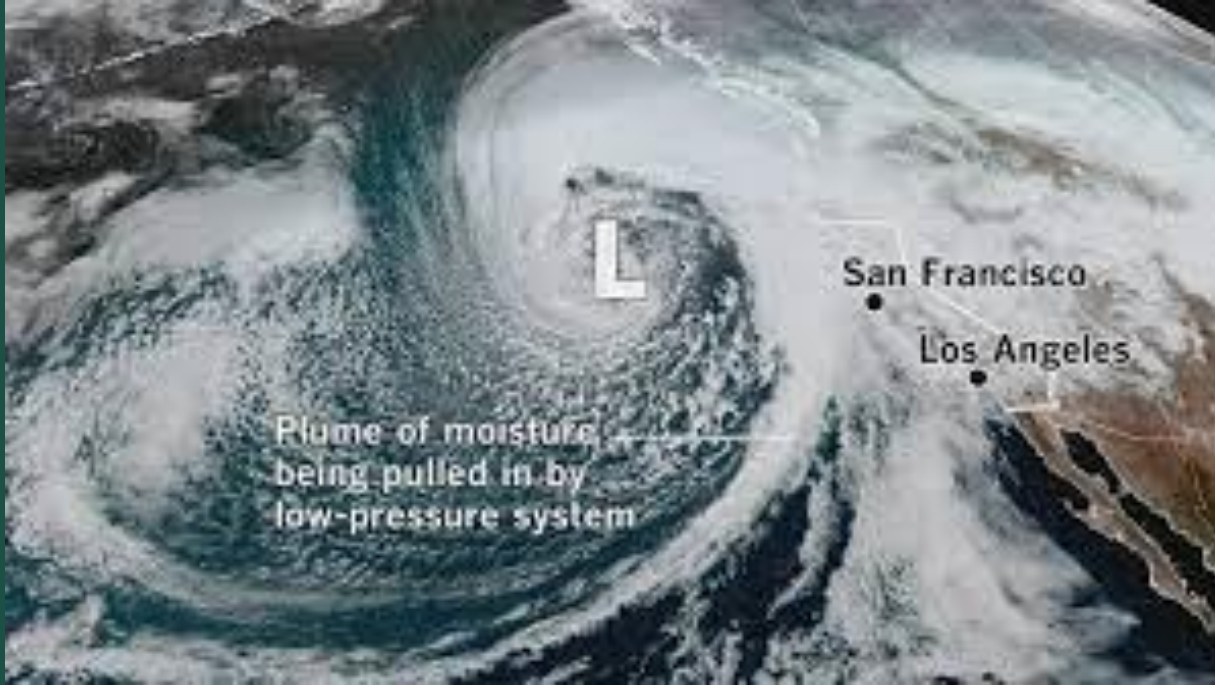
The role of climate in driving population synchrony among fishes of the Salish Sea

Dan A. Greenberg^{1,2,3}, Christy V. Pattengill-Semmens¹,
Brice X. Semmens²

¹Reef Environmental Education Foundation, ²Scripps Institution of Oceanography, ³Fisheries and Oceans Canada



4 days ago back home...



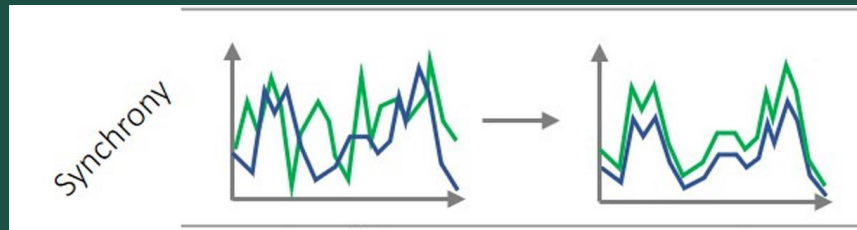
Synchrony in Marine Systems



- Long-term studies consistently show that climate variation is a predominant driver of population dynamics
- In turn, many studies have shown that climate can synchronize populations over large spatial extents (ie. Moran effect)
- Less explored -- does climatic variation also synchronize the population dynamics of *co-occurring* species in the same area?

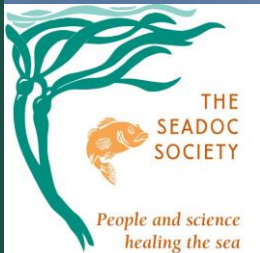
Why might we care?

- When interspecific synchrony is high due to shared drivers (like climate), increased risk of destabilizing ecosystem processes
- It also weakens the portfolio effect that can maintain stability despite higher fluctuations (e.g. multi-species fisheries)



How synchronous are nearshore fish communities in the Salish Sea?

Salish Sea



THE SALISH SEA BY THE NUMBERS

- Coastline length (including islands):
4,642 miles (7,470 km)
- Total number of islands: 419
- Sea surface area: 6,535 square miles
(16,925 square km)
- Maximum sea depth: 2,133 feet
(650 m) at Bute Inlet, BC
- Human population: About 8 million
- Number of animal species:
38 mammals, 172 birds, 253 fish,
2 reptiles, and more than 3,000
macroinvertebrates (creatures without
backbones that you can see without
a microscope)



A role for citizen science data?



Citizen science programs are amassing biodiversity for a vast number of Earth's coastal ecosystems

These datasets may be critical to unveiling the changing state of our coastal ecosystems and the fate of species

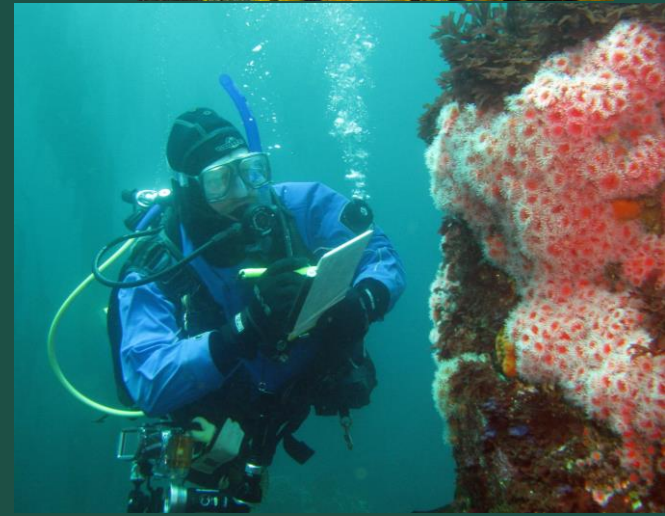
REEF Volunteer Fish Survey Project



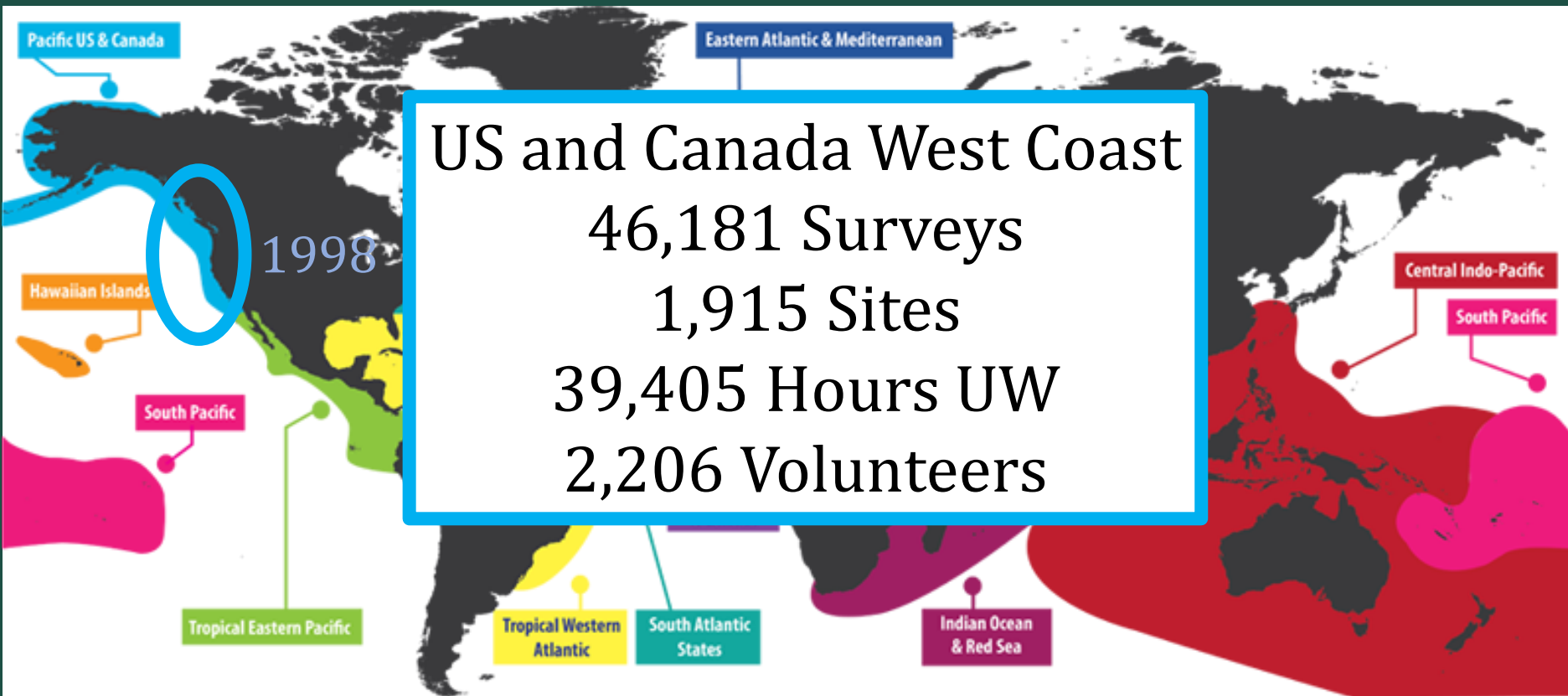
Started 1993 in Key Largo, Florida, USA

Roving Diver surveys

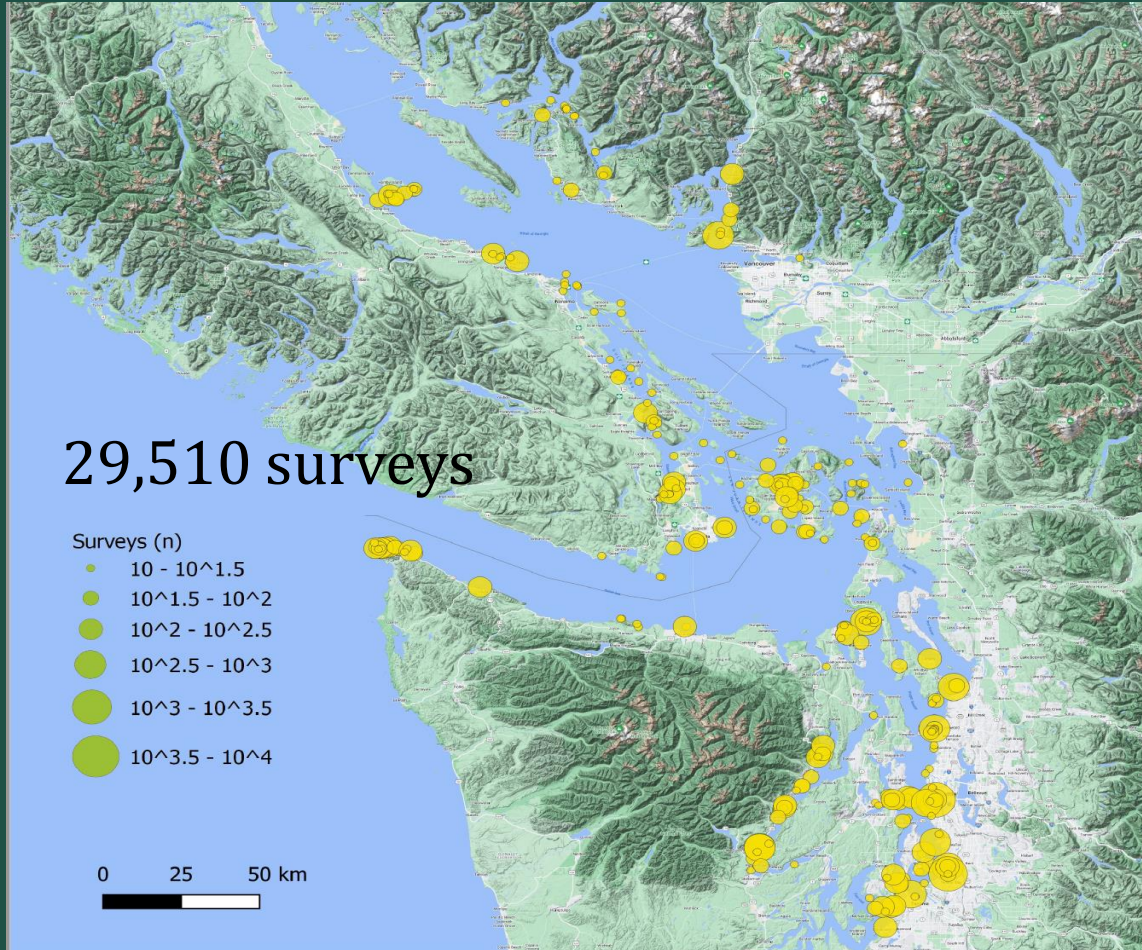
- Non-point method, free swimming range around site
- Divers, snorkelers, anytime and anywhere in survey regions
- Record all fish species and a set list of invertebrates and algae
- Estimate relative abundance for each species
 - Single (S) - 1
 - Few (F) – 2-10
 - Many (M) – 11-100
 - Abundant (A) - >100
- Submit sightings and metadata through online portal
- Automated and manual error checking before uploading
- Database publicly accessible www.REEF.org



Volunteer Fish Survey Project Regions



REEF Effort in the Salish Sea



How are nearshore fish communities changing in the Salish Sea?

Are populations of related species fluctuating synchronously?

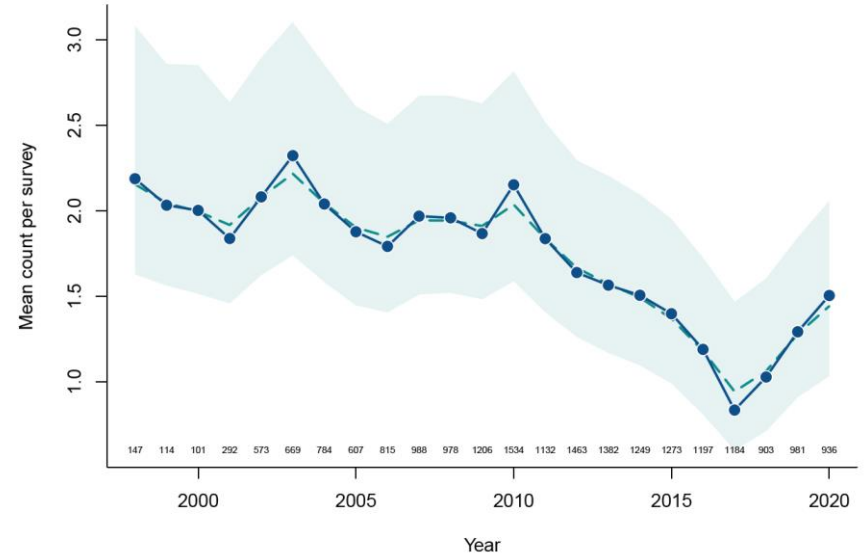


Two examples of single population trajectories from REEF data

Lingcod, Salish Sea



Kelp Greenling, Salish Sea



Here we combine in a single analysis, and estimate correlation in yearly changes...

How do we use REEF data to model regional abundance?

Abundance (A) = 0, 1, 2-10, 11-100, 100+

$P(0), P(1), P(2 - 10), P(11- 100), P(100+)$

$$P(A) \sim \text{Ordinal}(\alpha_t + \alpha_h + \alpha_s + \alpha_d + \alpha_c + \alpha_c + \beta X_i)$$

Year	Habitat	Site	Diver	Temp. day cluster	Temp. month cluster	Depth Effort Detection Expert
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$$\begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix}_t = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}_t + \begin{bmatrix} \tau_1 \\ \tau_2 \end{bmatrix}_t$$

$$x_{1,t} = x_{1,t-1} + \varepsilon_{1,t}$$

$$x_{2,t} = x_{2,t-1} + \varepsilon_{2,t}$$

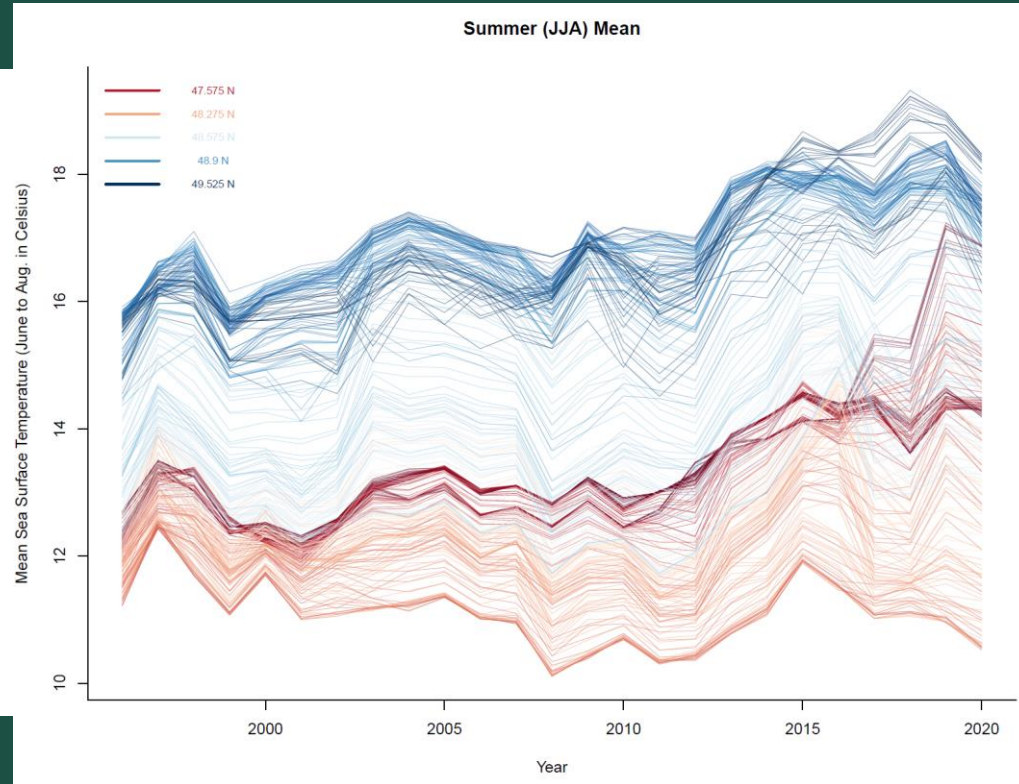
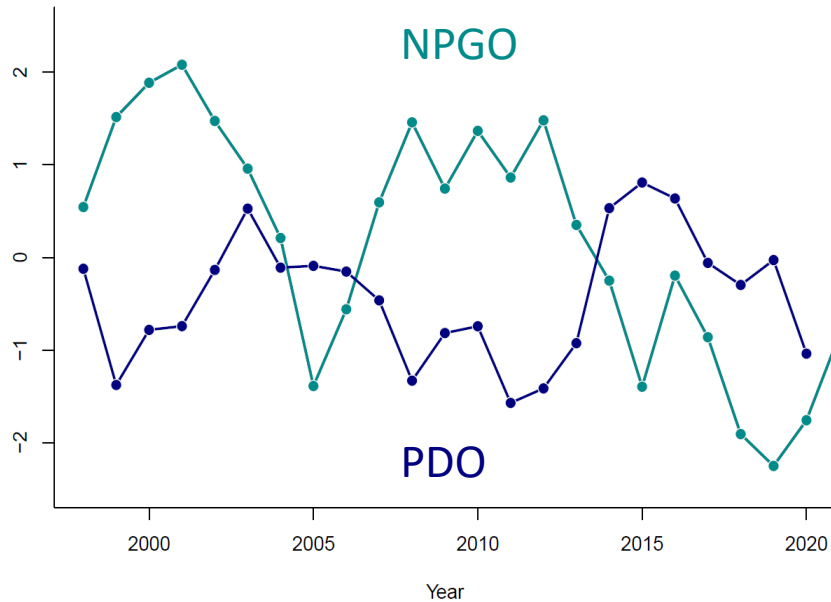
$$\varepsilon_{1:J,t} \sim \text{MVN}(0, J)$$

$$J = \begin{bmatrix} q_1 & q_1 q_2 \rho \\ q_1 q_2 \rho & q_2 \end{bmatrix}$$

What climatic signals to consider?

Local Sea Surface Temperature

Oceanic climate indices



Surfperch ($N = 4$)



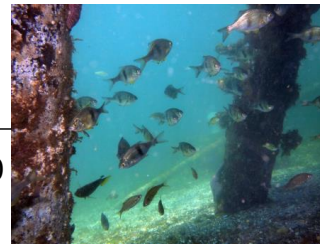
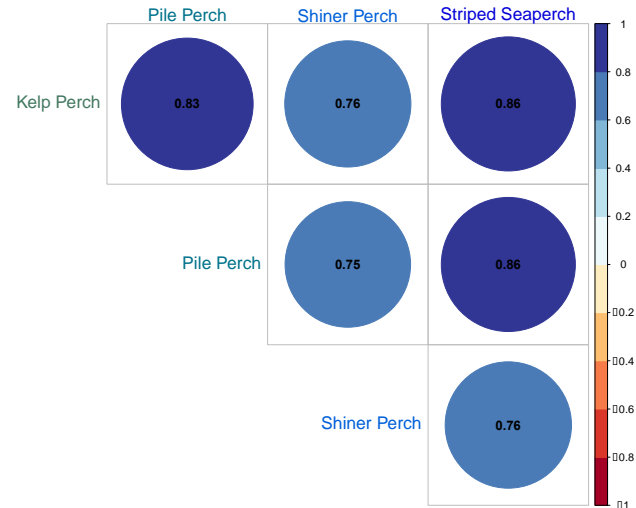
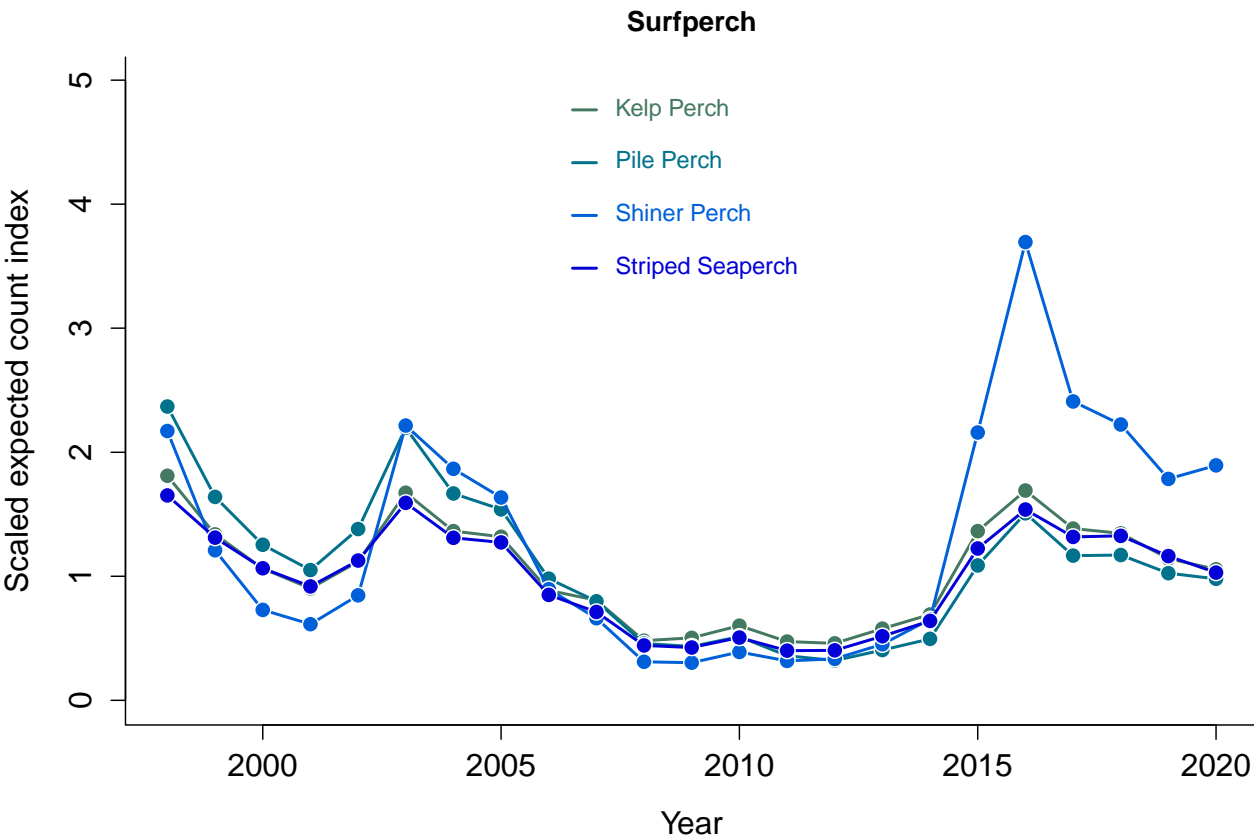
Rockfish ($N = 5$)

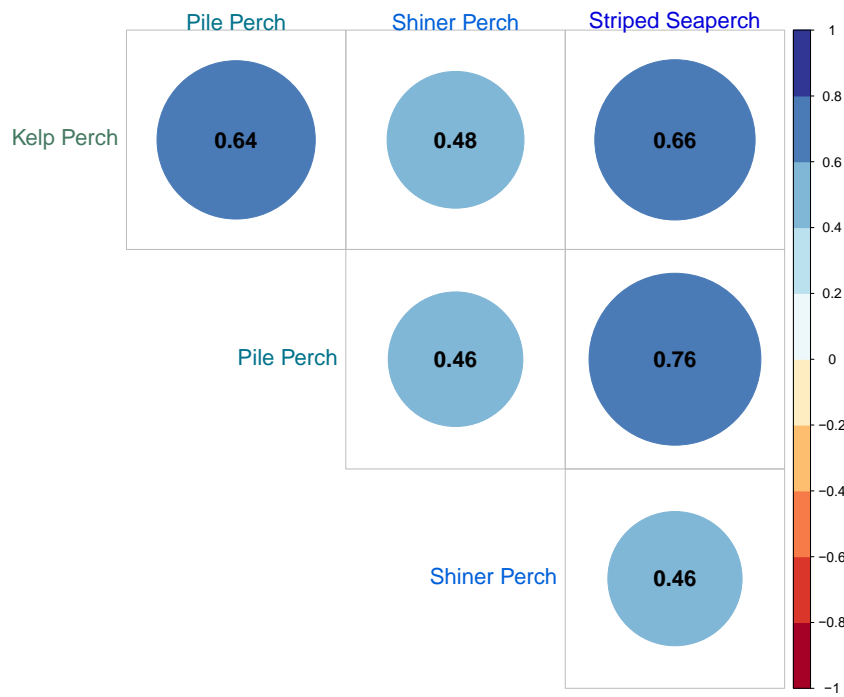
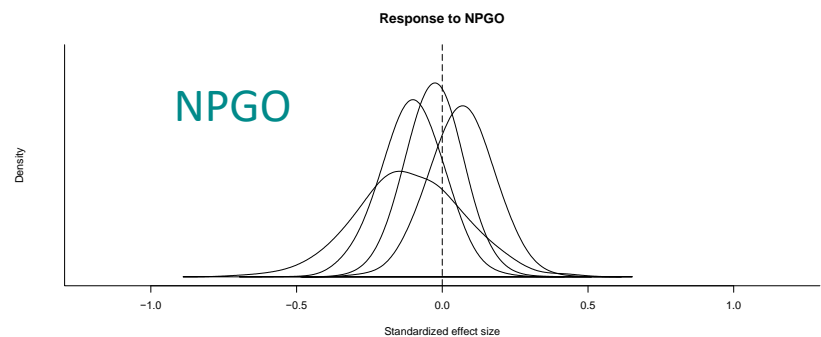
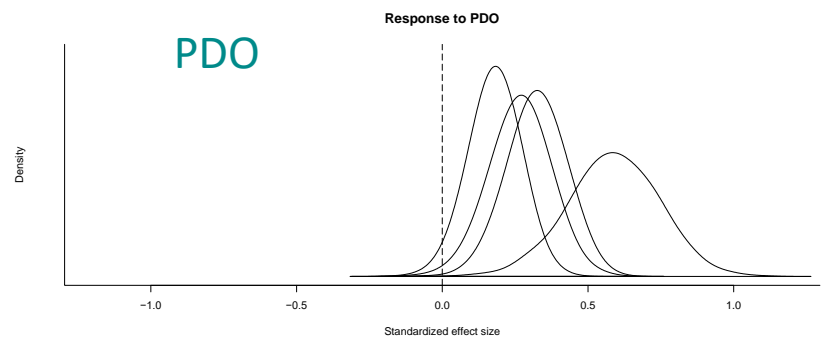
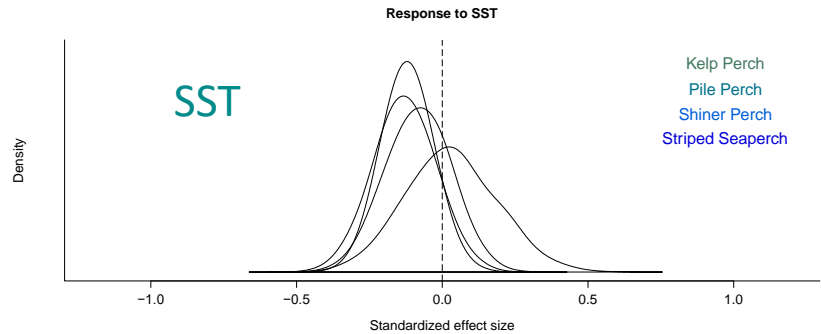


Greenling ($N = 4$)

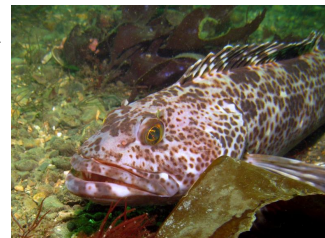
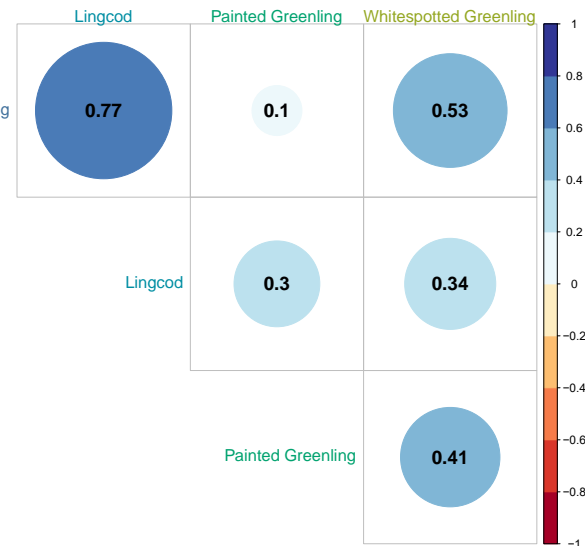
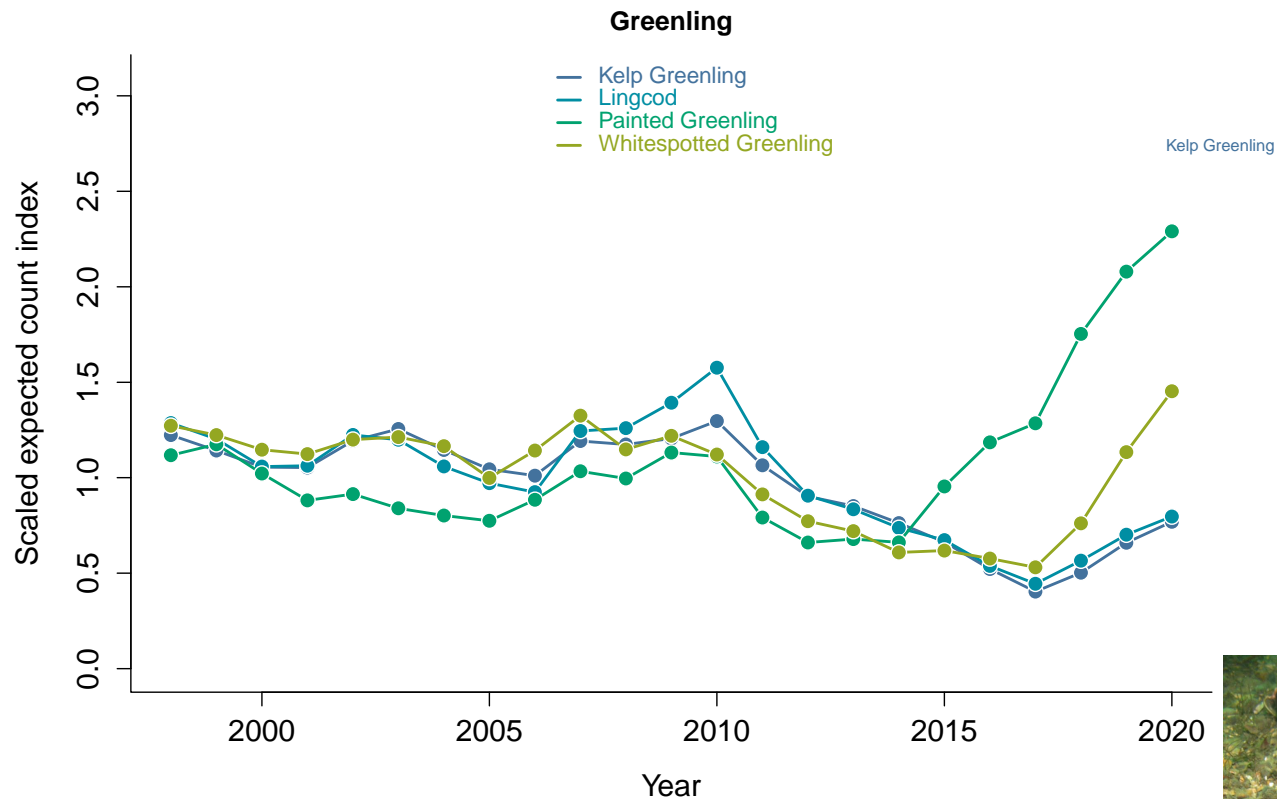


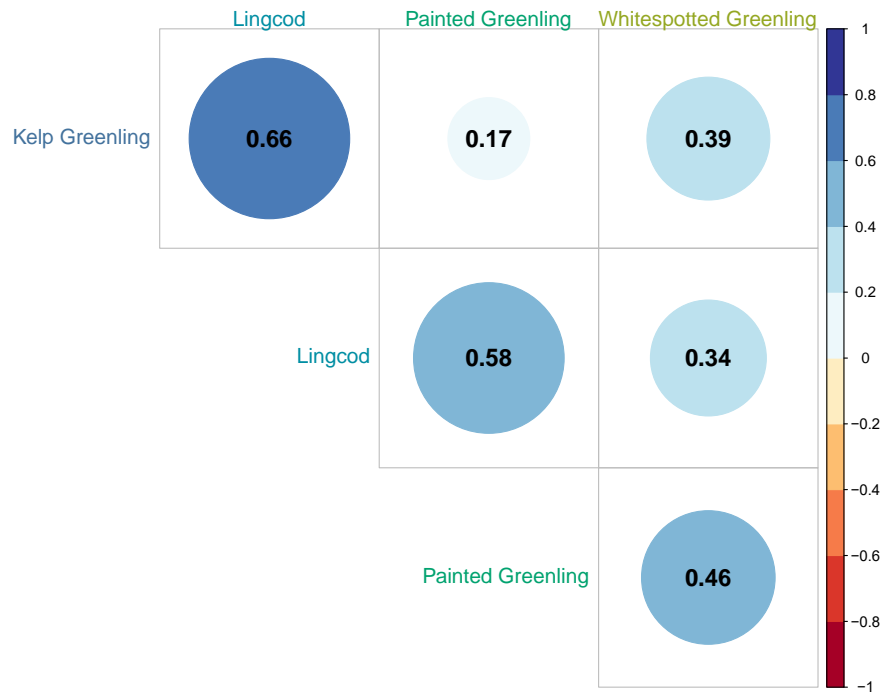
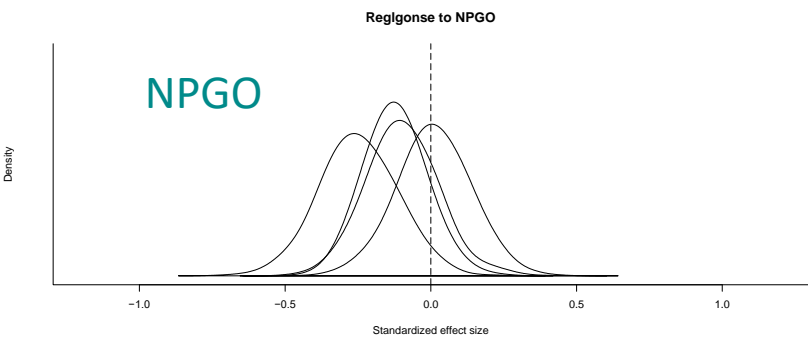
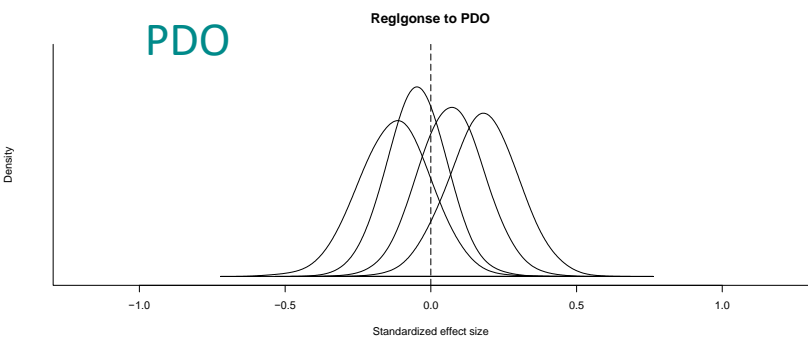
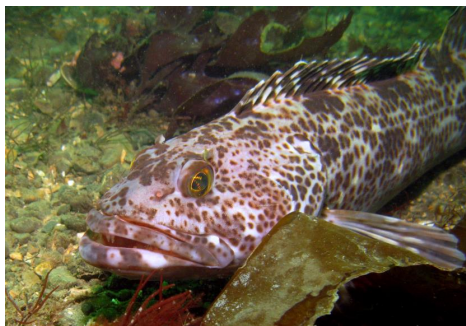
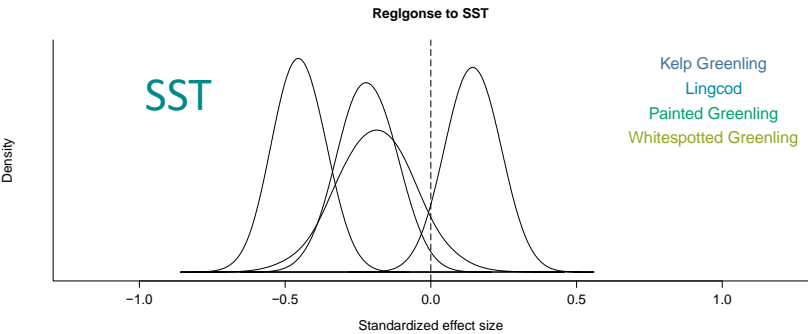
Surfperch (Embiotocidae)





Greenling (Hexagrammidae)

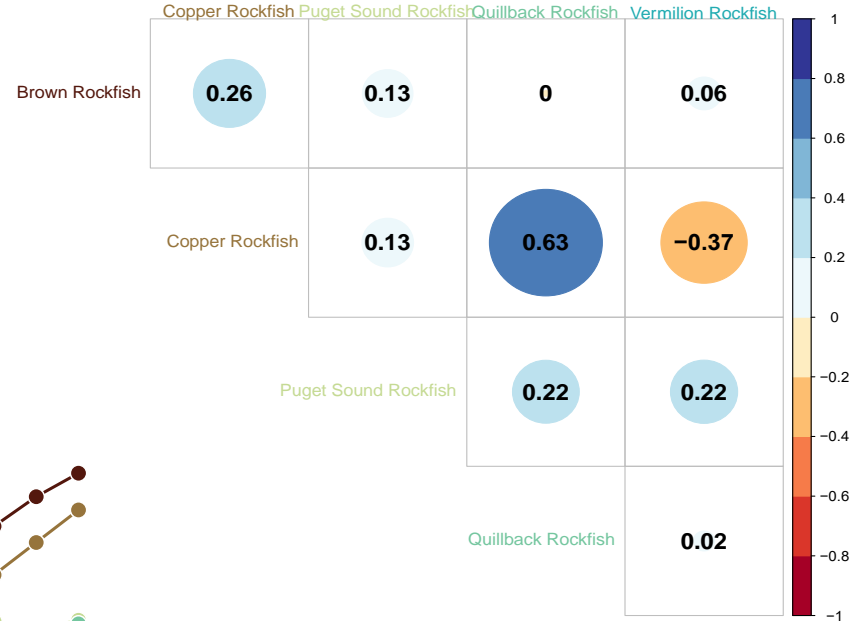


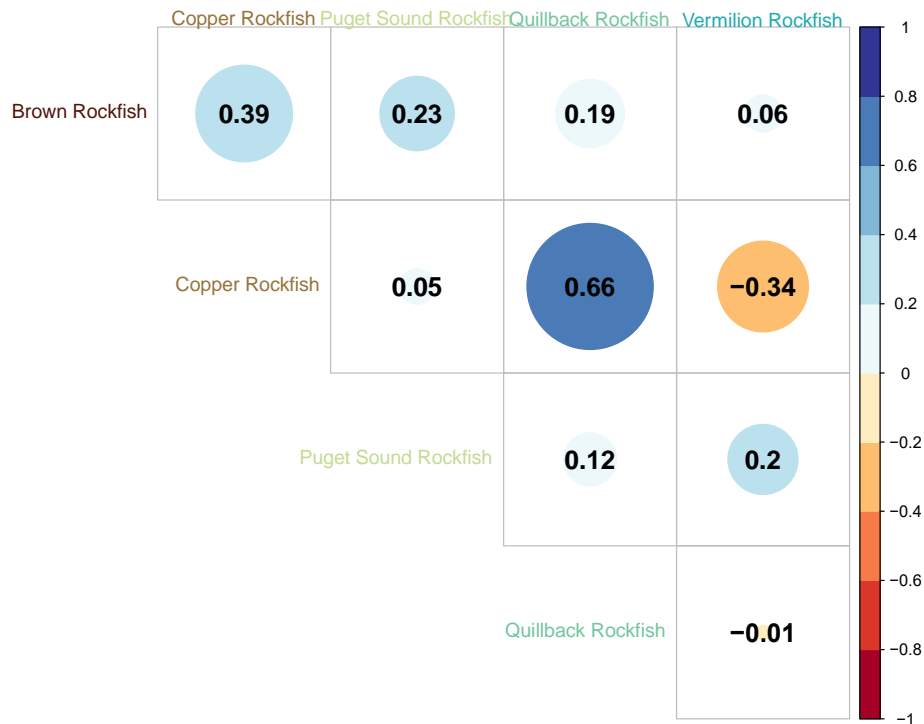
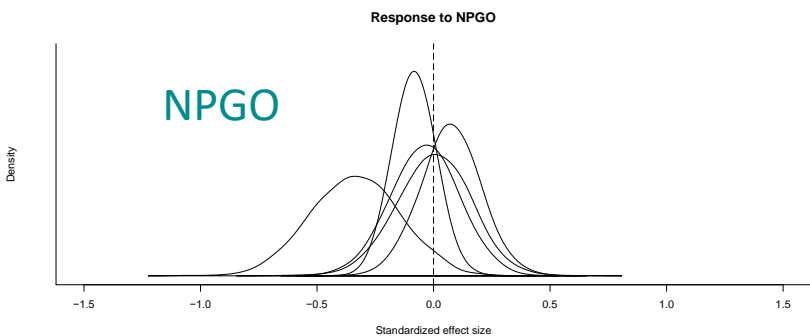
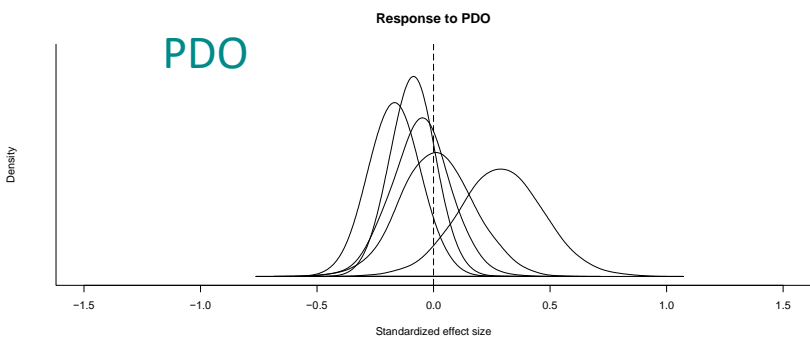
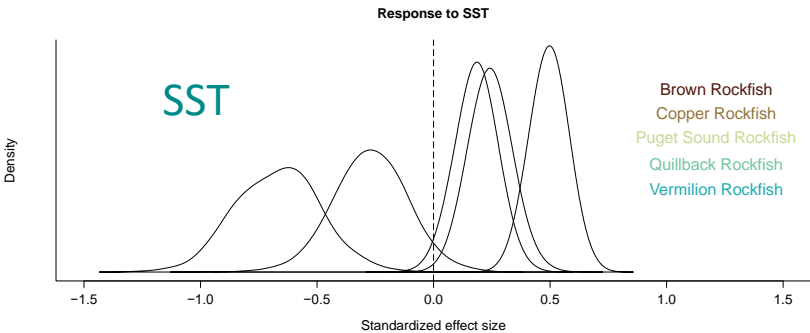


Rockfish (Sebastidae)

Rockfish

- Brown Rockfish
- Copper Rockfish
- Puget Sound Rockfish
- Quillback Rockfish
- Vermilion Rockfish





Concluding Thoughts



- Strong synchrony between species within families (mostly)
- Even families with ecologically disparate members show synchrony
- Climate variables account for only some of this synchrony
- Rockfishes, however, don't play by the rules here. Which is probably a very good thing.

Acknowledgments

A diver in a black wetsuit and a blue and black diving mask is underwater. The diver is holding a clipboard with a white sheet of paper and looking at it. The background is filled with brown and green seaweed. The water is clear and blue.

Joseph K. Gaydos and The Seadoc Society

The Lenstra Fund

And the
thousands of REEF volunteers who contributed to this
dataset