Apr 27th, 1:30 PM - 3:00 PM

Sea urchin populations in the Salish Sea: recent findings regarding invertebrates that support a prized fishery and play an important role in nearshore ecosystems.

Helen Berry

Dr. Daniel Okamoto

Dr. Ole Shelton

Taylor Frierson

Cynthia Catton

Sea Urchin Populations in the Salish Sea

Panel Discussion with

- Helen Berry (host)
- Daniel Okamoto
- Ole Shelton
- Taylor Frierson
- Cynthia Catton (facilitator)

SSEC 2022

Wednesday, 1:30 – 3:00

Photo credit: WDFW

Sea urchin barrens and the recovery of kelp forests in British Columbia

Daniel K. Okamoto

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Department of Biological Science
Florida State University

26 April, 2022

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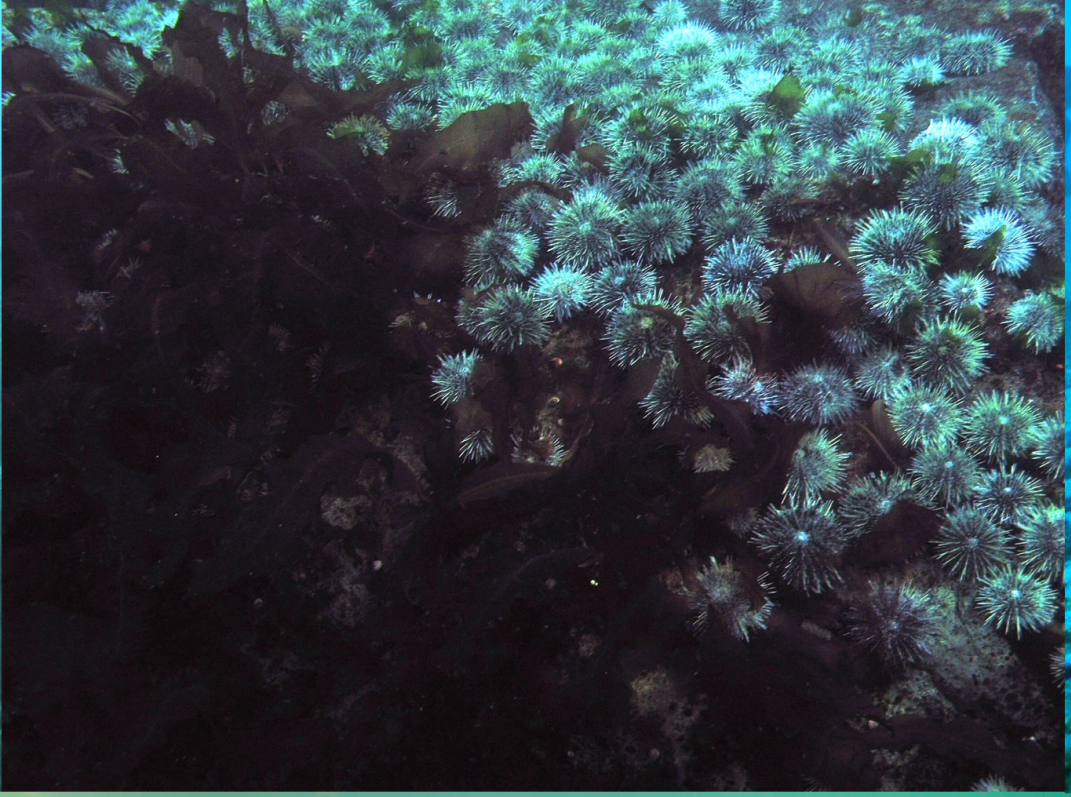
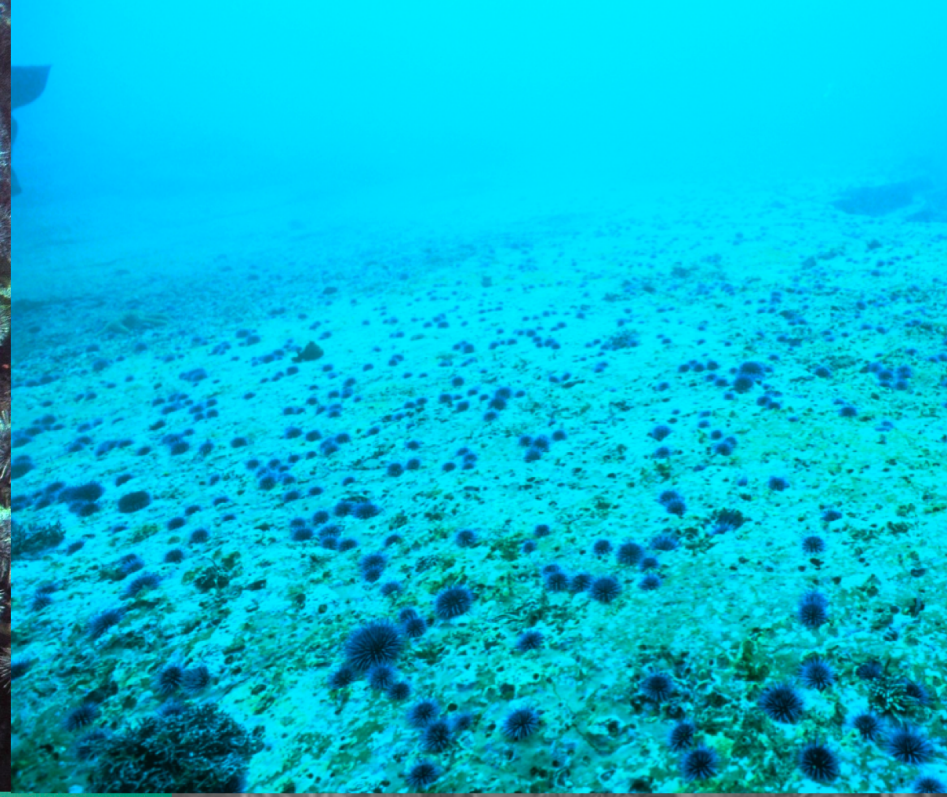
PRO DRY





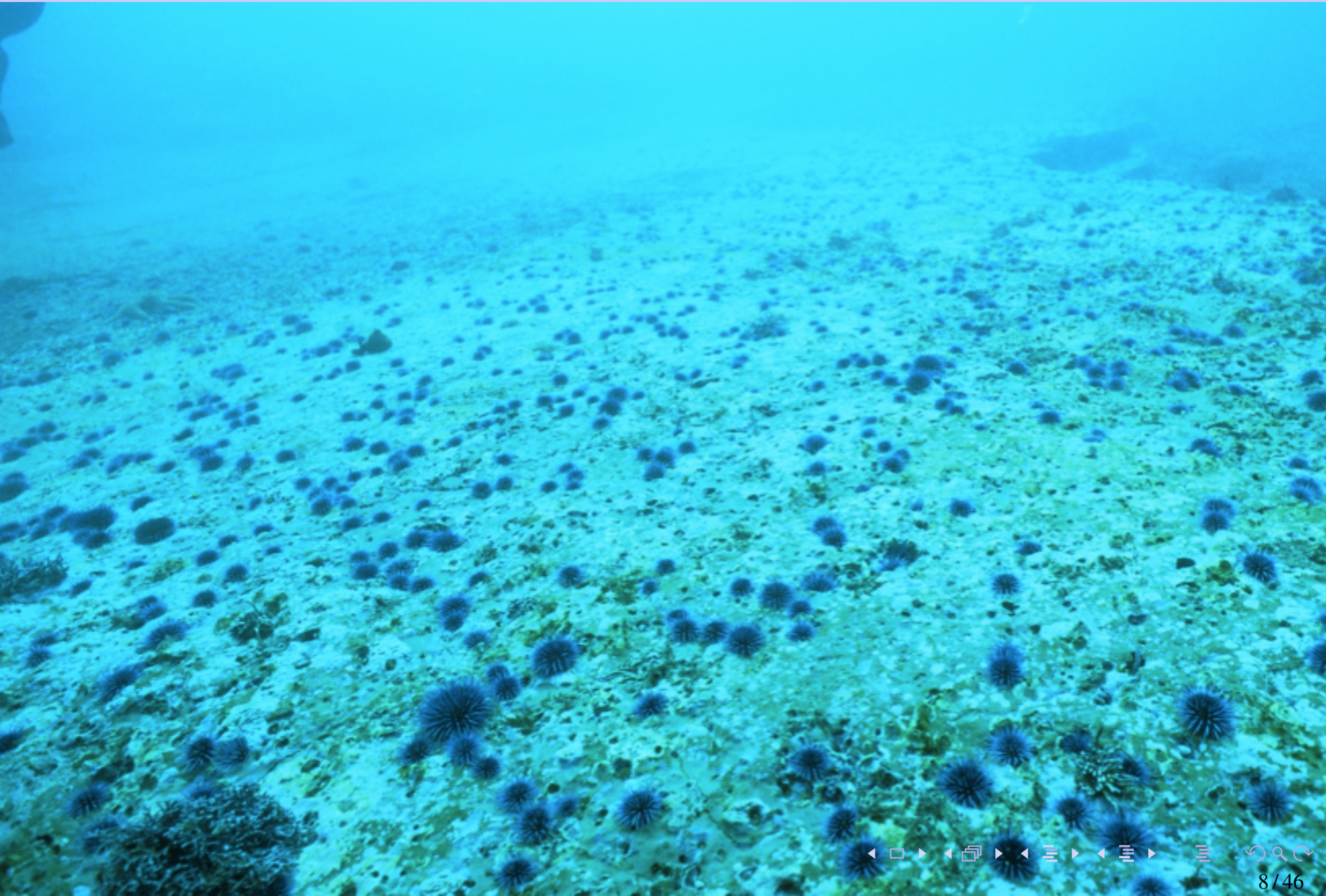
Below high water mark in some places the large urchins are very thickly strewn over the bottom

- George Dawson, 1877 - Haida Gwaii.

Photo: L. Lee

What makes some populations stable over time...

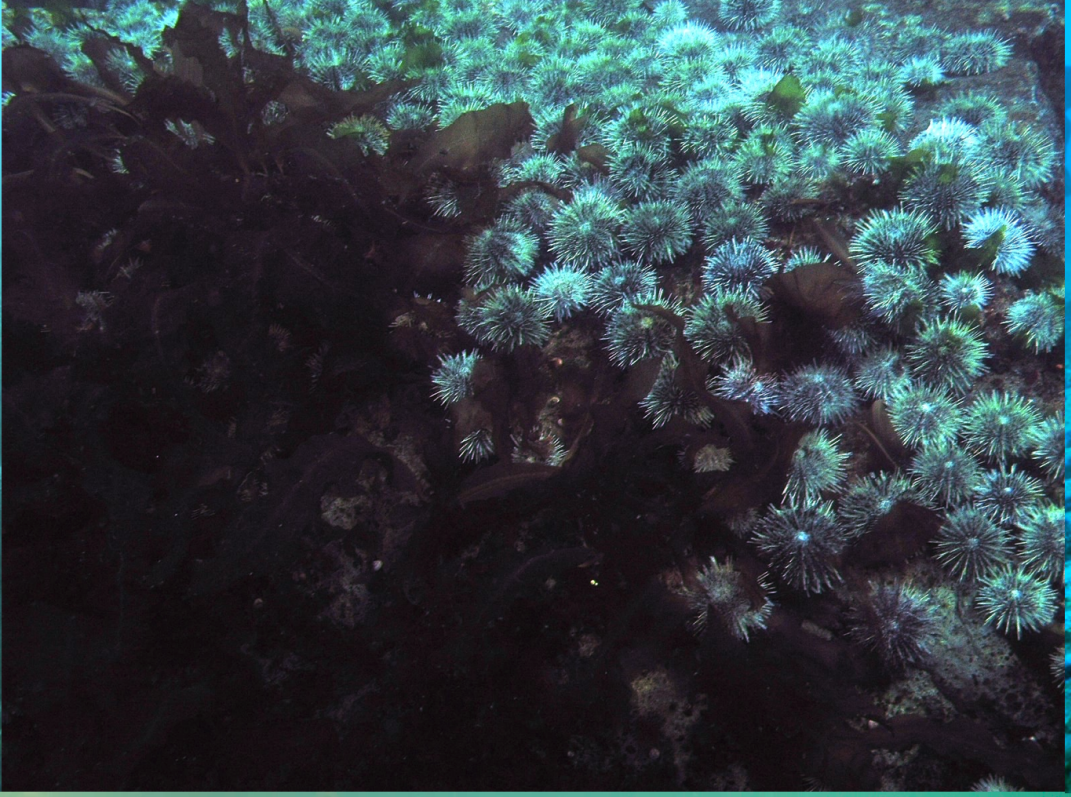
... and others volatile?

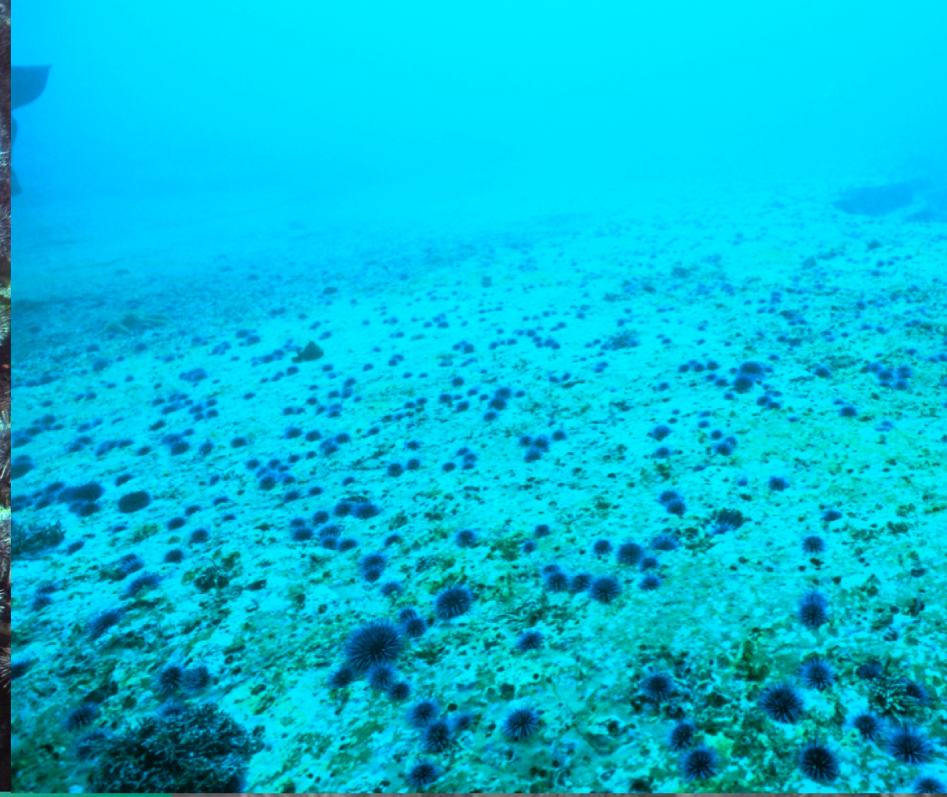


Ecological and physiological reactions and feedbacks

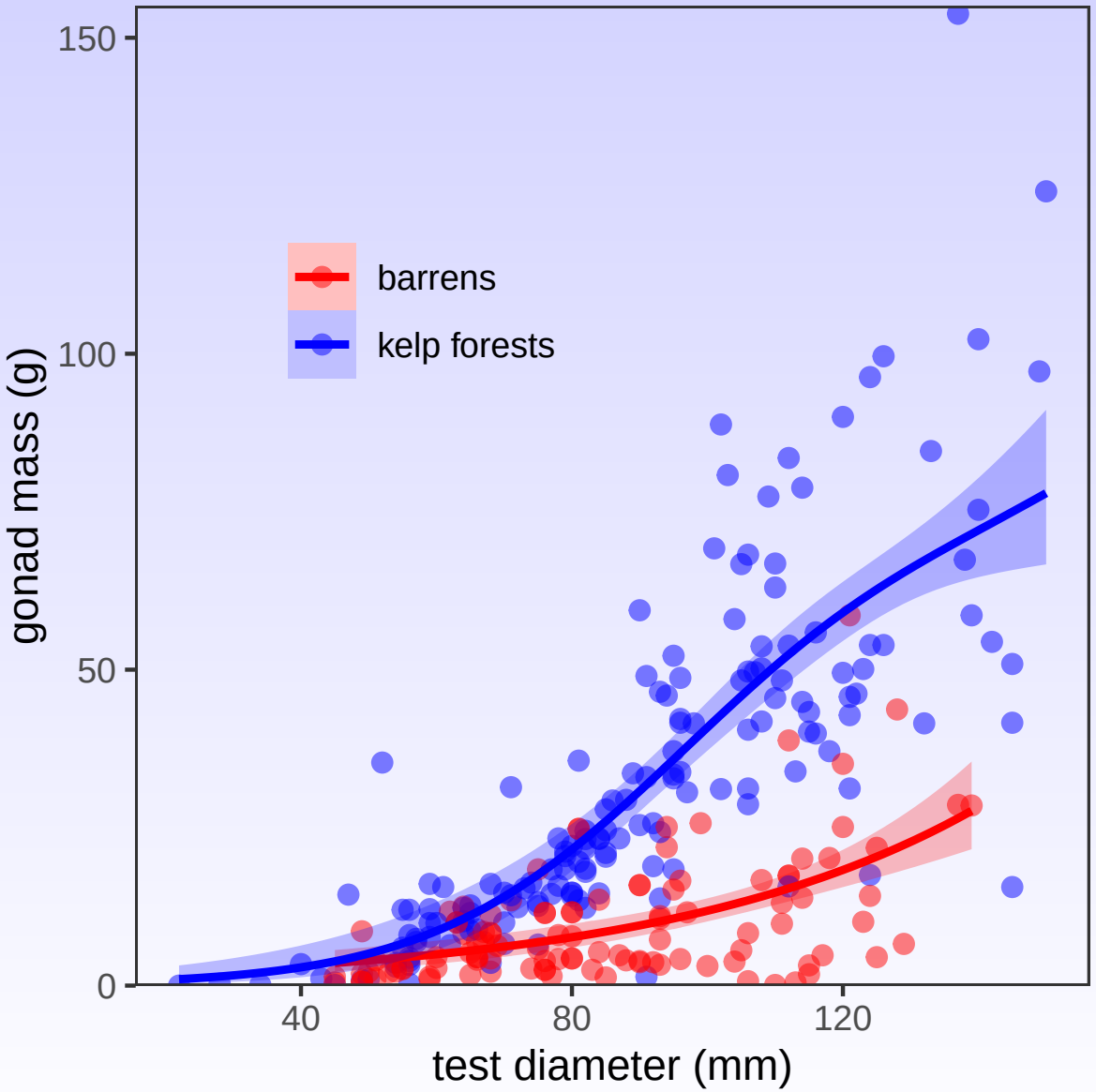
How do climate/harvesting/predator dynamics alter these dynamics?

- Ecological and physiological responses to barren state
- Responses of kelp and animals following restoration
- Reaction following otter re-colonization
- Climate impacts on populations & impacts on ecosystems

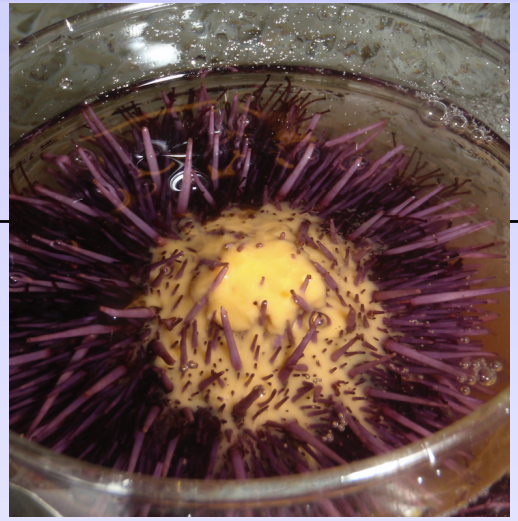


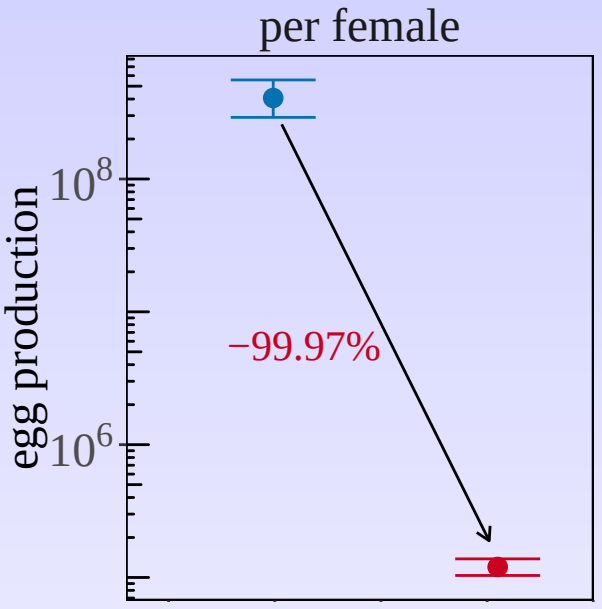


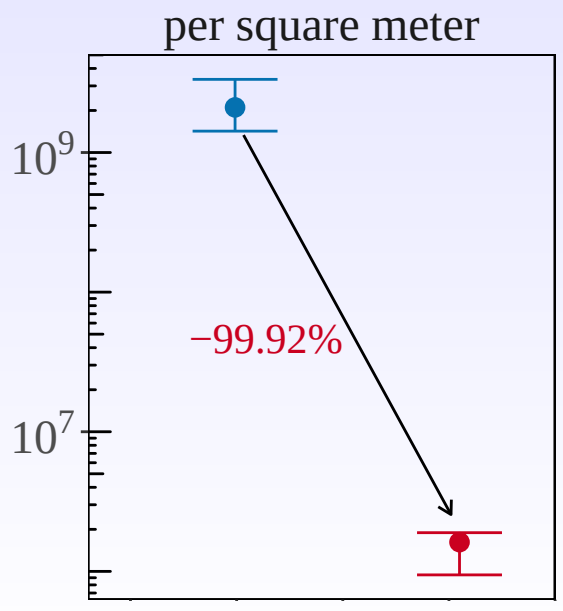
Reduced red urchin gonad mass in barrens (unmarketable)



Purple urchin barrens are reproductive sinks





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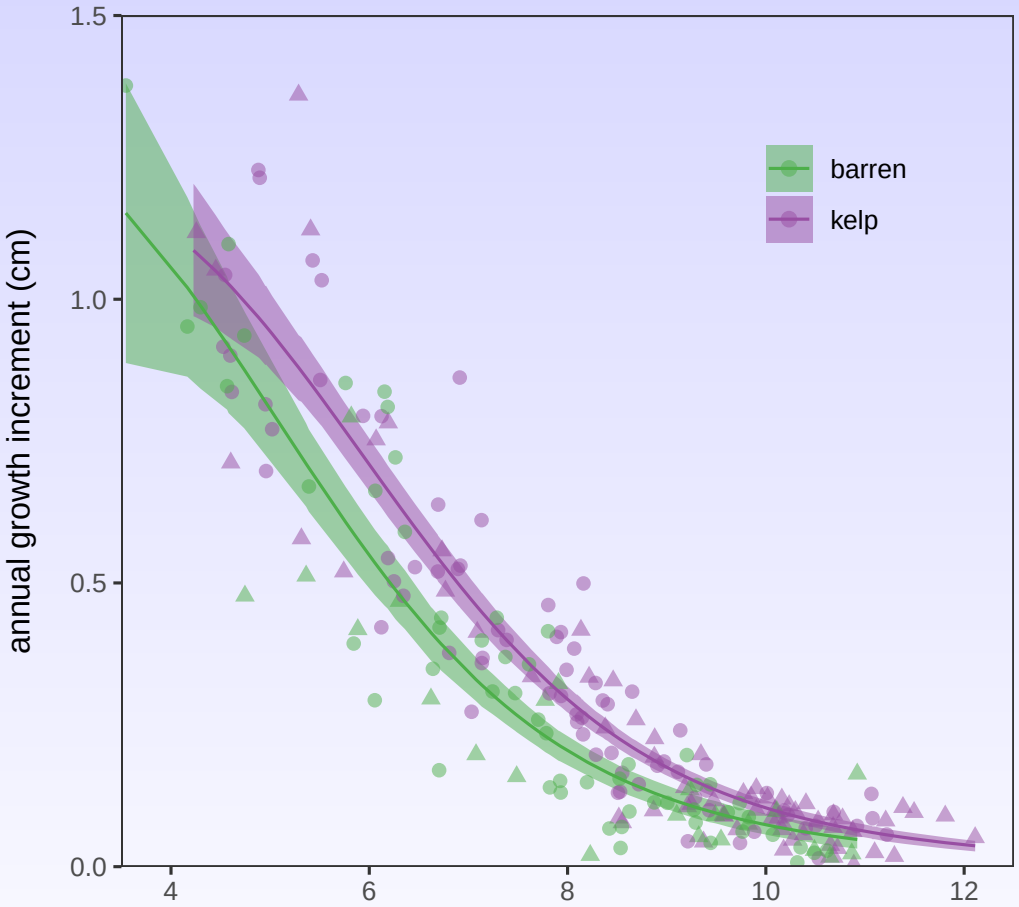
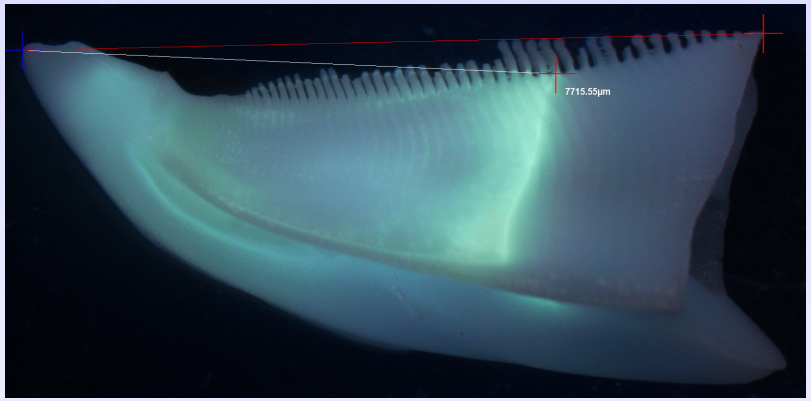
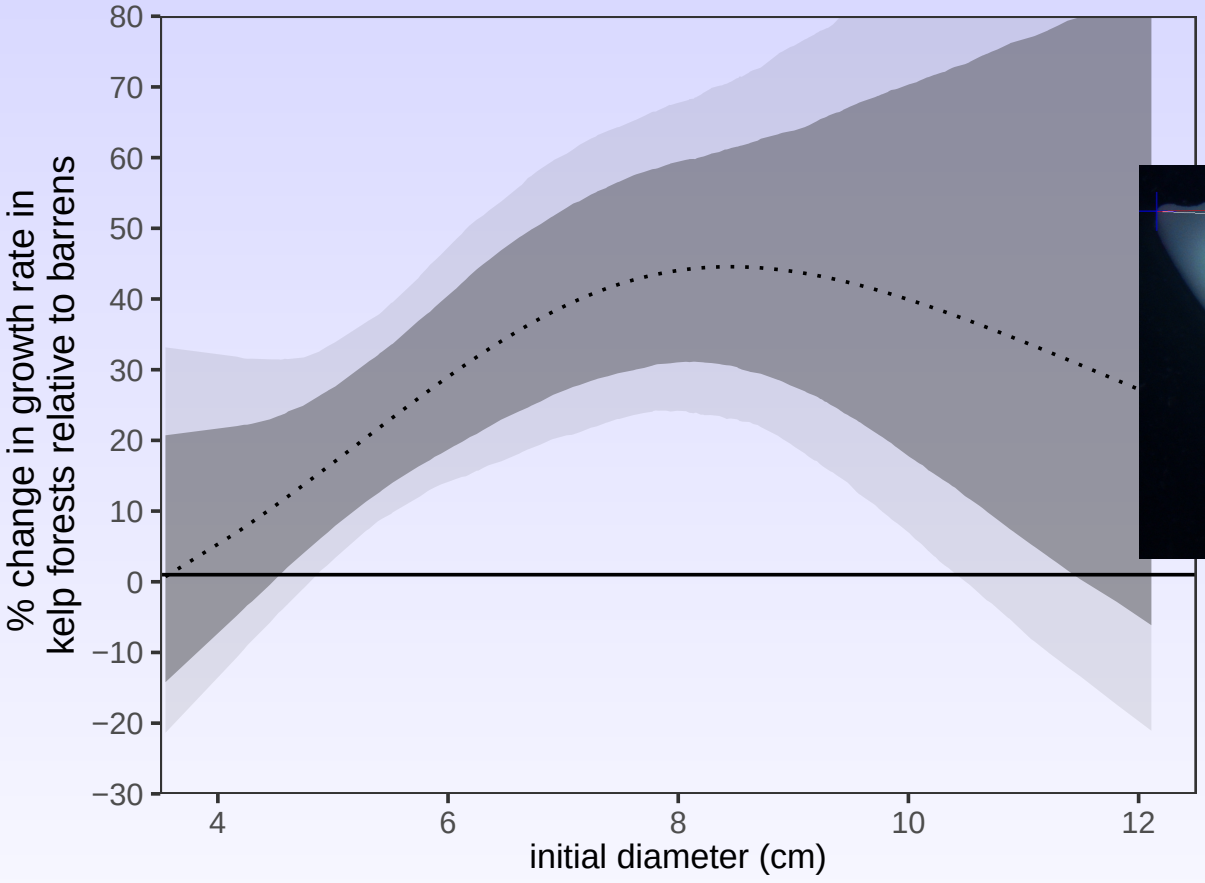
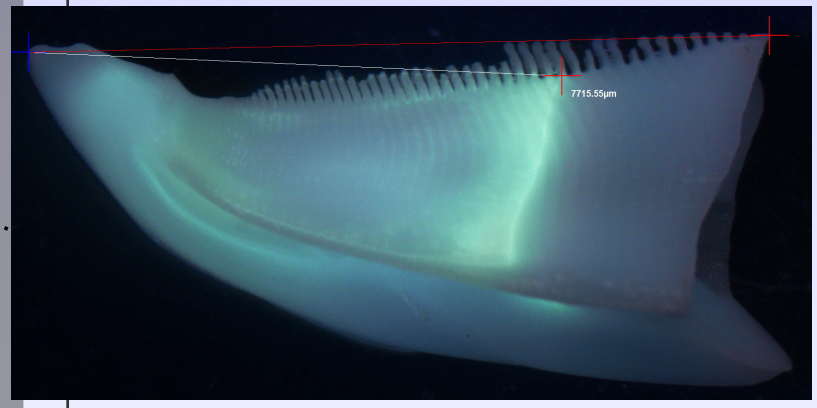
Size-specific cost in growth rates



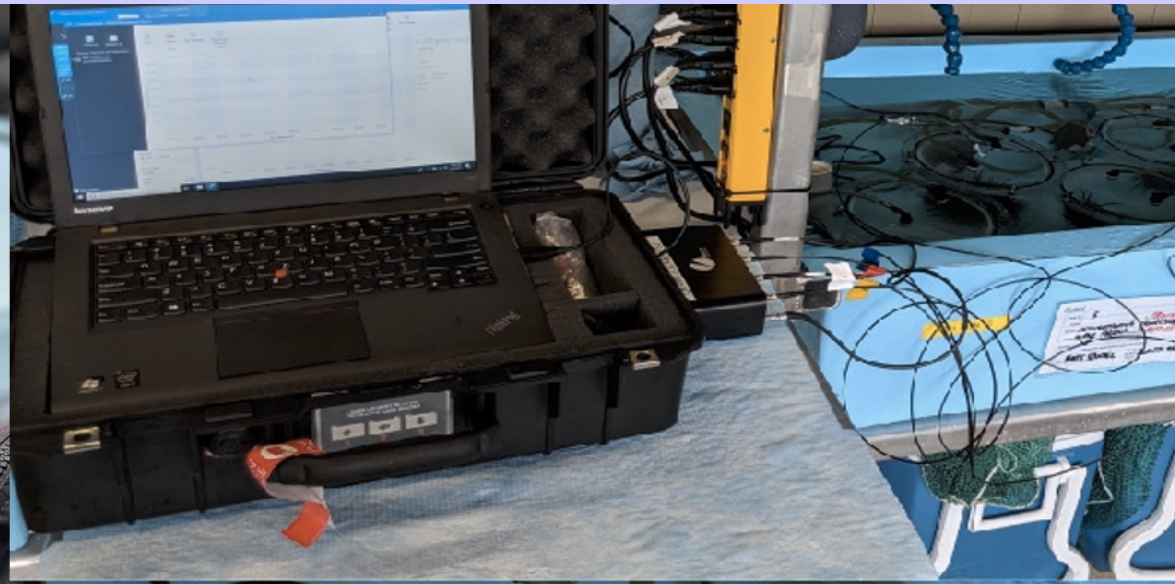


Size-specific cost in growth rates



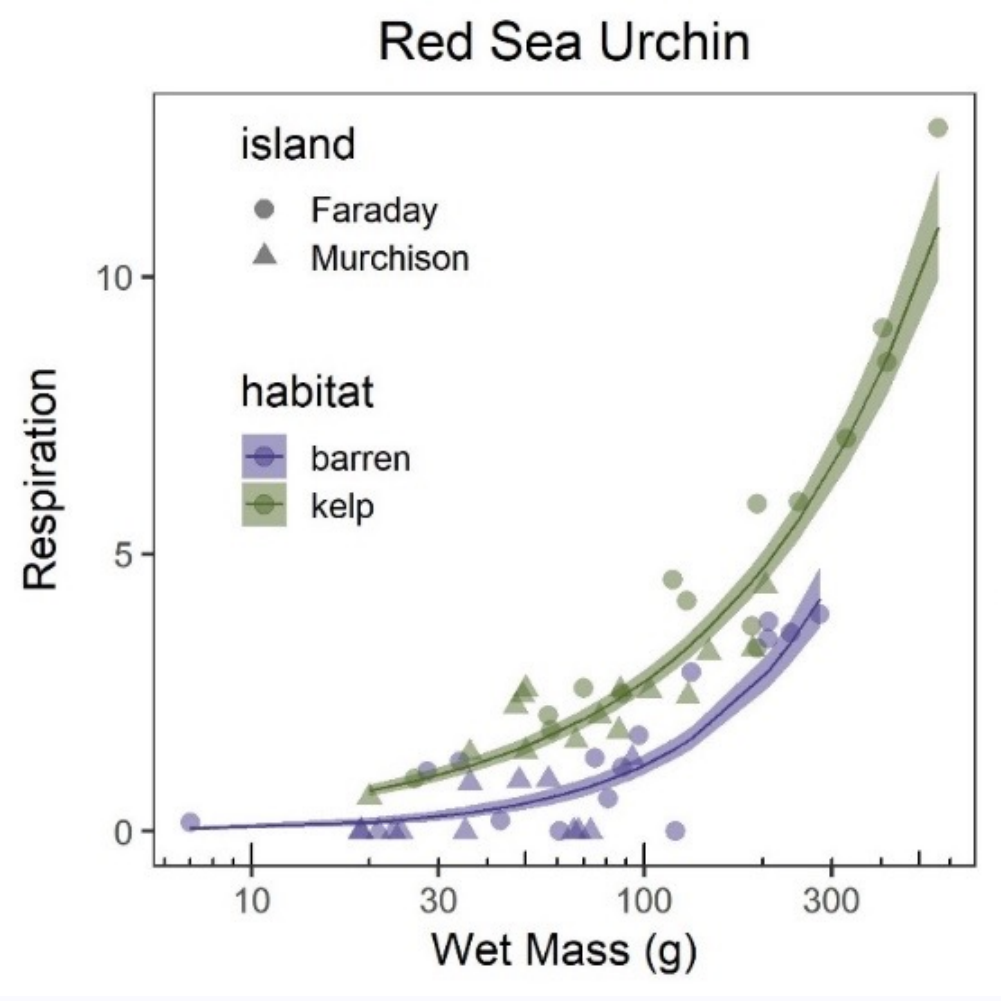


Size specific metabolic rate ↓ in barrens

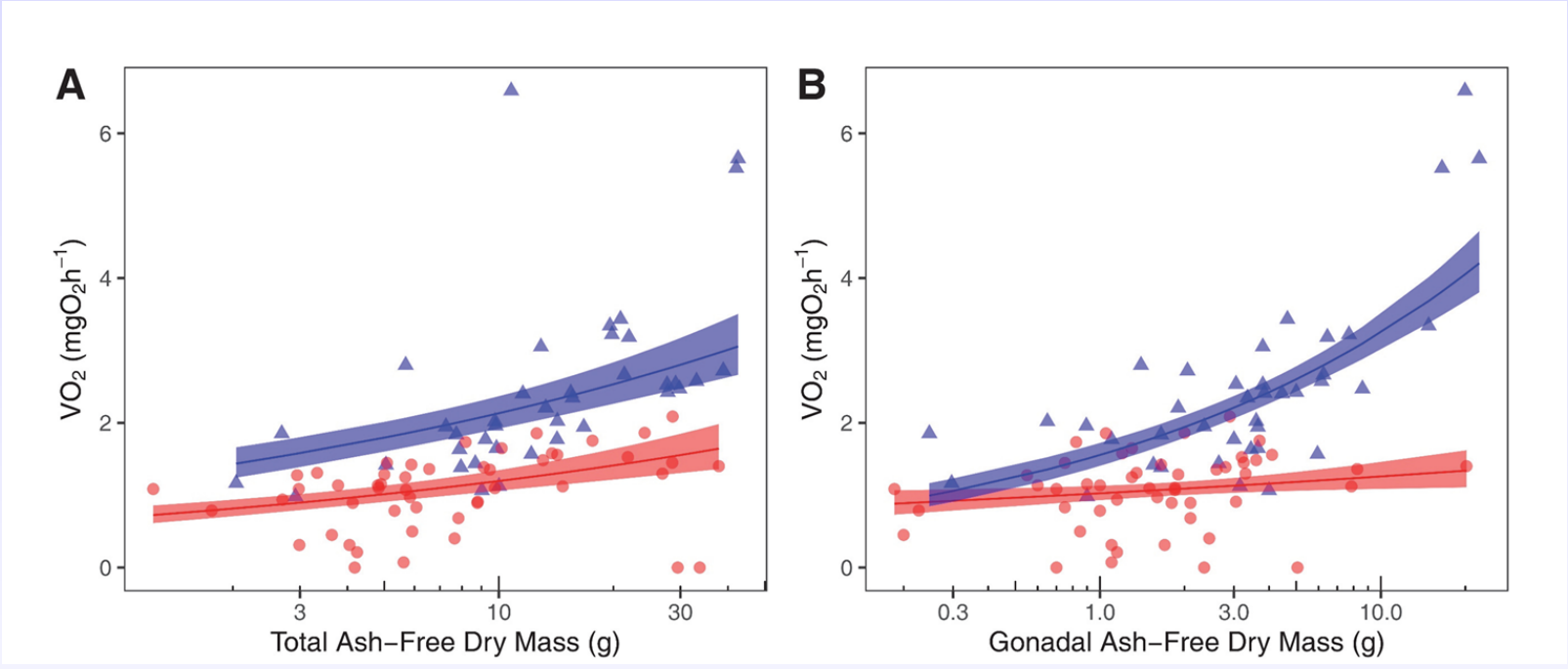


Spindel, Lee, & Okamoto. *2021* Ecology

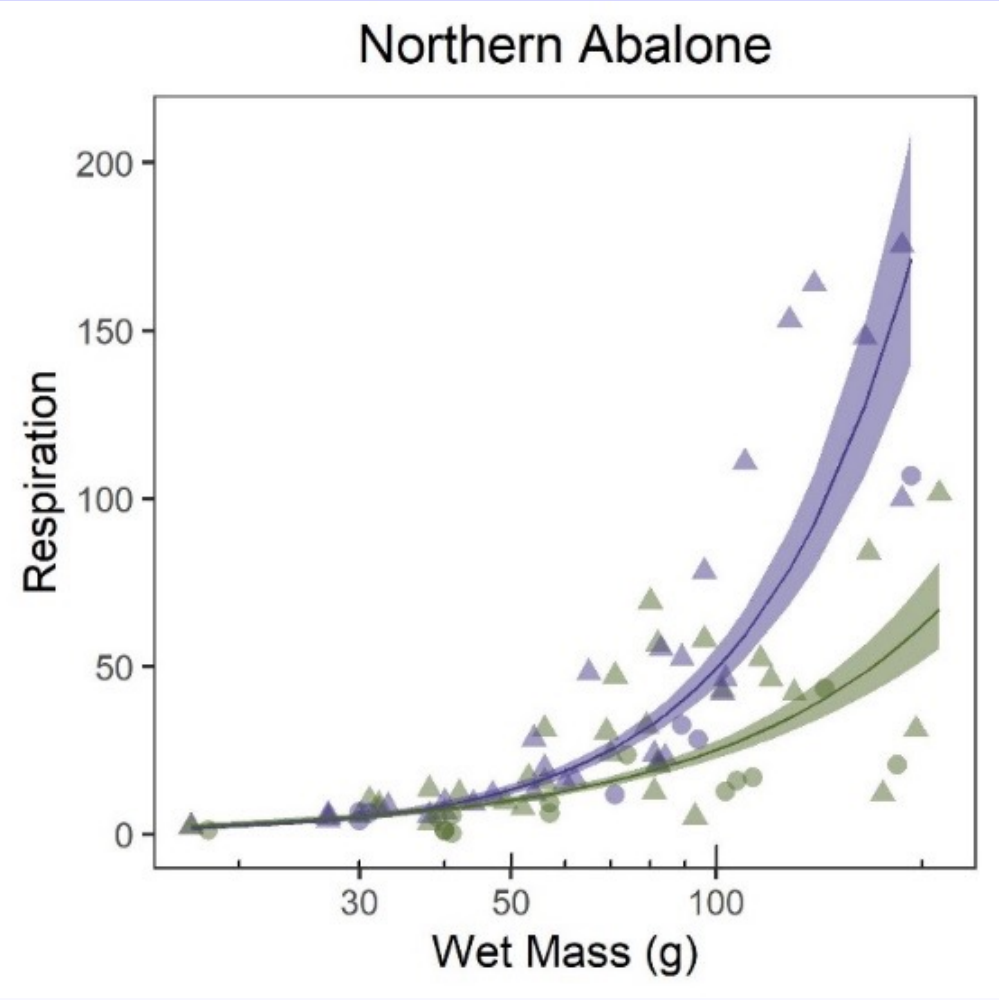
Mass specific metabolic depression in sea urchins living in barren



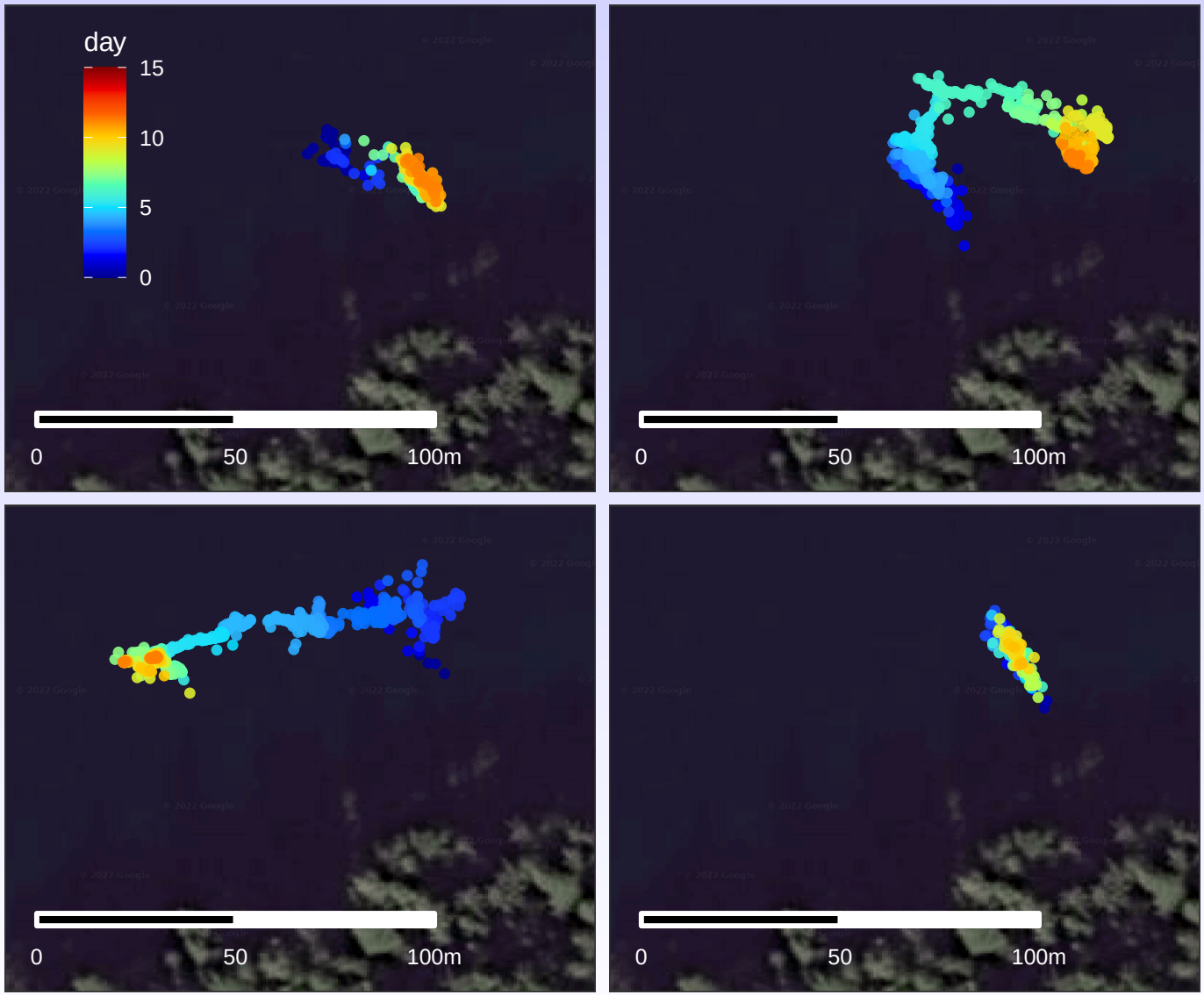
Mass specific metabolic depression in sea urchins living in barrens



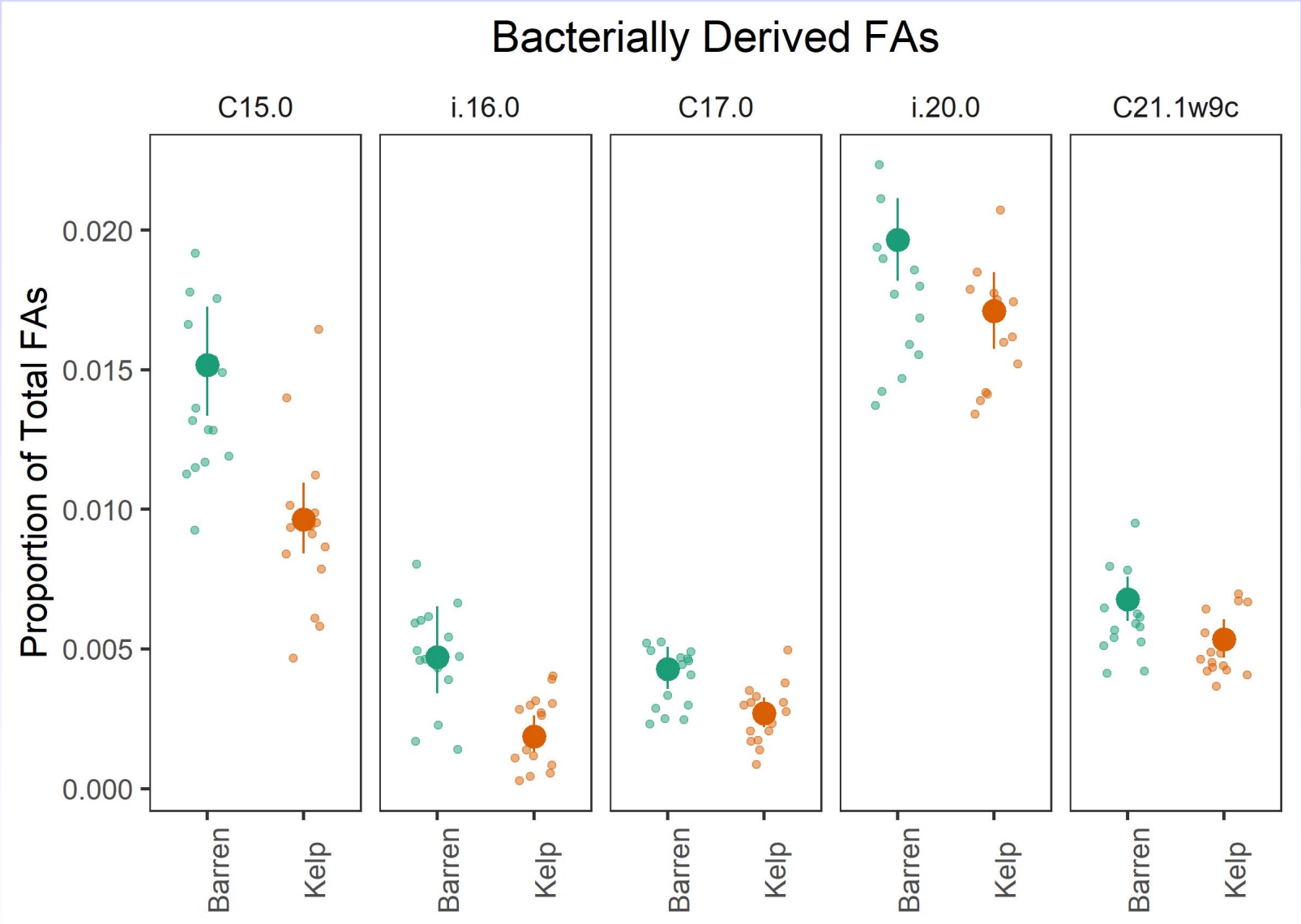
Opposite effects for abalone residing in barrens



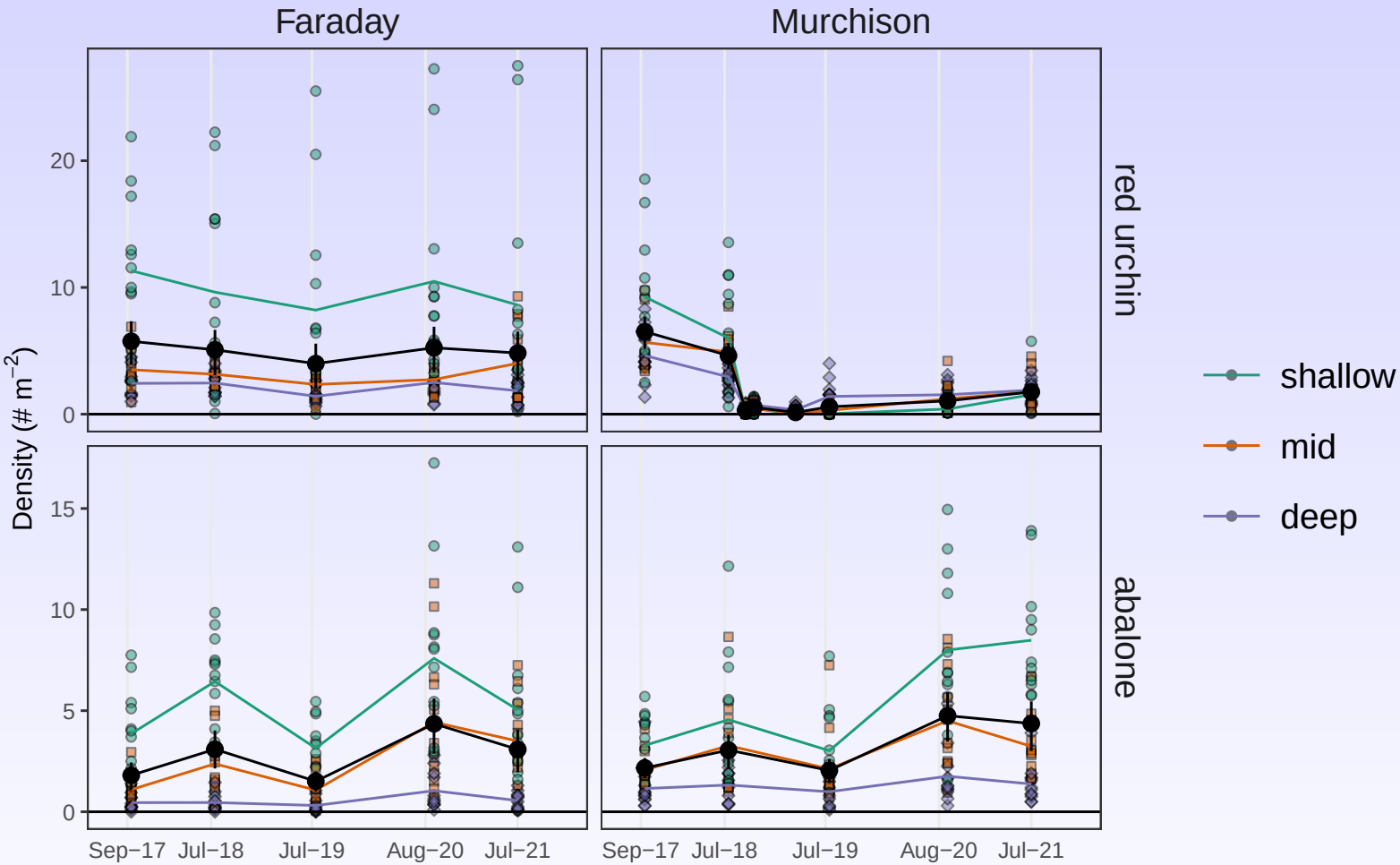
Abalone in barrens are movers



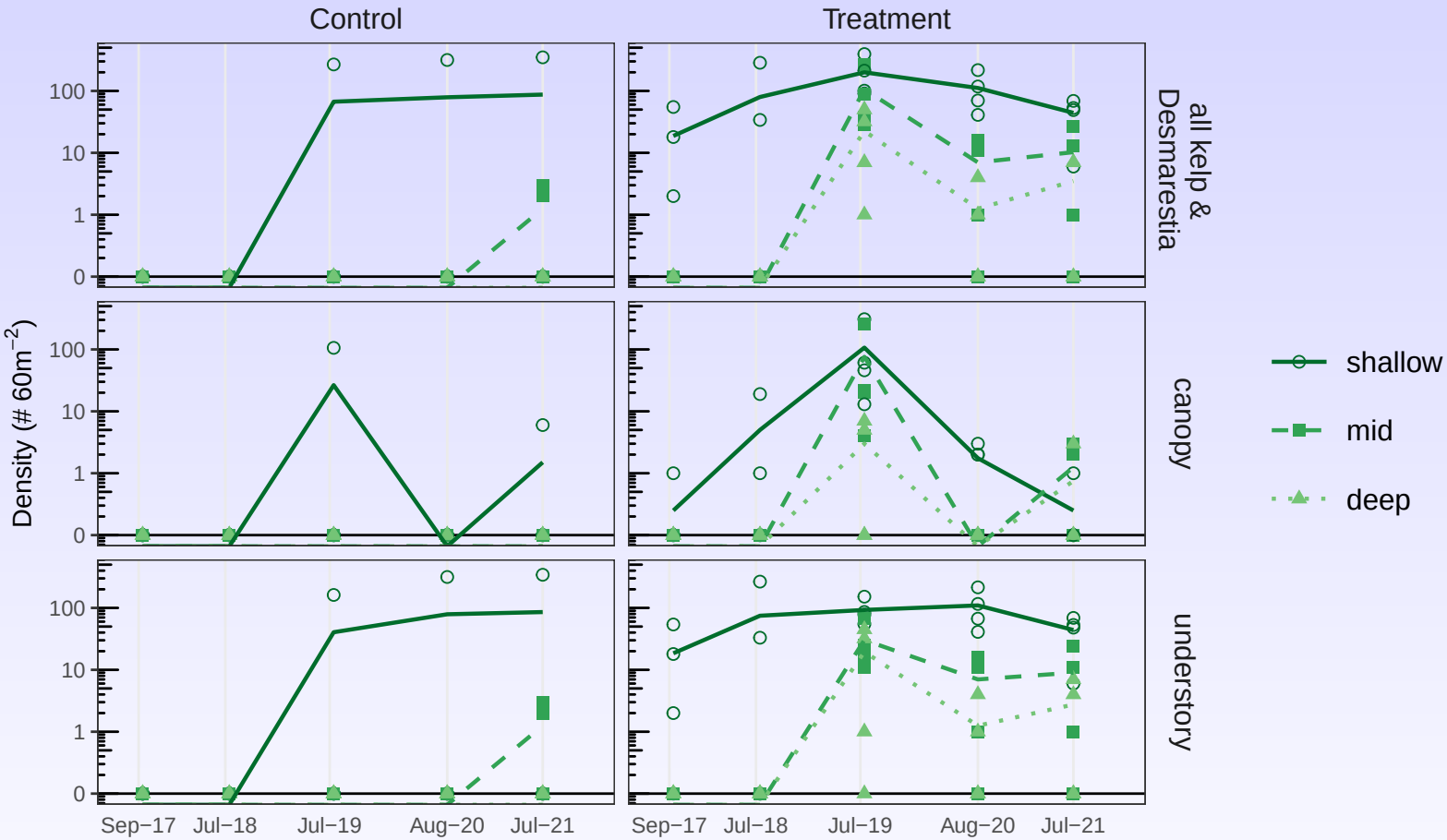
Fatty acids differ in barren urchin gonads, indicated reliance on alternative foods



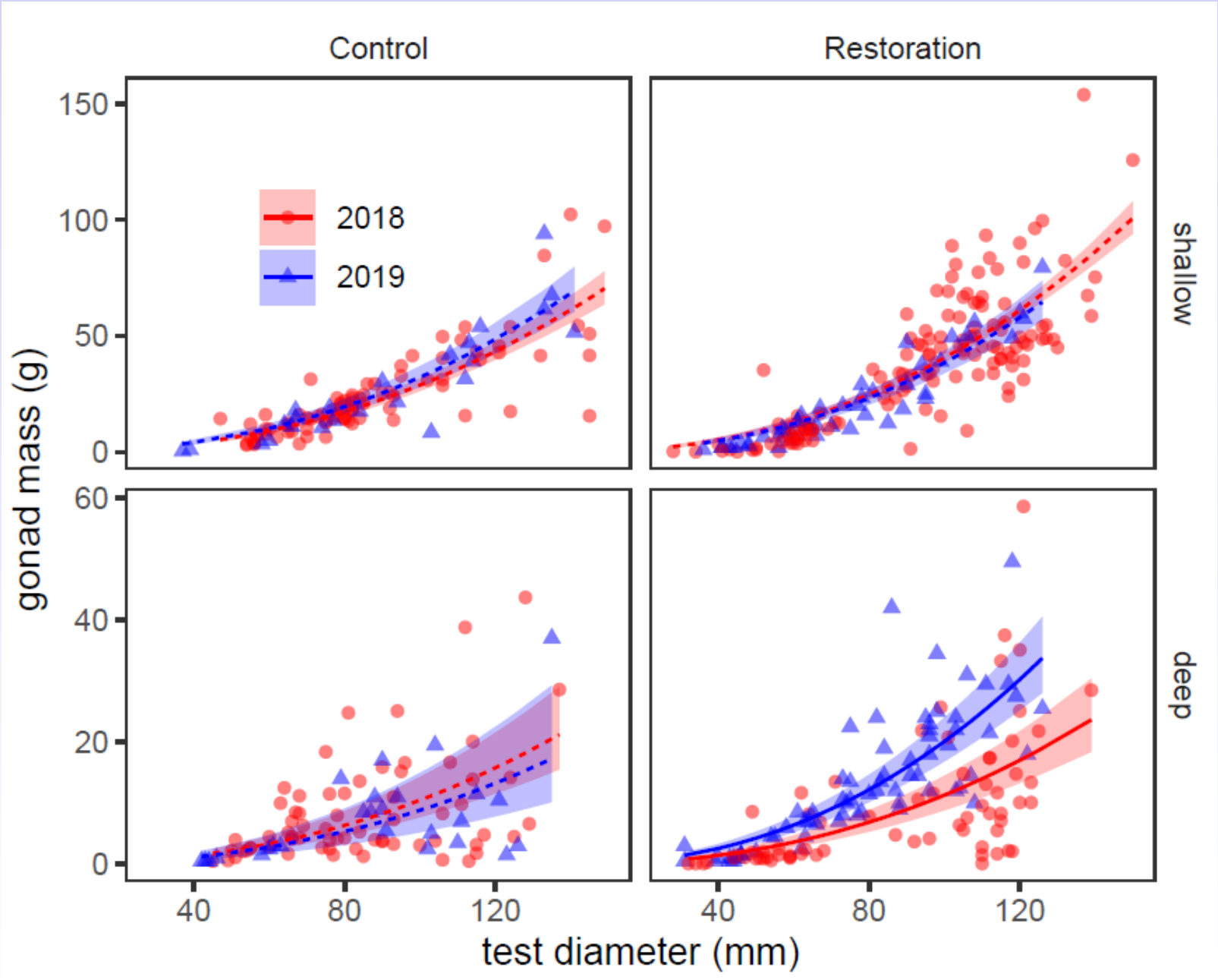
Experimental urchin removal:



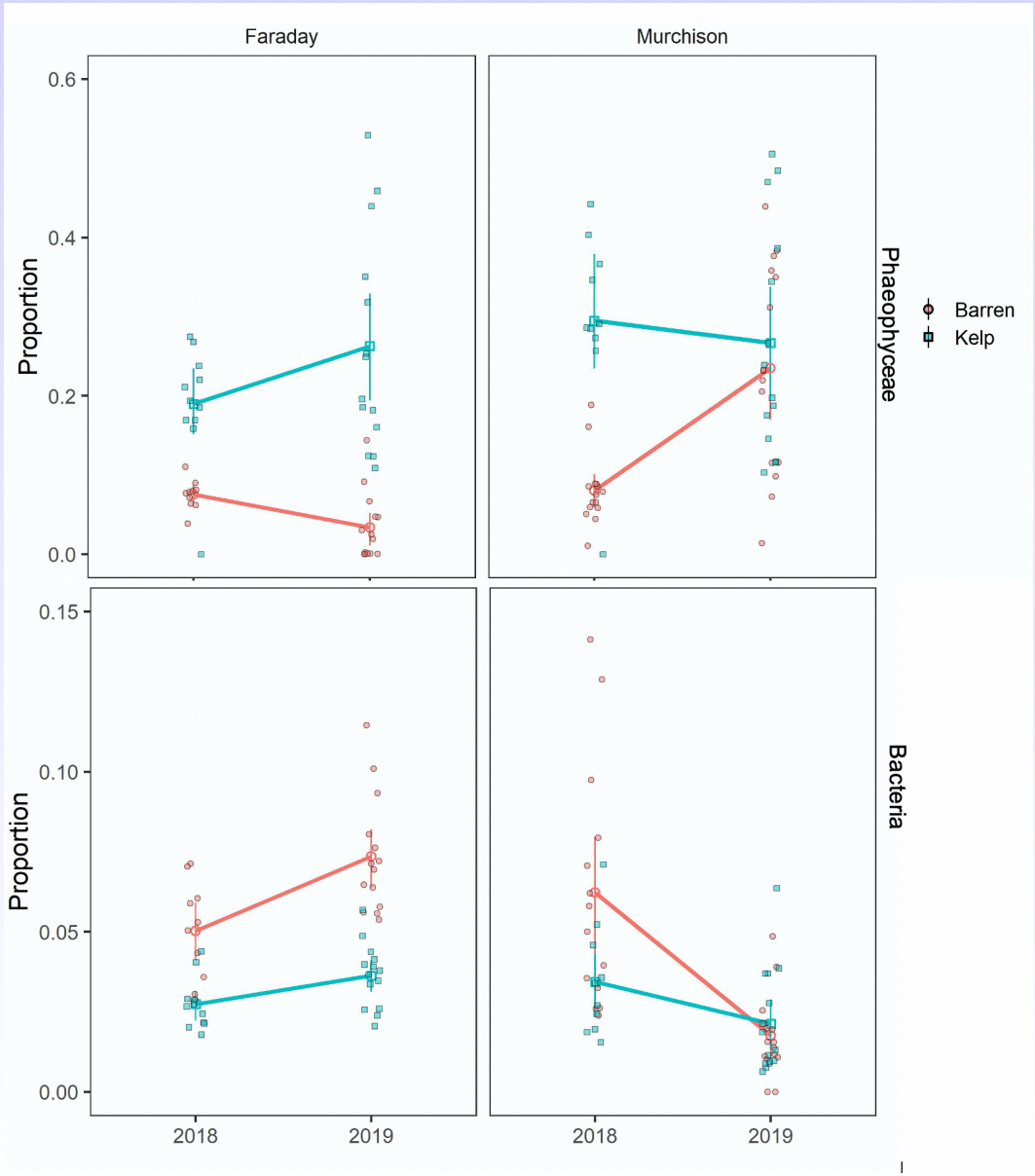
Kelp ↑ following restoration

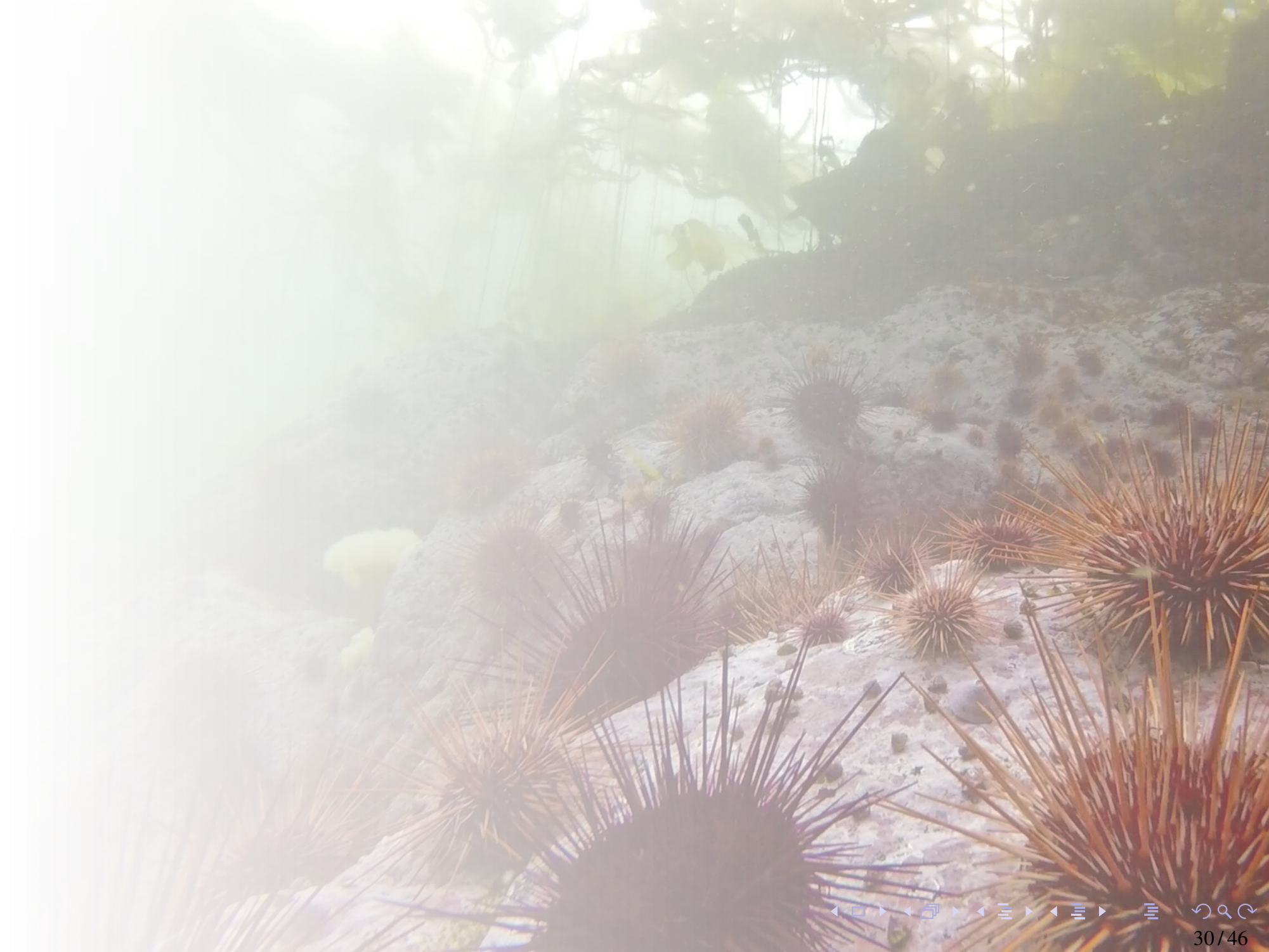


Gonad mass ↑ following restoration

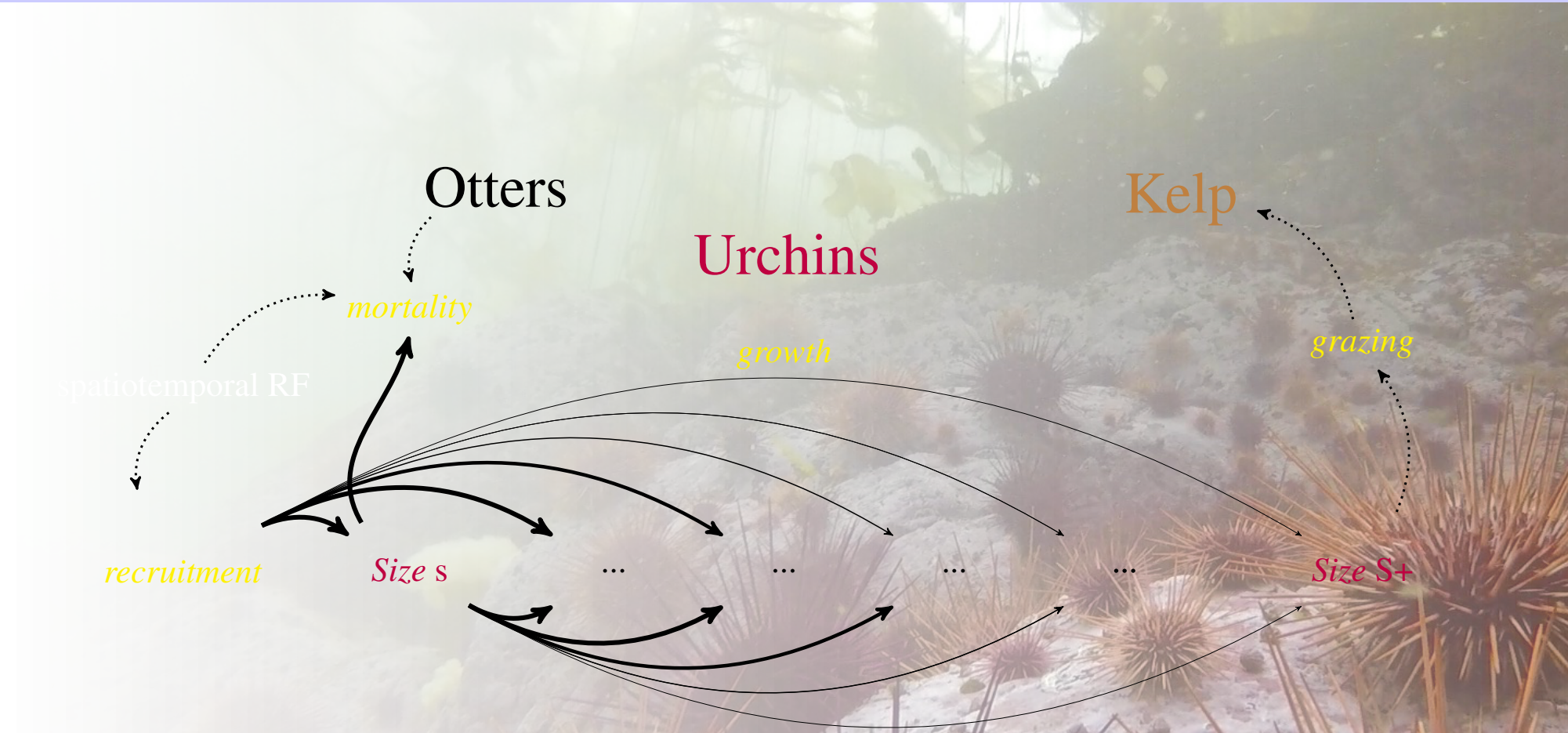


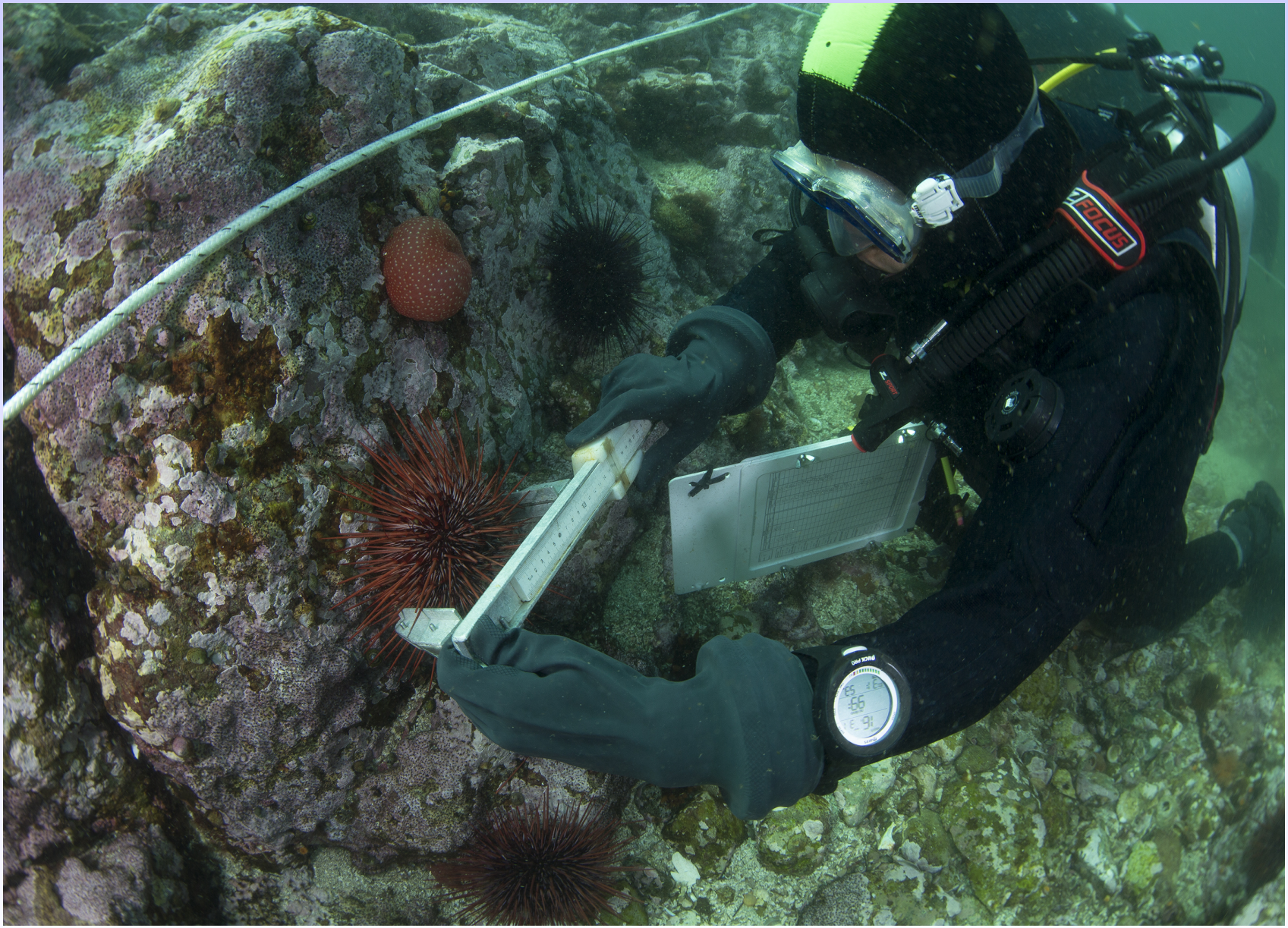
Kelp signatures ↑, bacterial signatures ↓ following restoration





Integrated state-space IPMs




FOCUS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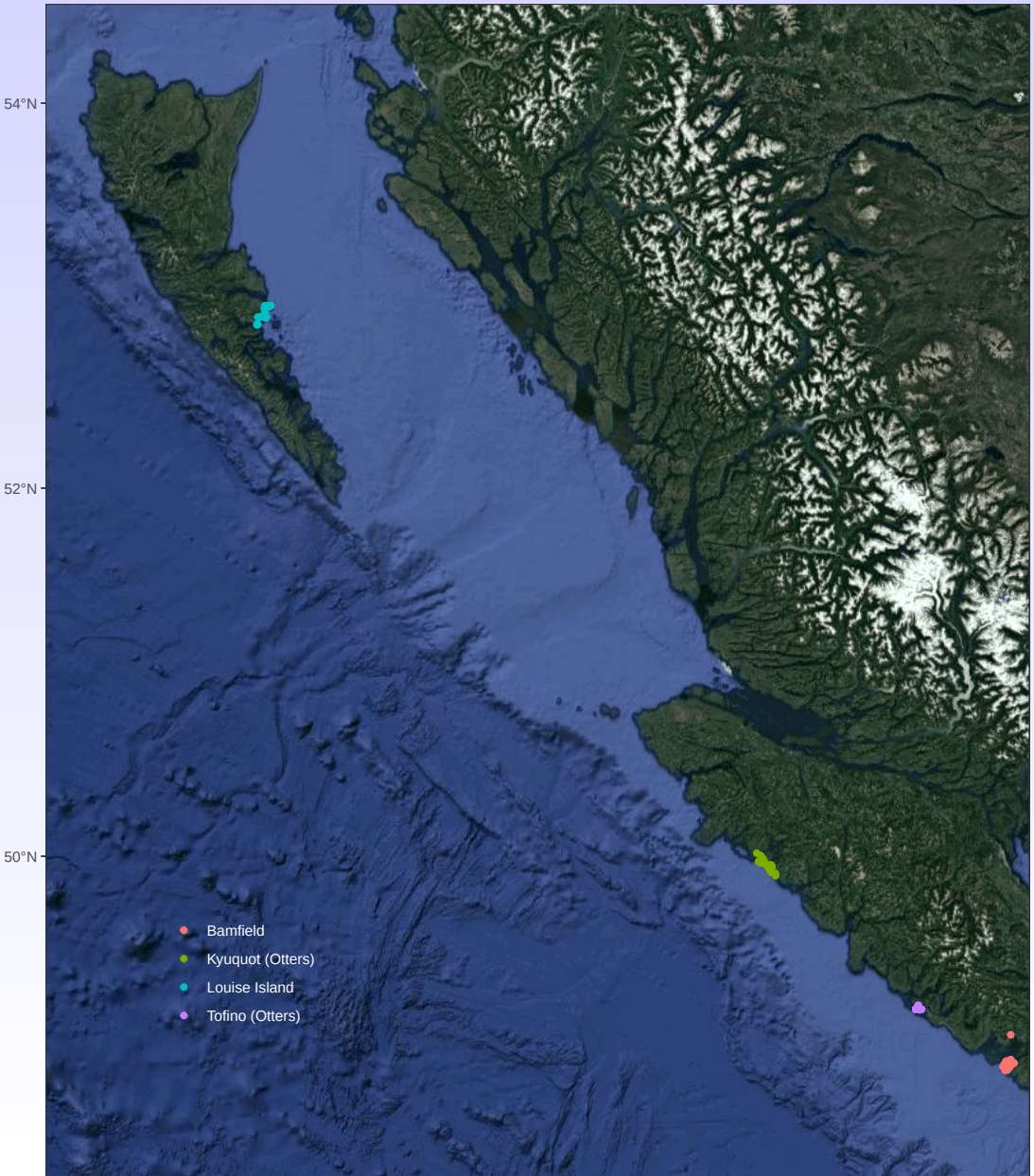
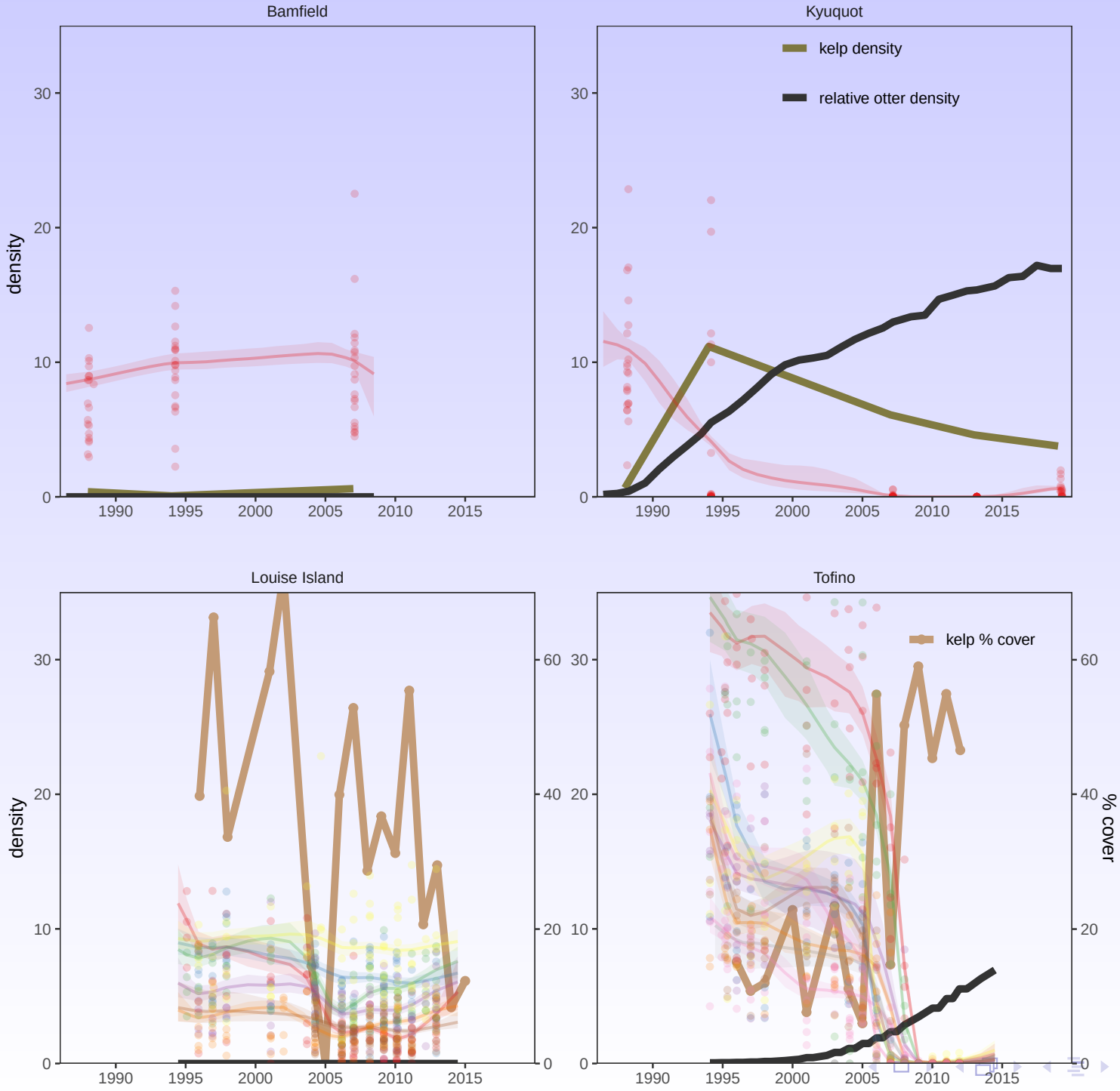
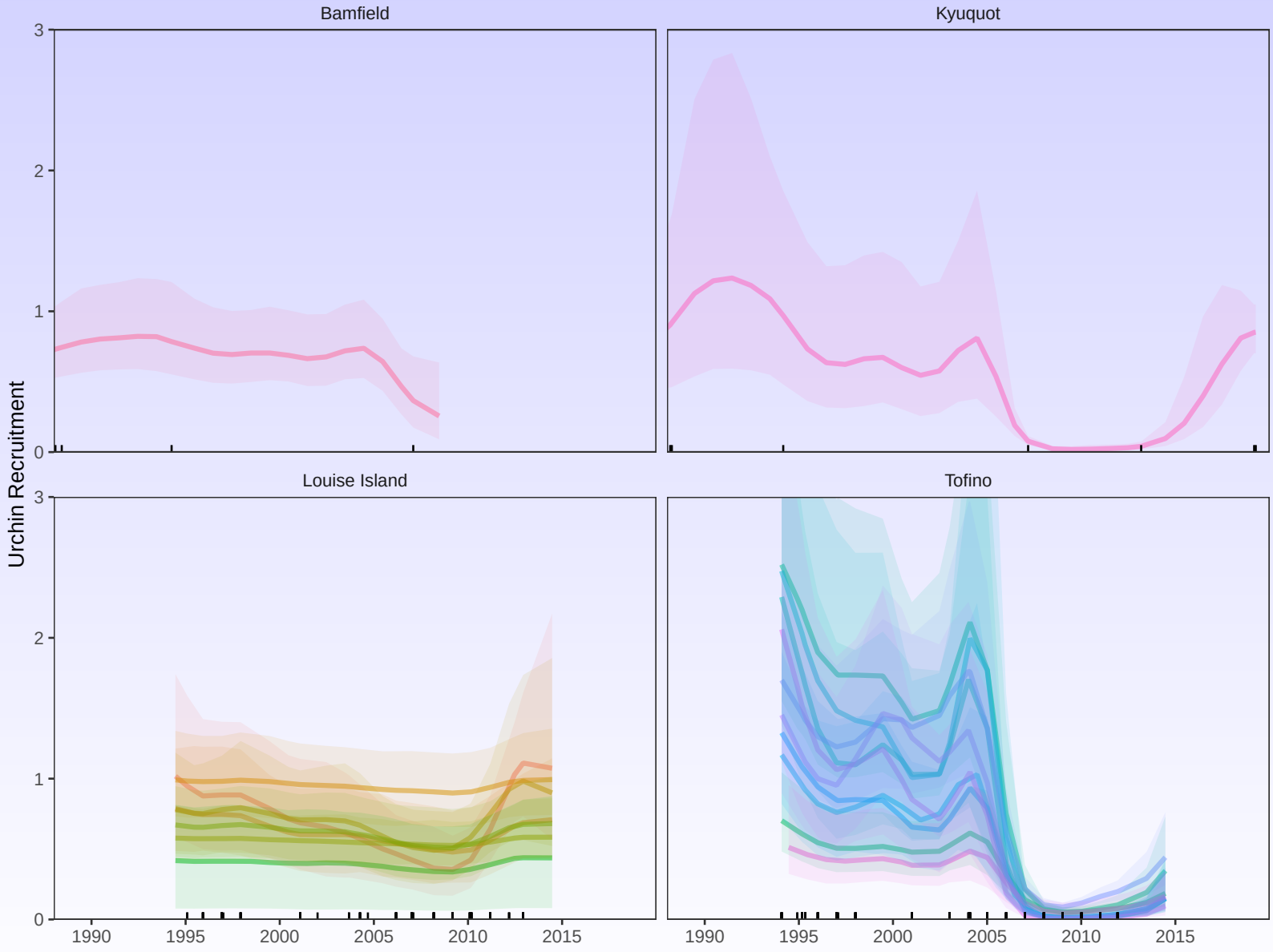
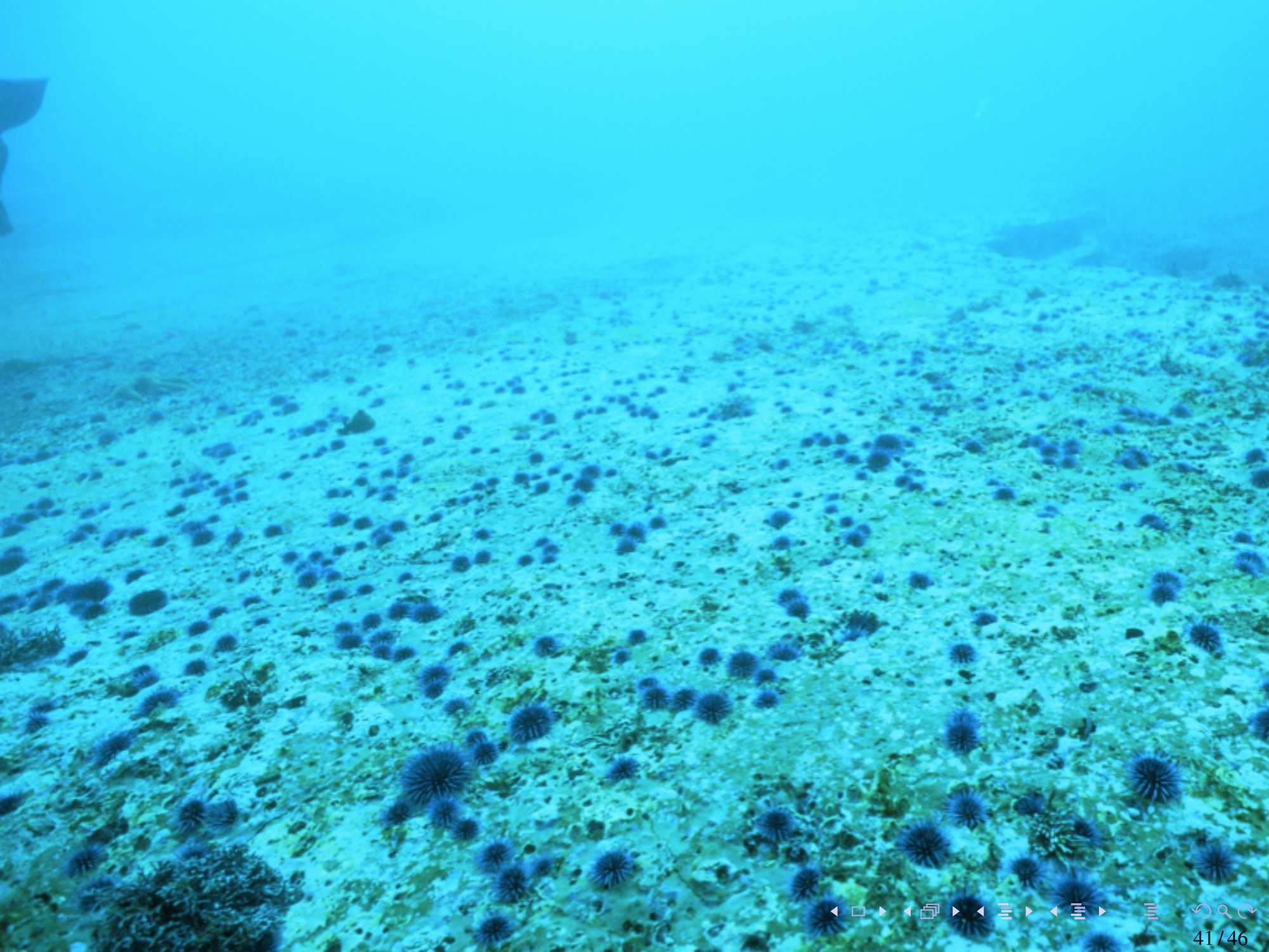
Stable red urchin barrens/mosaics until otters arrive



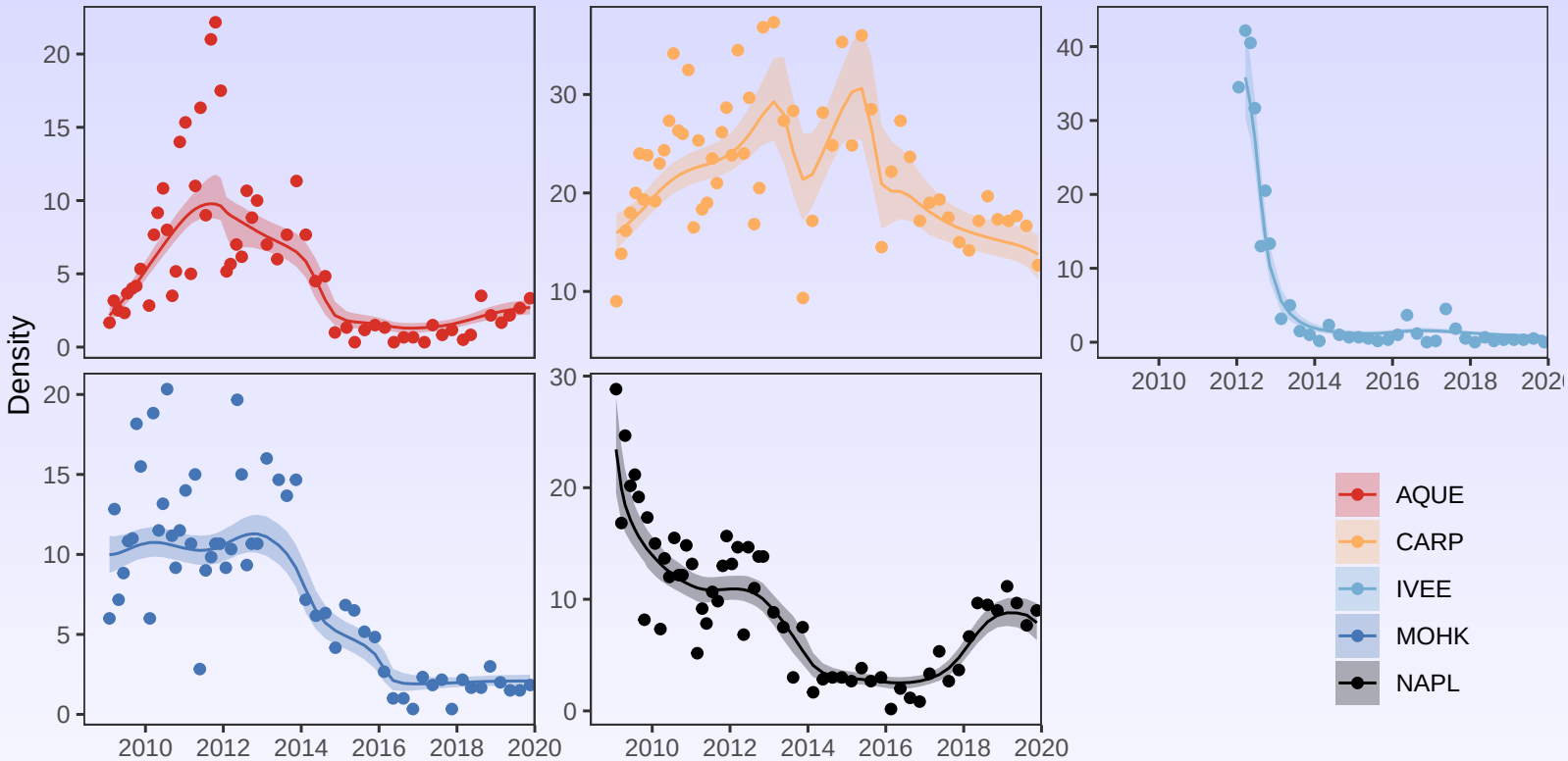

Bamfield
Kyuquot
Louise Island
Tofino
kelp density
relative otter density
kelp % cover
density
% cover
0
10
20
30
40
60
1990
1995
2000
2005
2010
2015

Slow/steady trickle of density dependent recruitment in red urchins





Volative purple urchin populations with massive swings in recruitment/mortality

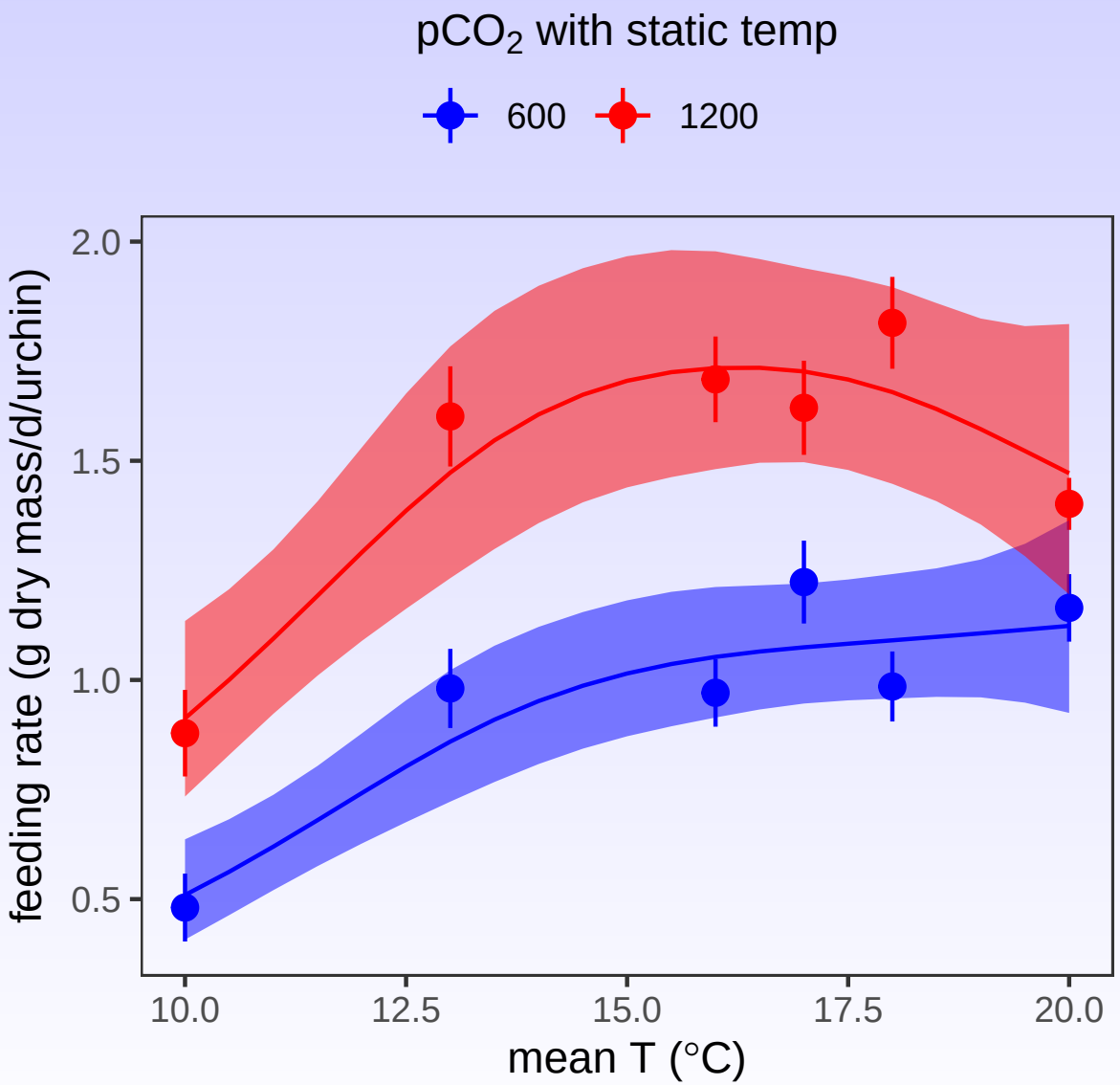


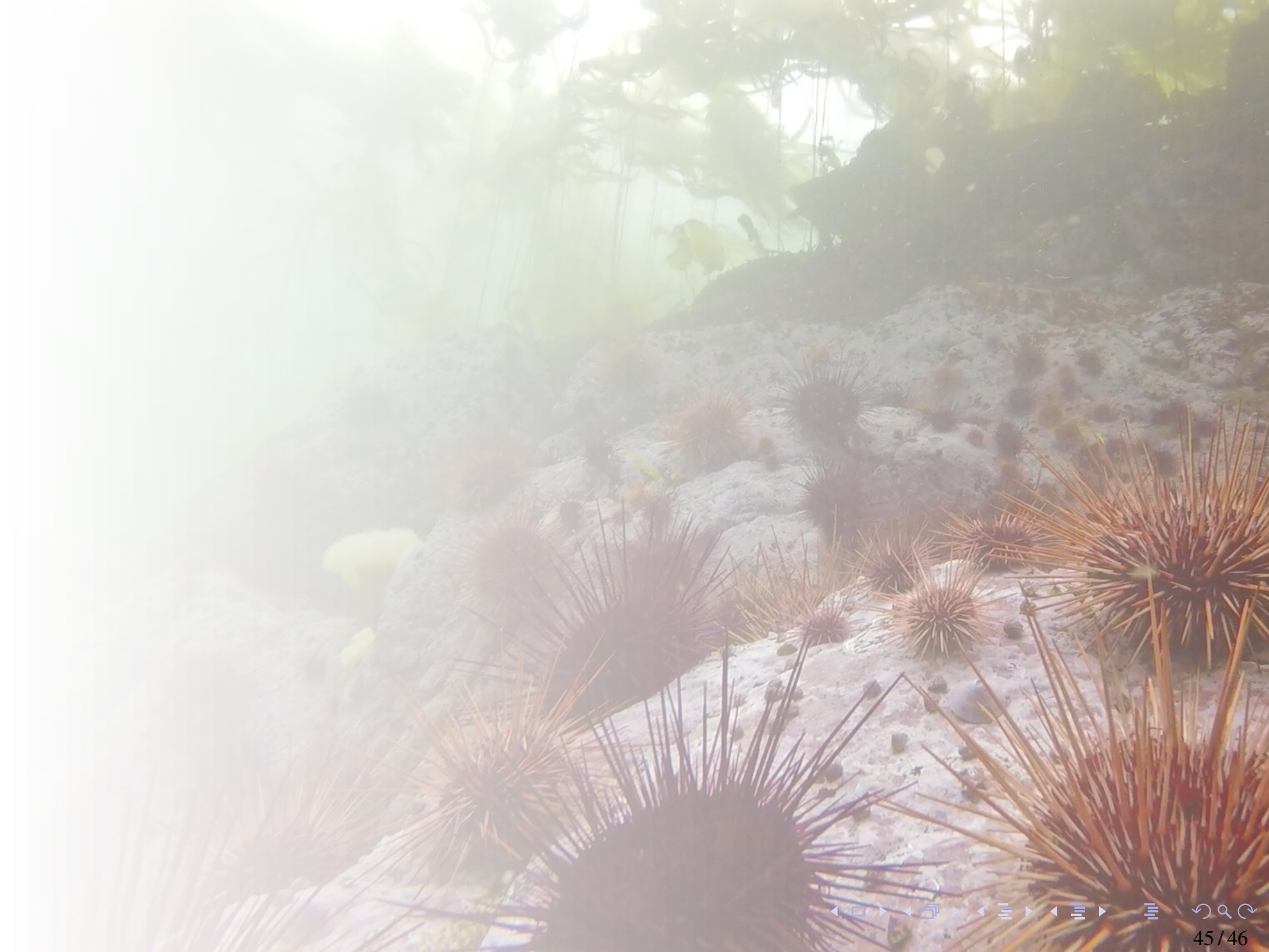
Effects of warming/ocean acidification

grazing, energetics, gametogenesis, and larval competency

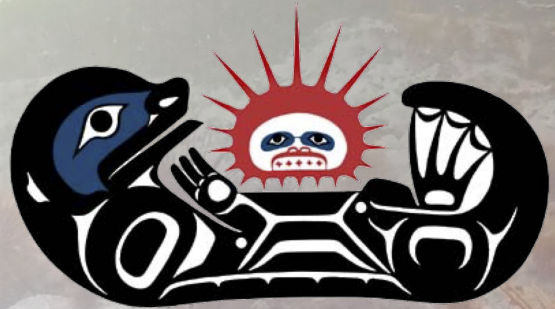
Mesocosm Experiments: Sept - Dec 2021

warming/ocean acidification: ↑ grazing pressure





THANK YOU!



NSERC
CRSNG

Sea urchin abundance observations in the Salish Sea: Washington Coast

NOAA's Northwest Fisheries Science Center &
Olympic Coast National Marine Sanctuary

NATIONAL MARINE SANCTUARIES

Kelp forests support many species and human uses

Kelp forests ecosystems support sustainable fisheries and promote endangered species recovery

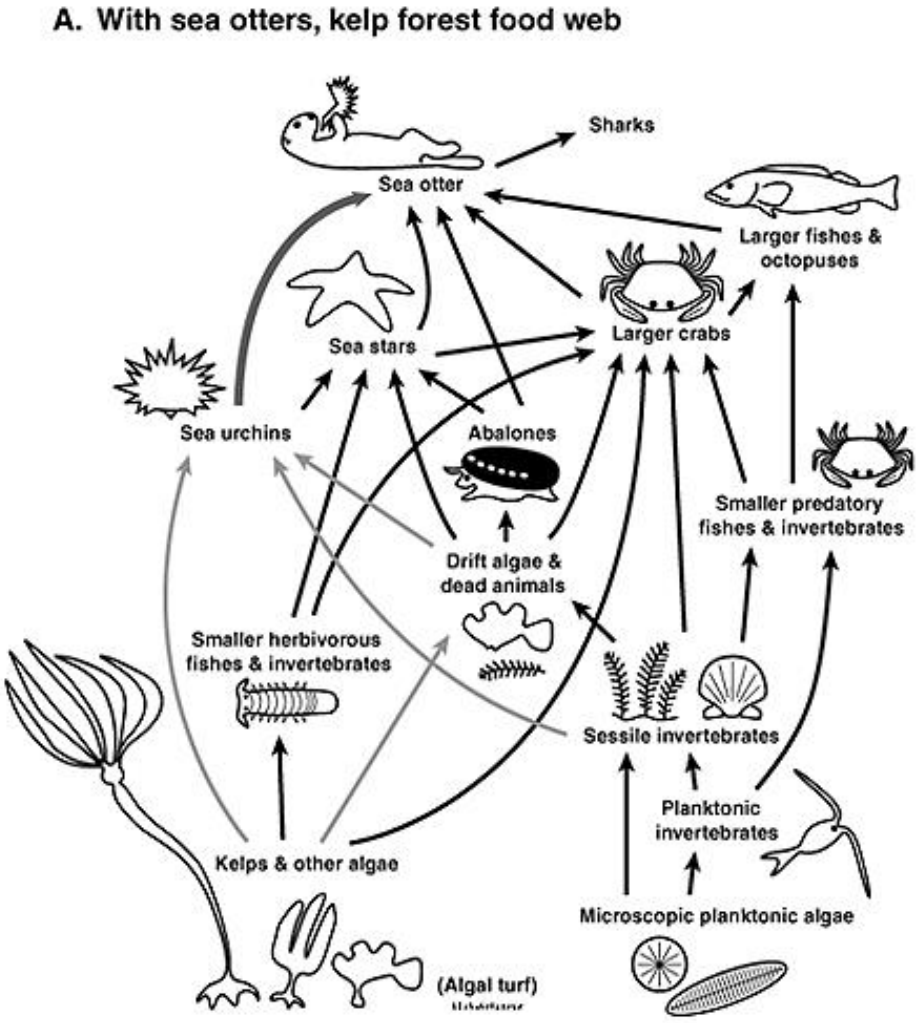
Kelp forests support many species and human uses

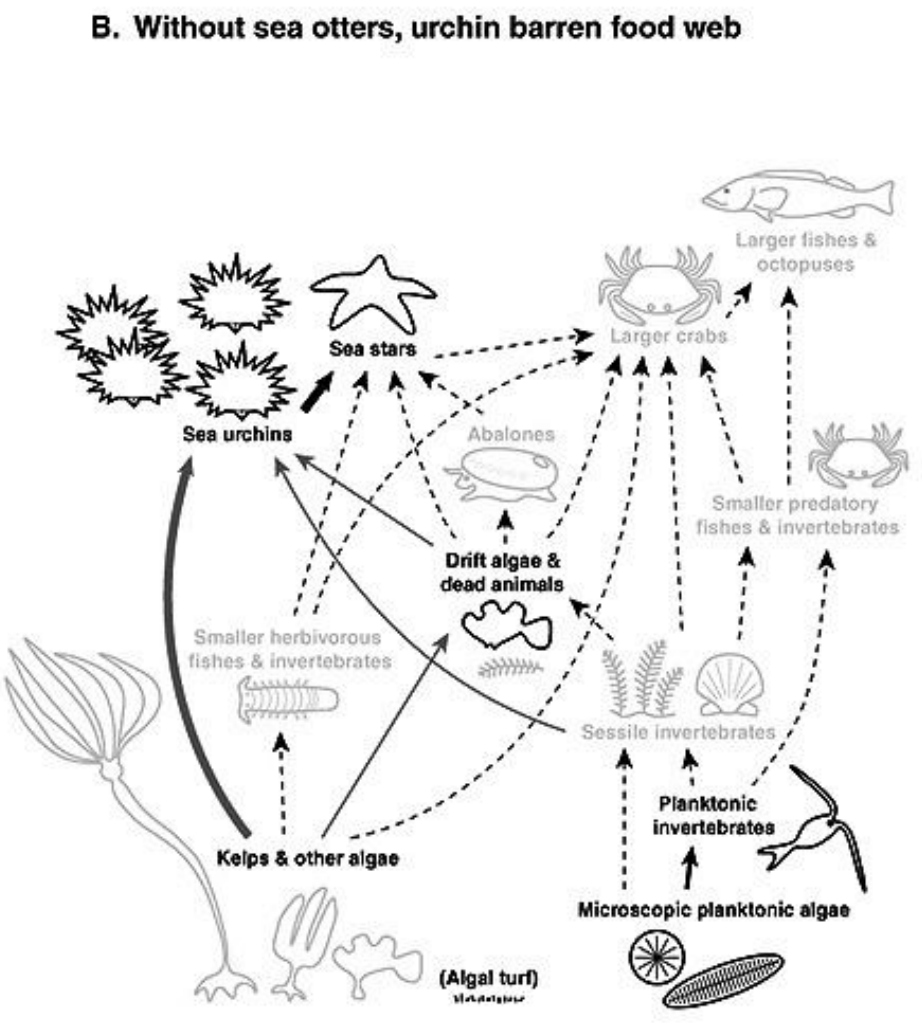
Two vignettes today:

Kelp, Urchins, Sea Otters
1980-2015
2015-2021

The value of looking at patterns at multiple scales.

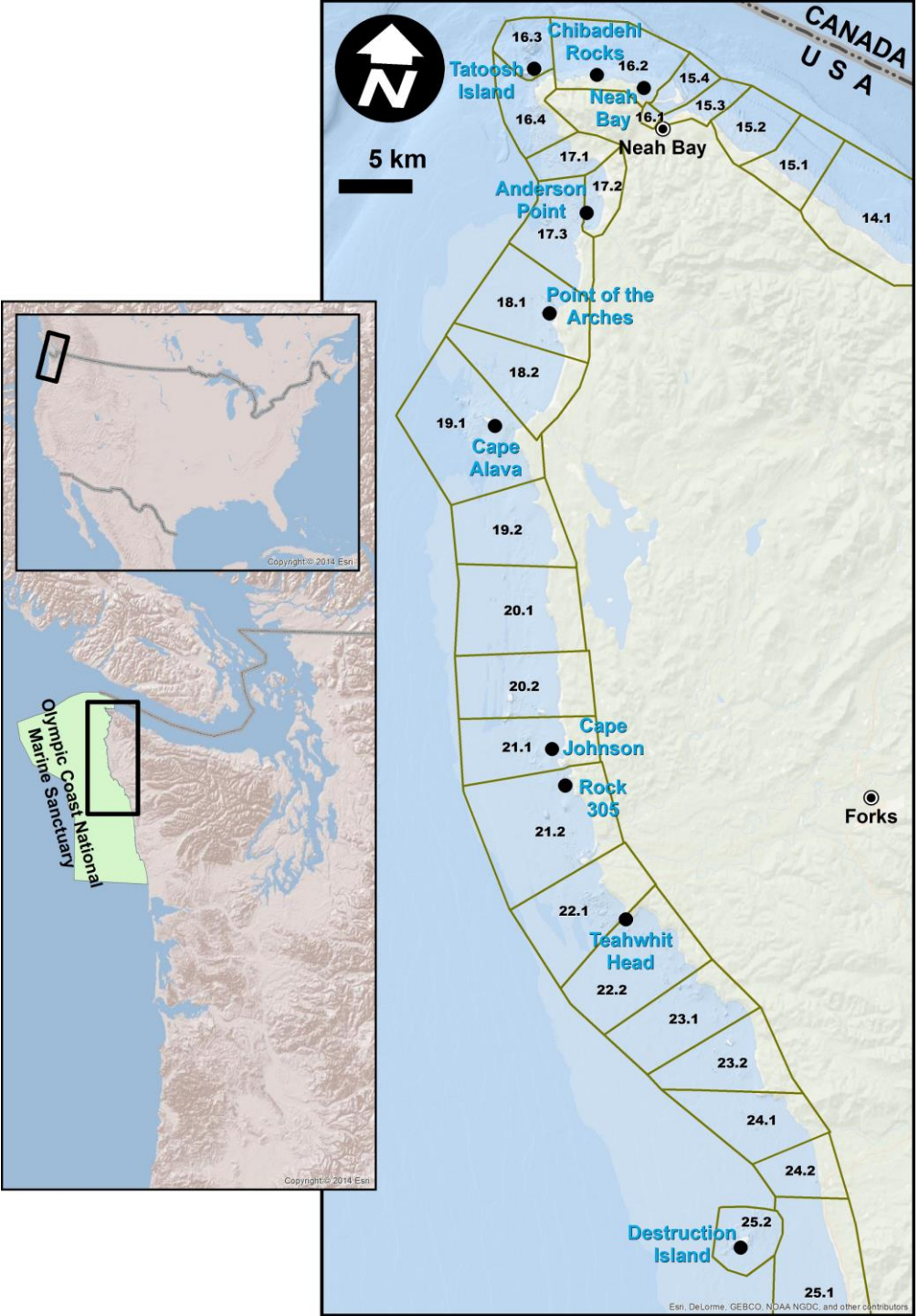
Sea Otters as keystone species

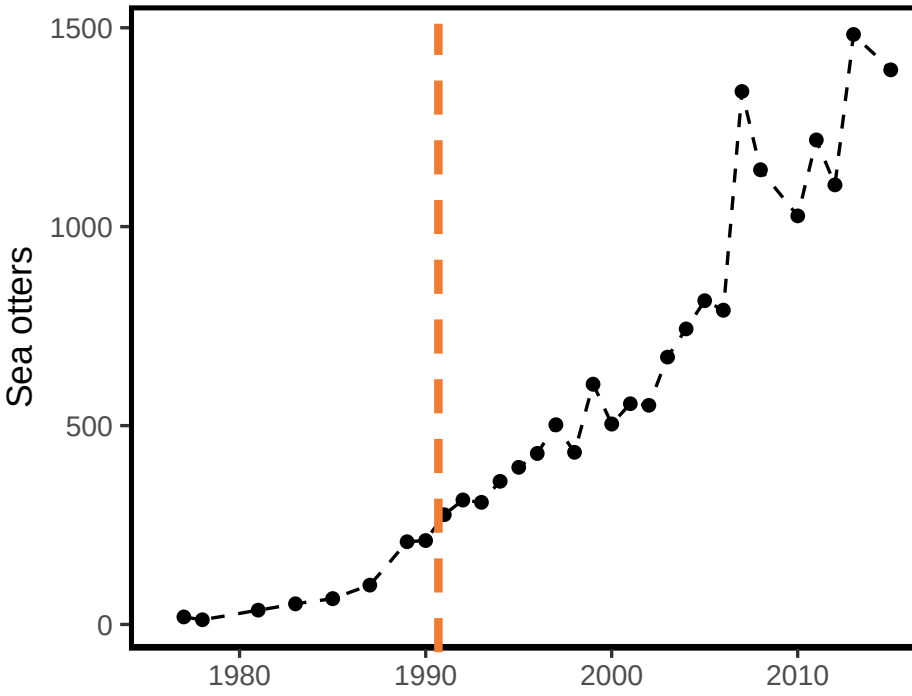




Source: [Center for Biodiversity and Conservation]

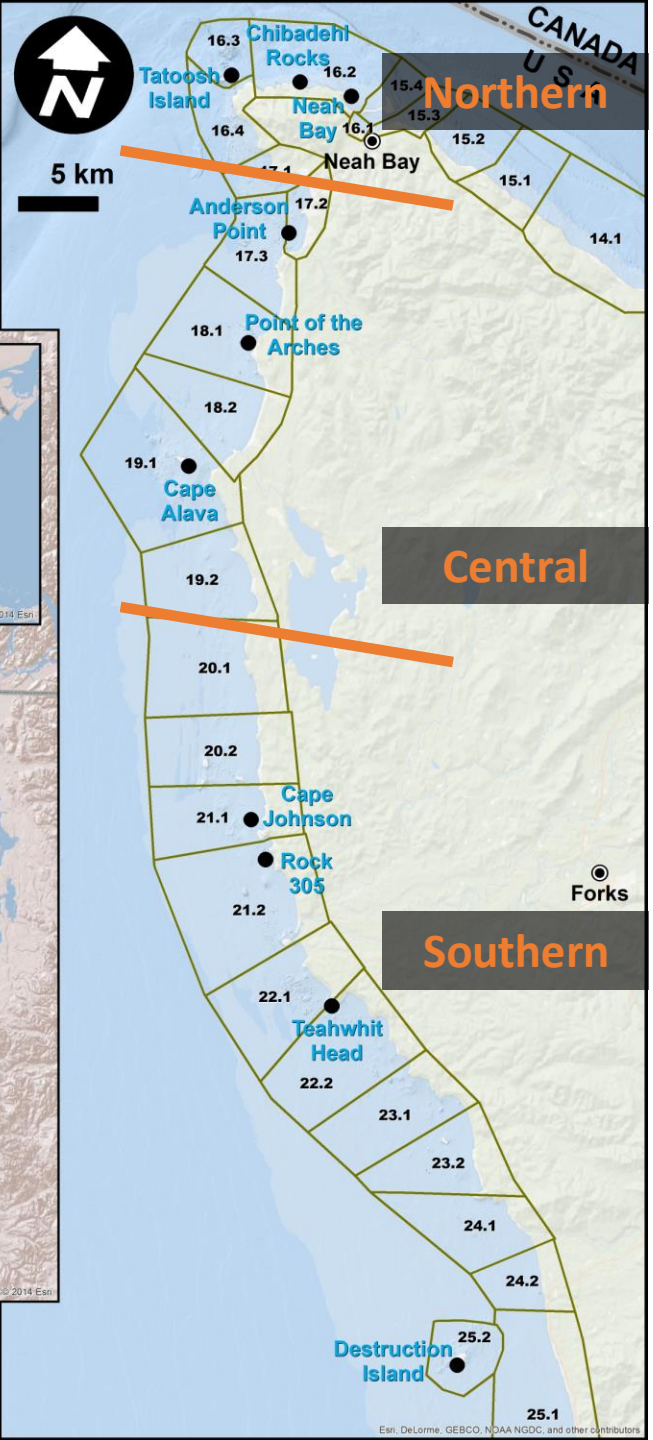
Sea otters reintroduced to WA in 1969-70

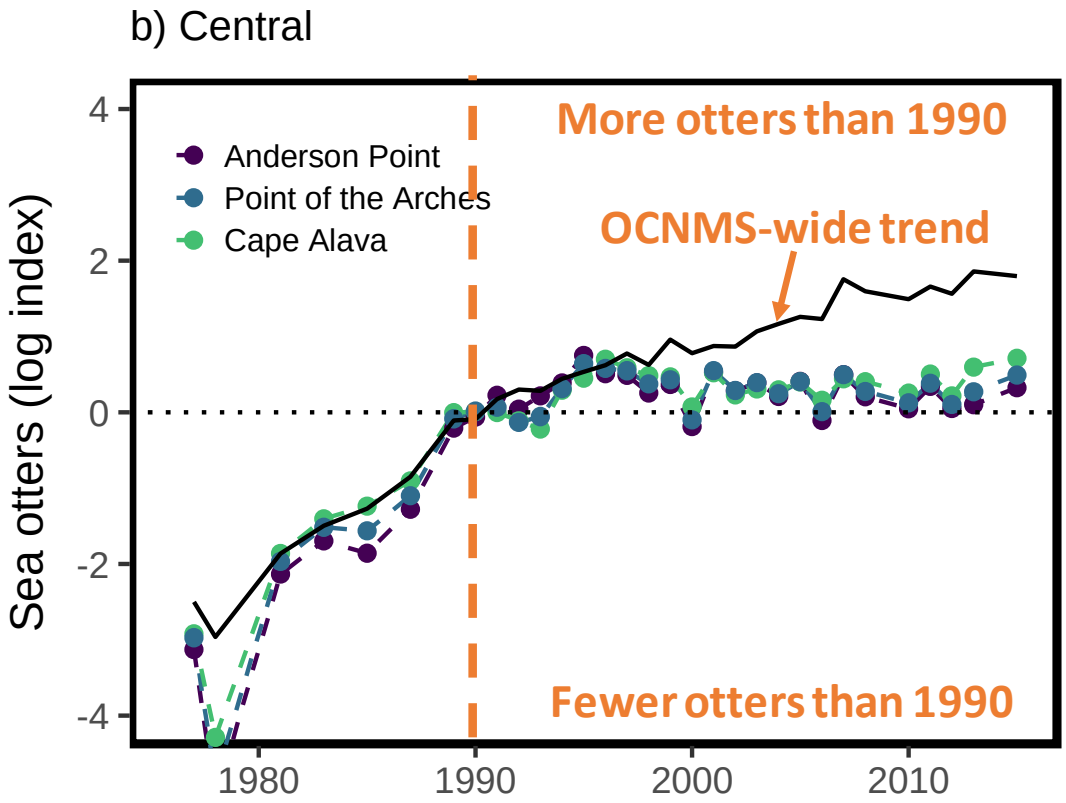


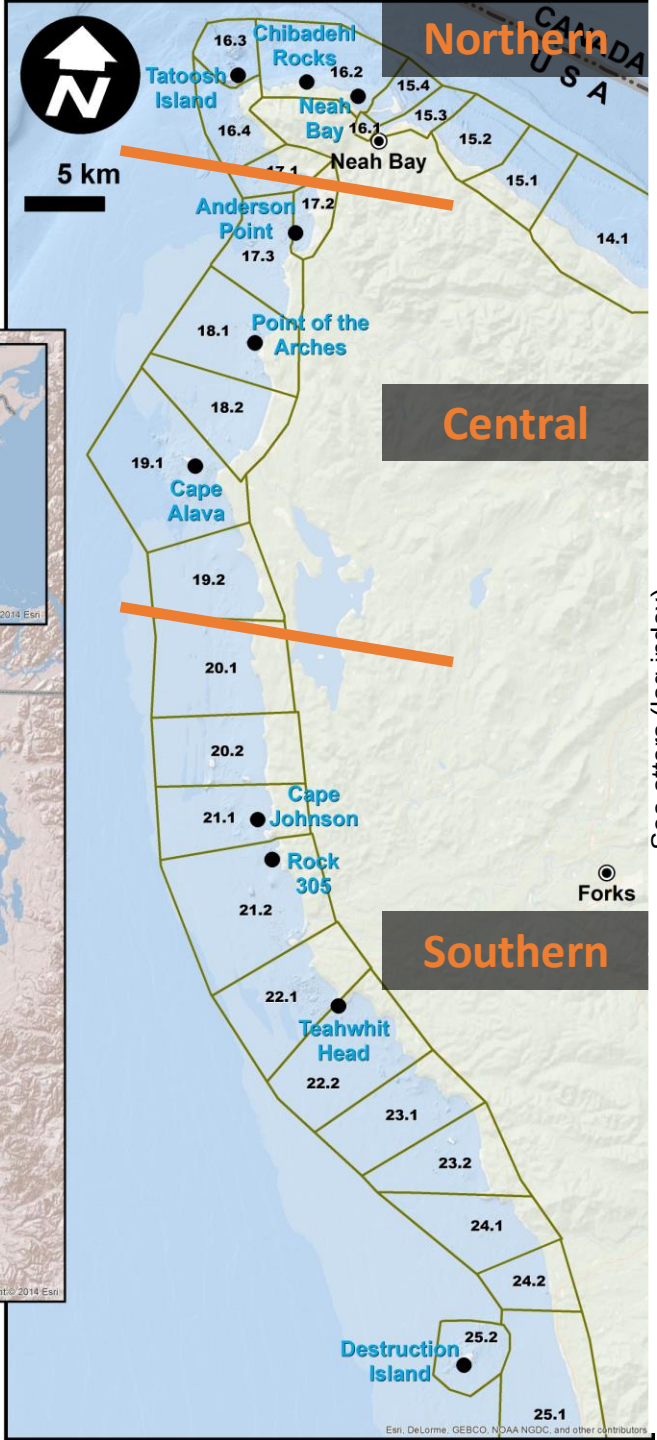


Reference Year
(WDNR kelp forest surveys)

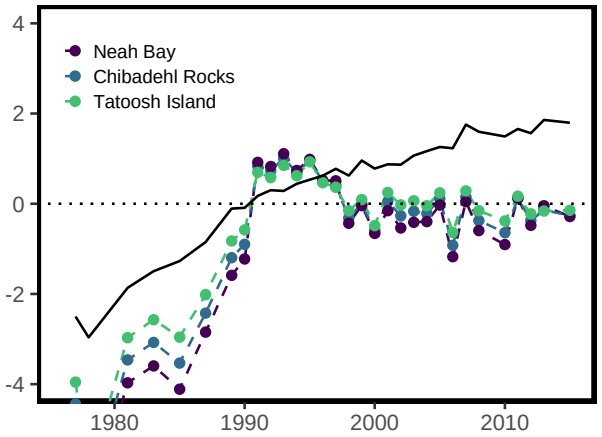
Sea Otter Trends



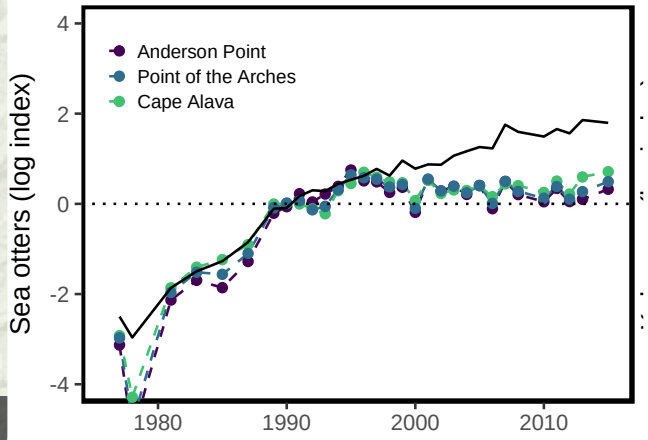




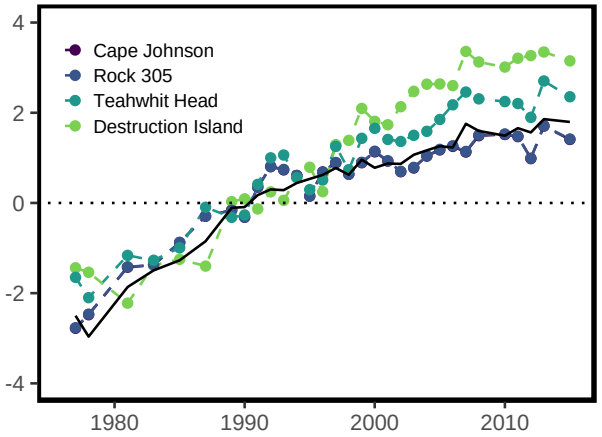
a) Northern

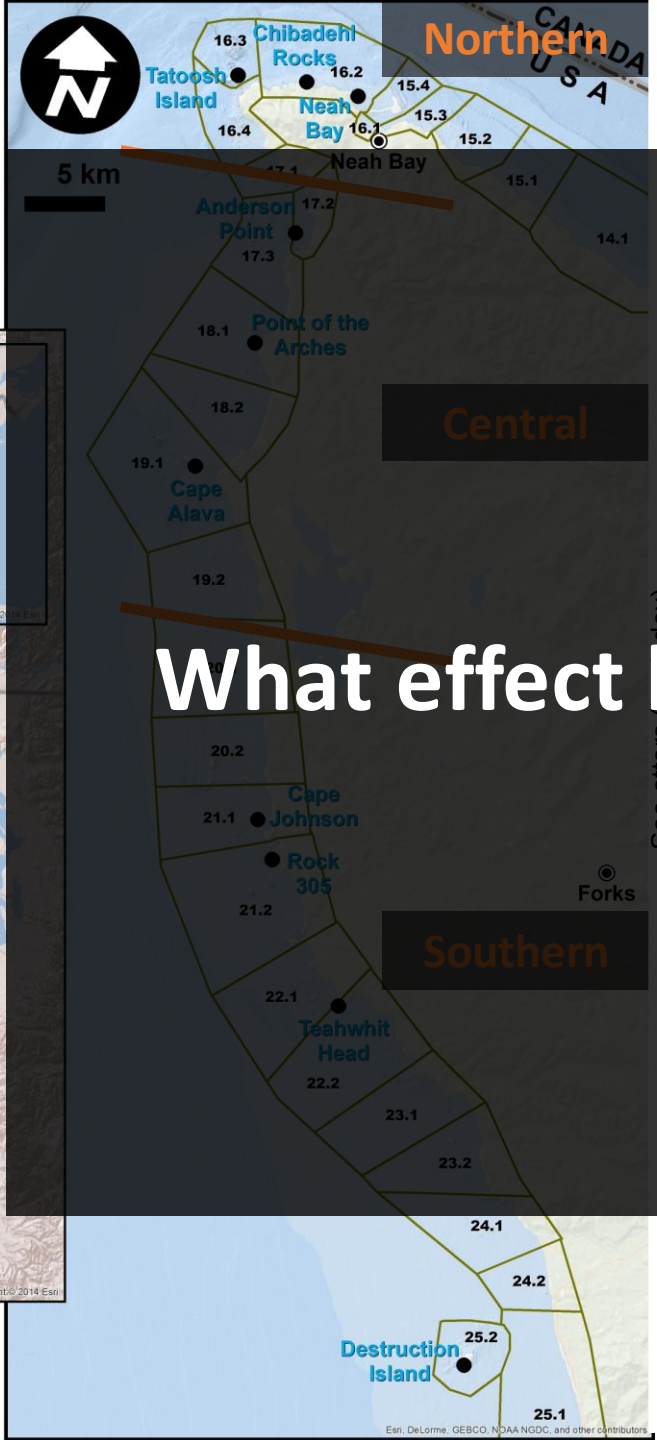


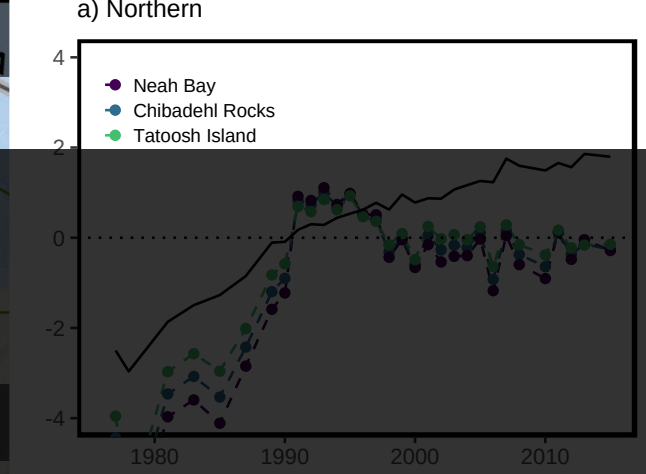
b) Central

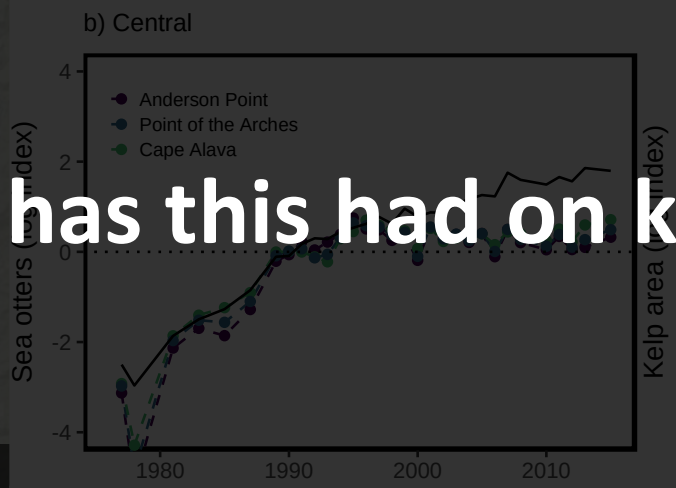


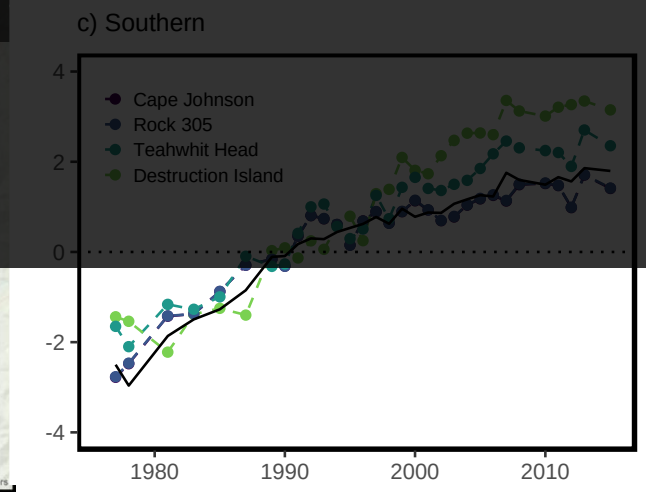
c) Southern



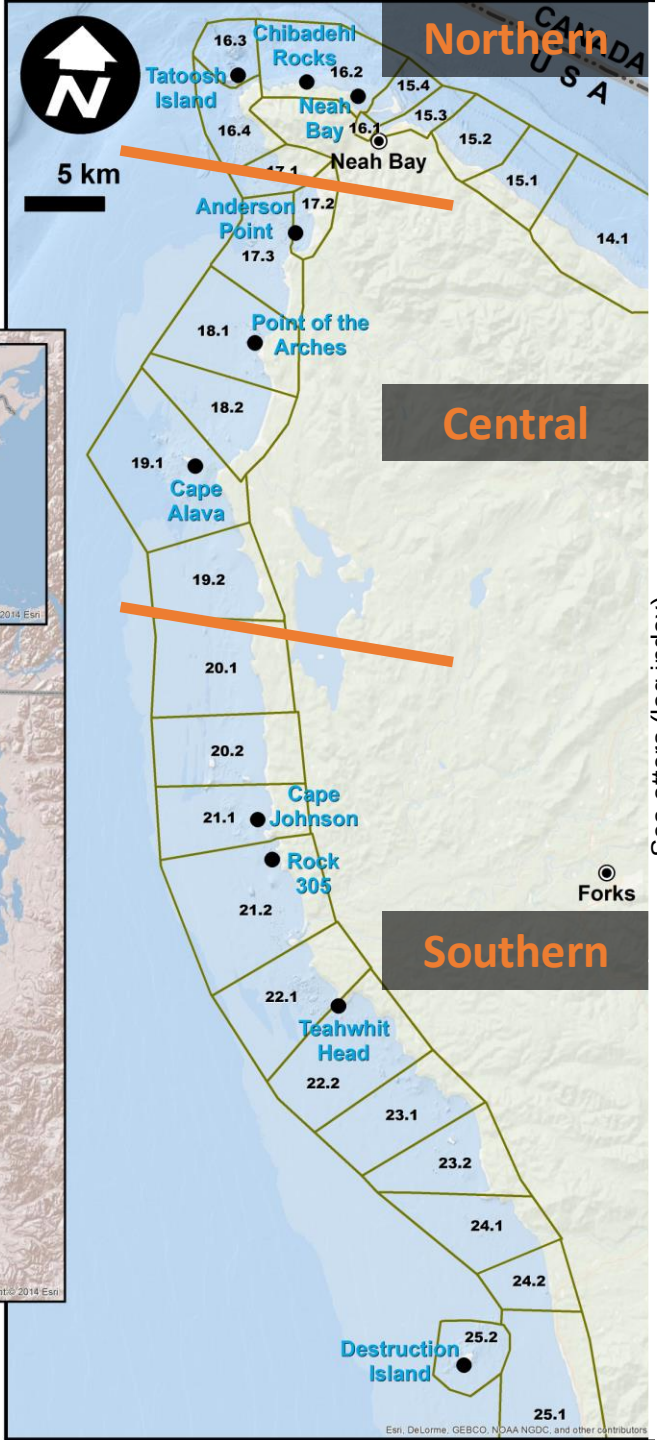


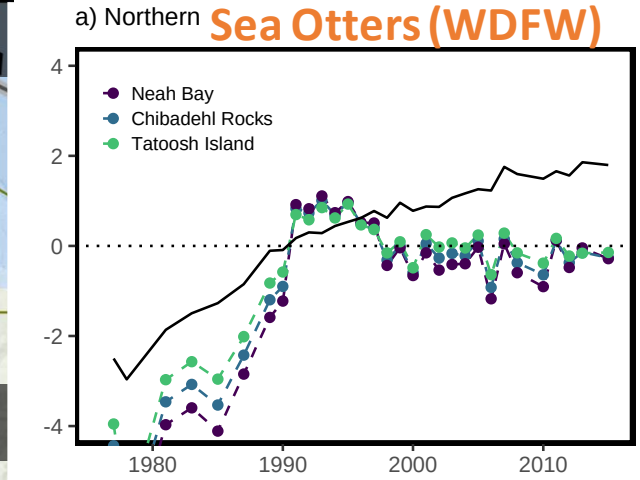


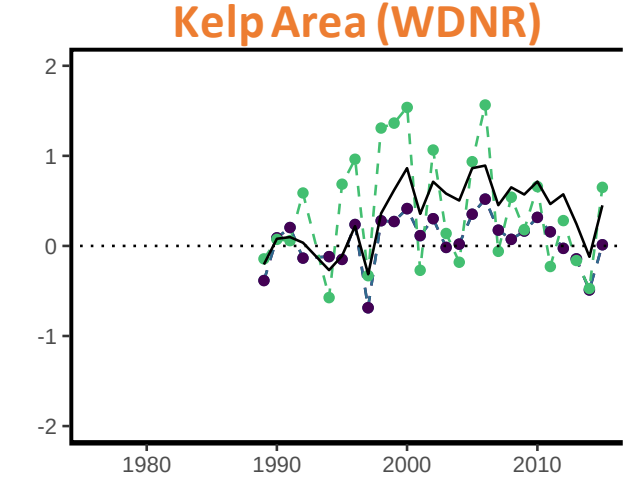


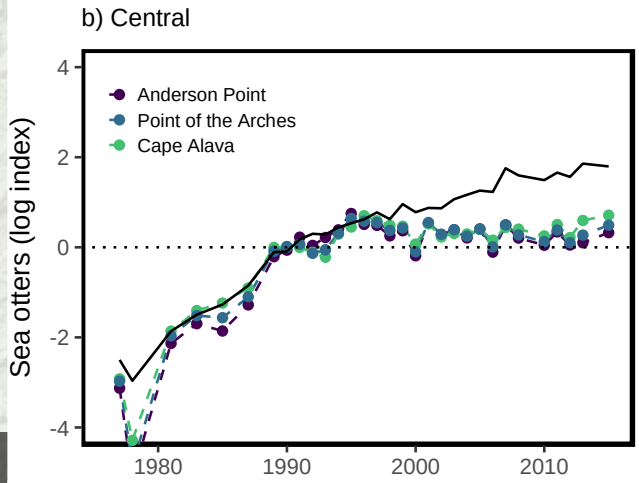


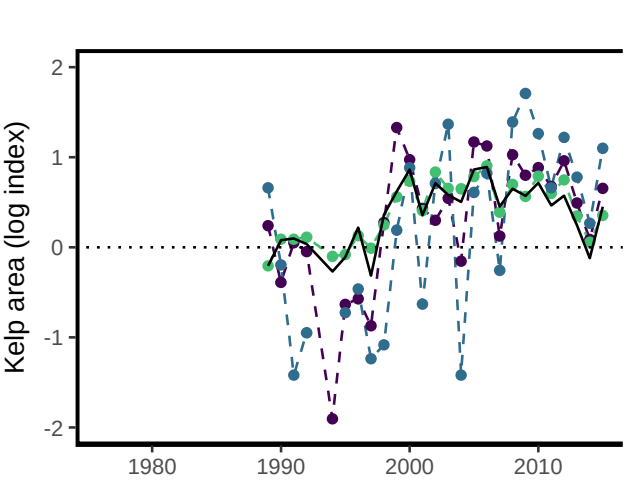
What effect has this had on kelp forests?

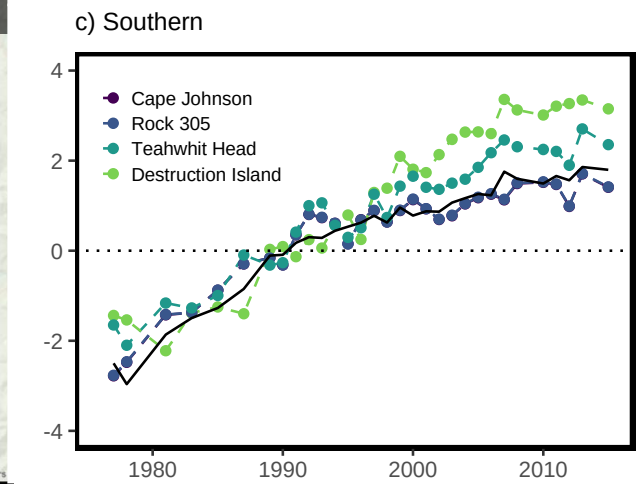

Northern
Central
Southern
CANADA
U S A
5 km
Tatoosh Island
Chibadehl Rocks
Neah Bay
Anderson Point
Point of the Arches
Cape Alava
Cape Johnson
Rock 305
Teahwhit Head
Destruction Island
Forks
16.3
16.2
15.4
15.3
16.4
16.1
15.2
15.1
17.1
17.2
14.1
17.3
18.1
18.2
19.1
19.2
20.1
20.2
21.1
21.2
22.1
22.2
23.1
23.2
24.1
24.2
25.2
25.1
Esri, DeLorme, GEBCO, NOAA NGDC, and other contributors

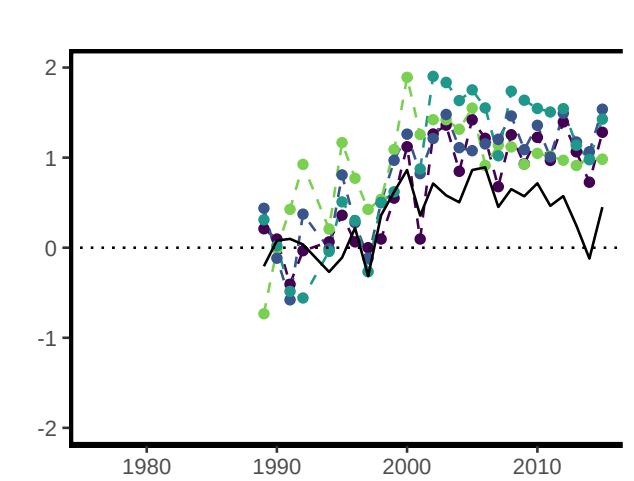

a) Northern
Sea Otters (WDFW)
Neah Bay
Chibadehl Rocks
Tatoosh Island
4
2
0
-2
-4
1980
1990
2000
2010

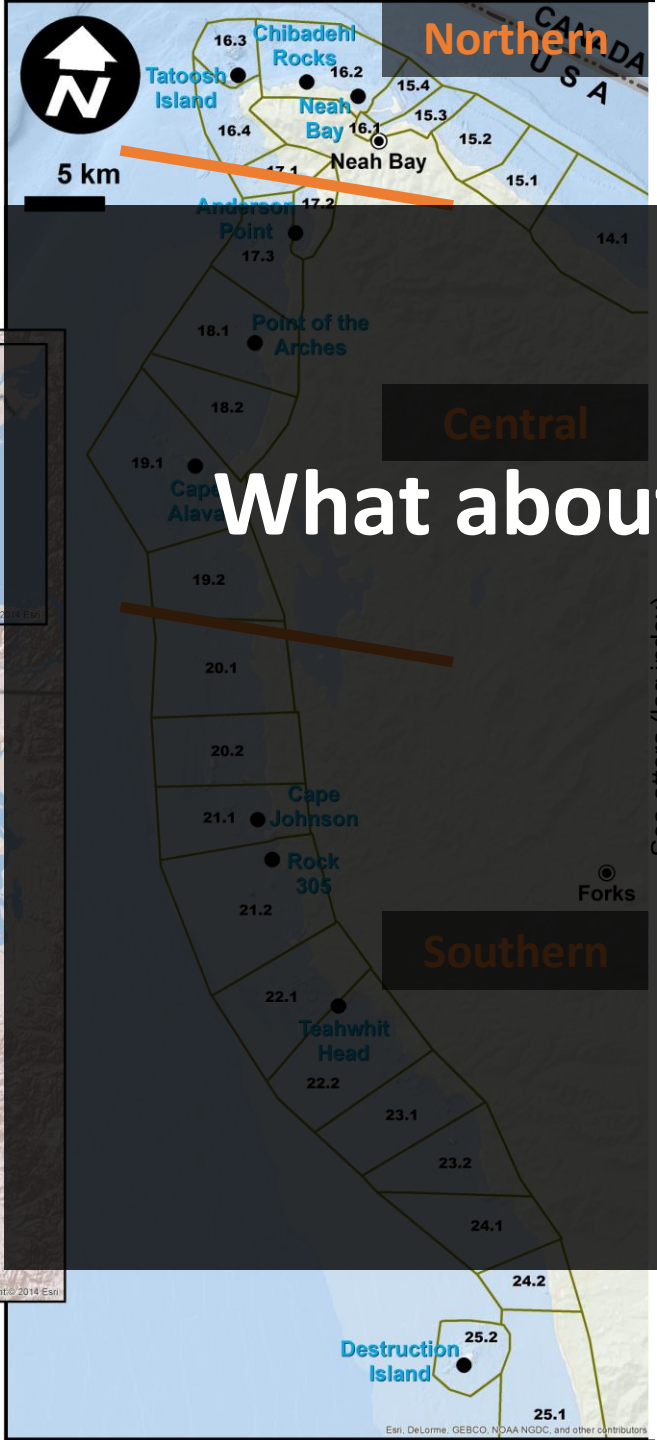

Kelp Area (WDNR)
2
1
0
-1
-2
1980
1990
2000
2010


b) Central
Sea otters (log index)
Anderson Point
Point of the Arches
Cape Alava
4
2
0
-2
-4
1980
1990
2000
2010

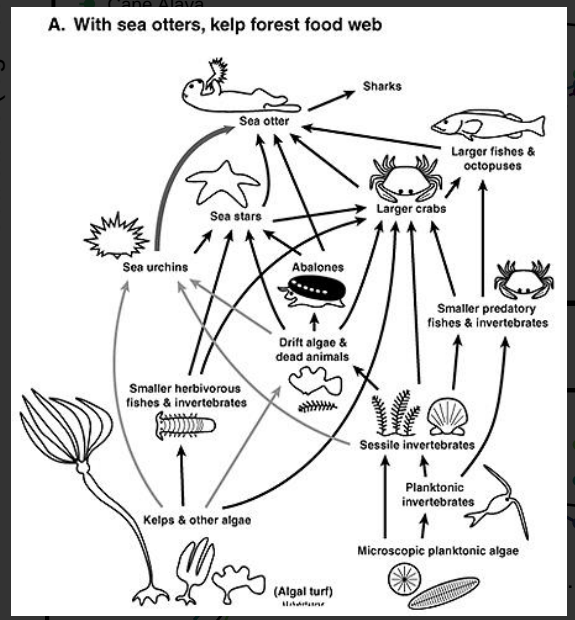

Kelp area (log index)
2
1
0
-1
-2
1980
1990
2000
2010


c) Southern
Cape Johnson
Rock 305
Teahwhit Head
Destruction Island
4
2
0
-2
-4
1980
1990
2000
2010

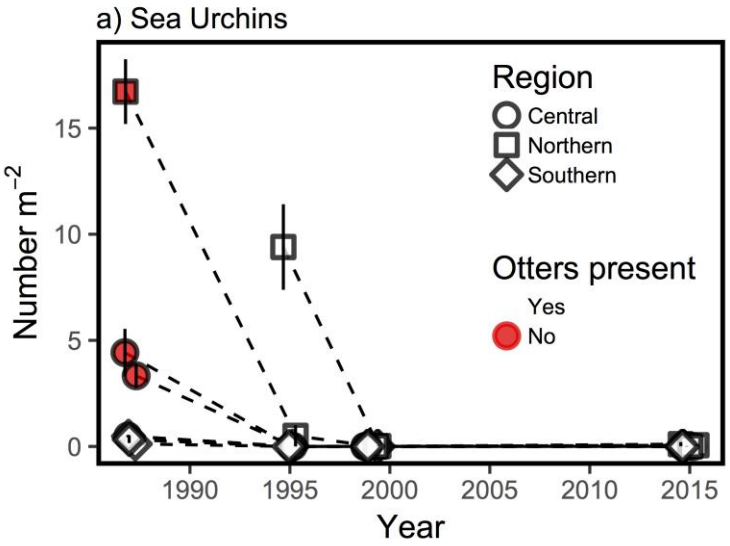

2
1
0
-1
-2
1980
1990
2000
2010



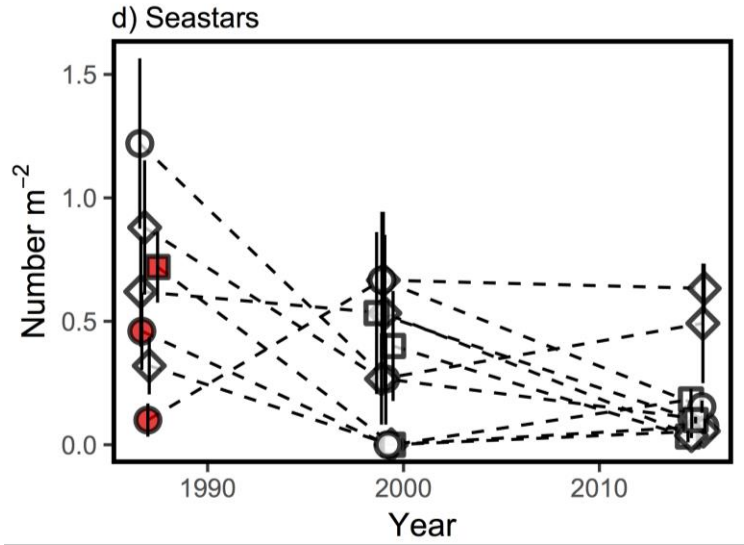
What about the invertebrate species?

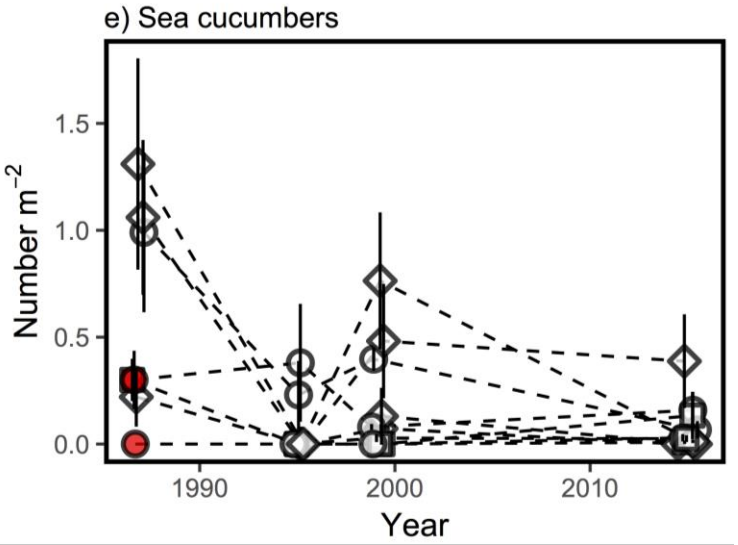


Invertebrates become rare with the introduction of sea otters.



Vary in the magnitude of decline.





Previous is through 2015

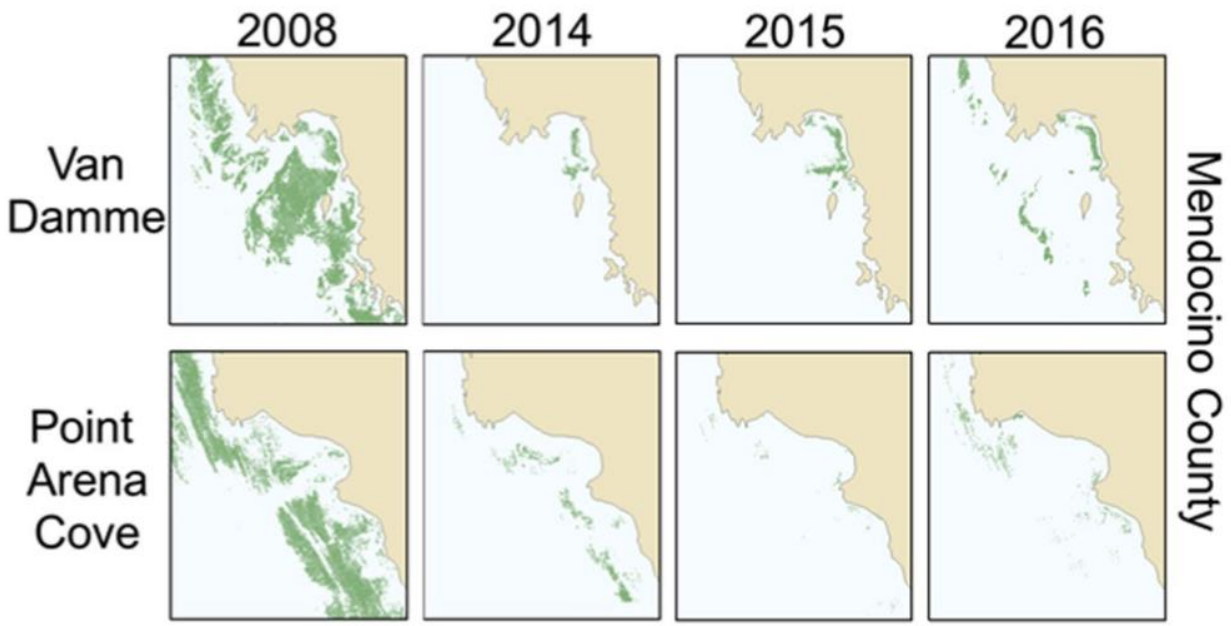
What about recent years?

Kelp forests collapse ca. 2014-15

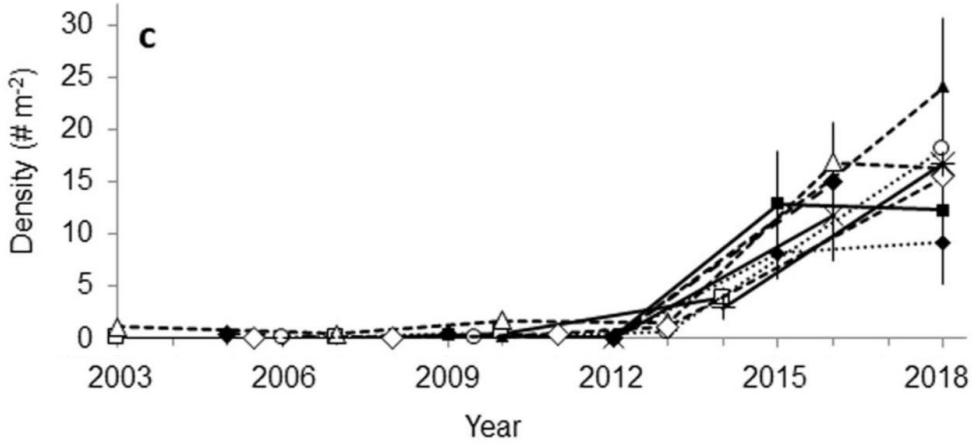
OPEN

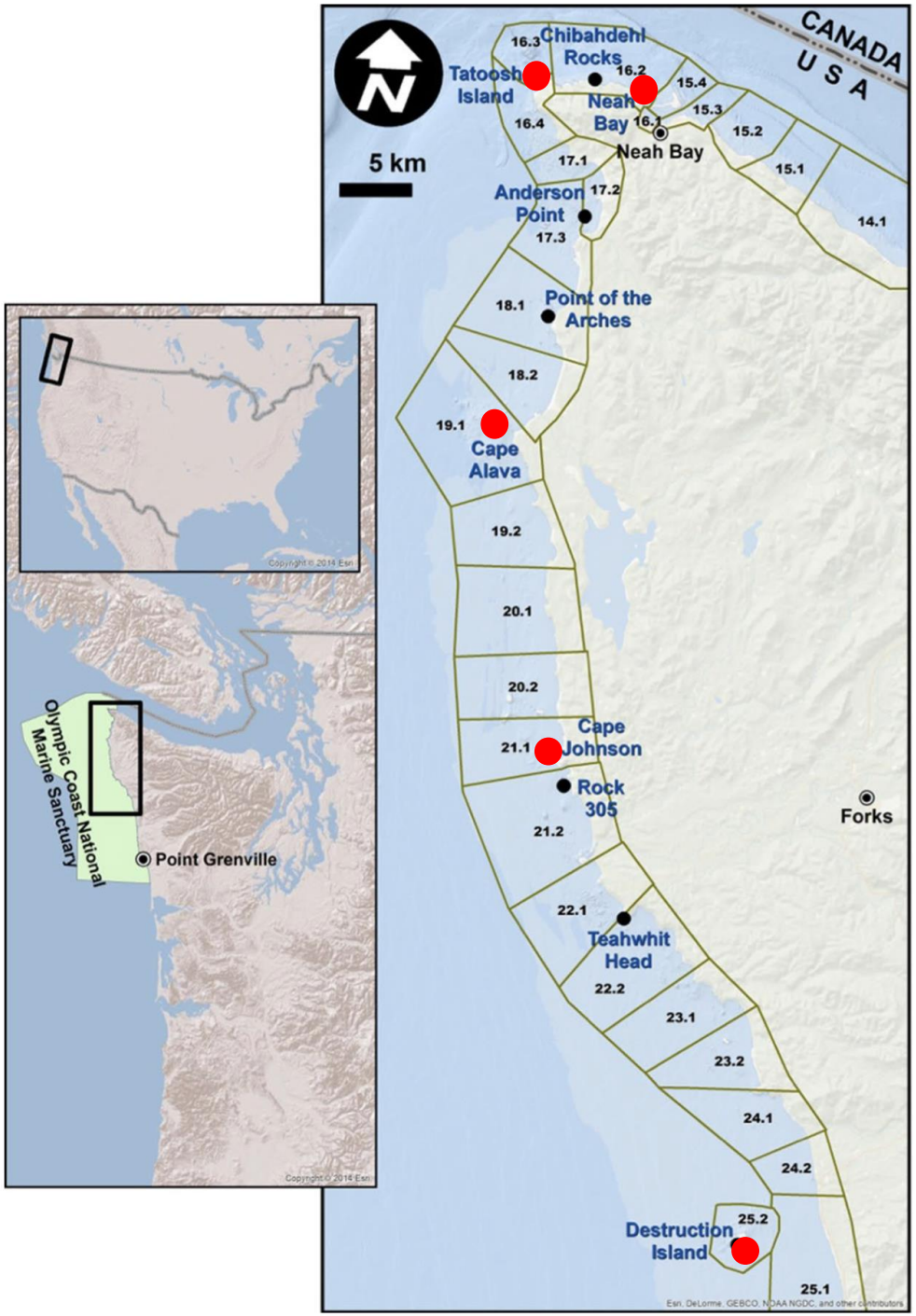
Marine heat wave and multiple stressors tip bull kelp forest to sea urchin barrens

L. Rogers-Bennett* & C. A. Catton



Marine heat wave
&
Sea Urchins





2015:

10 sites based on Kvitek et al. surveys from 1980's and 1990's

2016 –2021:

5 Index sites (red)

Kelp Forest Community

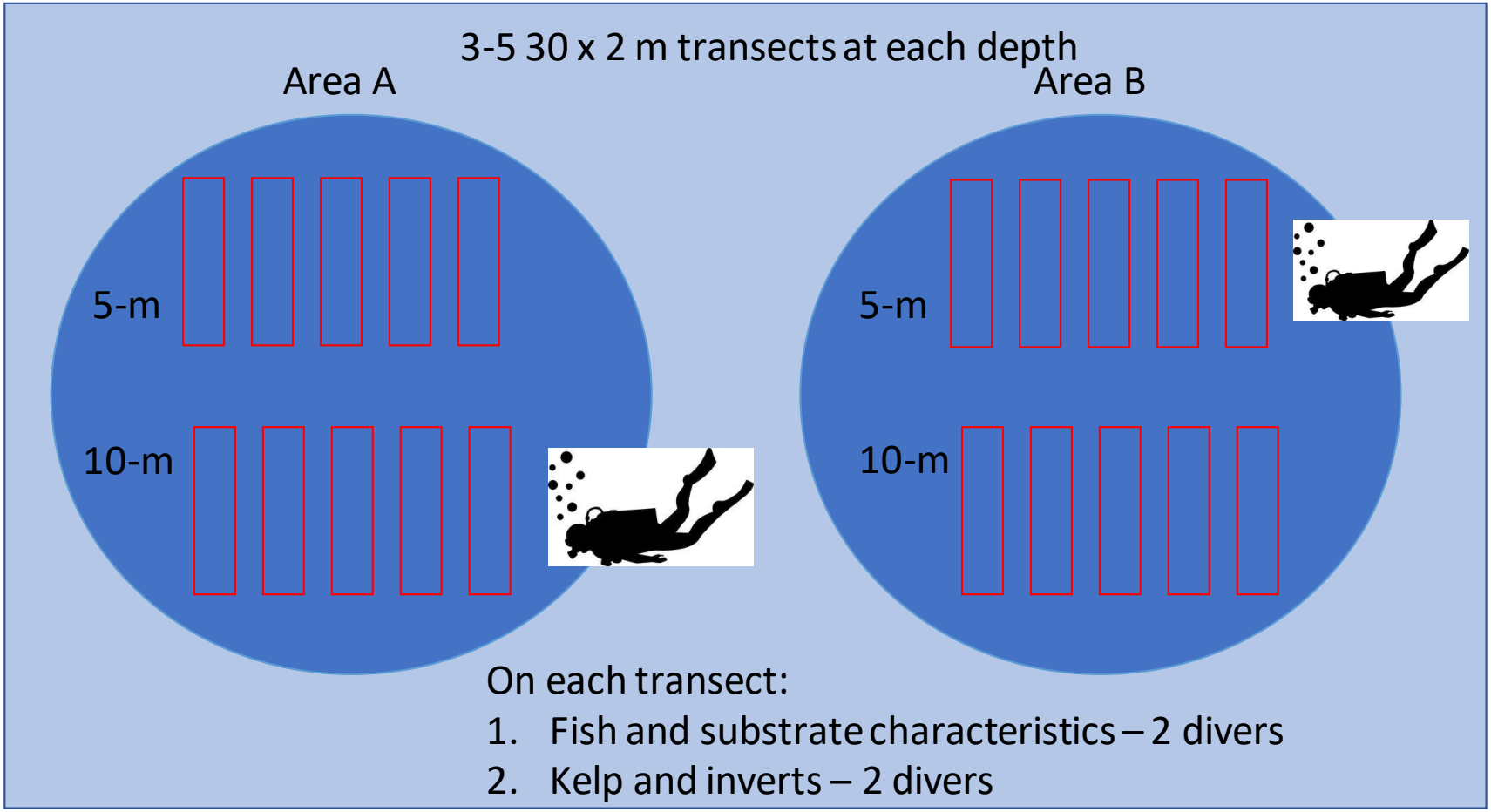
Kelp

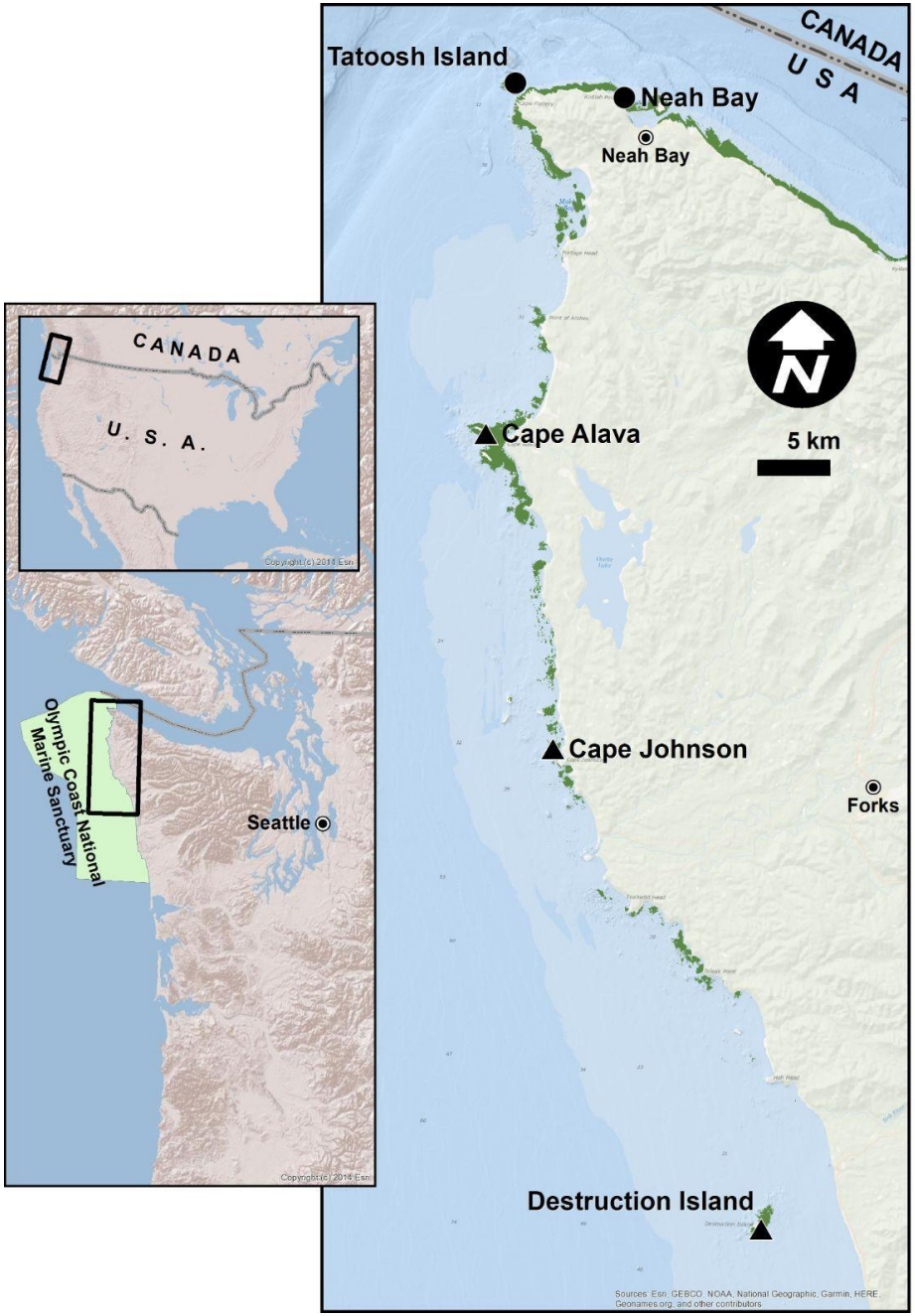
Invertebrates

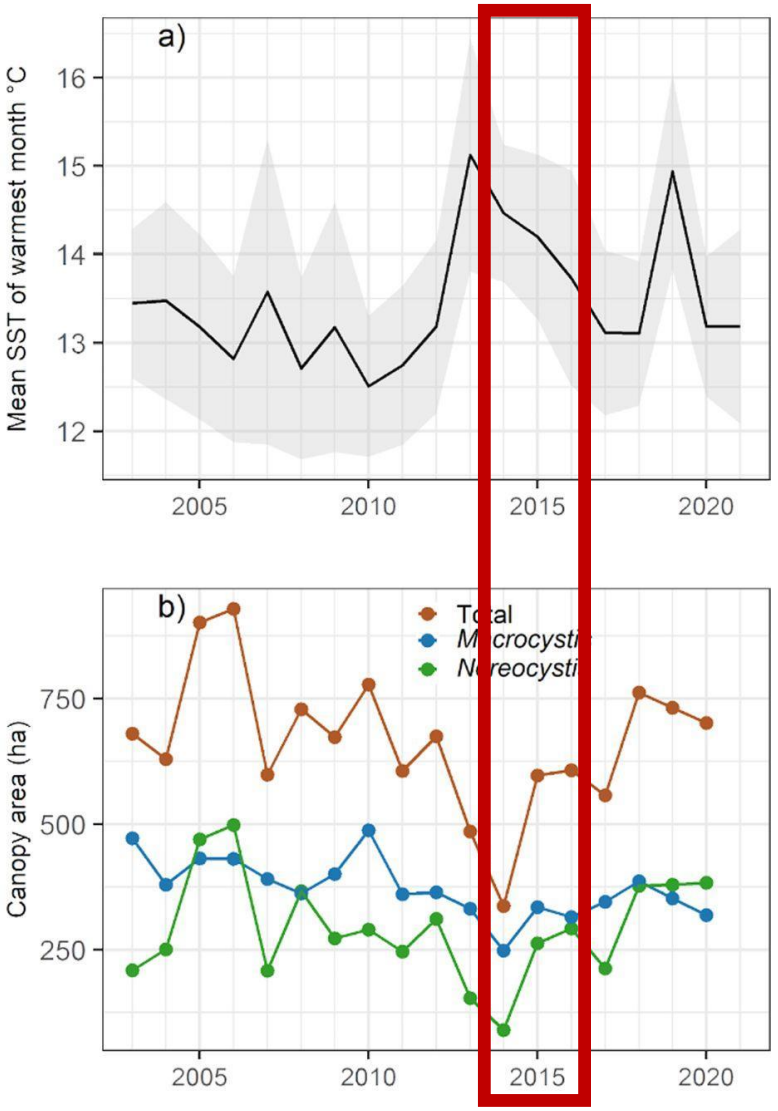
Large Fish

Rockfish recruits.

SCUBA sampling

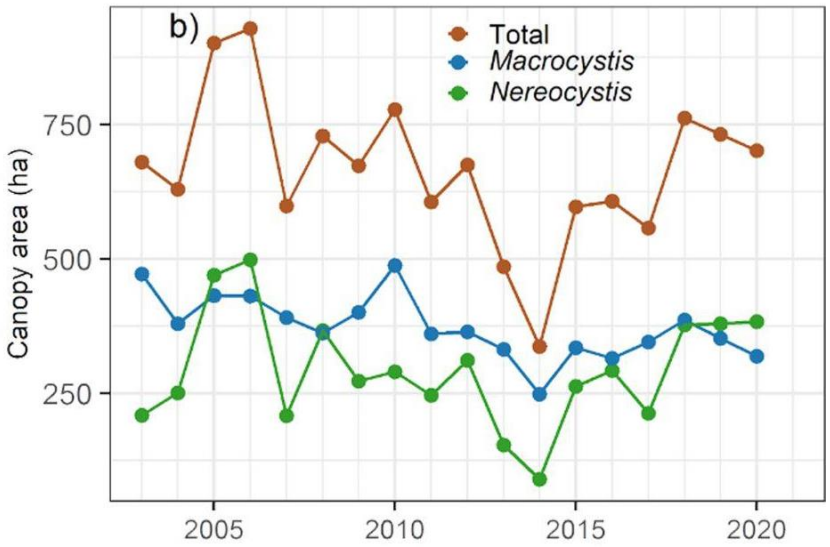


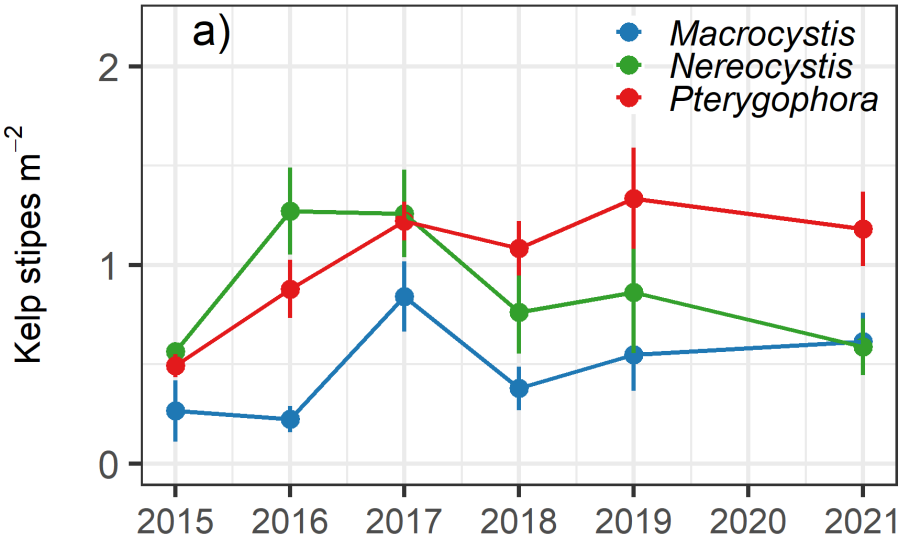




Marine heat wave

Coastwide to 5-site index.



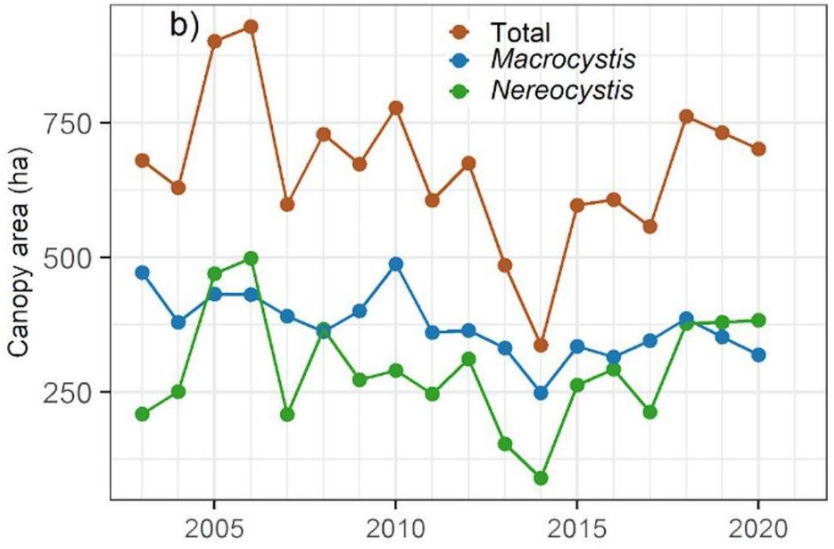


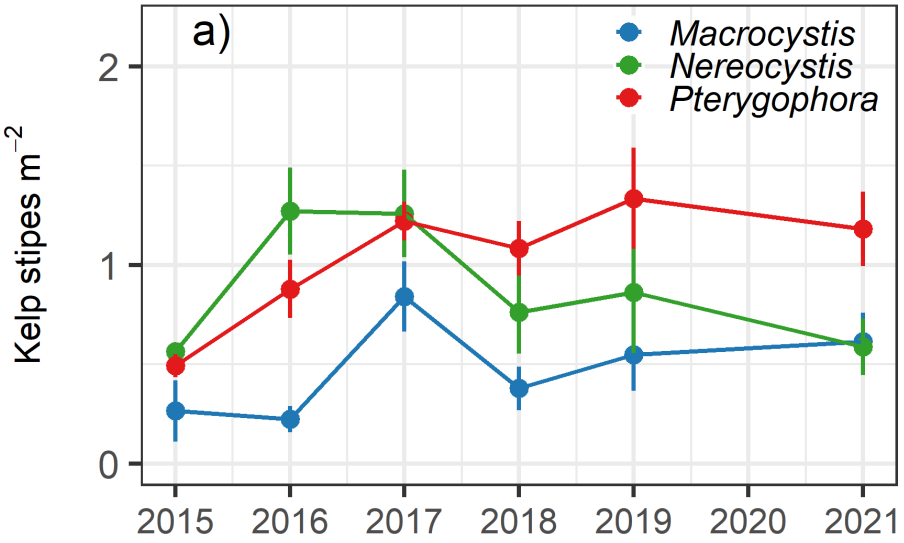
Big Picture:

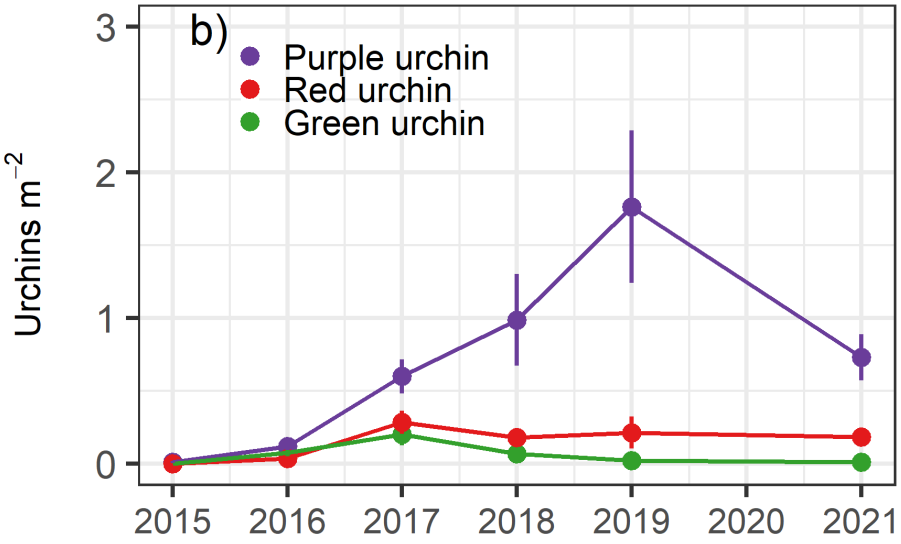
Stability since 2015

Some differences in trend between our sites and coastwide.

Coastwide to 5-site index.







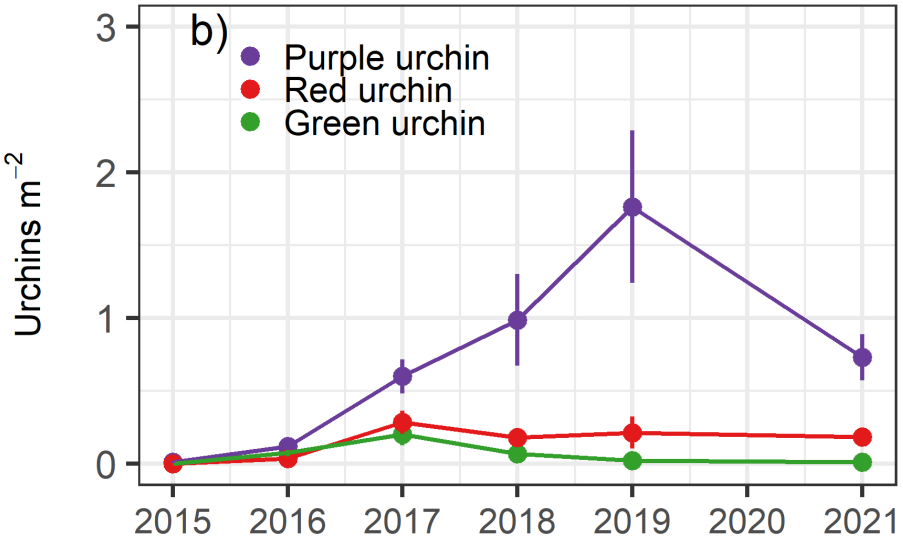
Urchins increase.

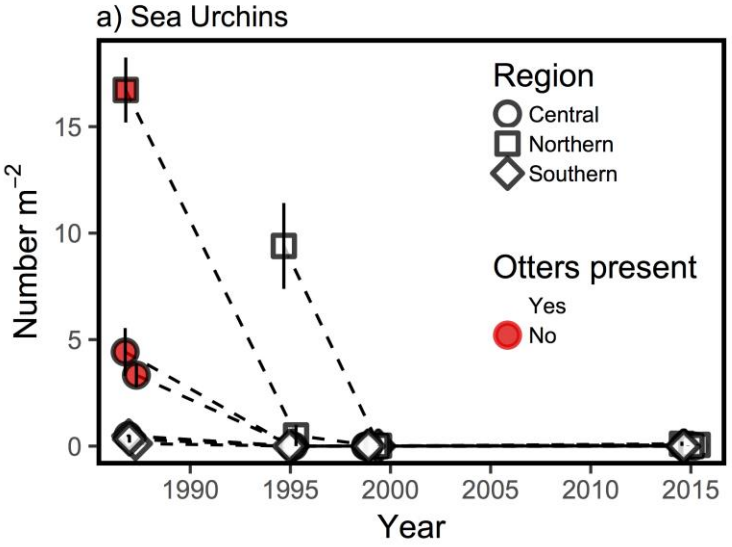
But…

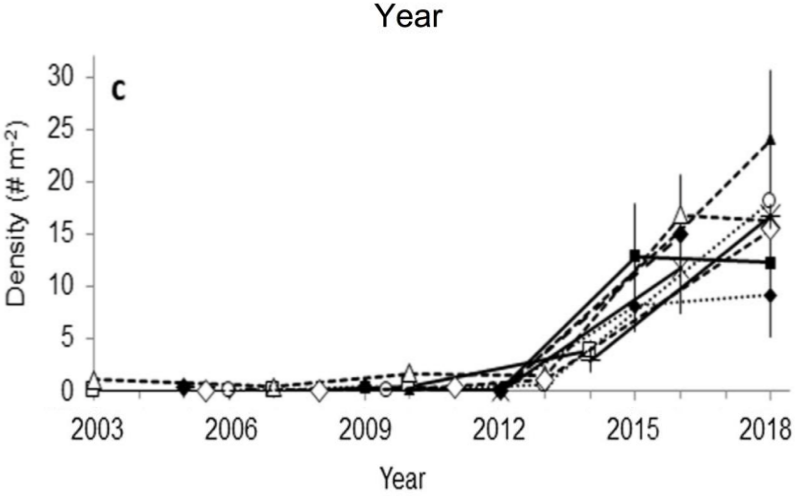
after MHW

after kelp crash.

Coastwide to 5-site Index

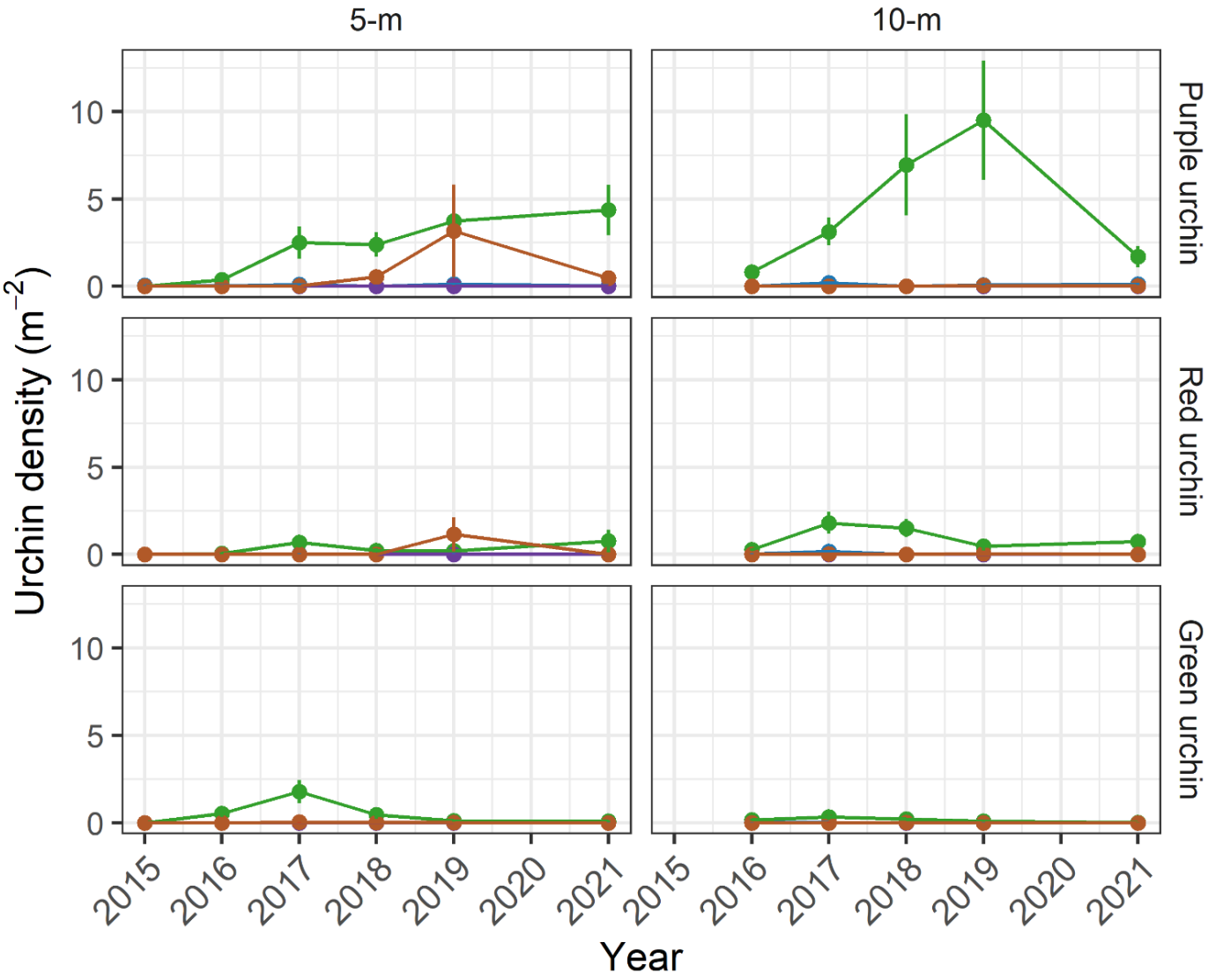


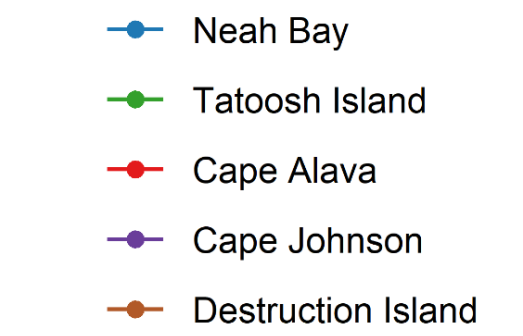


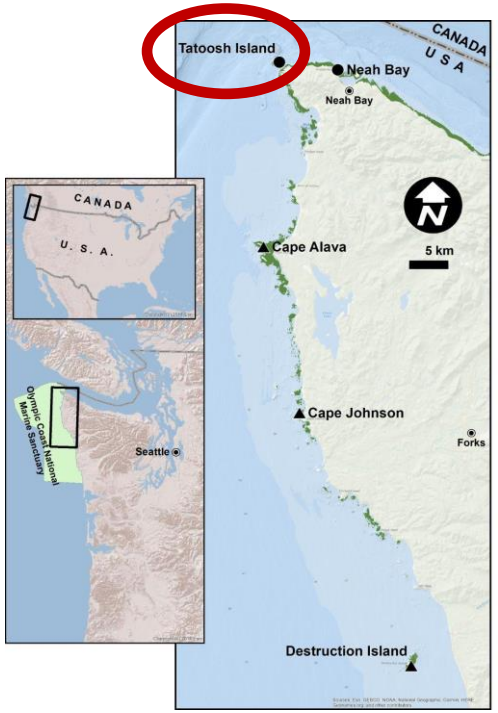


Urchin densities are not approaching pre-otter or northern CA densities.

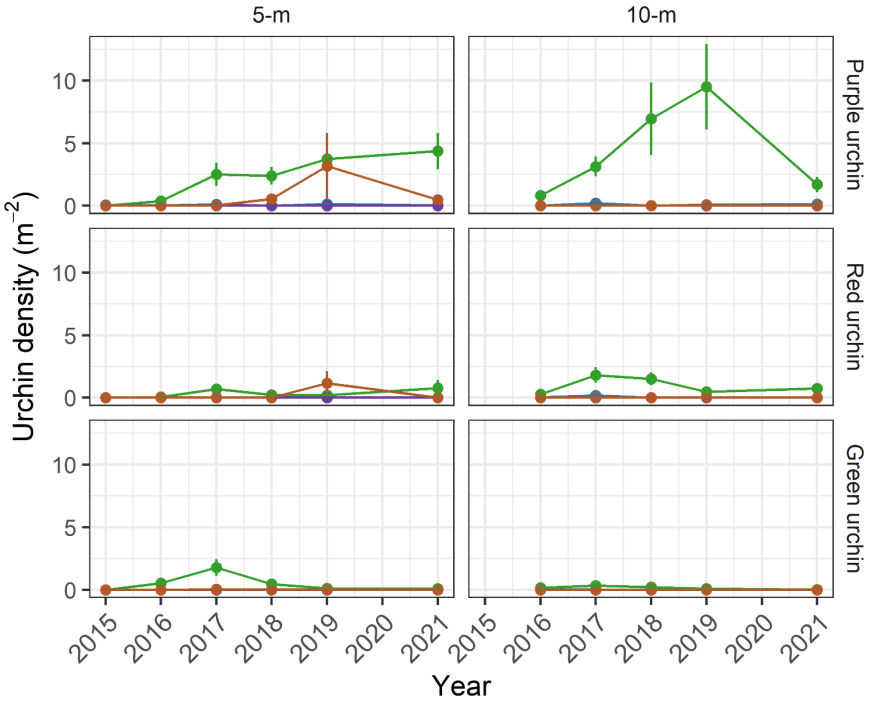
5-site Index to Sites

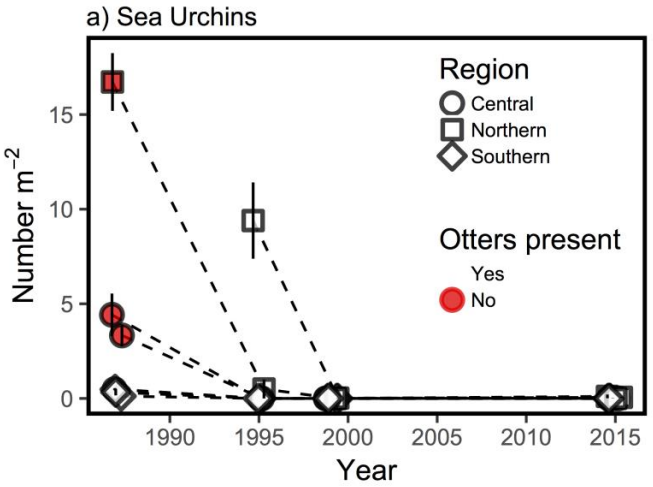






5-site Index to Sites





Among-site urchin trends are driven by one site: Tatoosh Island.

Tatoosh Is. has densities on the low end of pre-sea otter densities

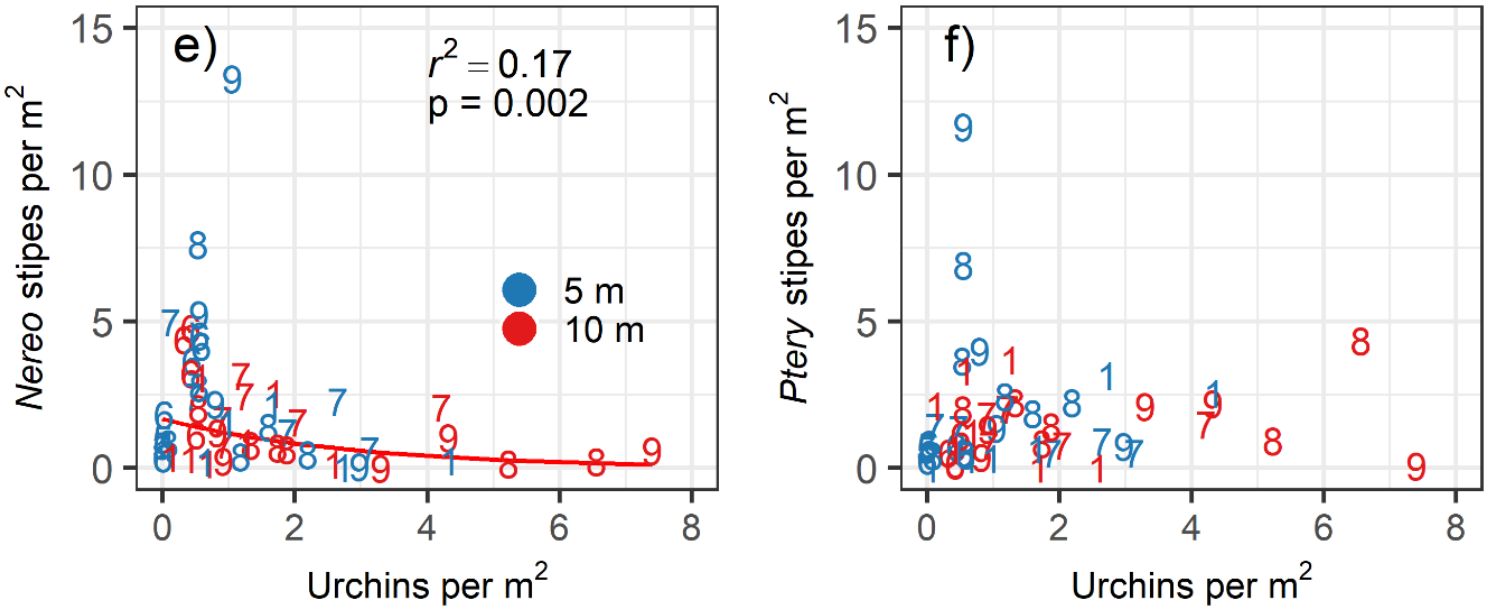
Variation by depth?

There are sea otters at Tatoosh Island currently

Tatoosh Island 2017

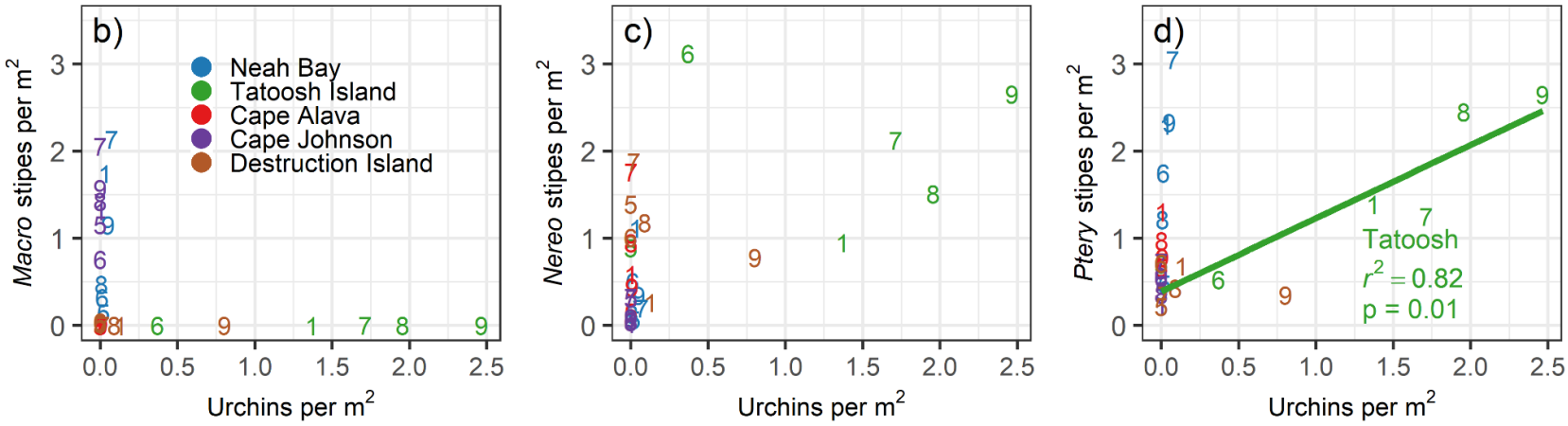
What has this meant for the kelp?

Sites to Transects



Mild negative kelp-urchin relationship at transect level.

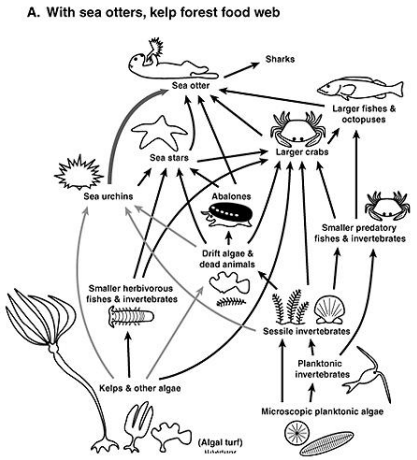
Transects to Sites



Confused kelp-urchin relationships at the site-level

Is Tatoosh just an odd site?

A harbinger of the future?



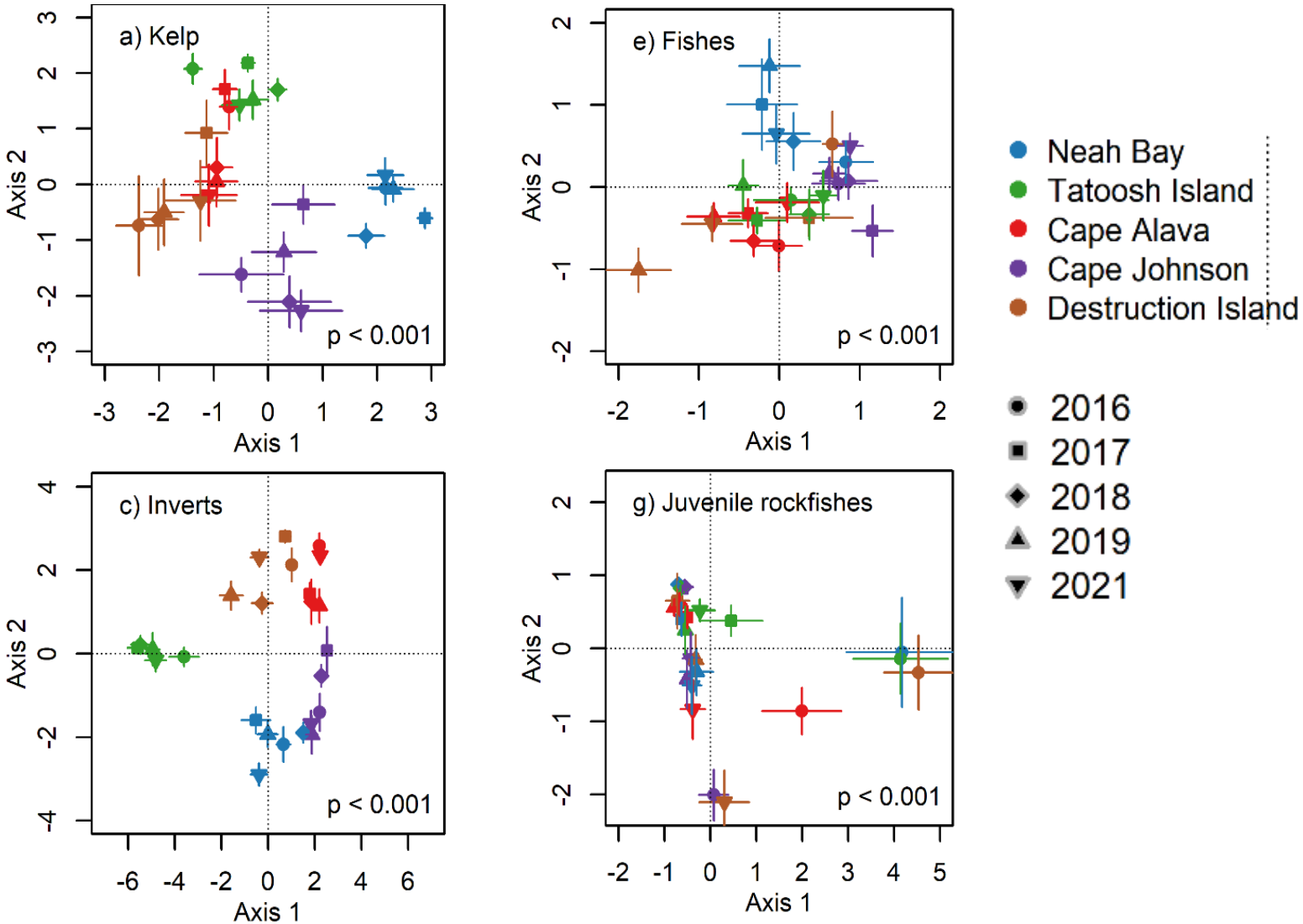
Reduced strength of otter-urchin-kelp interaction?

- at Tatoosh?

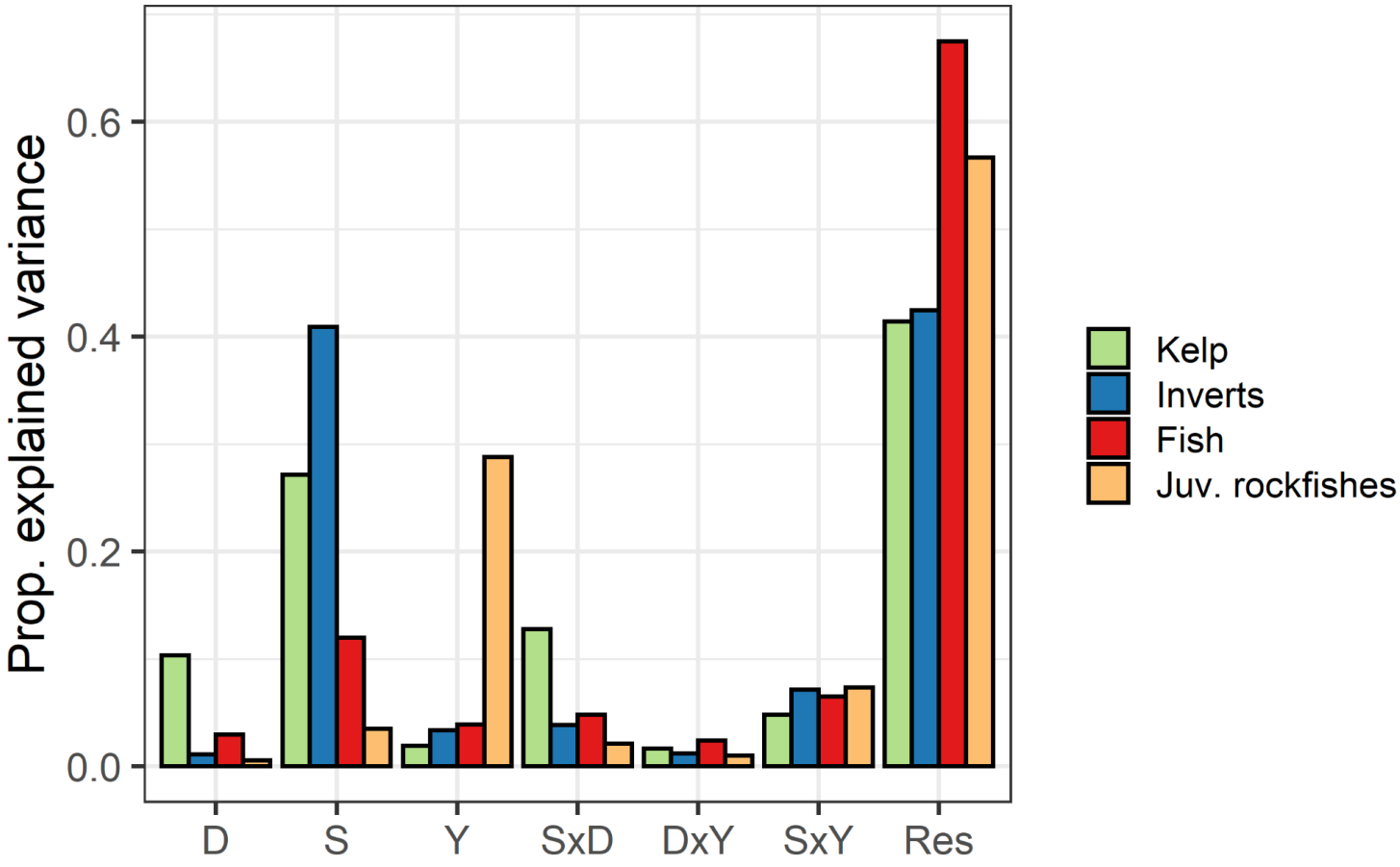
WA kelp forests appear to have weathered the marine heat wave of 2014-16 fairly well.

- we are not California

Multi-variate analyses of the entire kelp forest community



Different guilds have distinct spatio-temporal structure



Site (S) dominates multi-variate structure.

Only juvenile Rockfish show substantial year-to year variation (Y)

Thanks

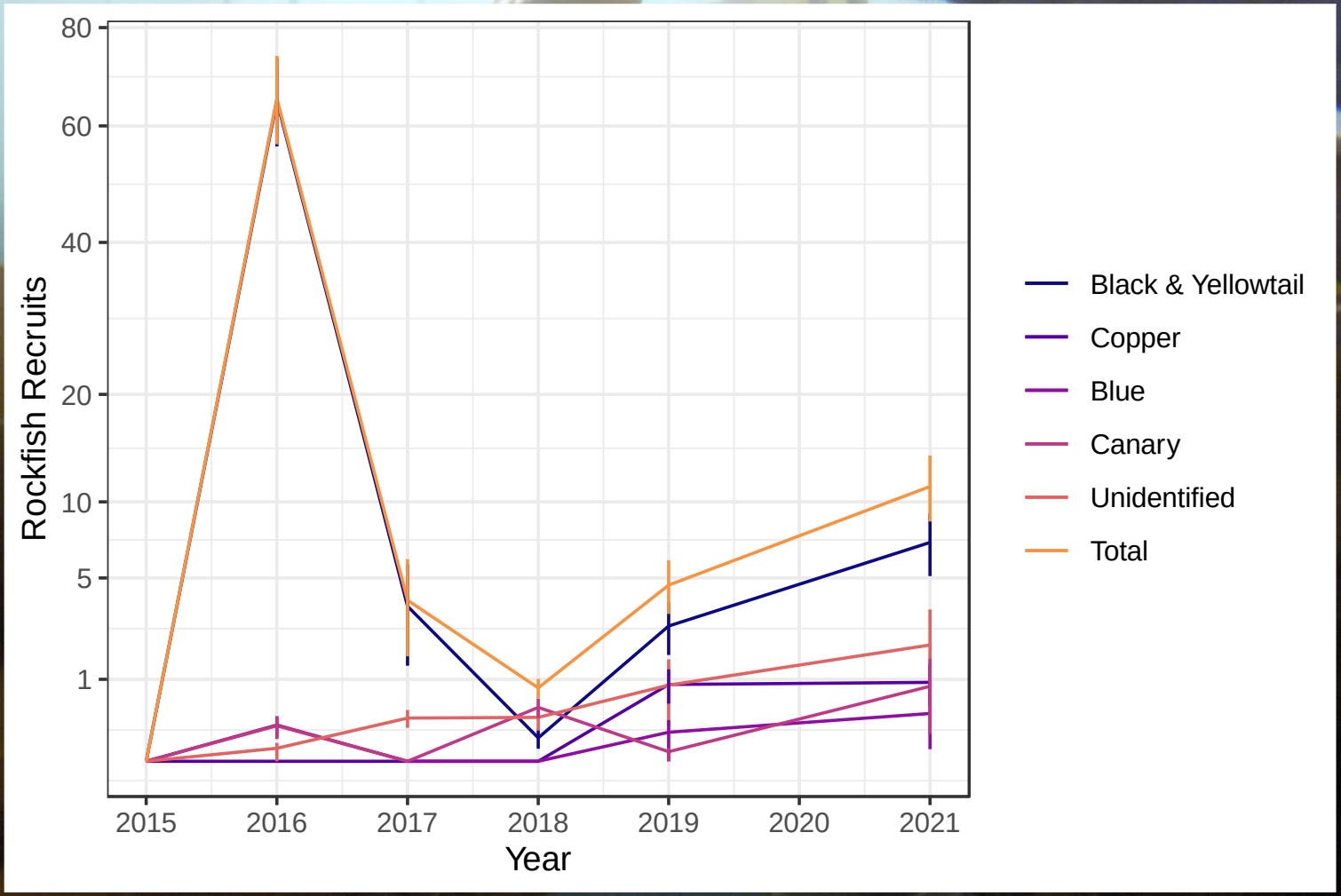

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE


MAKAH INDIAN NATION
DIAHT, WAATCH, OSETT, TSOO-YESS, BAADAH


NATIONAL MARINE
SANCTUARIES


WASHINGTON
DEPARTMENT OF NATURAL RESOURCES

What about the fish?



~100-fold variation in density among years

Are these surveys predictive of future populations?

Does kelp influence recruitment success?

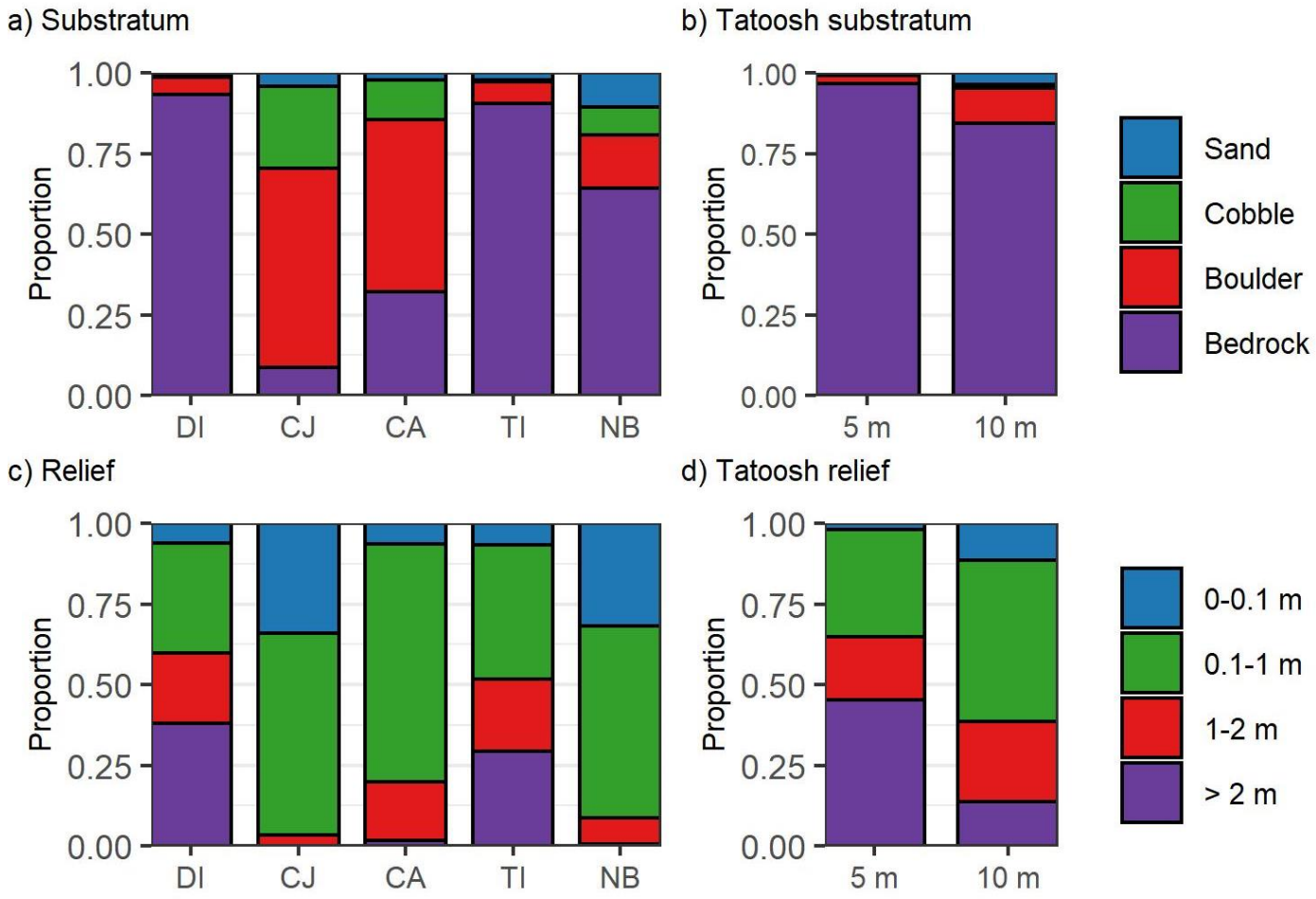
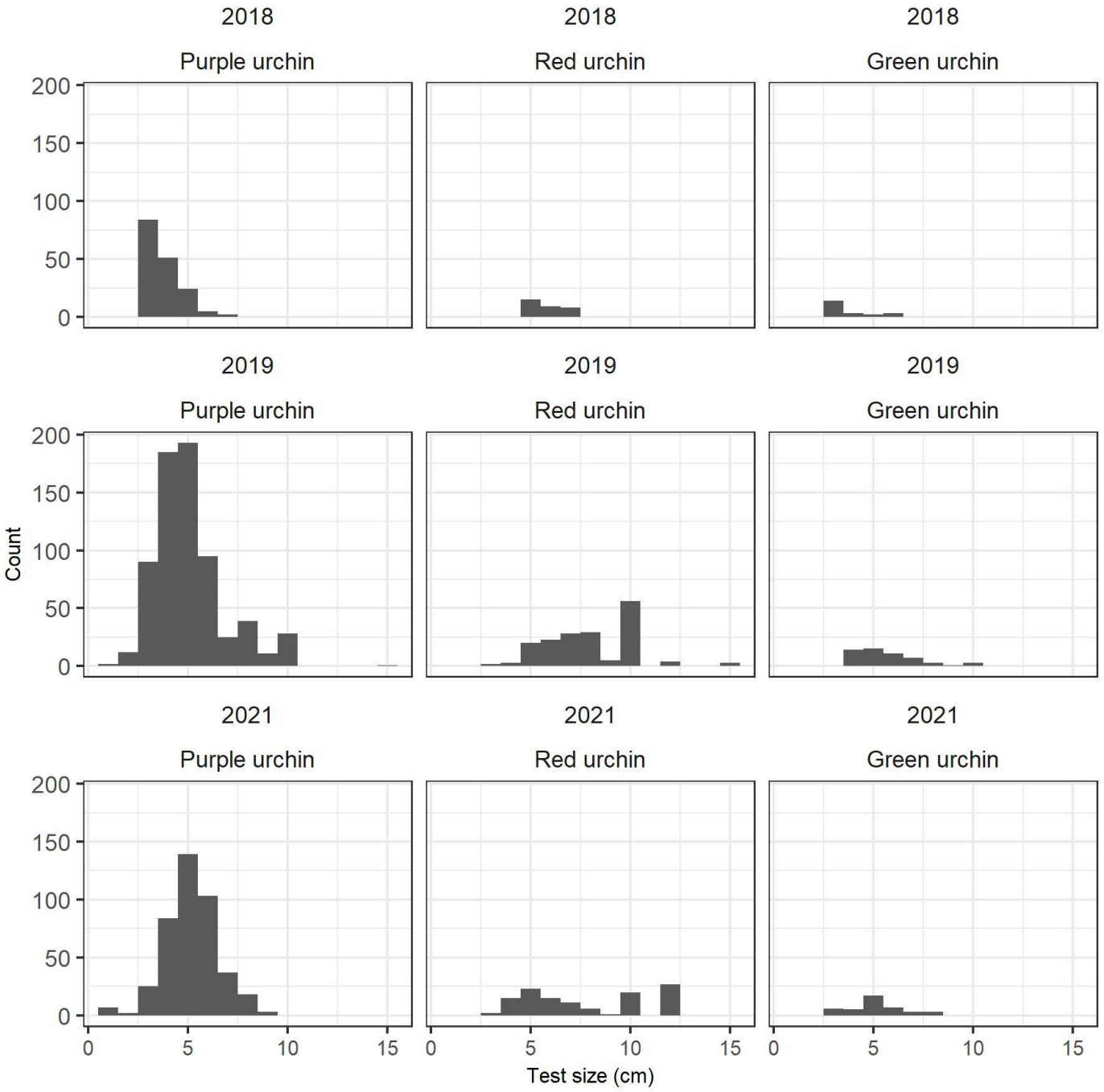


Figure S1. Substrate and relief at the five sites: DI = Destruction Island, CJ = Cape Johnson, CA = Cape Alava, TI = Tatoosh Island, NB = Neah Bay and at two depths (5 and 10 m) for Tatoosh Island. Relief categories measure the change in elevation across the width of the 2-m transect.


2018
Purple urchin
2018
Red urchin
2018
Green urchin
2019
Purple urchin
2019
Red urchin
2019
Green urchin
2021
Purple urchin
2021
Red urchin
2021
Green urchin
Count
Test size (cm)
0
50
100
150
200
0
5
10
15

Tatoosh Island 2017

What has this meant for the kelp?

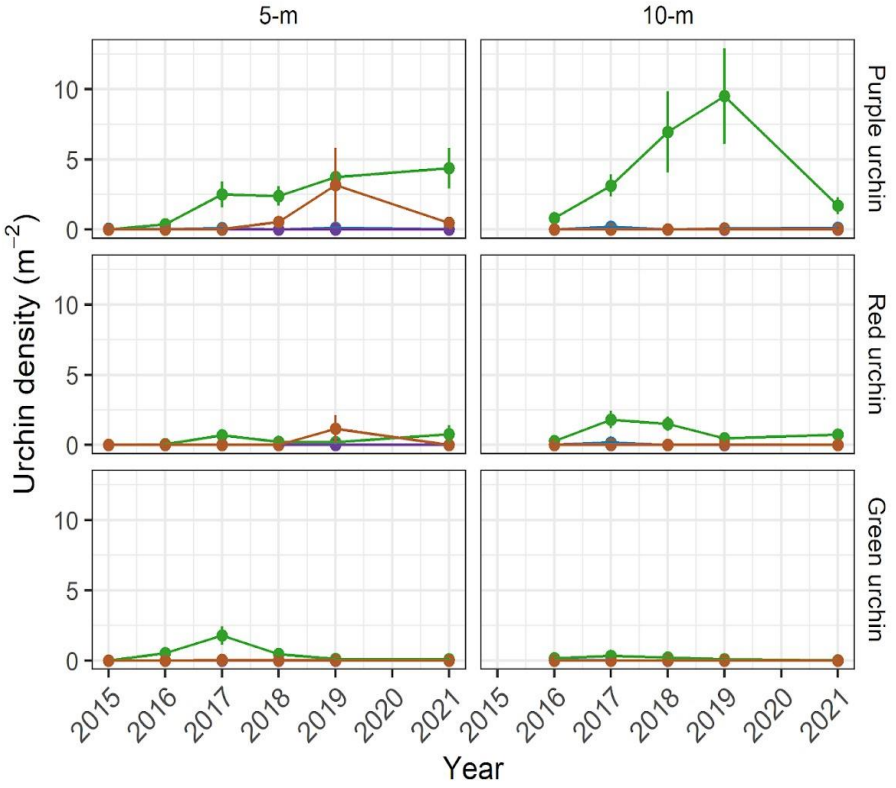
What about the fish?

What about the fish?

Preliminary Assessment of Purple Sea Urchin Grazing on Kelp Communities in the Strait of Juan de Fuca

Taylor Frierson
Subtidal Shellfish Biologist

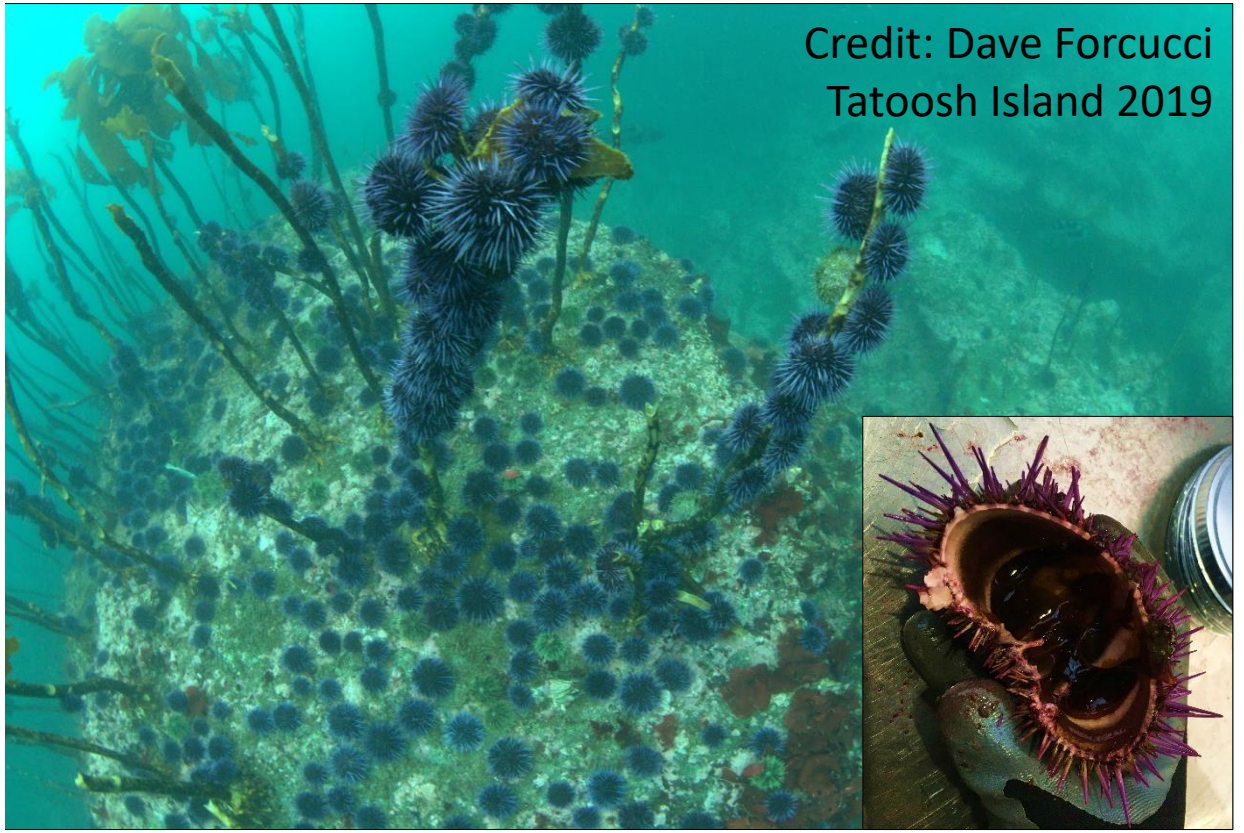
Washington Department of FISH and WILDLIFE



NOAA FISHERIES

- Neah Bay
- Tatoosh Island
- Cape Alava
- Cape Johnson
- Destruction Island

(Ole Shelton 2021)

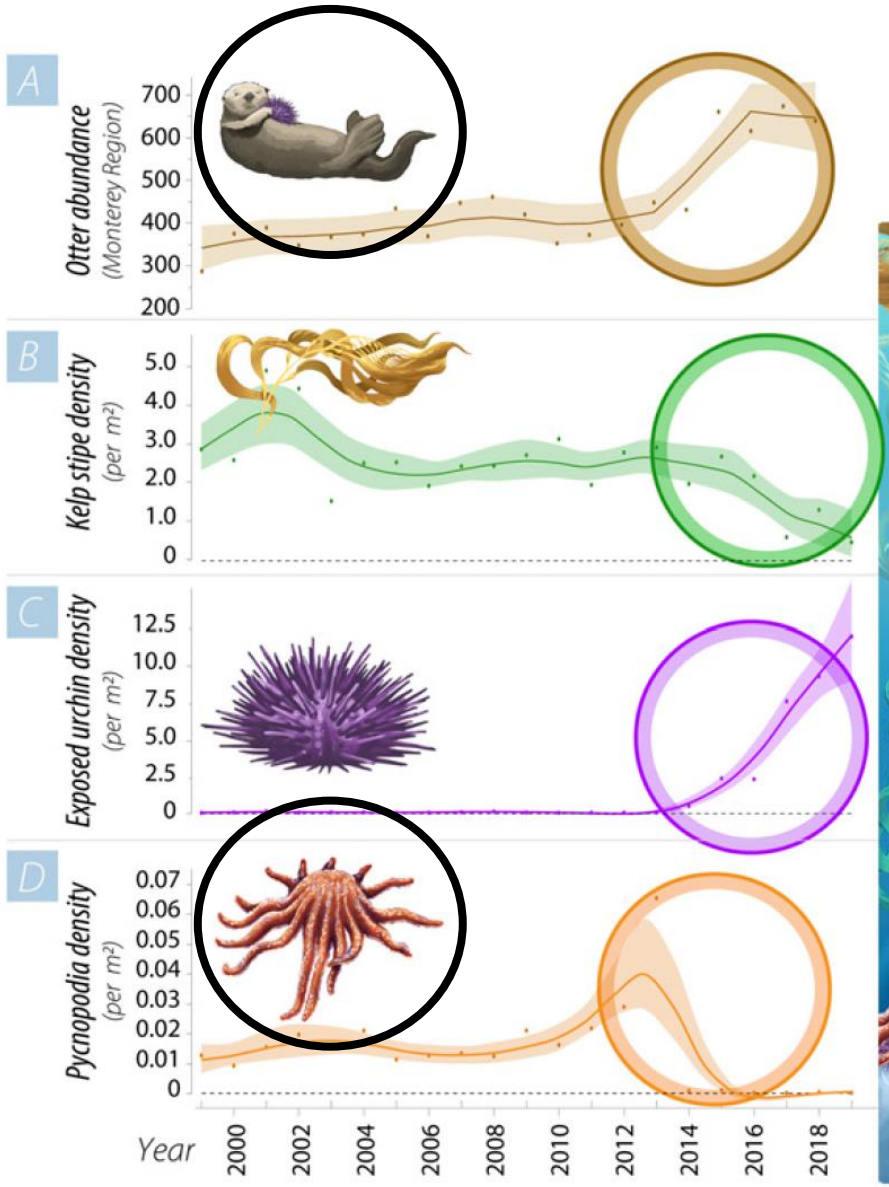


Purple sea urchin (PSU) in WA

- Common in the OCNMS, Strait of Juan de Fuca, San Juan Islands
- Only small scale personal-use harvest occurs annually (~1500 total est.)
- Minimal data exists, recent observations of high-density aggregations

Central CA

"Spatially explicit sea otter foraging enhanced the resistance of remnant forests to overgrazing but did not directly contribute to the resilience or recovery of the kelp forests."



Smith et al. 2021

Northern CA

- Rapid climate-driven shift in 2014
- PSU population increase 60x
- Bull kelp canopy reduced >90% by PSU overgrazing ***in one year***
- Mass abalone mortality and fishery closure ($44M)
- Red urchin fishery collapse ($3M)
- Action plans to reduce PSU grazing pressure and enhance kelp growth

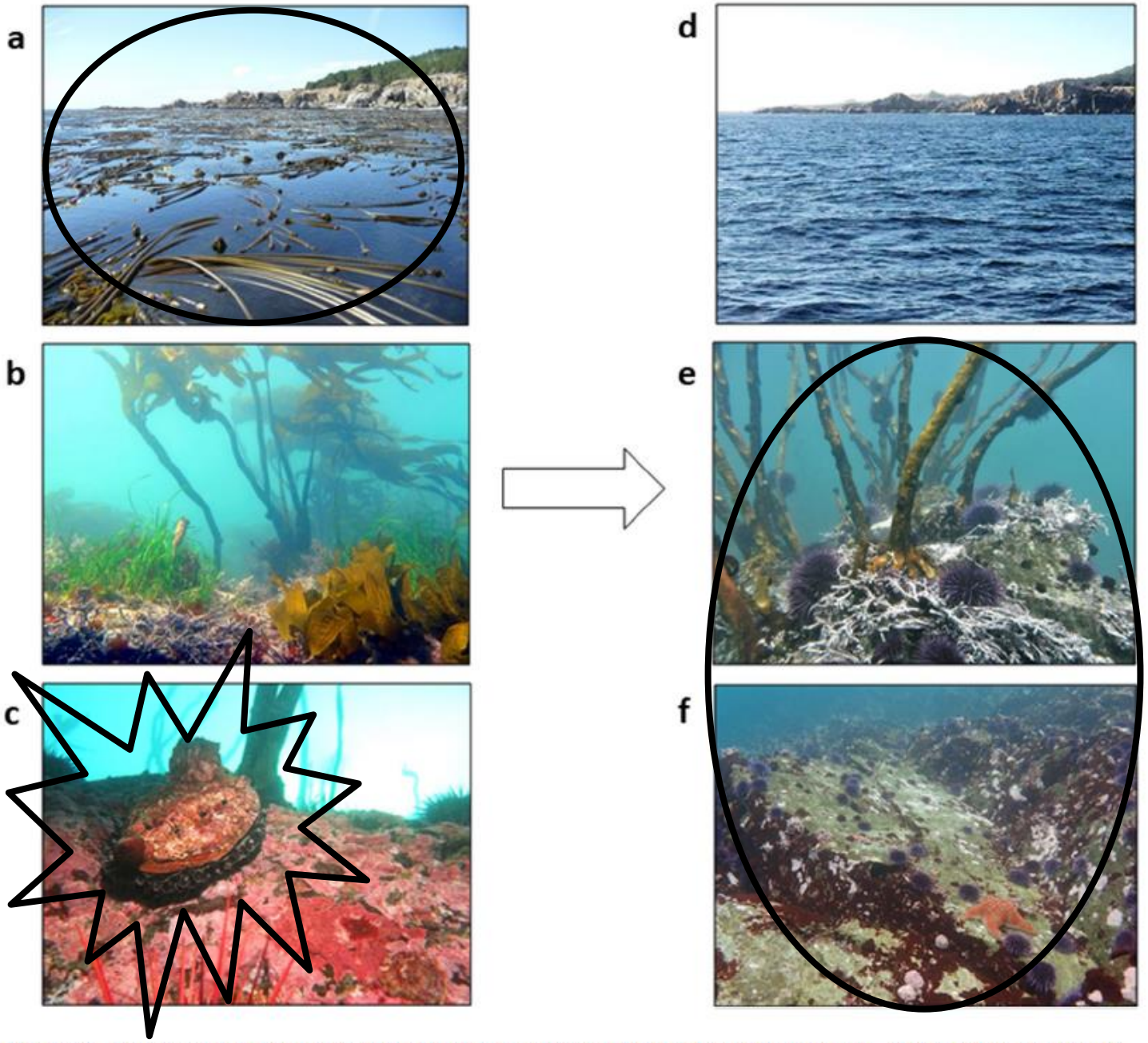
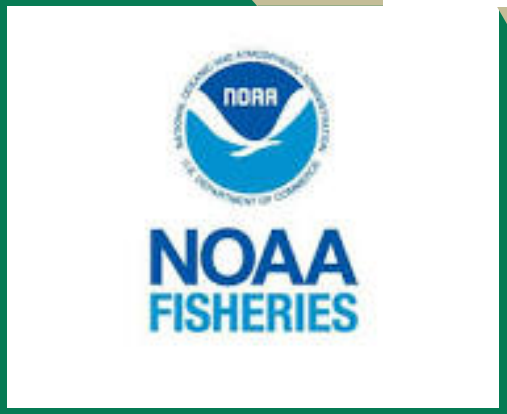
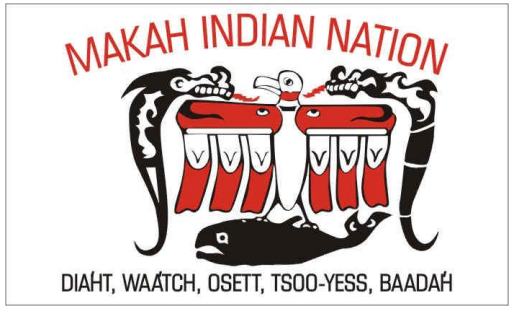


Figure 2. Ecosystem shifts observed for kelp forest canopy *(top)*, subcanopy *(middle)*, and benthose *(bottom)*, pre-impact (**a–c**) and post-impact (**d–f**). Photo credit: CDFW (K. Joe (**a,c,e**); L. Rogers-Bennett (**b**); C. Catton (**d,f**)).

Rogers-Bennett & Catton 2019





How can we detect any signals of expanding purple urchin barrens and kelp decline in WA?

Dive Survey Methods

Paired index stations

- High-low urchin density
- 5m & 10m depths
- 30m x 2m transects

Data collection

- Urchin and kelp counts
- Urchin test measurements
- Collections for gonad%
- Photo quadrats

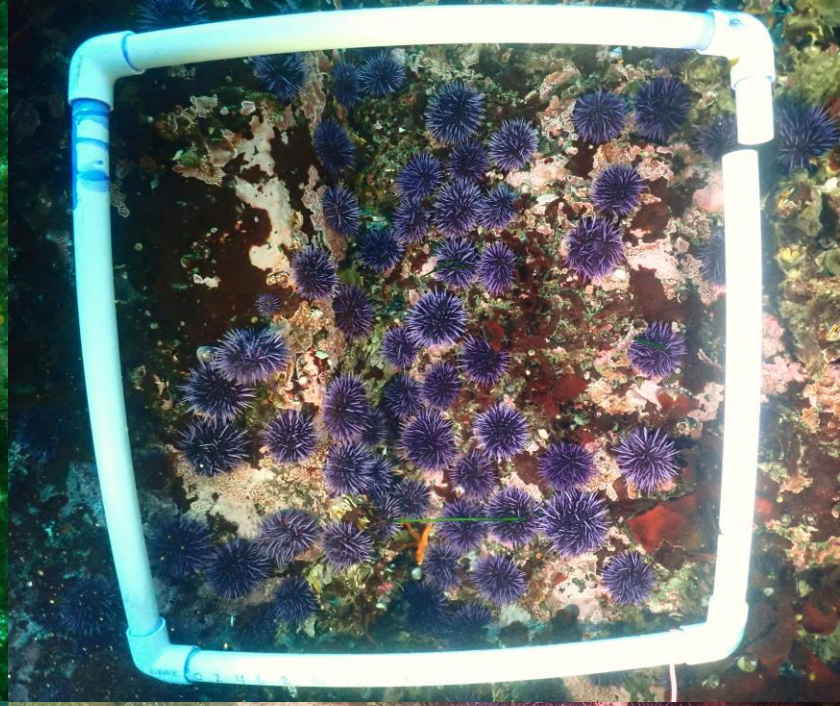
Dive Survey Methods

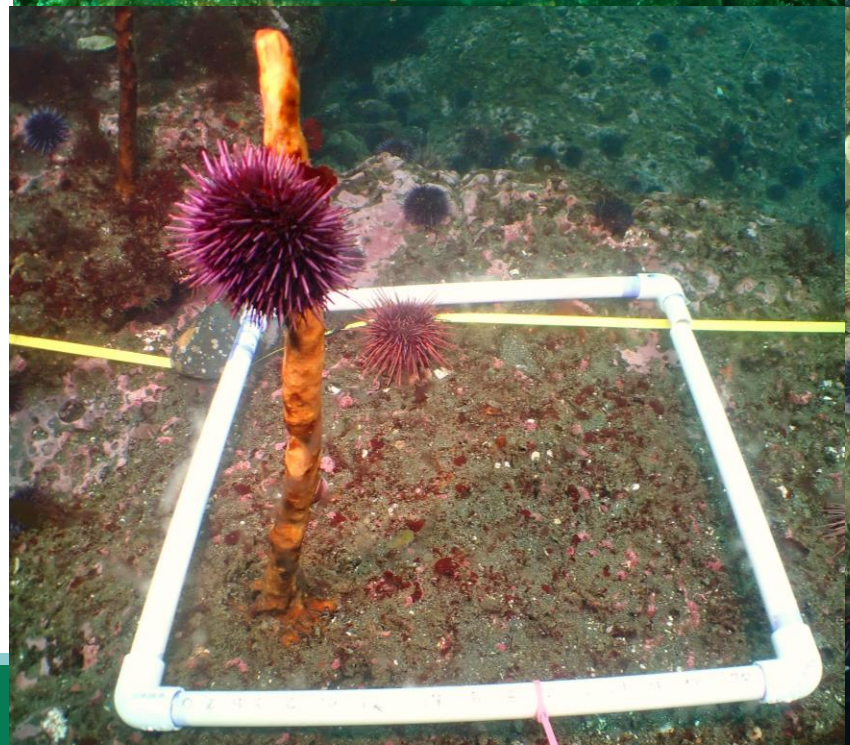
Photo quadrats

- Macroalgae % cover
- Kelp density by species
- Urchin density by species
  - Grazing behavior, % exposed
- Sea star density by species

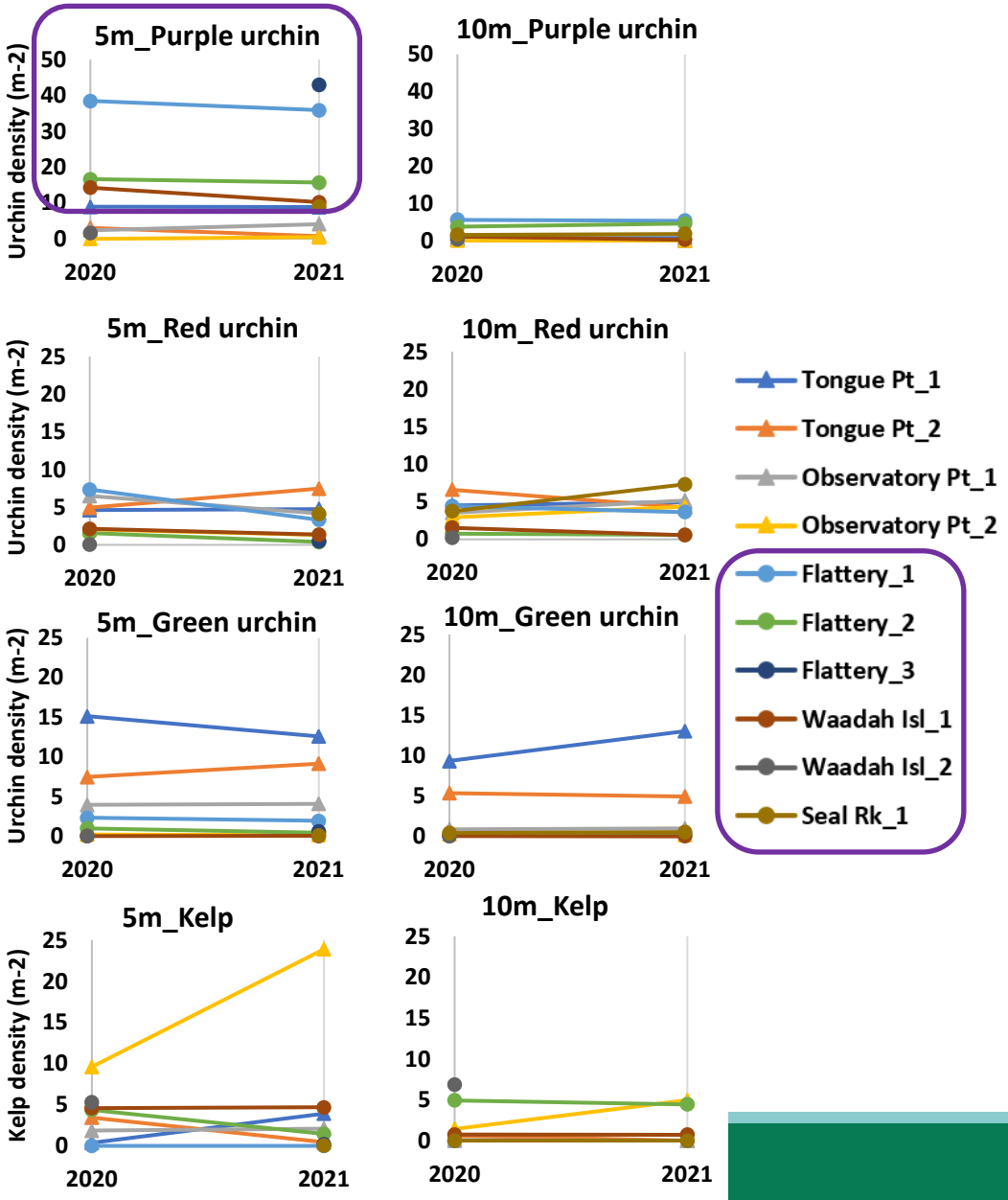
Some limitations

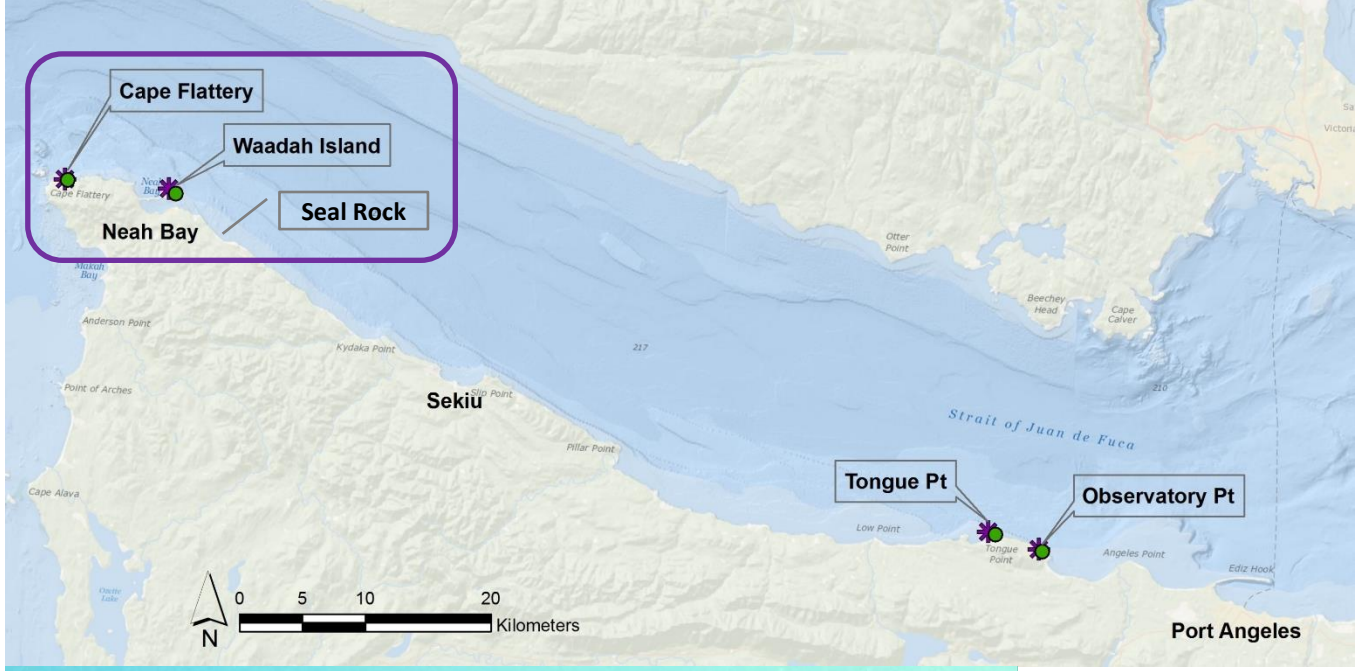
- Viewpoint
- Visible layers
- Holdfast vs. canopy





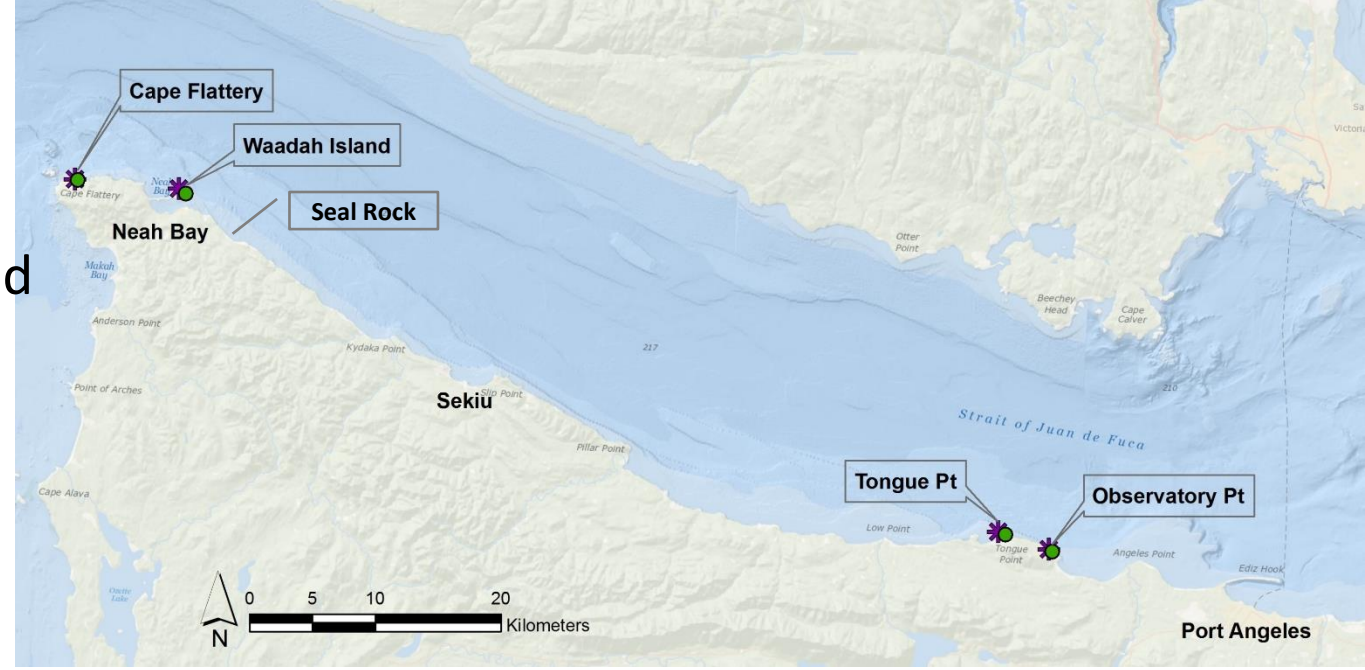
Preliminary Results

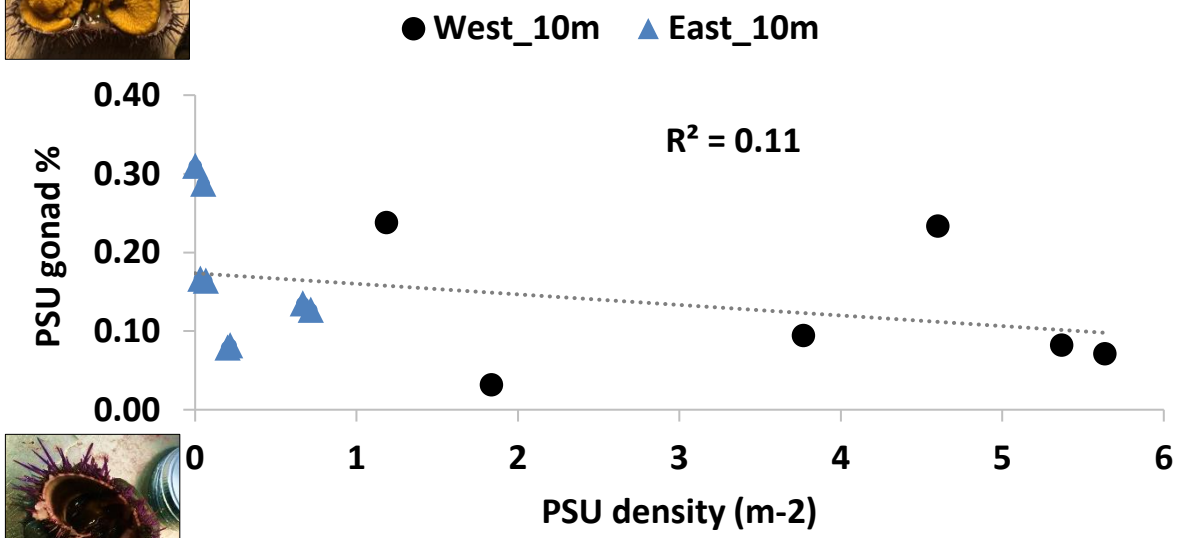


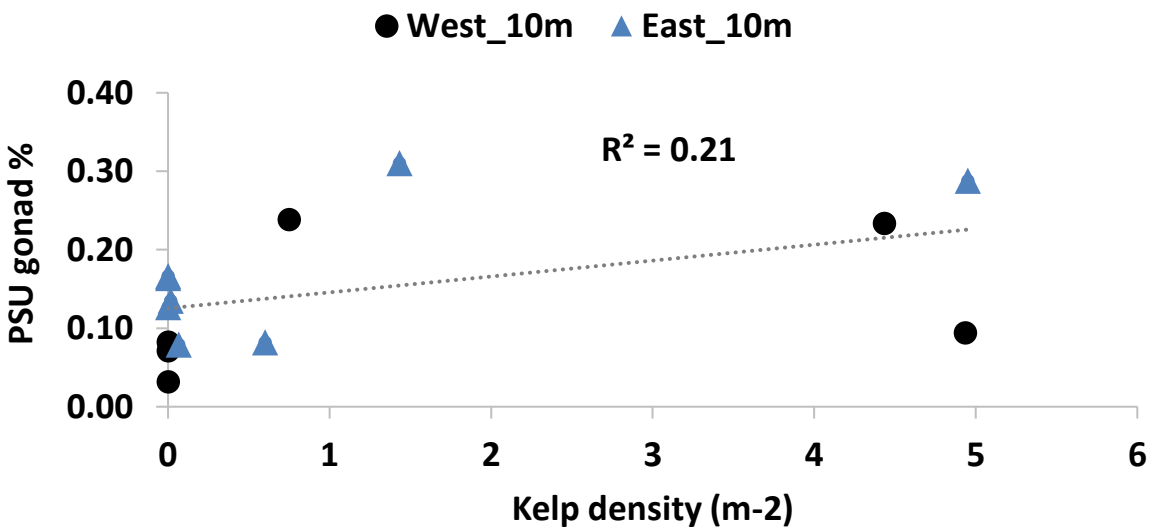


Preliminary Results

- PSU density and gonad% **negatively** associated
- Kelp density gonad% **positively** associated
- Shallow (5m): regression p-values < 0.05
- Deep (10m): similar trends but not significant





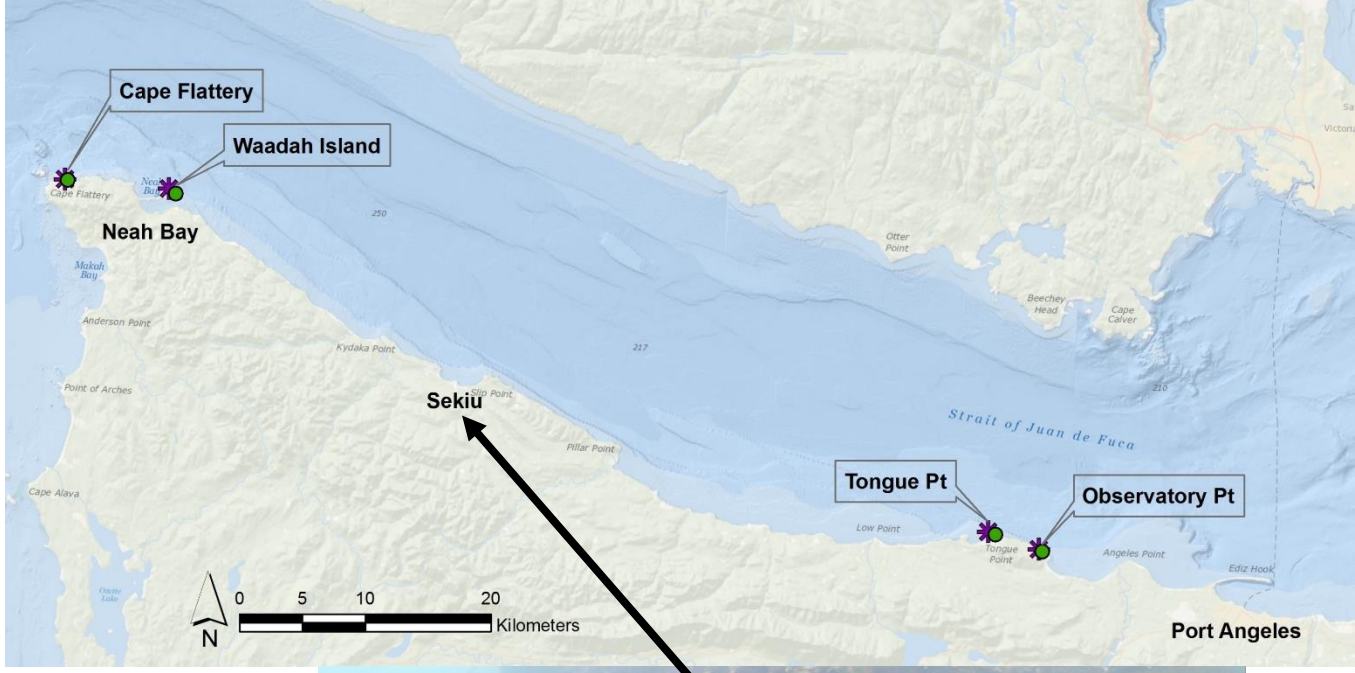


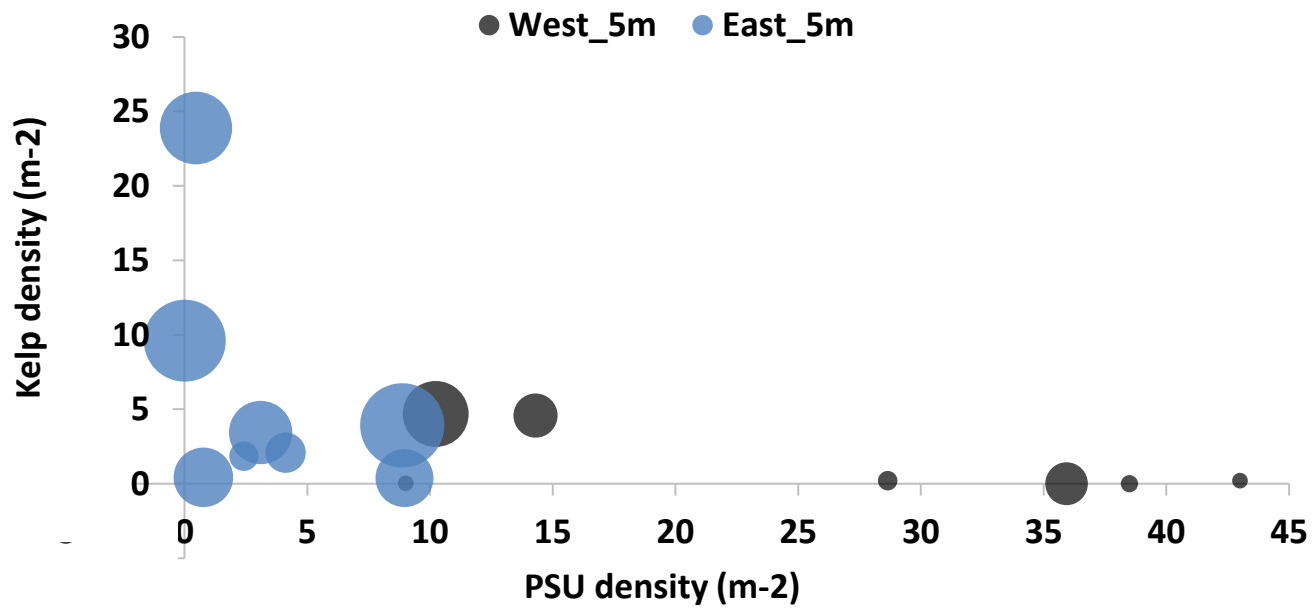
Preliminary Results

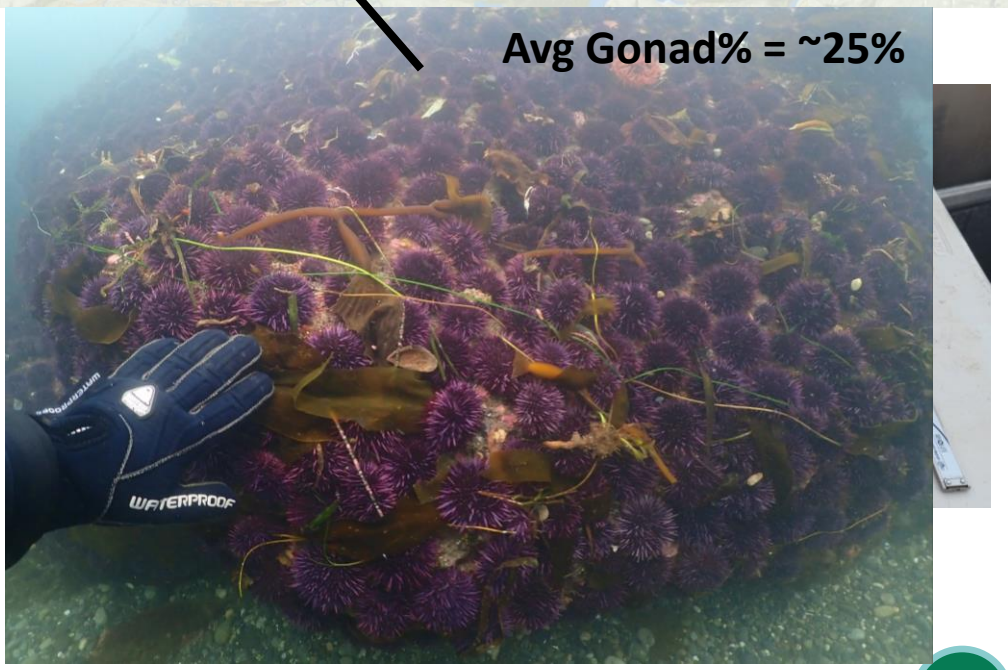
- PSU-Kelp-Gonad% associations
- Urchin barren signal in West sites?

Area	Depth	n PSU	Avg Gonad%
West	5m	193	11.4%
West	10m	170	10.5%
East	5m	240	*24.5%
East	10m	166	*15.7%

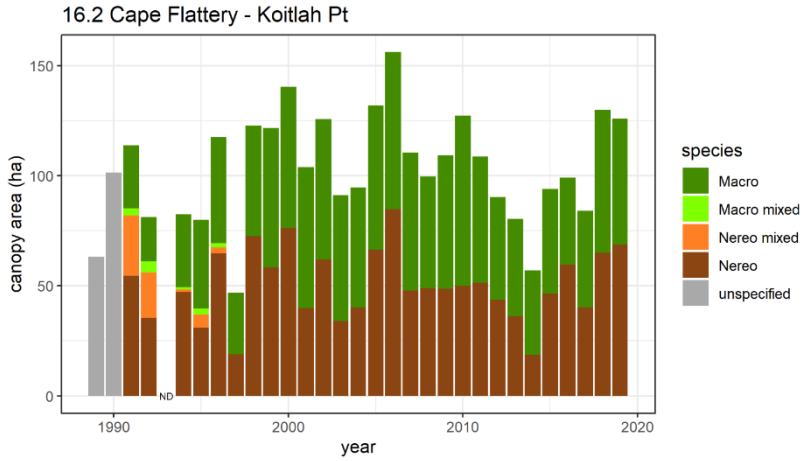
Pairwise analysis
*p-value <0.01

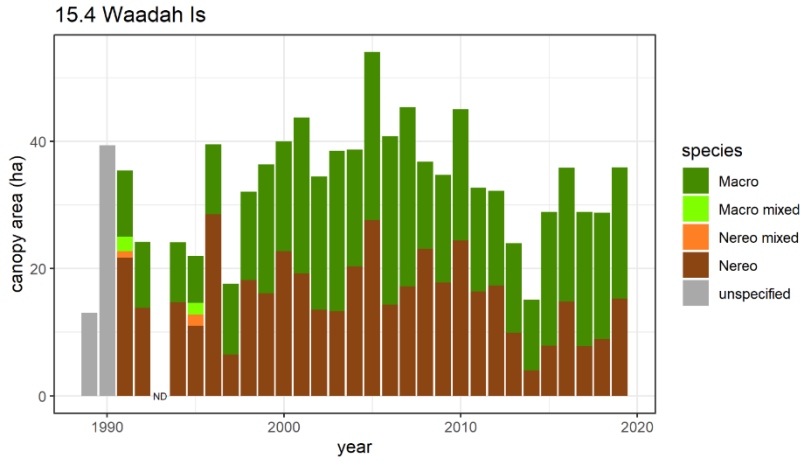


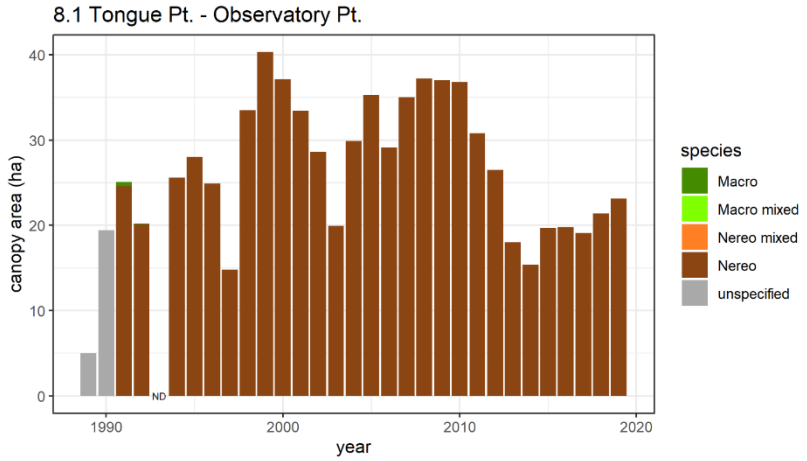


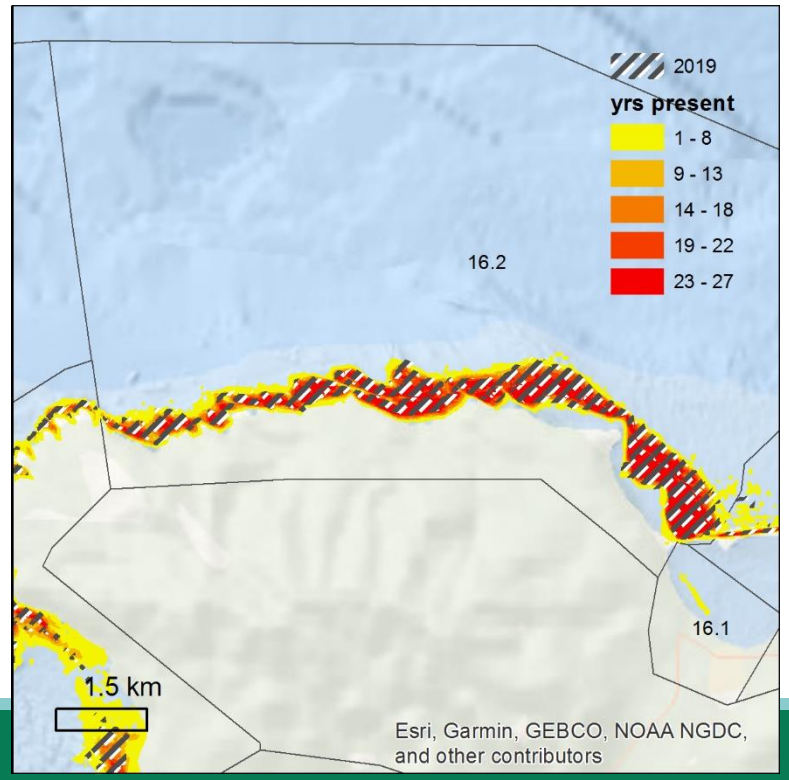


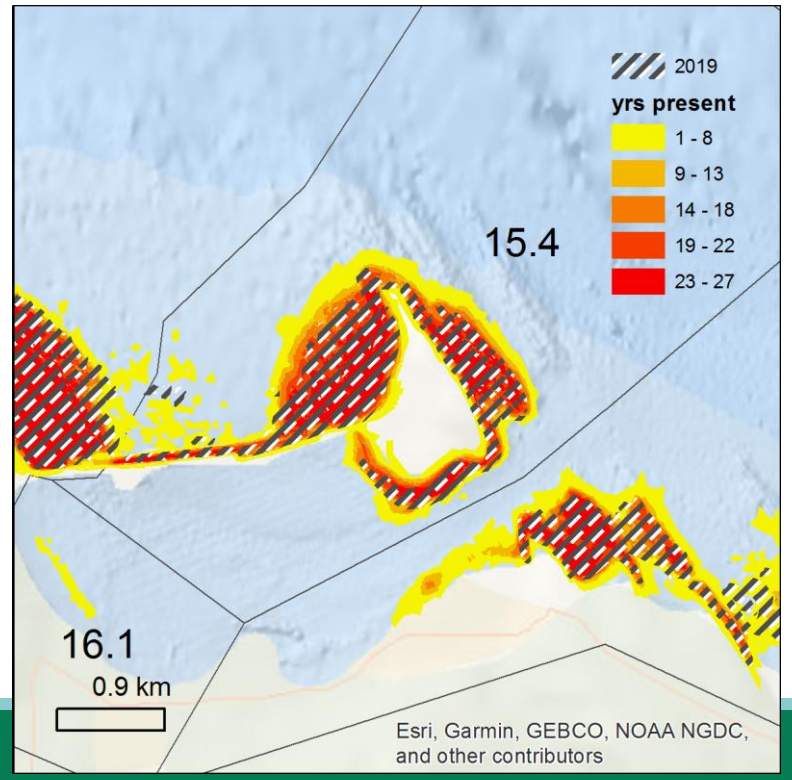
2019: No major losses at WDFW dive areas

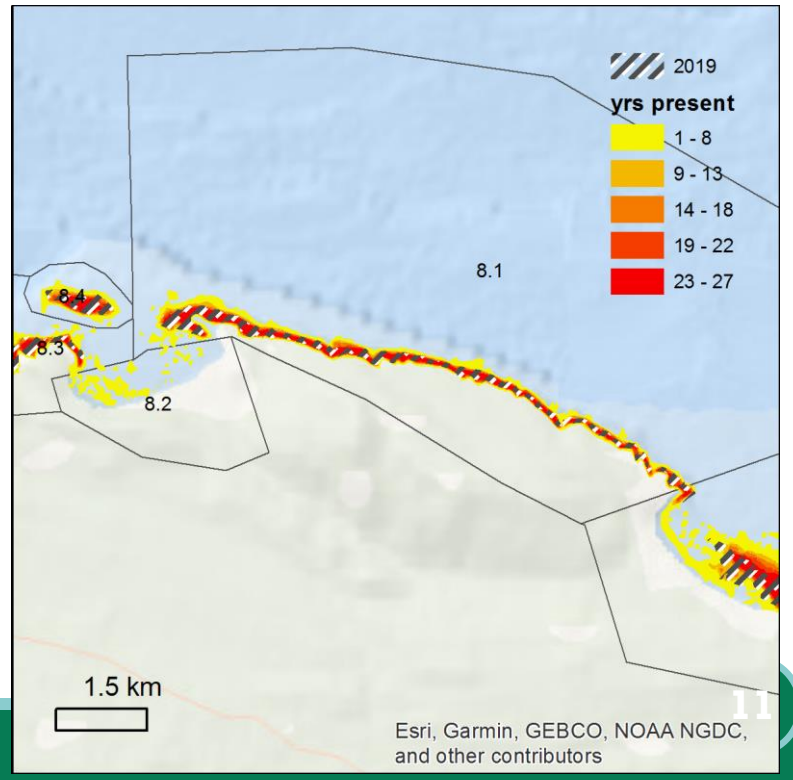










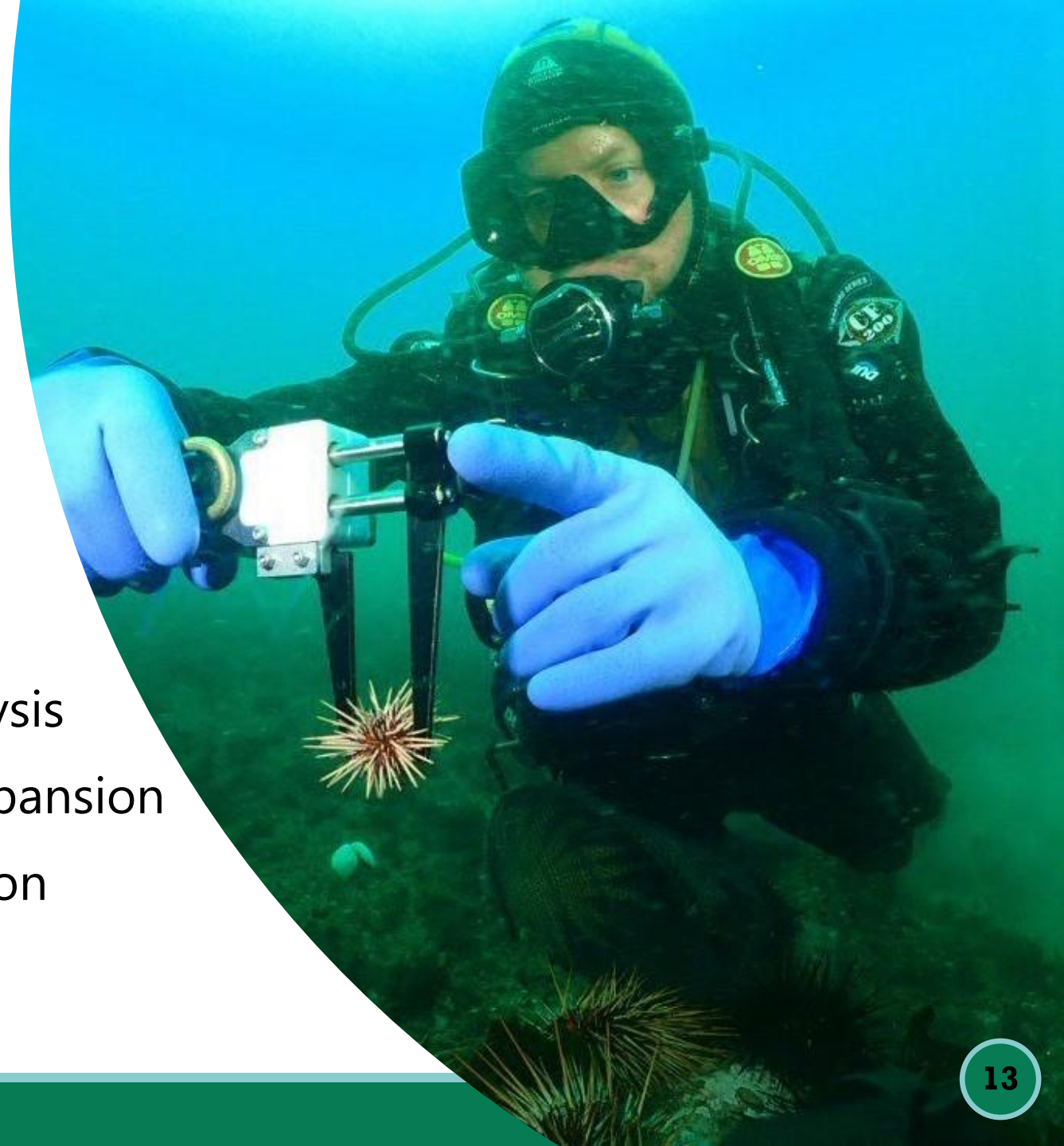


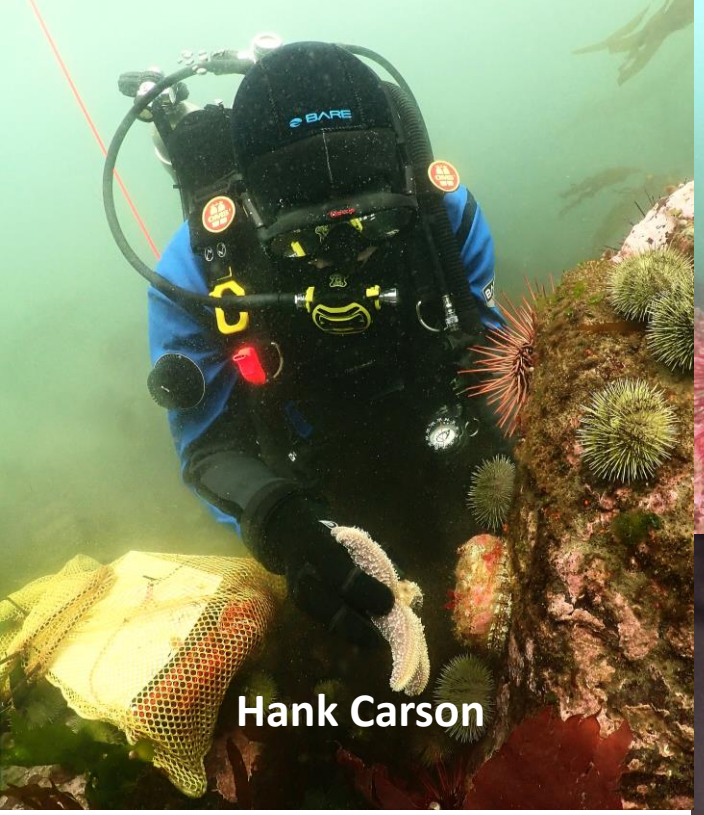
2020 analysis underway: along portions of strait, lower density/decreases

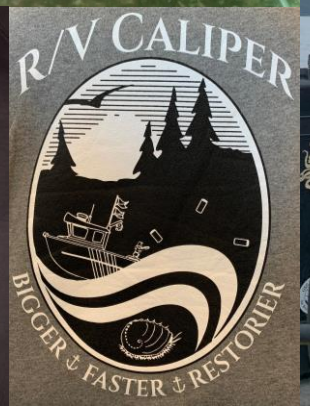
Waadah Island – lower density

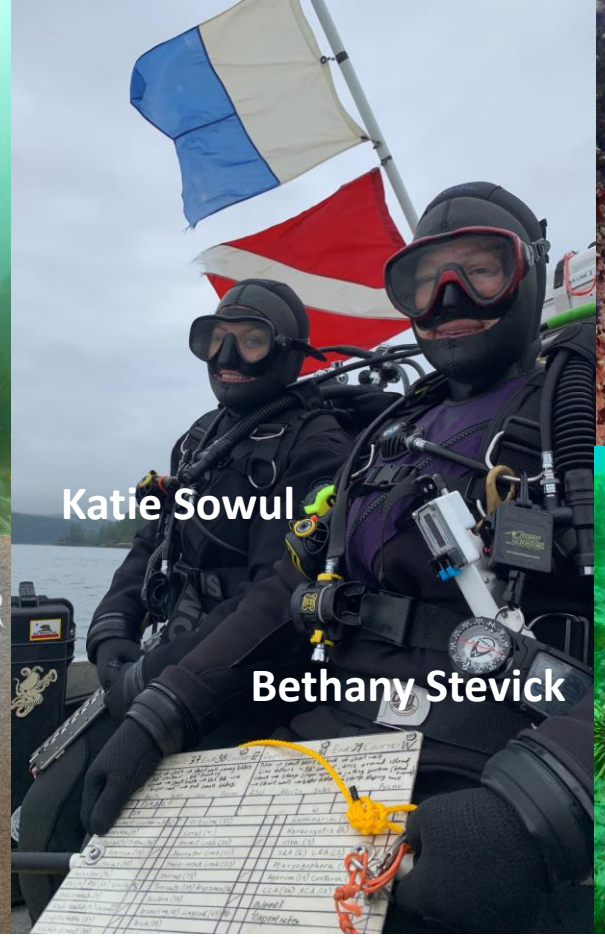
Next Steps

- Continued collaboration!
- More data throughout a time series
  - 2020, 2021, 2022
- Urchin test measurement data analysis
- Photo quadrat data analysis and expansion
- Pinto abalone surveys and restoration









Thank You!

Helen Berry, Max Calloway, Will Jasper, Adrianne Akmajian, Liz Allyn, Rebecca Mahan, Tim Cochnauer, Alisa Taylor, Ole Shelton, Nick Tolimieri, Steve Lonhart, Josh Smith, Jay Dimond, USCG-Neah Bay

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