Optimizing Ocean Observing Networks for Detecting the Coastal Climate Signal Workshop

Bringing a focus to the nearshore:
A case for refining projections to aid coastal communities

Jan Newton: University of Washington
Samantha Siedlecki: University of Connecticut
Simone Alin: NOAA PMEL
John Mickett: University of Washington
Julie Ann Koehlinger: Hoh Indian Tribe
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Jenny Waddell: NOAA Olympic Coast National Marine Sanctuary
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The Olympic Coast as a Sentinel:
An Integrated Social-Ecological Regional Vulnerability Assessment to Ocean Acidification

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Funding: NOAA Ocean Acidification Program, UW College of the Environment, NOAA PMEL

Olympic Coast: a place-based approach

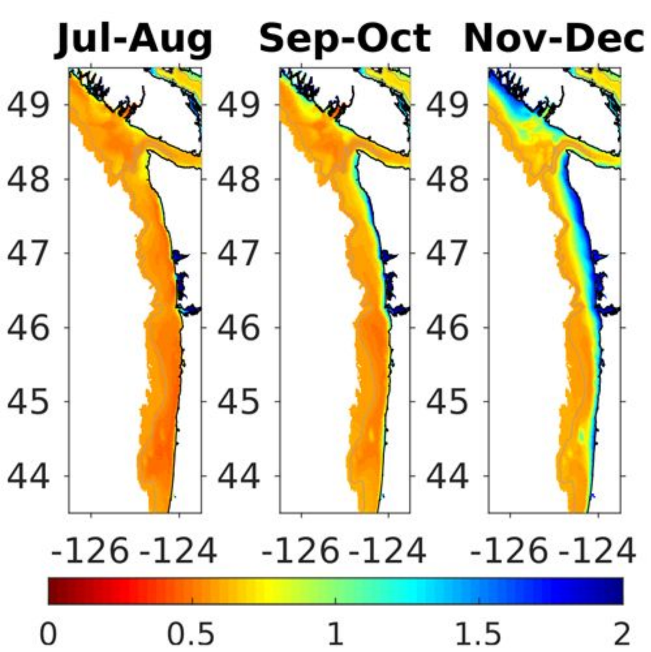
Social science — Natural science

Grounded in community priorities

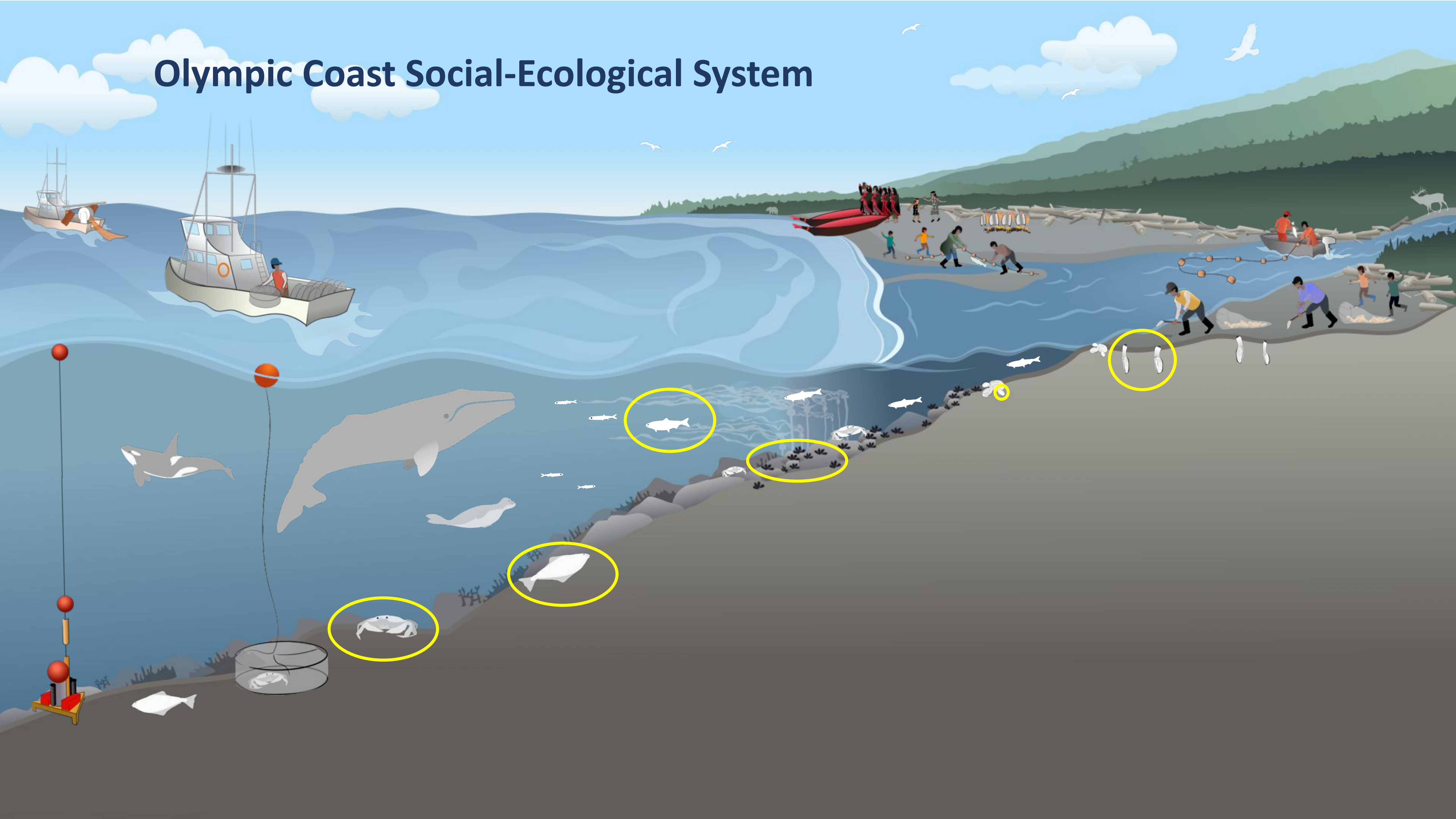
Integrated Regional Vulnerability Assessment Approach

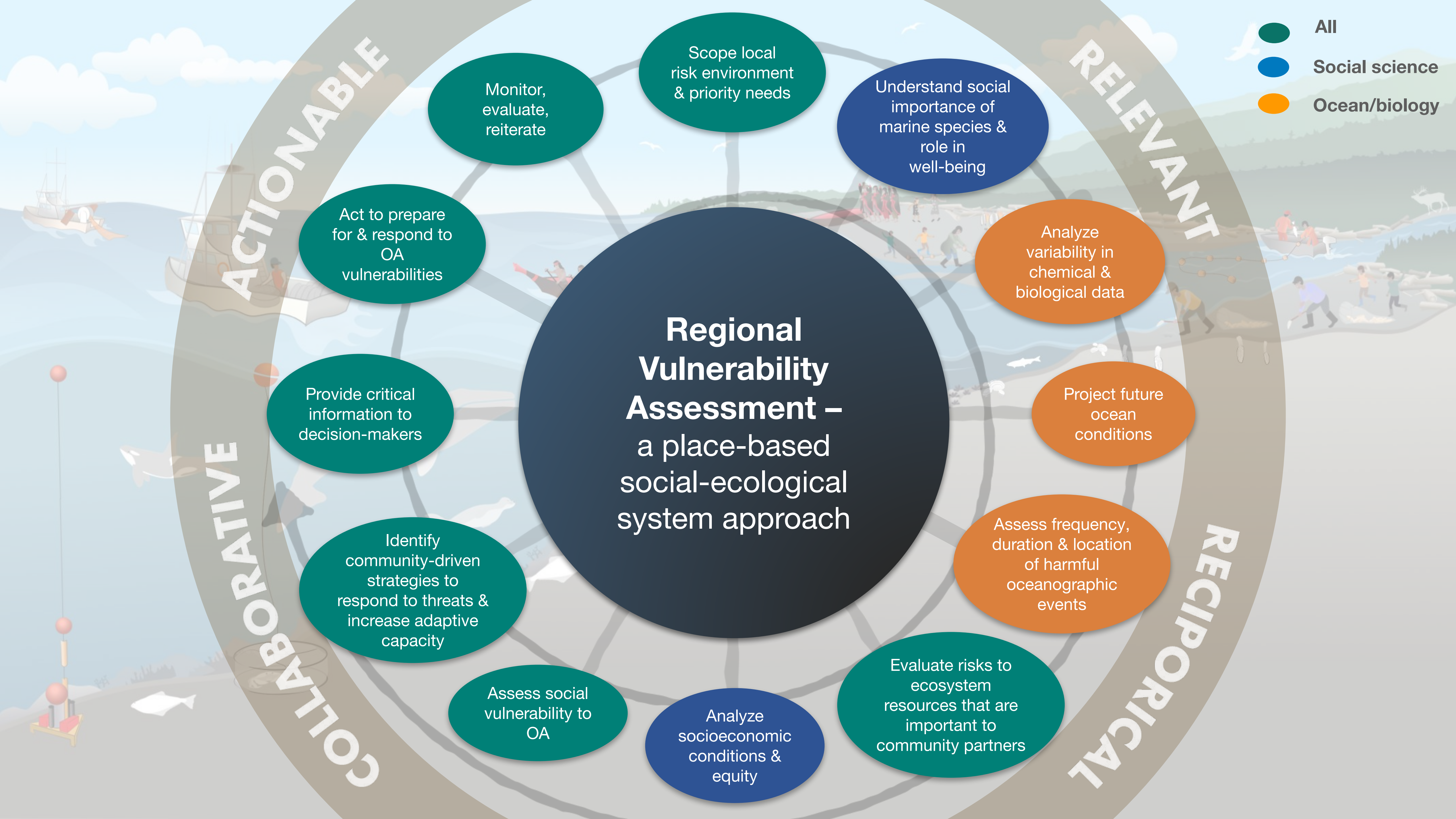

Credit: Northwest Treaty Tribes


Credit: Carothers



Olympic Coast Social-Ecological System

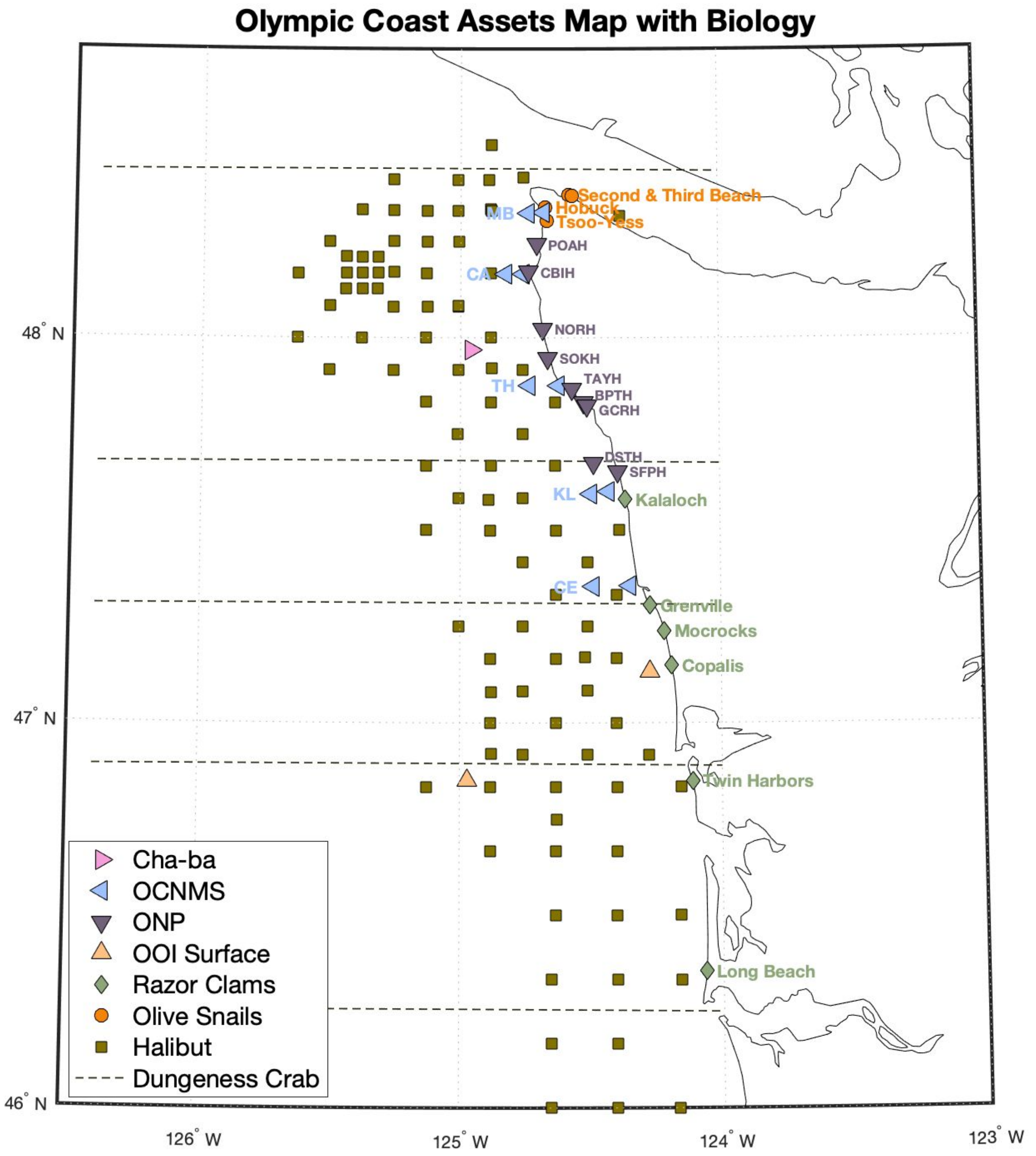




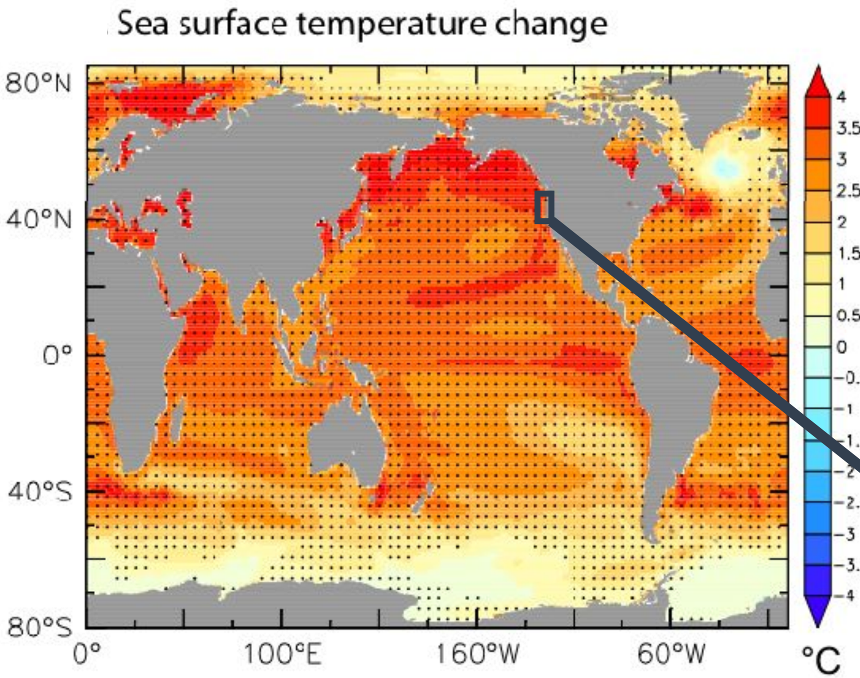
All
Social science
Ocean/biology
ACTIONABLE
RELEVANT
RECIPROCAL
COLLABORATIVE
Regional Vulnerability Assessment – a place-based social-ecological system approach
Scope local risk environment & priority needs
Understand social importance of marine species & role in well-being
Analyze variability in chemical & biological data
Project future ocean conditions
Assess frequency, duration & location of harmful oceanographic events
Evaluate risks to ecosystem resources that are important to community partners
Analyze socioeconomic conditions & equity
Assess social vulnerability to OA
Identify community-driven strategies to respond to threats & increase adaptive capacity
Provide critical information to decision-makers
Act to prepare for & respond to OA vulnerabilities
Monitor, evaluate, reiterate

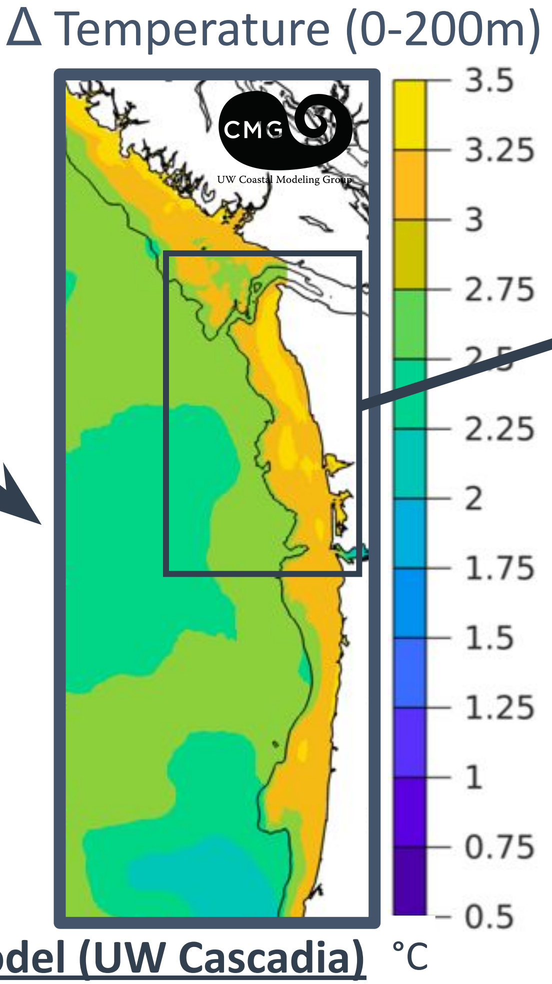
Assessing risk to biology

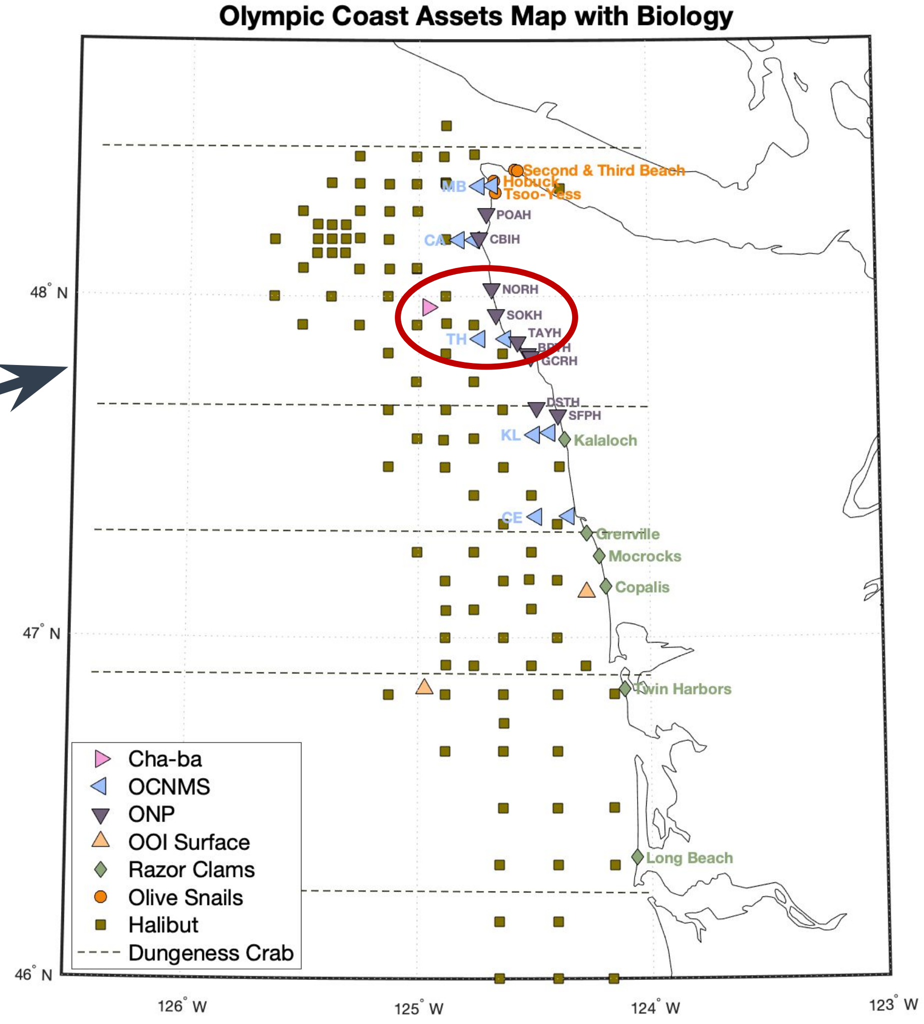
- Synthesized oceanographic observations, species locations
  - We do not have physical & chemical observations at same time and locations with biology.
- Picked "focus" species with different life history patterns:
  - Razor clams, Dungeness crab, Olive snails, Pacific halibut
- Used a model (*Siedlecki et al. 2021)* to assess present and future OA risks for **bottom waters**



Using regional oceanographic projections







CMIP5 Model

~200 km atmospheric resolution

~50 km ocean resolution

RCP 8.5 Scenario

Bopp et al. 2013

Regional Ocean Model (UW Cascadia)

~1.5 km resolution

Future projections for 2100

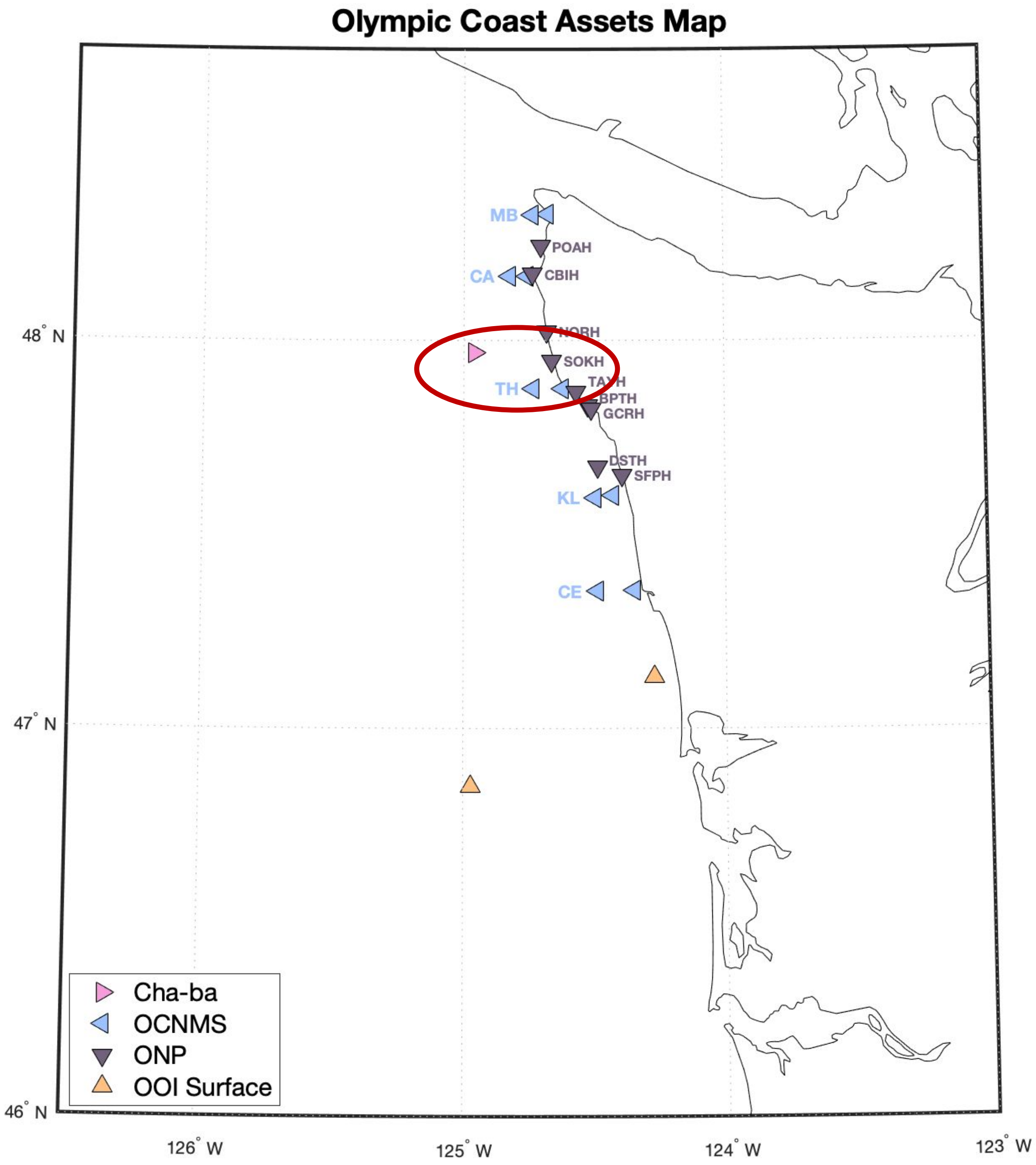
Siedlecki et al. 2021

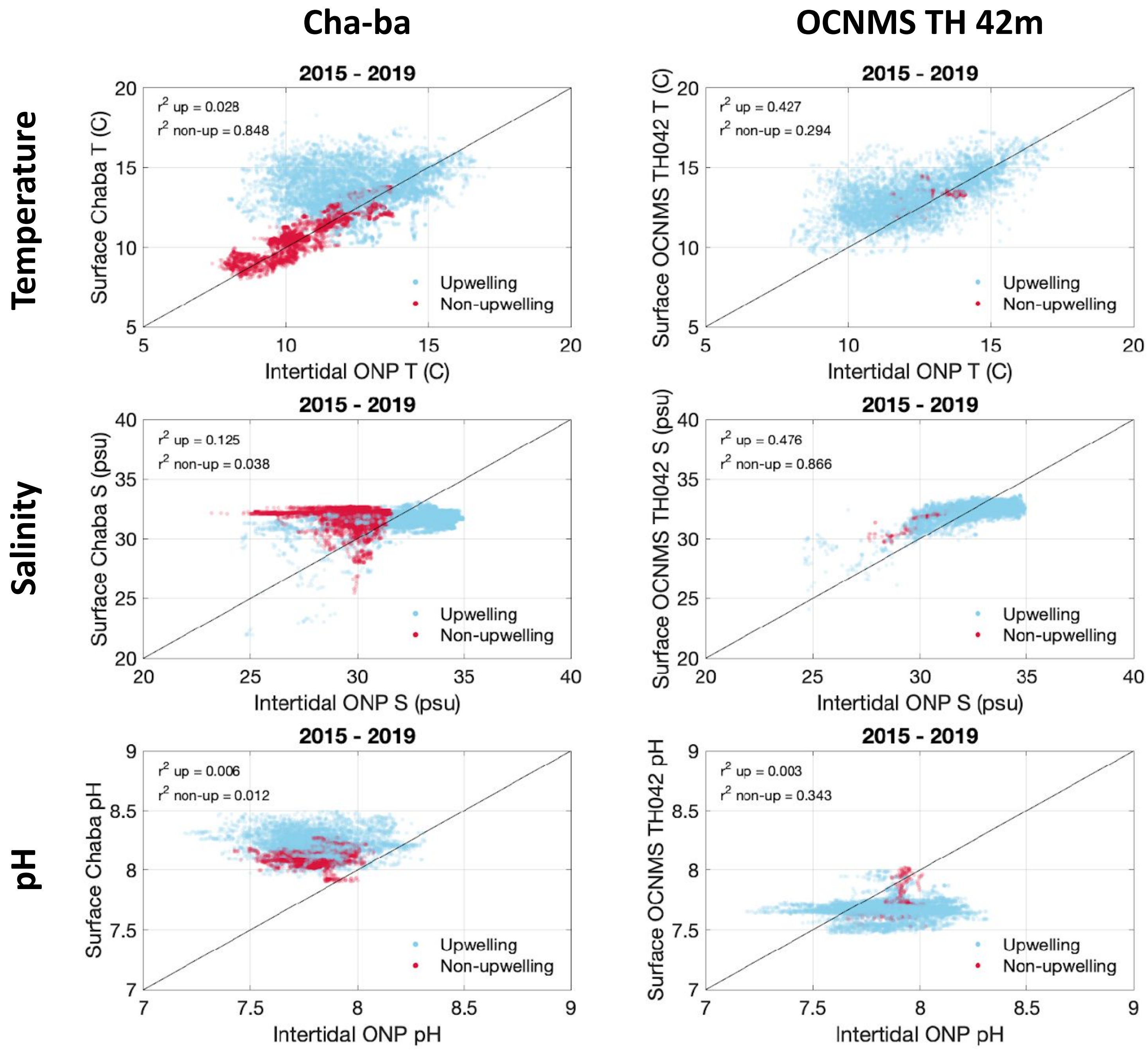
What about performance in the nearshore?

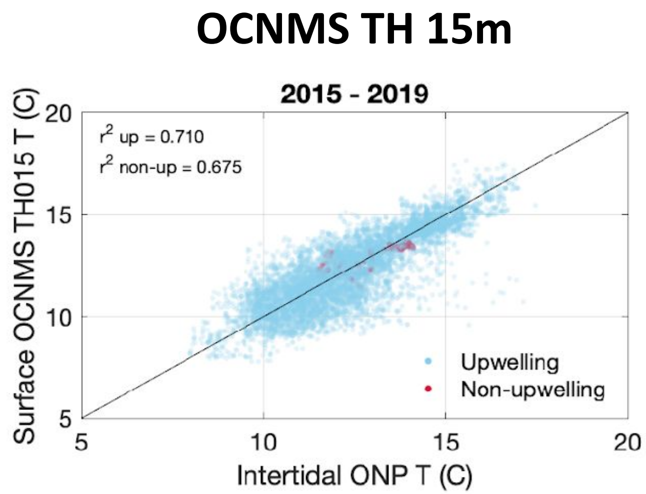
- Intertidal to 15 m r^2=0.53 (upw); 0.71 (down)
- OA algorithm & model agree +/- 20%

Physical & Chemical Observations

- Do we see a correlation or trend between offshore and onshore observations?
- Can we use offshore data as a proxy for the water conditions intertidal species experience?
- We investigate these questions using
    - Cha-ba
    - OCNMS Teawhit Head (TH)
    - ONP Sokol Point (SOKH)





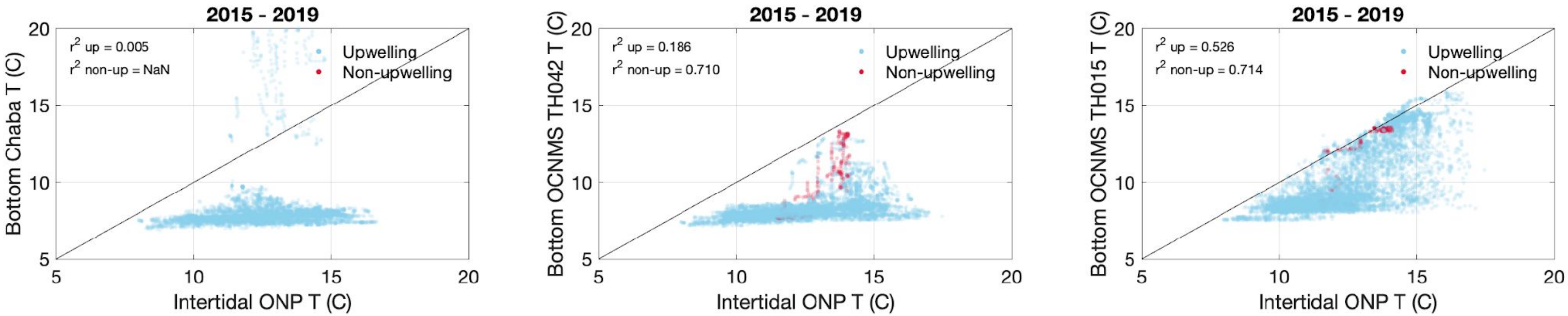


Surface Data 2015-2019

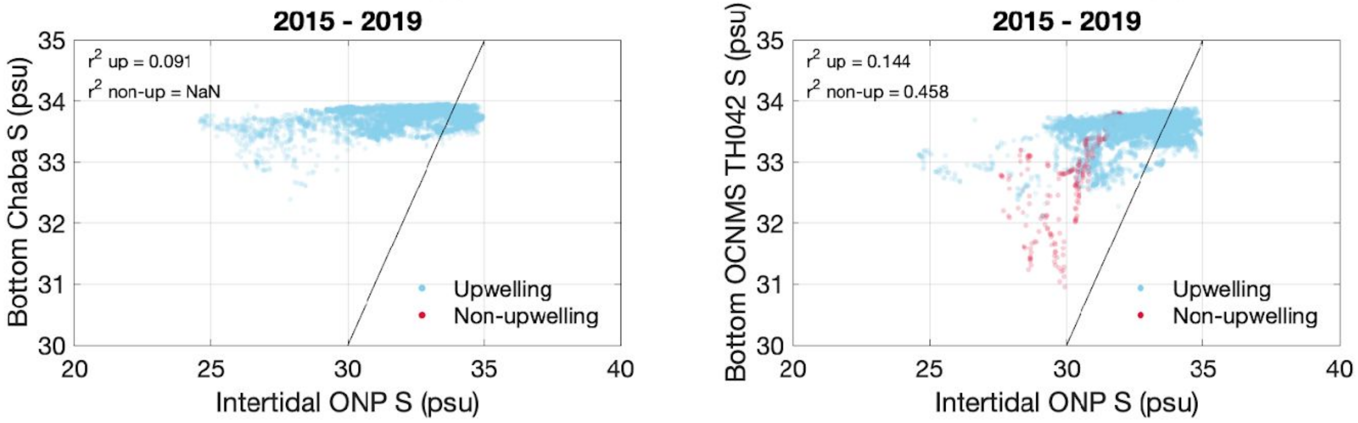
- Offshore **temperatures** correlate with intertidal during non-upwelling, but not during upwelling; tighter correlations with intertidal as go inshore.
- **Salinity**: influence of freshwater on intertidal data
- **pH**: local processes dominate; freshwater and biology (respiration/photosynthesis) drives variation in ways that do not show correlations.

	Cha-ba	OCNMS TH 42m	OCNMS TH 15m

Temperature



Salinity



pH

Bottom Data 2015-2019

- Offshore-Onshore temperature correlations are for shallow data only, bottom data does not show correlations, implying not source water.

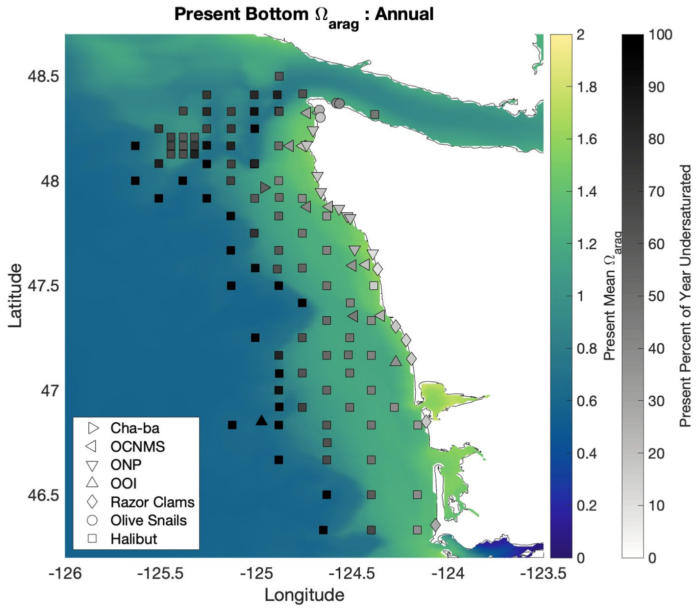
So…

- Do we see a correlation or trend between offshore and onshore observations?
  - For temperature only
  - For Cha’ba, only during non-upwelling season; For OCNMS, yes: 15m > 42m

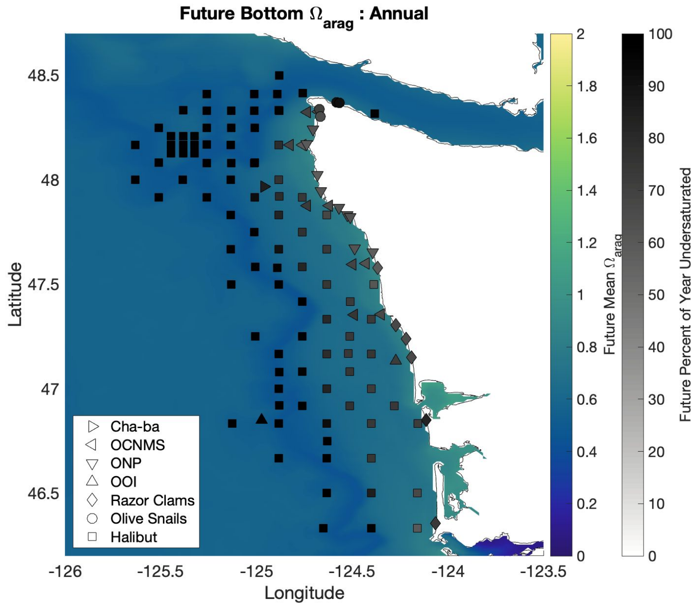
- Can we use offshore data as a proxy for the water conditions that intertidal species experience?
  - Non-upwelling: Cha’ba surface, temperature only (85%)
  - Upwelling: OCNMS 42 reasonable for temperature (43%) and salinity (48%)
    OCNMS 15 good for temperature (71%)

Bottom Omega aragonite - Annual

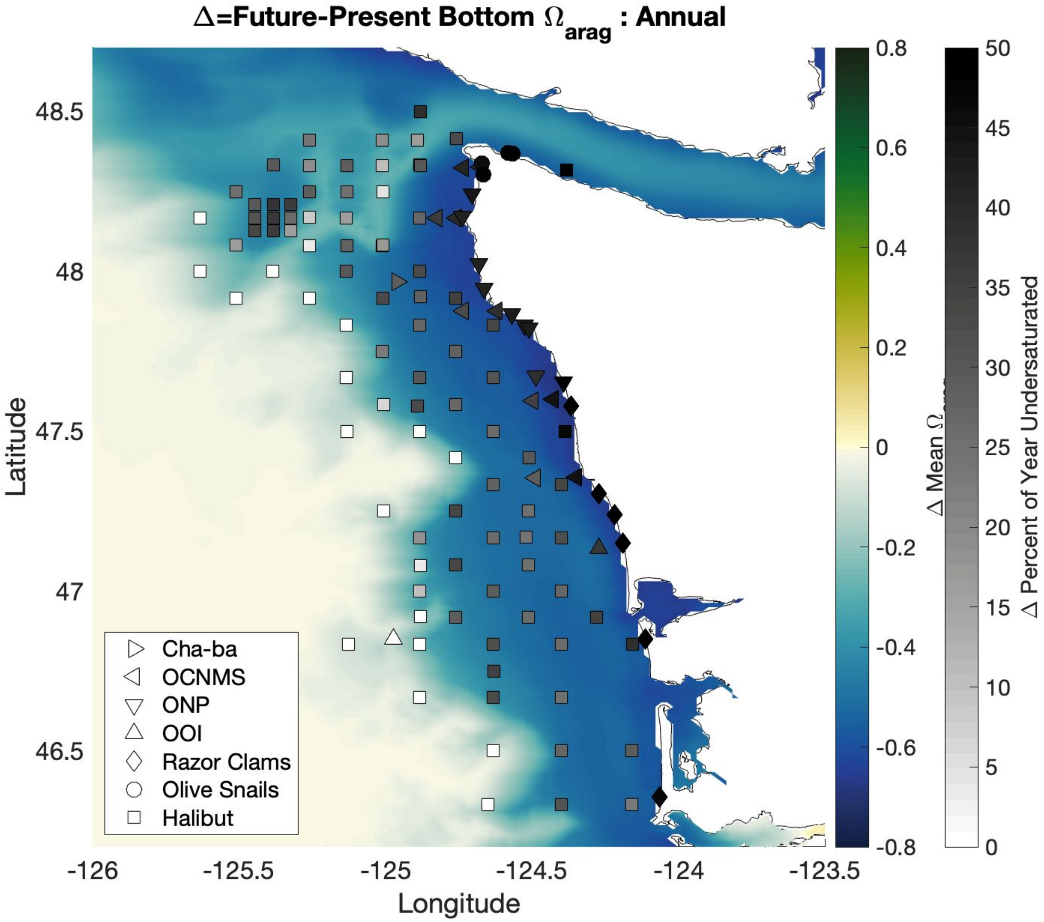
Present



Future

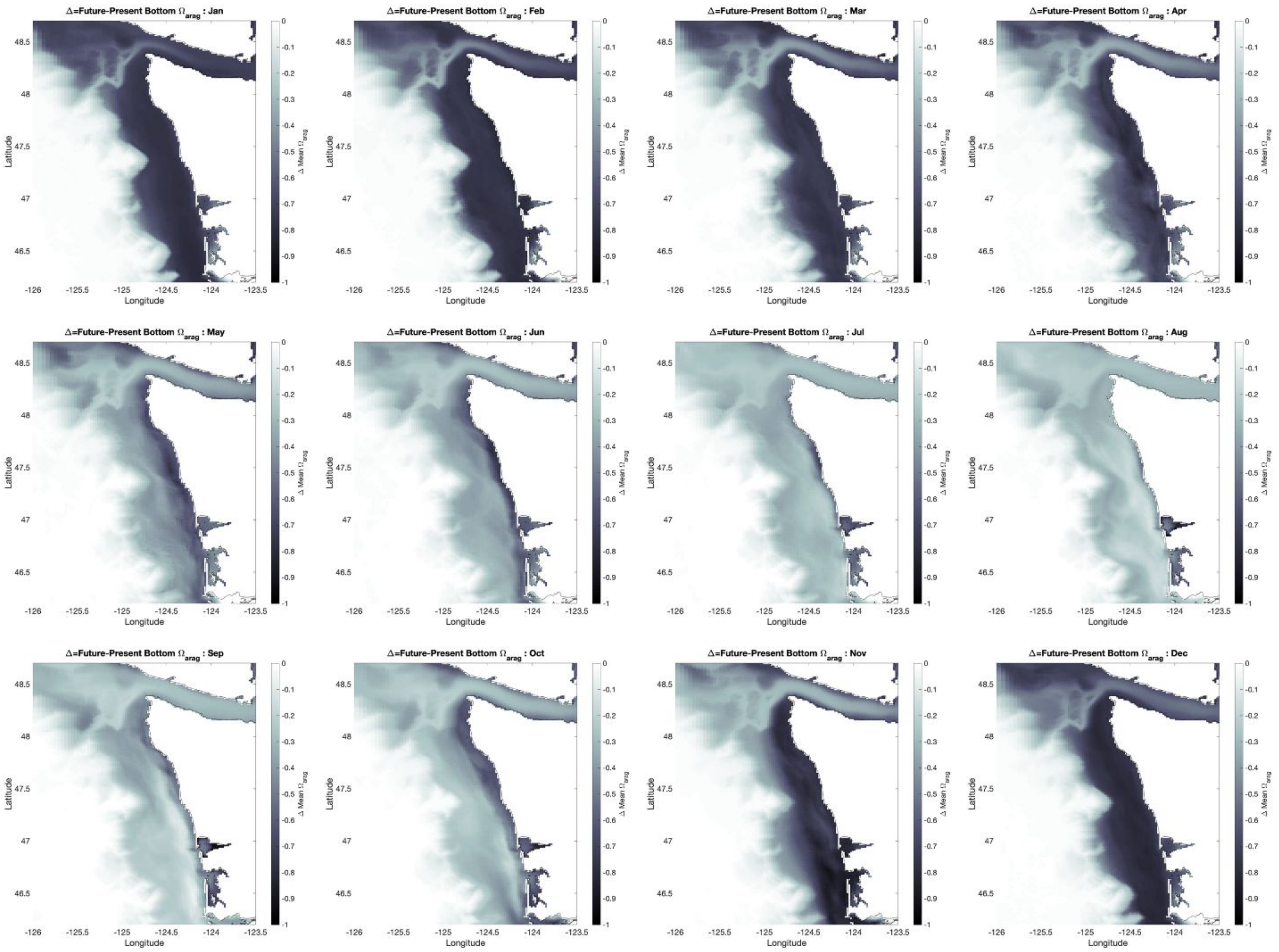


'Delta'



- Omega Aragonite decreases, most dramatically over the shelf
- Percent of year undersaturated increases, especially nearshore
- **The greatest change in saturation state of aragonite is in the nearshore and over the shelf (0.6-0.8 decrease).**
- **The greatest change in percent of year undersaturated is along the coast/nearshore intertidal (50% or greater), and to a lesser extent approaching the shelf edge.**

Monthly Bottom Aragonite Sat’n:



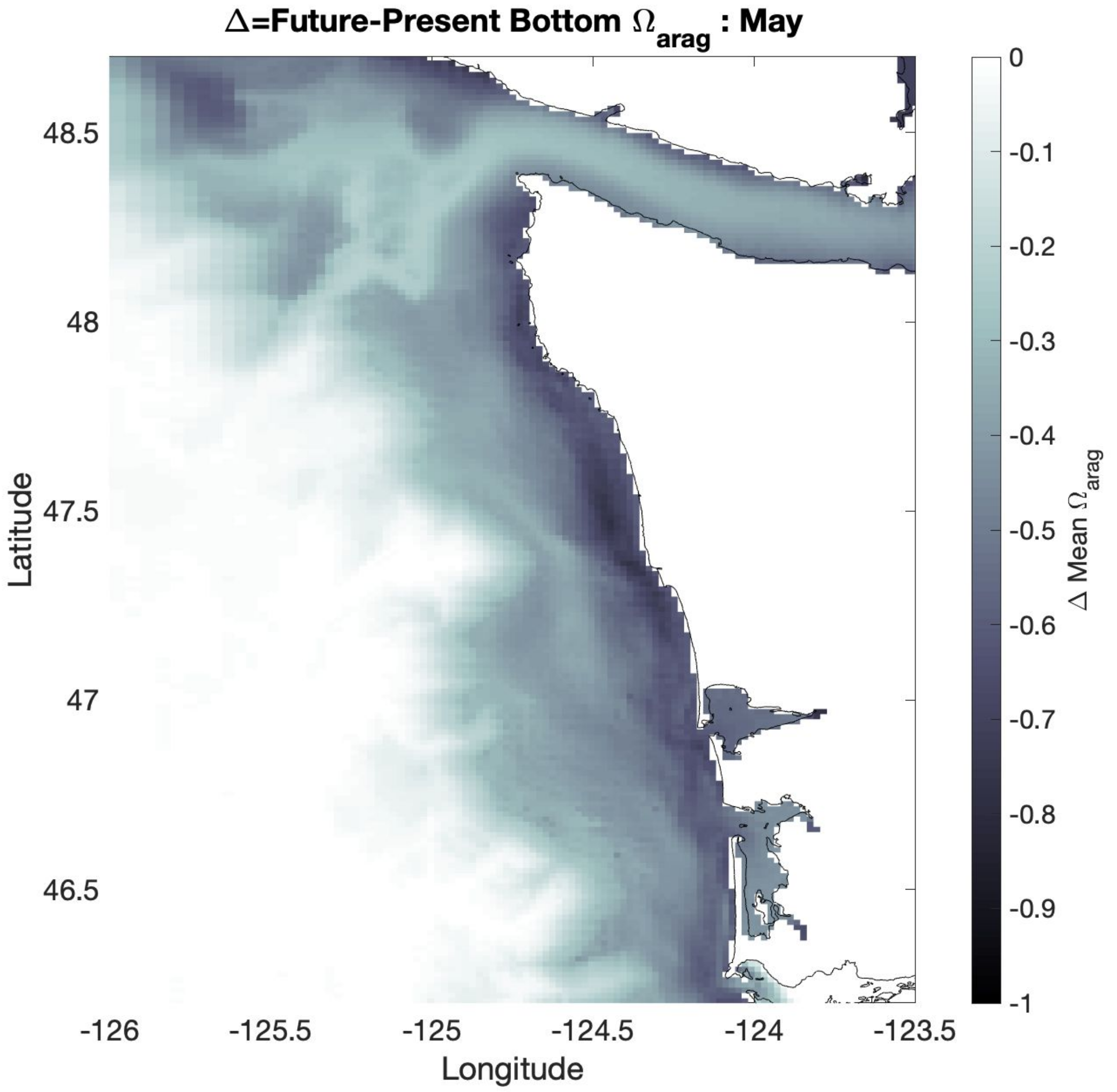
- The decrease in aragonite saturation state is strongest Jan-Apr and Nov-Dec, with decreases 0.9-1.
- **Generally, extending season of under-saturation, adding more stressors to winters, which we already know will be warmer.**

Razor Clams settle on the Olympic coast in April & May

Photos: Quinault Indian Nation and Larry Workman

Change in bottom aragonite sat'n in May:

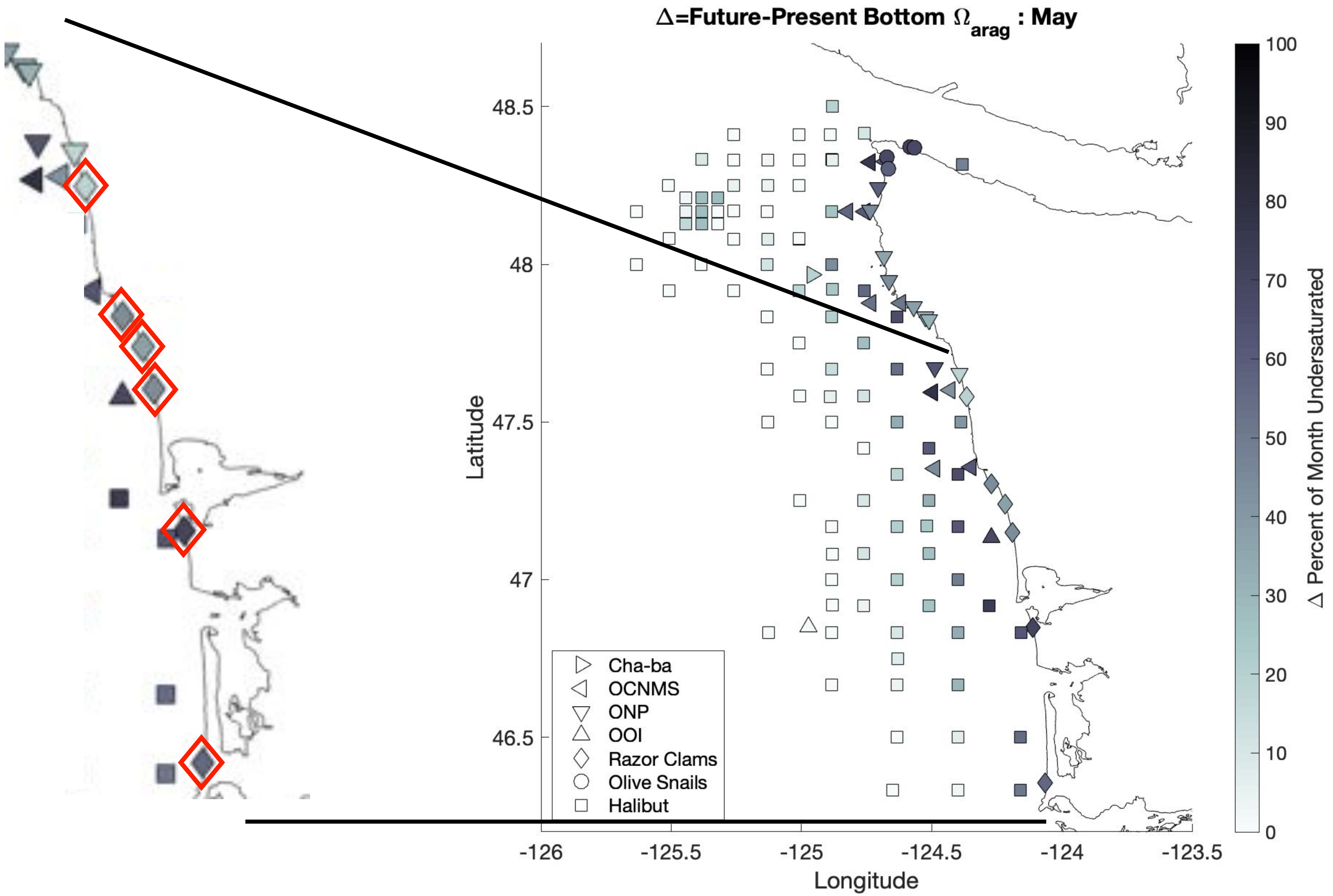
Razor clams settle on Olympic coast in April & May



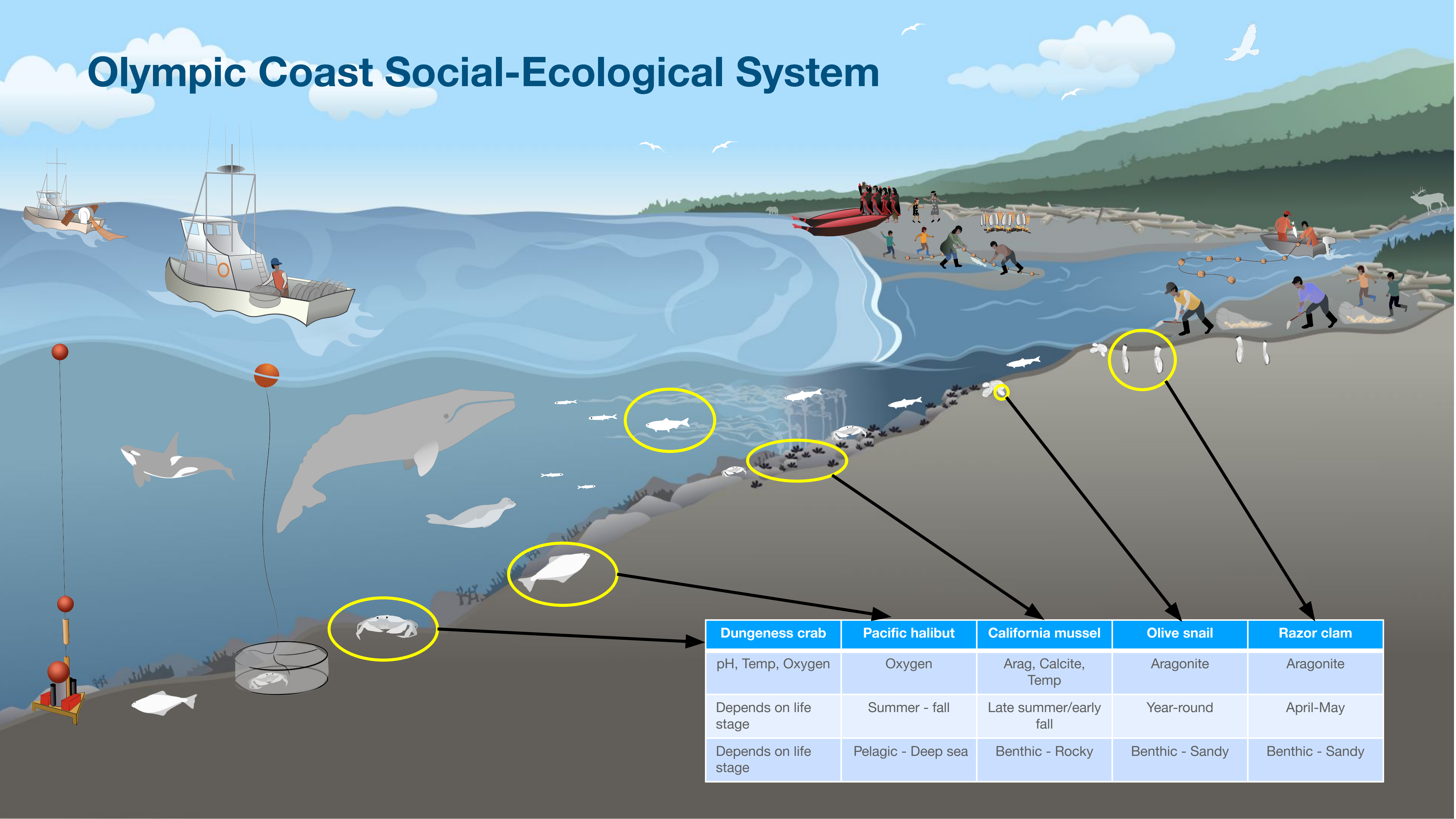
Change is greatest near the coast, increasing stressful conditions by 2100

Percent of month with undersaturated aragonite in May where razor clams collected:

North-South gradient; more stress to the south

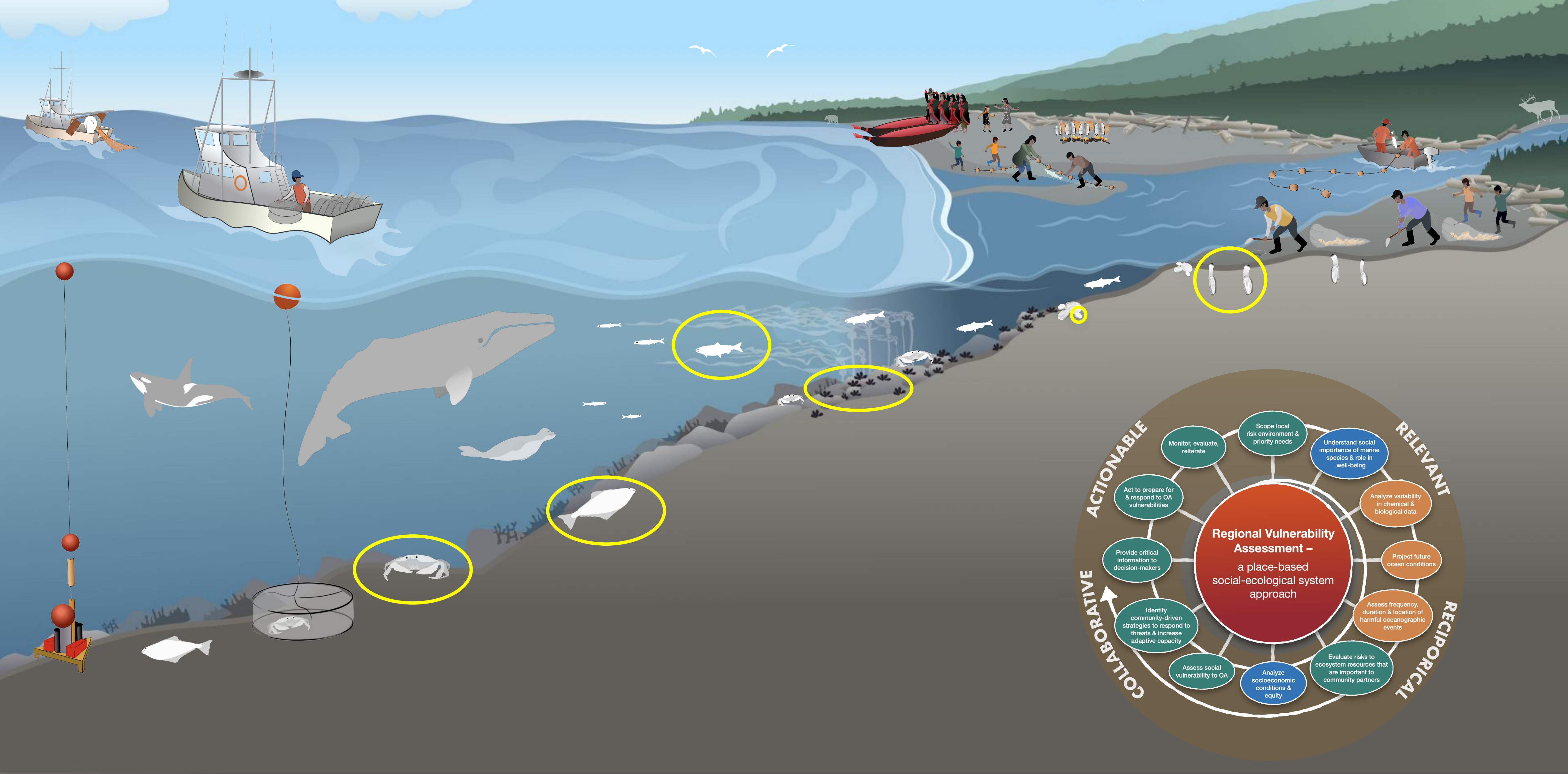


Olympic Coast Social-Ecological System



Dungeness crab	Pacific halibut	California mussel	Olive snail	Razor clam
pH, Temp, Oxygen	Oxygen	Arag, Calcite, Temp	Aragonite	Aragonite
Depends on life stage	Summer - fall	Late summer/early fall	Year-round	April-May
Depends on life stage	Pelagic - Deep sea	Benthic - Rocky	Benthic - Sandy	Benthic - Sandy

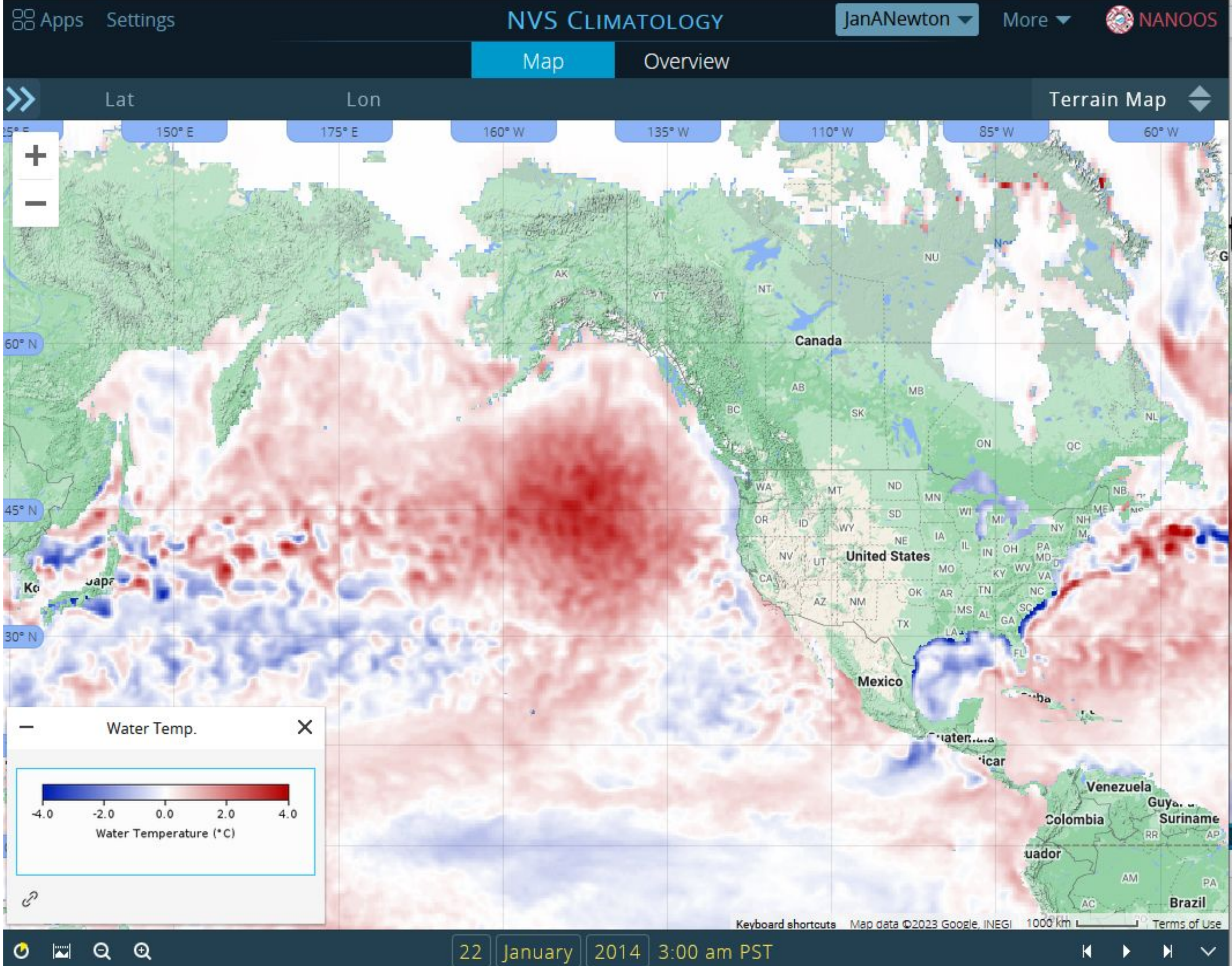
Olympic Coast Social-Ecological System



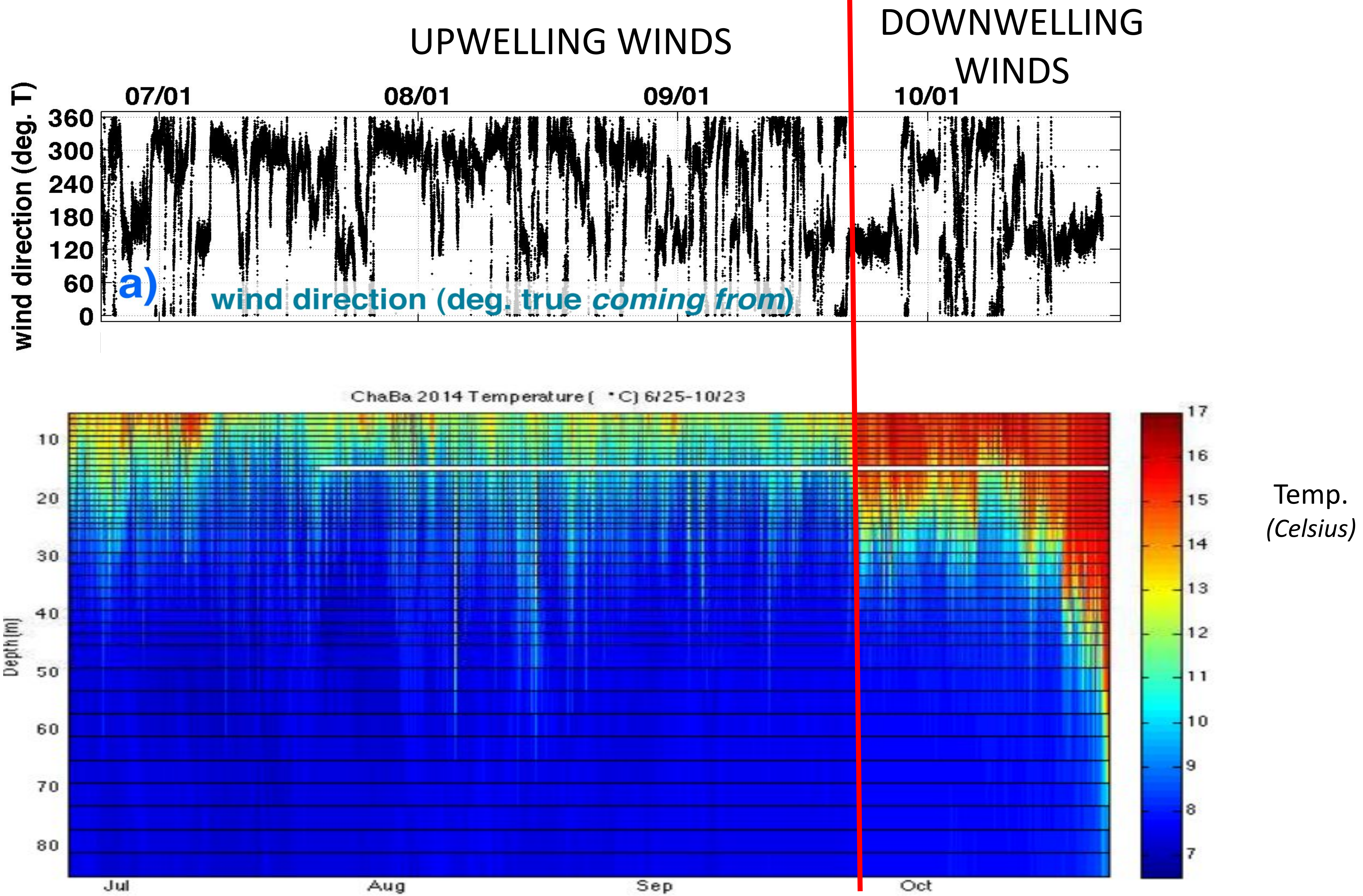
“the blob”

Jan 2014

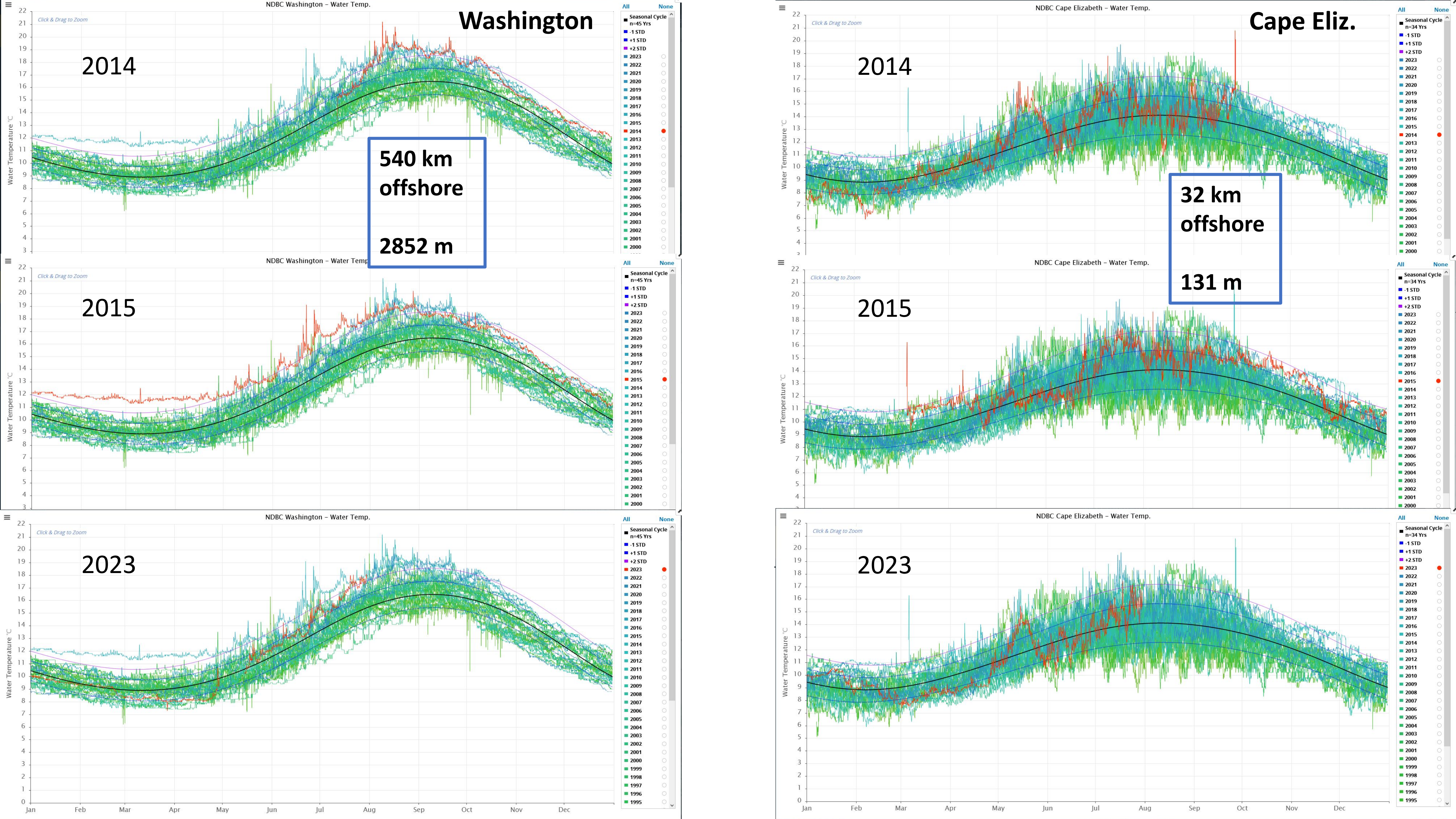
https://nvs.nanoos.org/Climatology



2014



J. Mickett, UW



NDBC Washington – Water Temp.
Washington
2014
540 km
offshore
2852 m
NDBC Washington – Water Temp.
2015
NDBC Washington – Water Temp.
2023
Click & Drag to Zoom
Water Temperature °C
Seasonal Cycle n=45 Yrs
-1 STD
+1 STD
+2 STD
All
None
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
NDBC Cape Elizabeth – Water Temp.
Cape Eliz.
2014
32 km
offshore
131 m
NDBC Cape Elizabeth – Water Temp.
2015
NDBC Cape Elizabeth – Water Temp.
2023
Seasonal Cycle n=34 Yrs

PLOS ONE

RESEARCH ARTICLE

Large and transient positive temperature anomalies in Washington's coastal nearshore waters during the 2013–2015 northeast Pacific marine heatwave

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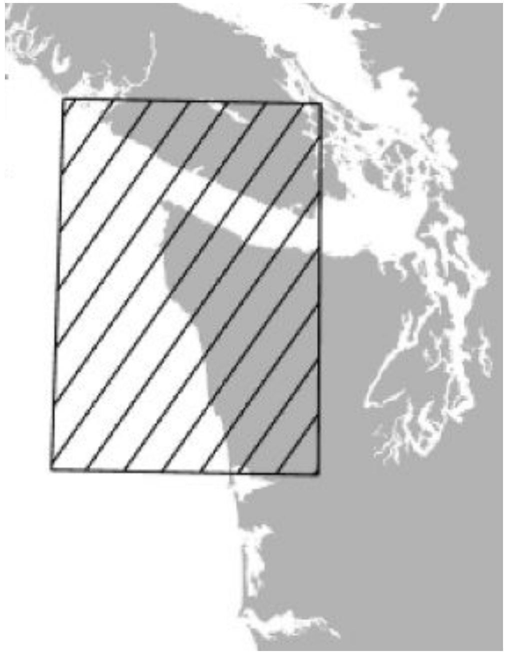
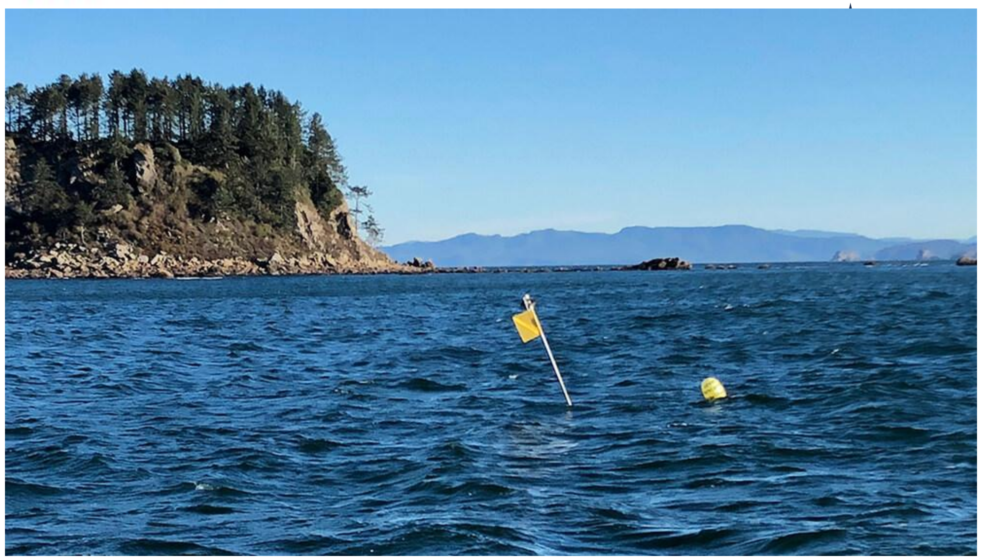


UW School of Marine and Environmental Affairs

JAK's Masters project



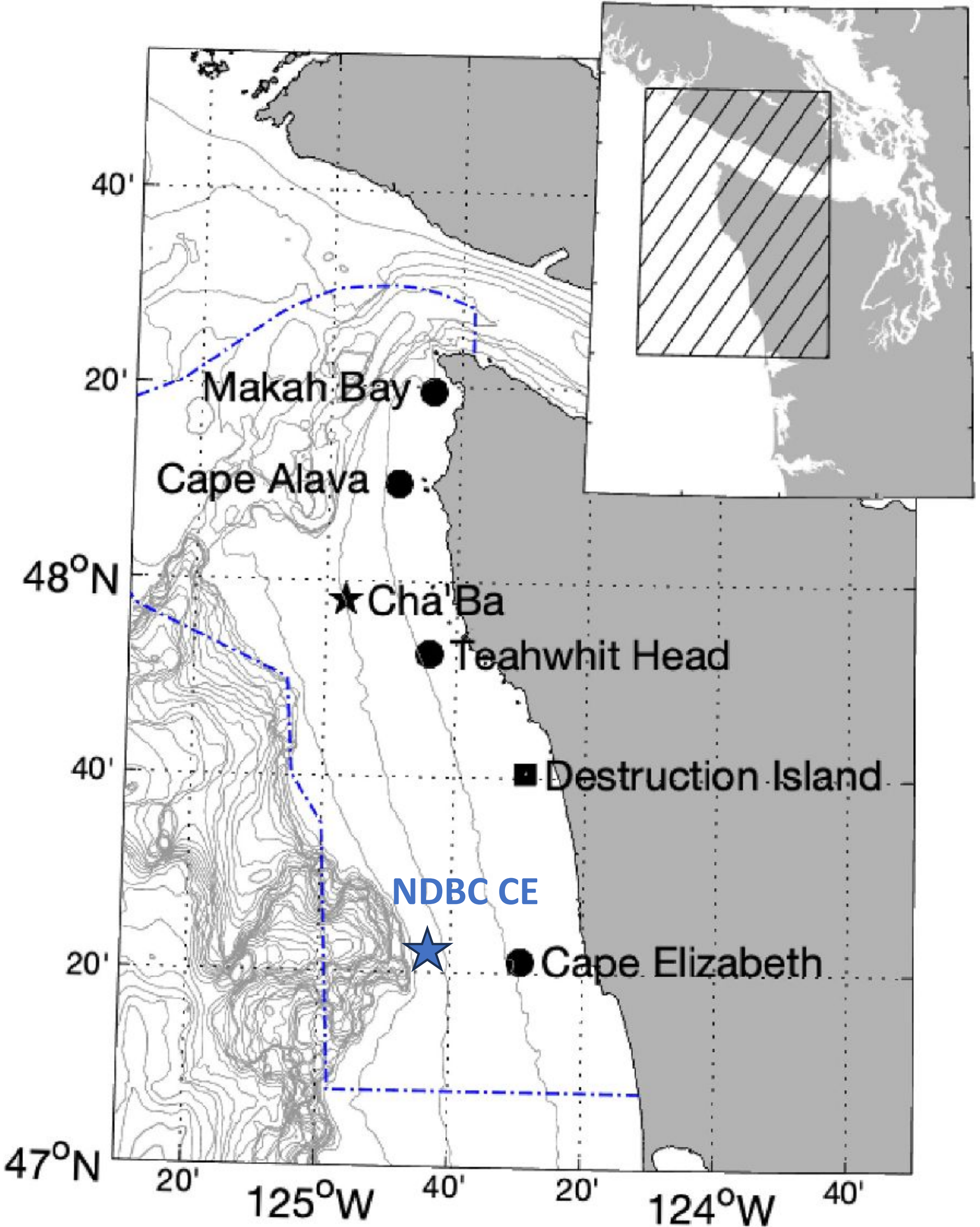
Koehlinger JA, et al. 2023. PLoS ONE 18(2): e0280646.
https://doi.org/10.1371/journal.pone.0280646

Observations:

Olympic Coast National Marine Sanctuary (OCNMS) stations (circles) are within 15 km offshore with bottom depths of approximately 42 m.

Cha'ba (black star) is 25 km offshore at 100 m depth

Cape Elizabeth NDBC (blue star) is 32 km offshore at 131 m depth

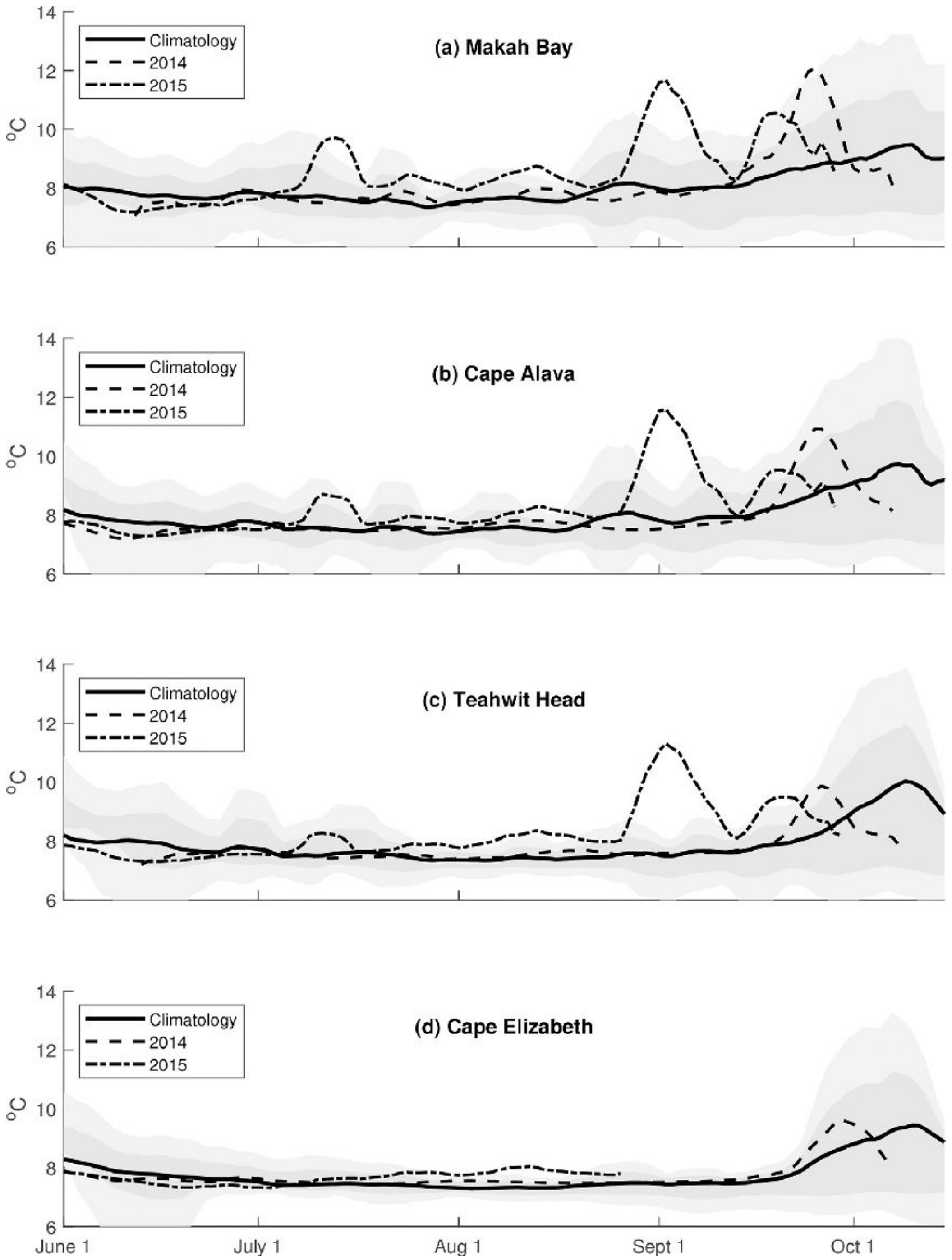


Episodic positive temperature anomalies observed

- Compared to a long-term climatology of 2001–2013, seven-day smoothed **temperature anomalies of up to 4.5˚C** are found at 40m depth during 2014 and 2015, seen as short-term events lasting 10–20 days.

- These periods of warming occurring within the Northeast Pacific marine heatwave (MHW) were about **twice the seasonal temperature range** in the climatology at that depth.

- These warm events were strongly correlated with periods of northward long-shore winds and upper ocean currents, consistent with what is expected for the **response to downwelling-favorable winds.**



Koehlinger JA, et al. 2023.

Implications for OOS vv. coastal climate change

- We need to increase nearshore observations and develop or maintain observations along offshore – onshore gradients in order to better understand how coastal dynamics are different or linked.

- We need to encourage and promote nearshore modeling beyond typical “coastal” resolution to capture nearshore dynamics, which are different (in some areas). We need to better constrain where things are similar and where they are not.

- We need to bridge those doing coastal ocean obs and coastal nearshore modeling to promote the increase of forecasting skill.

- We need to promote working across social and natural sciences to reveal information useful to society in light of climate change.

Assessing risk to biology

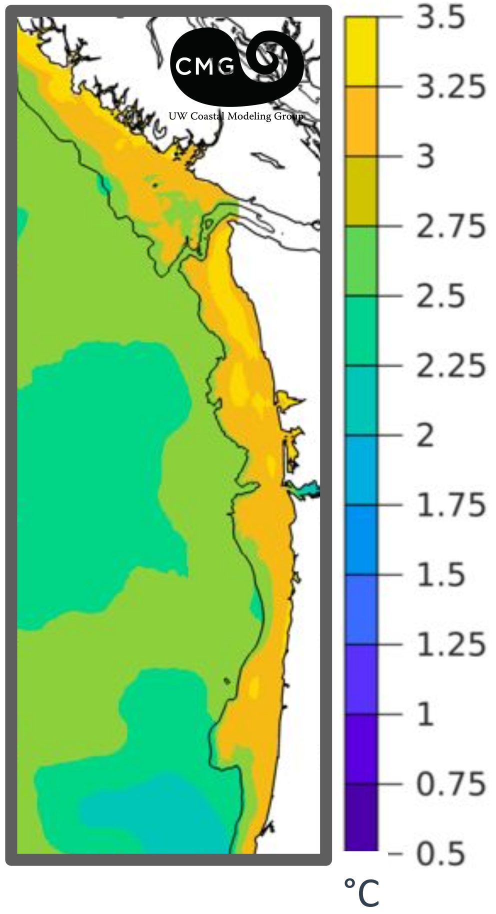
- Evaluated **change** for the multiple stressor variables
- Calculated metrics (e.g., **frequency of condition**)
- Assessed three different values of **assumed thresholds**
- Put in **context of focal species**

Yielding:

- A compendium of plots:
  - seven variables
  - averages (annual and by month)
  - delta (future - present)
  - change in frequency of condition (e.g., corrosive, hypoxic, etc.) or variability (S.D.)
  - analysis of oceanographic gradients from observations
- Allows for exploration in context of given species, area, season, or specific question by users

Model

Δ Temperature (0-200m)



Ocean Variables:

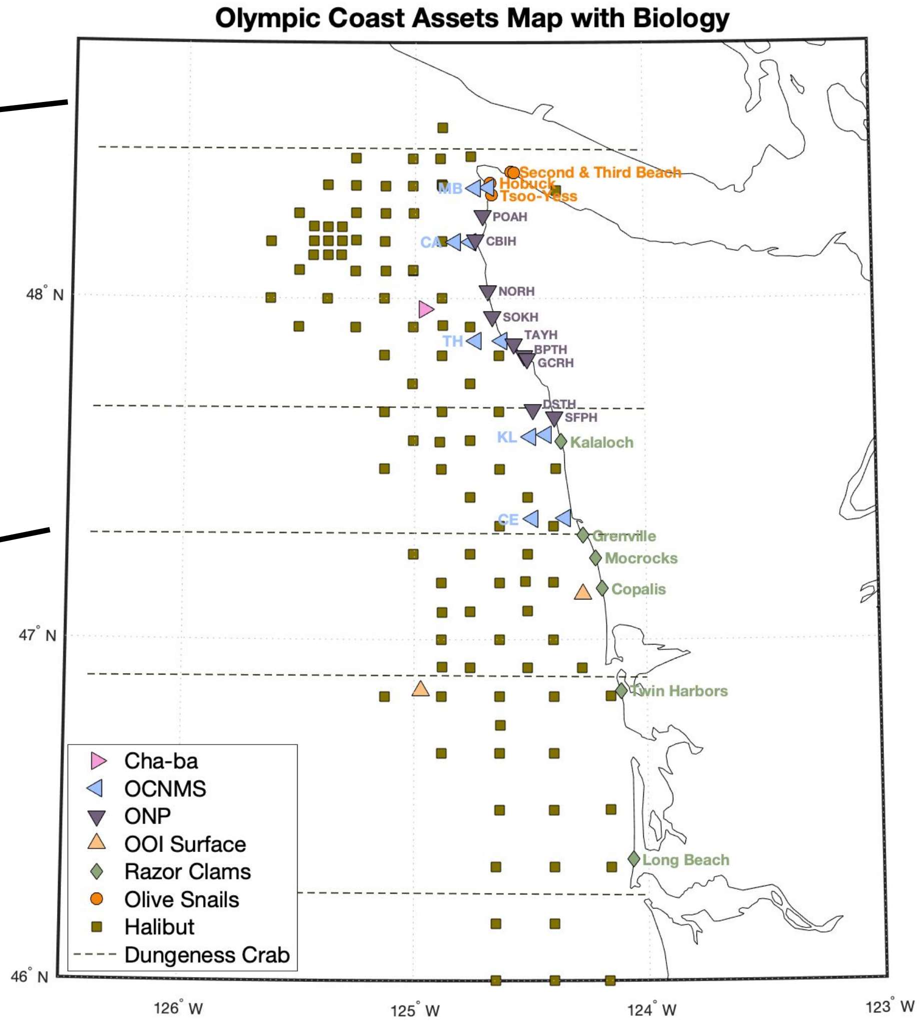
Temperature
Oxygen
pH
Aragonite sat'n
Calcite sat'n

Species:

Razor clam
Olive snail
Pacific halibut
Dung. crab
CA mussels

You!

Data



HOH TRIBE

California mussels settle on the Olympic coast in late summer - early fall

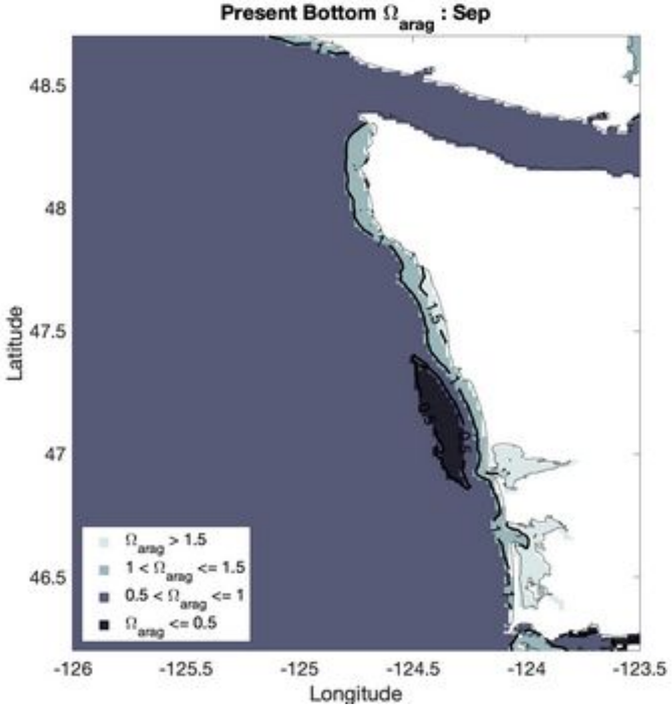
Their shells are both aragonite and calcite, and temperature can be important

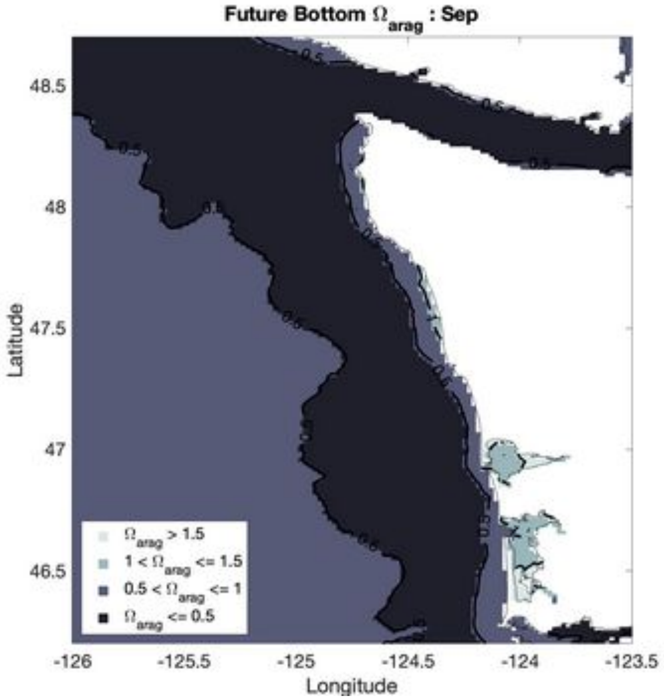
Currently, August conditions are stressful with some areas more severe.

In the future, the severe region expands to envelop much more benthic habitat.

Conditions get better as upwelling relaxes in October on.

Aragonite (and calcite) conditions during Sept:





Olive Snails settle on the Olympic coast year-round

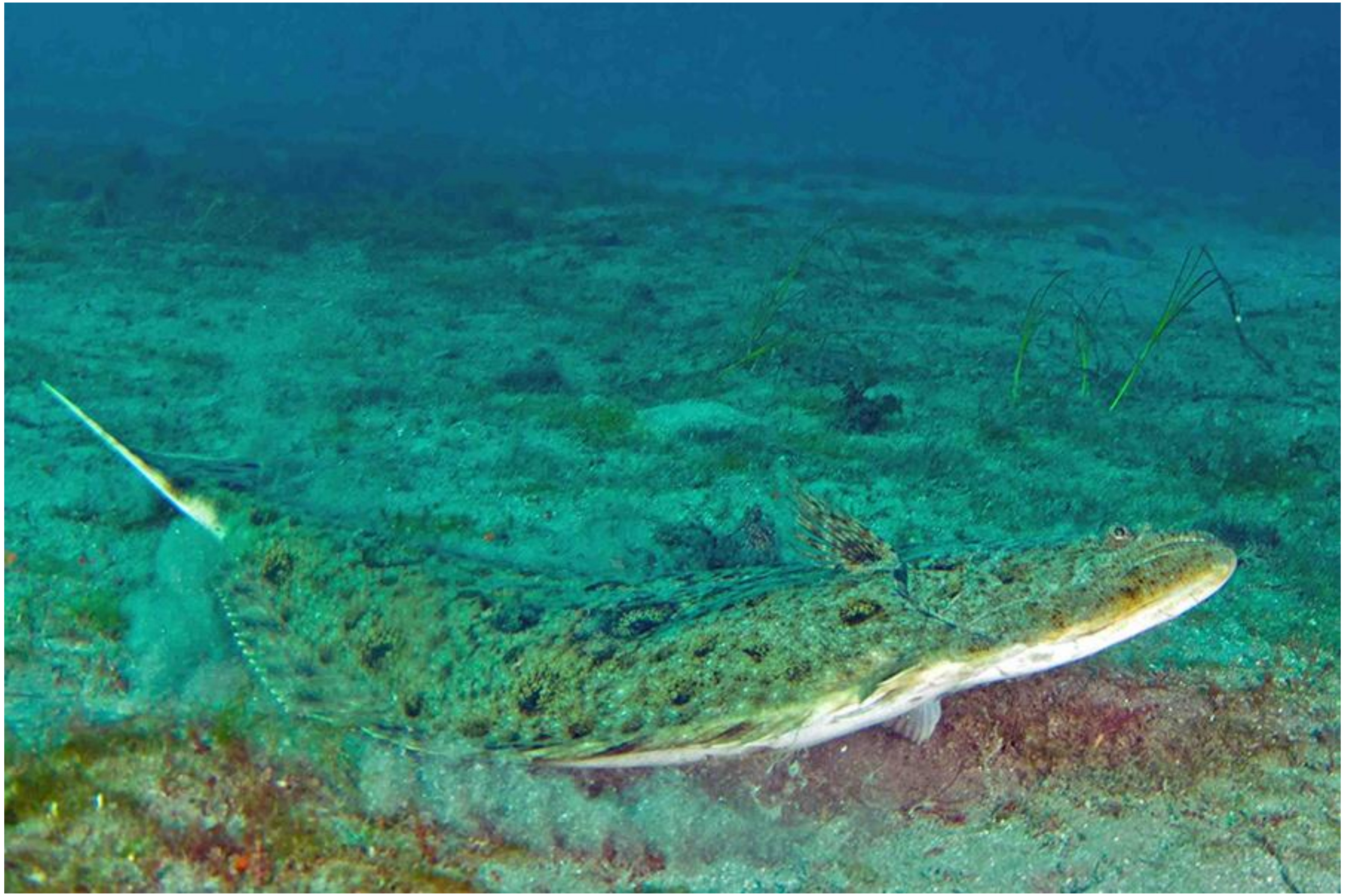
Their shells are made of aragonite.

- Presently, stressful aragonite conditions are primarily during July-August.
- In the future, the stressful conditions are also found March-June and Sept-October, with more severe conditions July-August.
- **So, suboptimal conditions expand from a 2-month period to an 8-month period**

Pacific halibut are sensitive to oxygen summer to fall

Currently, onshore pockets of low oxygen bottom waters are found primarily in August-September in the southern half of the coast.

In the future, these areas expand substantially in size and extend farther out to the shelf.



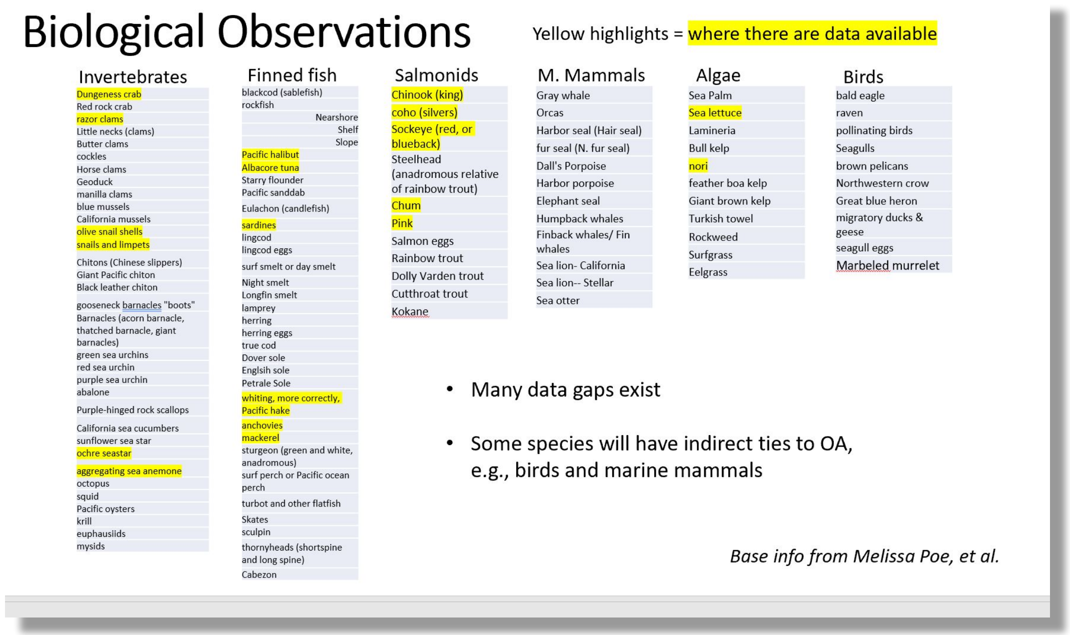
Dungeness crab reach adult on Olympic coast in August

Multiple stressors impact salmon, temperature, oxygen, OA.

Effects happen over their whole life-cycle, so differs for larvae versus juvenile & adults.

Found OA impact on all life stages but especially larval stage.

Issues:



Biological Observations

Yellow highlights = where there are data available

Invertebrates
- Dungeness crab
- Red rock crab
- razor clams
- Little necks (clams)
- Butter clams
- cockles
- Horse clams
- Geoduck
- manilla clams
- blue mussels
- California mussels
- olive snail shells
- snails and limpets
- Chitons (Chinese slippers)
- Giant Pacific chiton
- Black leather chiton
- gooseneck barnacles "boots"
- Barnacles (acorn barnacle, thatched barnacle, giant barnacles)
- green sea urchins
- red sea urchin
- purple sea urchin
- abalone
- Purple-hinged rock scallops
- California sea cucumbers
- sunflower sea star
- ochre seastar
- aggregating sea anemone
- octopus
- squid
- Pacific oysters
- krill
- euphausiids
- mysids

Finned fish
- blackcod (sablefish)
- rockfish
- Nearshore
- Shelf
- Slope
- Pacific halibut
- Albacore tuna
- Starry flounder
- Pacific sanddab
- Eulachon (candlefish)
- sardines
- lingcod
- lingcod eggs
- surf smelt or day smelt
- Night smelt
- Longfin smelt
- lamprey
- herring
- herring eggs
- true cod
- Dover sole
- Englsih sole
- Petrale Sole
- whiting, more correctly, Pacific hake
- anchovies
- mackerel
- sturgeon (green and white, anadromous)
- surf perch or Pacific ocean perch
- turbot and other flatfish
- Skates
- sculpin
- thornyheads (shortspine and long spine)
- Cabezon

Salmonids
- Chinook (king)
- coho (silvers)
- Sockeye (red, or blueback)
- Steelhead (anadromous relative of rainbow trout)
- Chum
- Pink
- Salmon eggs
- Rainbow trout
- Dolly Varden trout
- Cutthroat trout
- Kokane

M. Mammals
- Gray whale
- Orcas
- Harbor seal (Hair seal)
- fur seal (N. fur seal)
- Dall's Porpoise
- Harbor porpoise
- Elephant seal
- Humpback whales
- Finback whales/ Fin whales
- Sea lion- California
- Sea lion-- Stellar
- Sea otter

Algae
- Sea Palm
- Sea lettuce
- Lamineria
- Bull kelp
- nori
- feather boa kelp
- Giant brown kelp
- Turkish towel
- Rockweed
- Surfgrass
- Eelgrass

Birds
- bald eagle
- raven
- pollinating birds
- Seagulls
- brown pelicans
- Northwestern crow
- Great blue heron
- migratory ducks & geese
- seagull eggs
- Marbeled murrelet

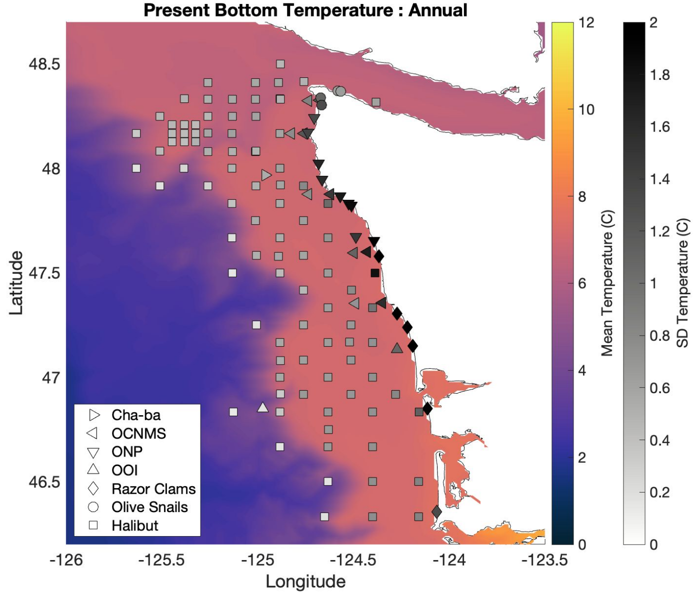
- Many data gaps exist
- Some species will have indirect ties to OA, e.g., birds and marine mammals

Base info from Melissa Poe, et al.

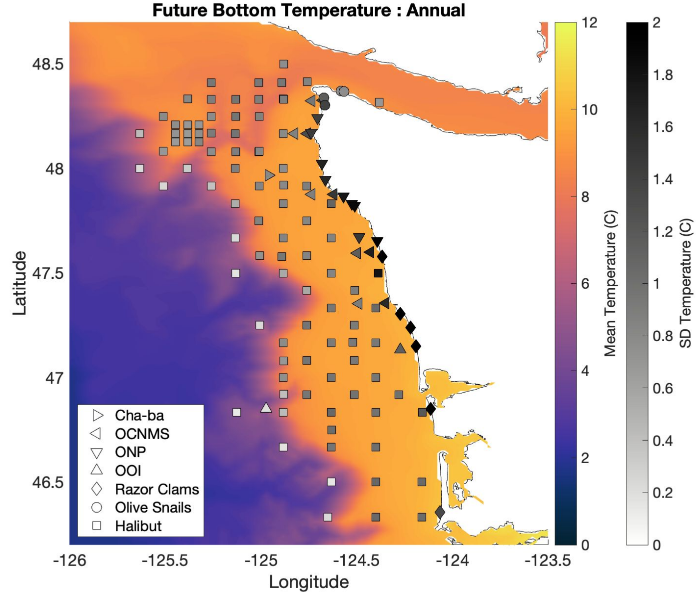
- Insufficient data
- Insufficient knowledge of thresholds
- Geospatial data lacking for some species
  - General areas or zones in many cases
- Multiple stressors

Bottom temperature - Annual

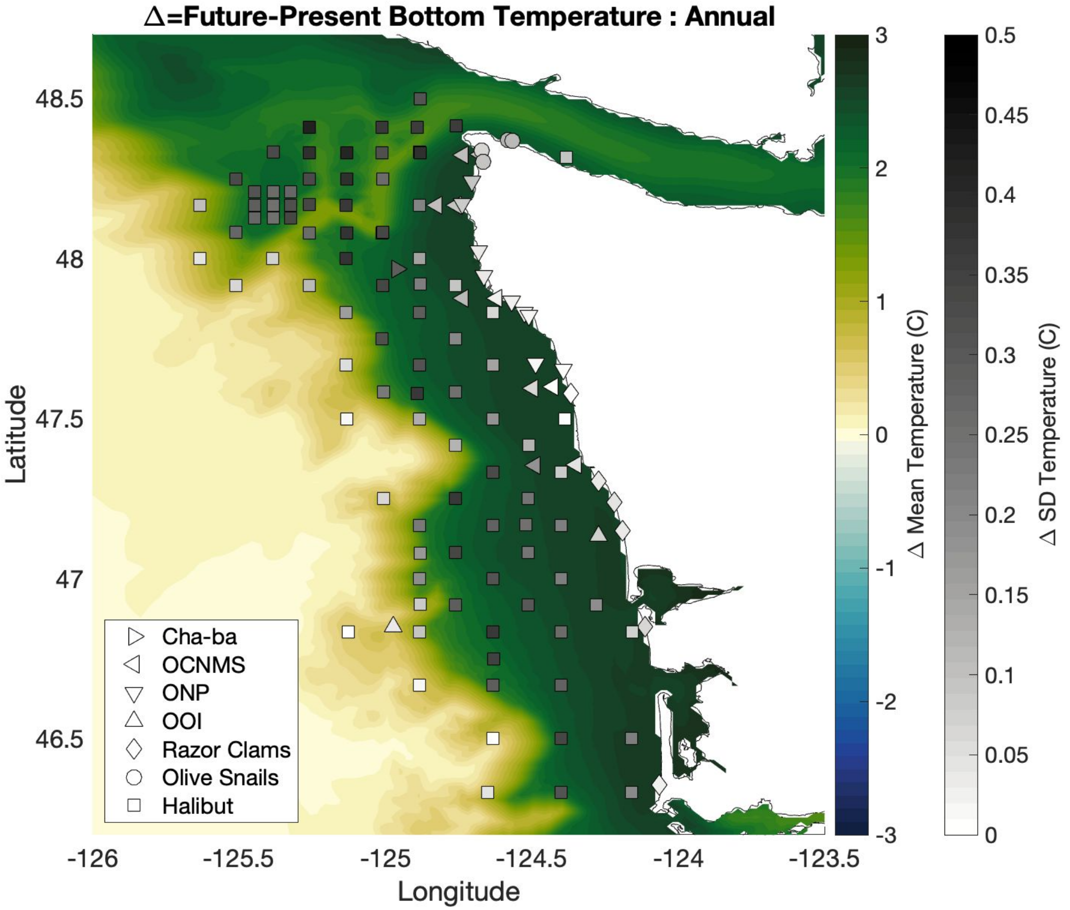
Present



Future



'Delta'



- Temperature increases, most dramatically over the shelf; ~2-2.5 C
- Variation in temperature (S.D.) increases most along shelf edge
- At present, T is warmest over the shelf, **in future, the increase is strongest over the shelf**
- At present, the SD of T is largest in the intertidal to nearshore, **in the future, the SD of T increases, most notably at mid-shelf, but is still largest in the intertidal to nearshore.**

Species stories

Razor clam	Olive snail	California mussel	Pacific halibut	Dungeness crab
Aragonite	Aragonite	Arag, Calcite, Temp	Oxygen	pH, Temp, Oxygen
April-May	Year-round	Late summer/early fall	Summer - fall	Depends on life stage
Benthic - Sandy	Benthic - Sandy	Benthic - Rocky	Pelagic - Deep sea	Depends on life stage

Razor clams – **Aragonite, April-May**

- The major impact to razor clams from future conditions will be from the increased presence of undersaturated aragonite conditions over what they are exposed to now.

- Since razor clams primarily settle in April and May, that may be a critical period for this species, though settlement has been noted at other times.

- During April and May, we see a decrease in aragonite saturation of ~0.7 along the coast in the future from current conditions.

- **Currently along the coast, aragonite saturation is not below 1.0 in April and May, with most sites above 1.5 at present. In the future, these values are predominately 0.5-1.0.**

- At sites where razor clams have been sampled, in the future 30-60% of the month of May will be undersaturated.

- Future temperature and oxygen appear to be within ranges of what razor clams will tolerate, with temperature increasing 2-2.5 C and oxygen decreasing 0.5 mg/L. Calcite is not an important factor to razor clams.

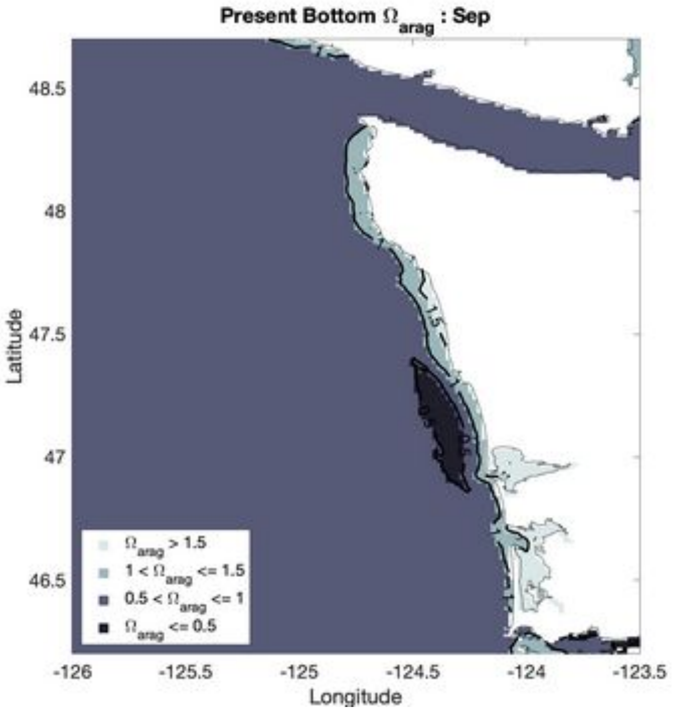
Olive snails – **Aragonite, year round**

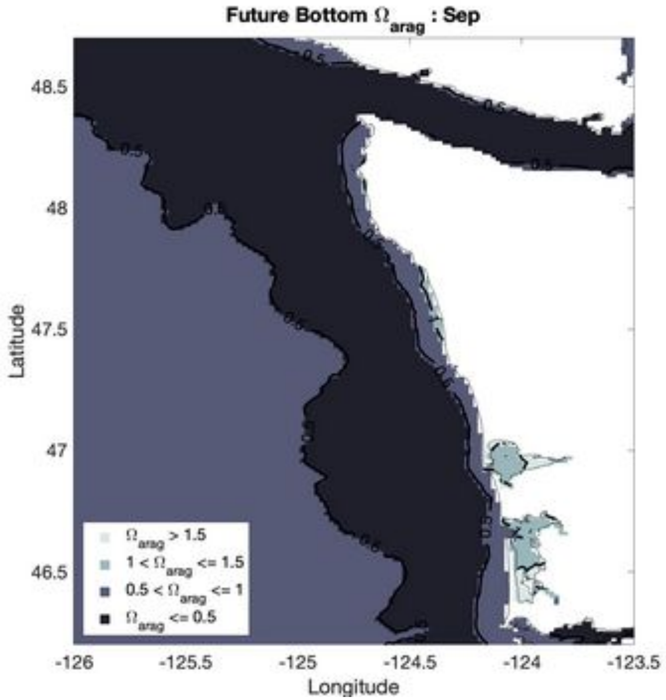
- Olive snail shells are 100% aragonite and they reproduce year-round.
- Thus, changes in aragonite saturation state will be of most importance at the sites they are found, within the lower intertidal and shallow sub-tidal zones of wave-swept fine sandy beaches.
- At present, aragonite saturation of 0.5-1 are primarily present during July and August, with some localized areas in June and September. In the future, 0.5-1 is found in March-June and Sept-Oct, with severely undersaturated conditions <0.5 in July-Aug.
- **So, suboptimal conditions go from a 2-month period to an 8-month period.**

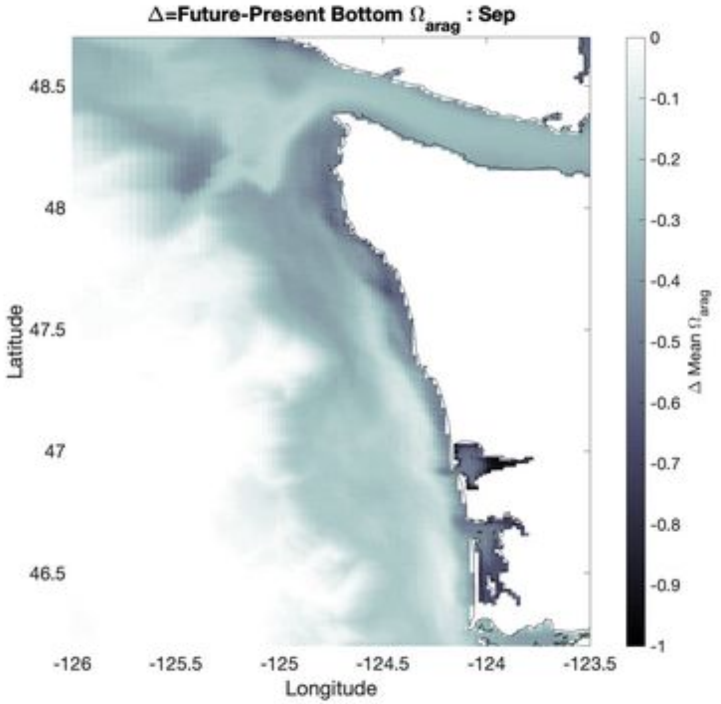
Mussels – **Aragonite and Calcite, August - Sept**

- OA is of high concern for mussels, including for their attachment via byssal threads.
- Of importance are aragonite and calcite saturation states in late summer to early fall; with a sat’n threshold of ~1.5
- Currently, August bottom water conditions for aragonite saturation vary 0.5-1, with some areas severely undersaturated at <0.5. In the future, however, the <0.5 region expands dramatically to envelop much more benthic habitat.
- Conditions above 1.5 currently exist in the bays (August) and in a thin strip along the coast as well as the bays in September.
- Conditions get better as upwelling relaxes in Oct on.

Aragonite (and calcite) conditions during Sept:



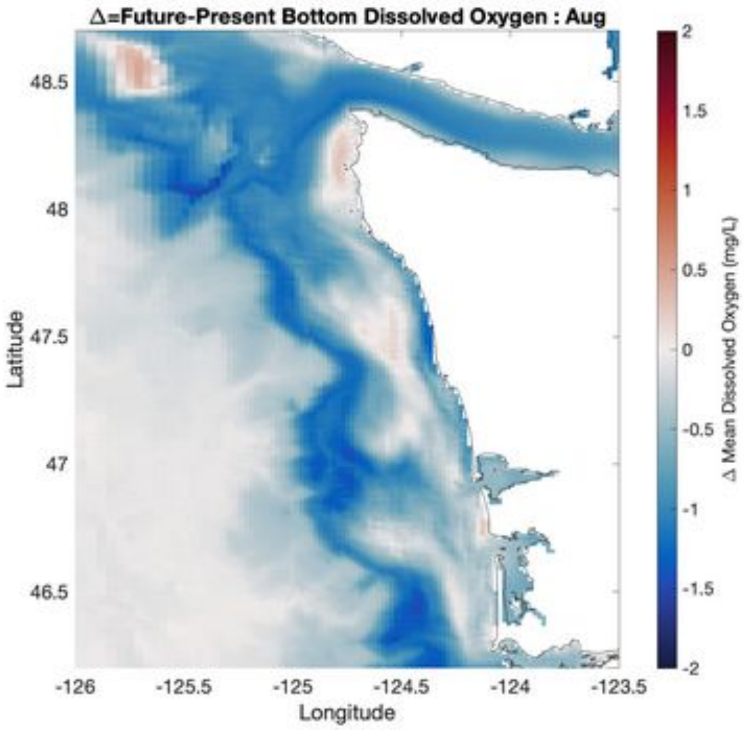


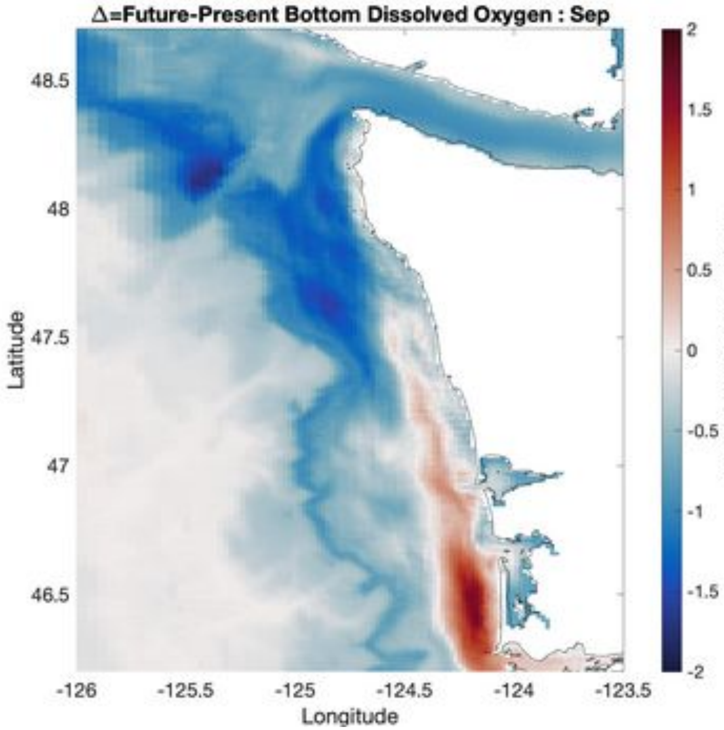


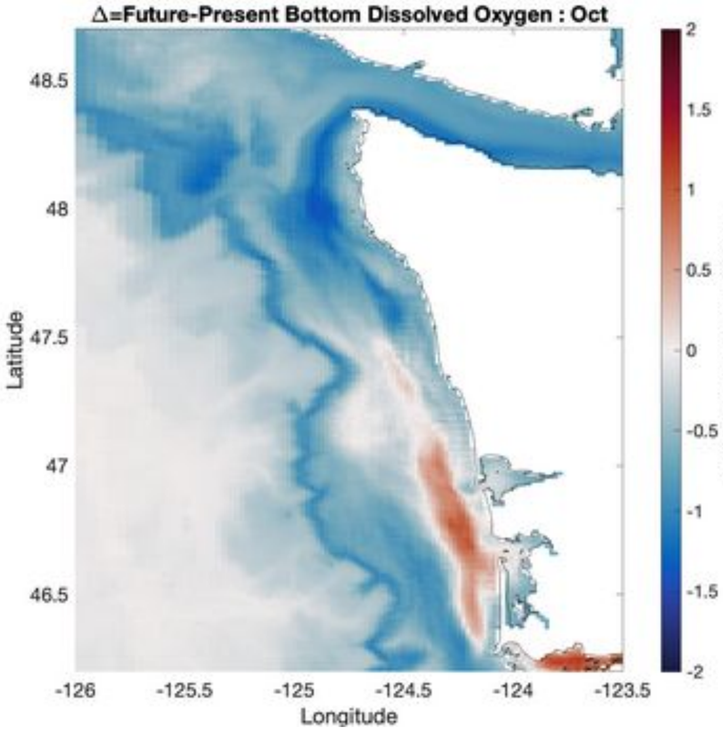
Halibut – **Oxygen, August - Sept**

- The body of knowledge for halibut is focused on impacts from oxygen.
- From January to June, bottom waters less than 1.3 mg/L are primarily found off the coast, overlapping with known halibut collection sites.
- These zones get wider in the future.
- Onshore pockets of bottom waters <1.3 mg/L are found primarily in Aug and September in the southern half of the coast.
- In the future, these areas expand substantially in size and extend farther out to the shelf, but are constrained to the southern half of the coast.

Oxygen conditions in August, Sept, and Oct:



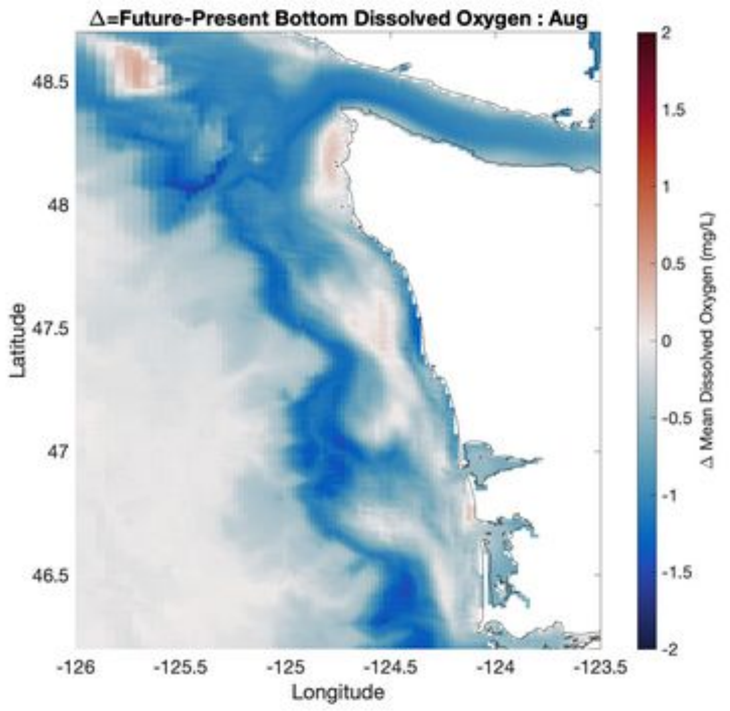


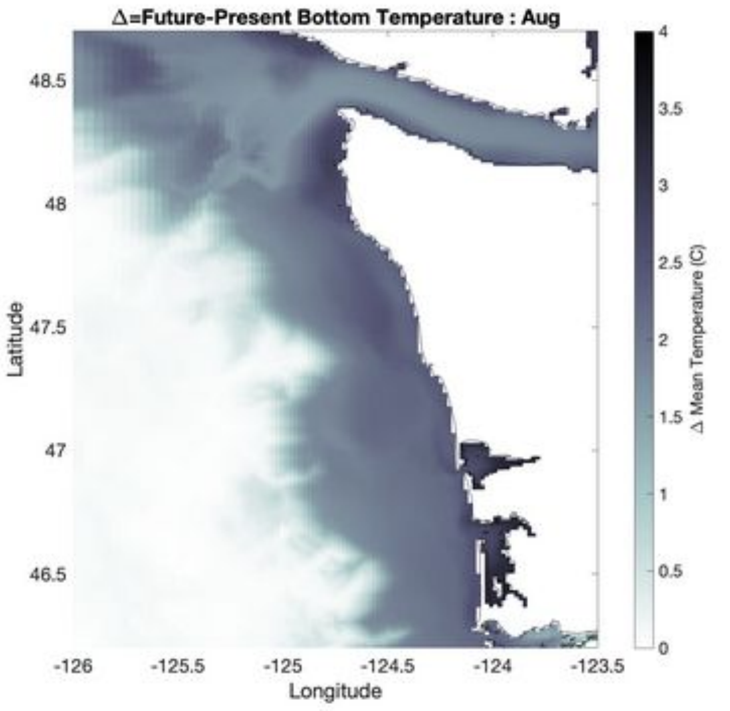


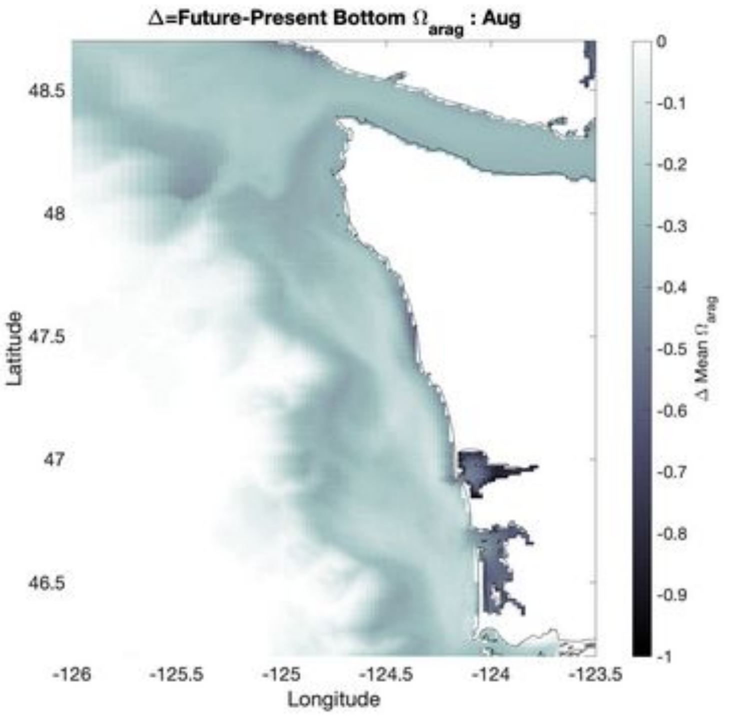
Adult crab – **Temperature, oxygen, aragonite, calcite, Sept**

- As Berger et al., 2021 showed, the crab life history necessitates assessing conditions for both pelagic zoea and larva as well as the benthic adult stages.
- Adults settle to the benthos primarily in August. Crab will be susceptible to future conditions from aragonite, calcite, and oxygen. Temperature during August stays at 12C or below.
- Currently, August bottom water conditions for aragonite saturation vary 0.5-1, with some areas severely undersaturated at <0.5. In the future, however, the <0.5 region expands dramatically to envelop most all crab benthic habitat.
- Currently calcite has a longitudinal pattern; nearer the shore there is a band of 0.5-1 and offshore of that another band of 1-1.5. In the future, the dominant condition is 0.5-1, with a smaller region <0.5 off of and north of Grays Harbor. Oxygen patterns are also spatially variable with similarities to the calcite pattern.
- There are more severe conditions to the south and offshore of xx m (find out).
- At present, the oxygen ranges are in either 0.5 - 2.0 or >2-5 mg/L. In the future, the habitat with 0.5 - 2.0 mg/L expands northwards, and there is the emergence of oxygen conditions at 0-0.5 mg/L in the south, located offshore to north of Grays Harbor.

Oxygen, temp., and aragonite conditions in August:







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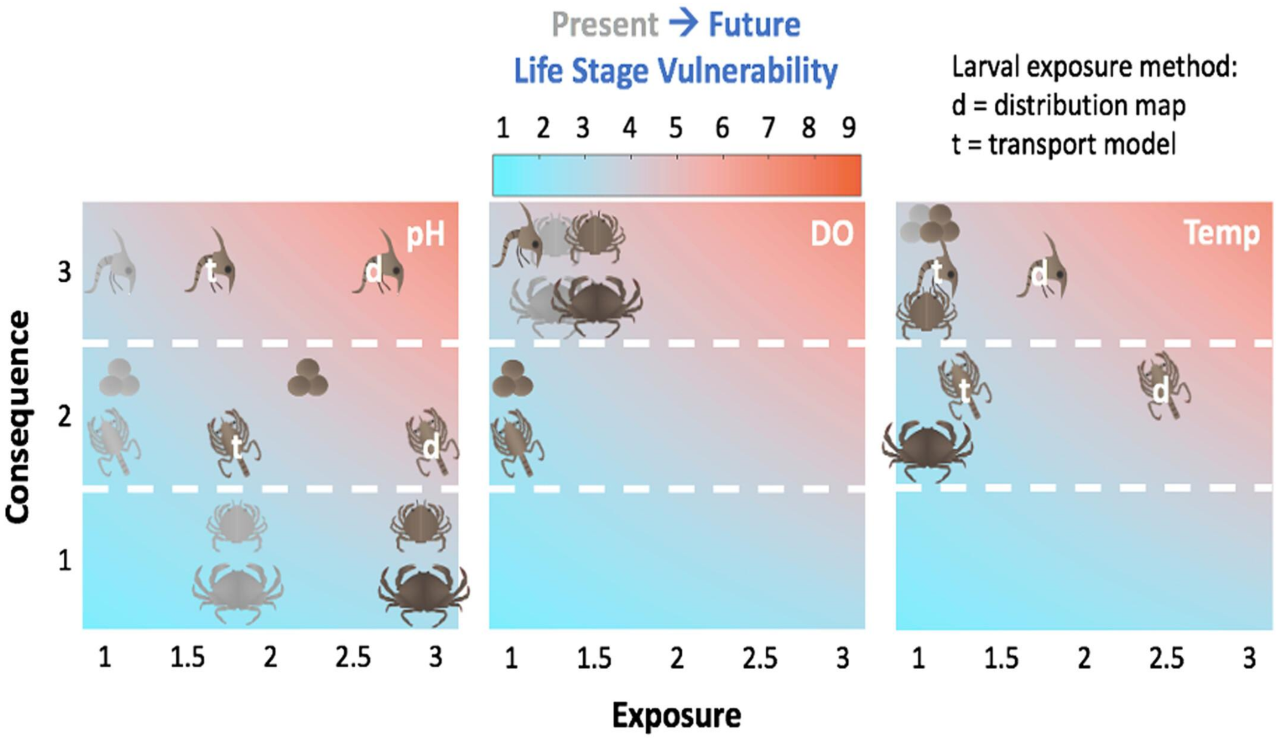
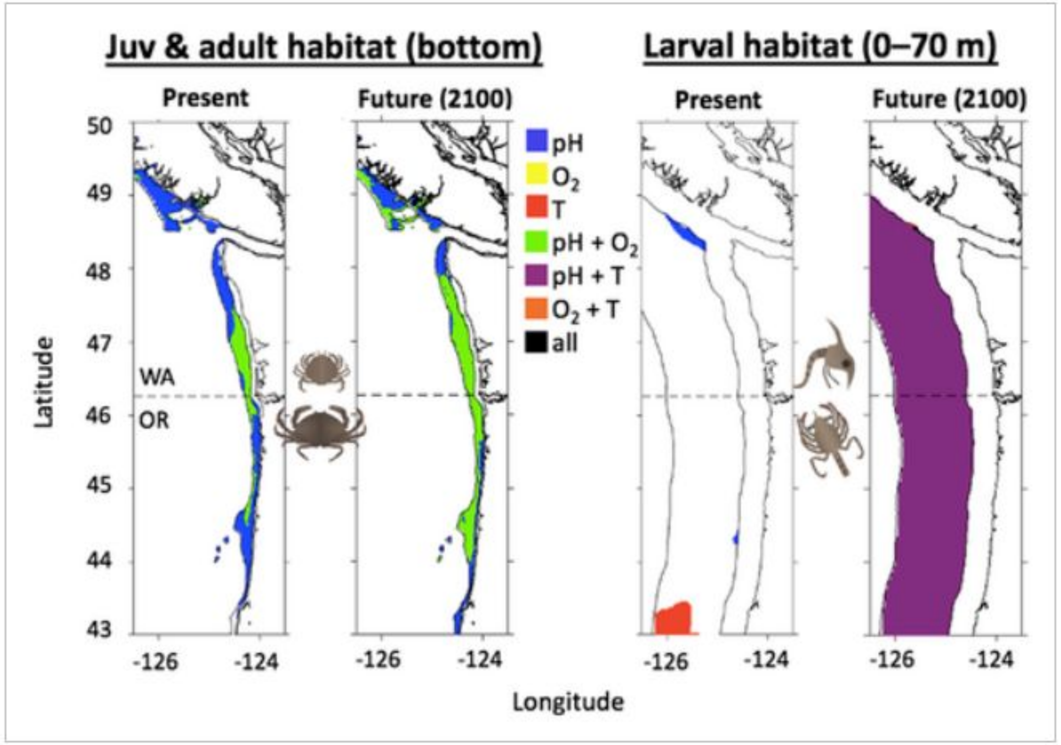
Seasonality and Life History Complexity Determine Vulnerability of Dungeness Crab to Multiple Climate Stressors

Halle M. Berger, Samantha A. Siedlecki, Catherine M. Matassa, Simone R. Alin, Isaac C. Kaplan, Emma E. Hodgson, Darren J. Pilcher, Emily L. Norton, Jan A. Newton





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Salmon –

- Salmon stocks are extremely variable in space and time, with multiple runs.
- Much less is known regarding the impact of OA on them, however, Williams et al., found that coho salmon were susceptible to losing their ability to sense prey, whereas black cod were not.