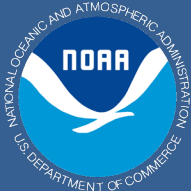


2021-22 California Current Ecosystem Status Report

NOAA California Current IEA Team

Presented to the Pacific Fishery Management Council
March 13, 2022



2021-2022 CALIFORNIA CURRENT ECOSYSTEM STATUS REPORT

*A report of the NOAA California Current Integrated Ecosystem Assessment Team (CCIEA)
to the Pacific Fishery Management Council, March 13, 2022*

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Summary

Favorable Physical Conditions Over Much of the Shelf and Slope

- La Niña conditions, Negative Pacific Decadal Oscillation (PDO)
- Above-average upwelling season, coolest shelf conditions since 2013
- Good nutrient supply to the base of the food web



Positive Ecological Responses



Lipid-rich northern copepods highly abundant off Oregon



Favorable conditions for juvenile salmon off Washington and Oregon



Further south, continued very high abundances of anchovies in surveys and in predator diets



Positive trends in productivity and growth rates of upper level predators



Unfavorable Conditions and Risk Factors



Marine Heatwave

7th largest marine heatwave on record since 1982, largely remained offshore US EEZ



Terrestrial Disturbances

Early snowmelt, drought, warm streams



Record heat, extreme & widespread wildfires



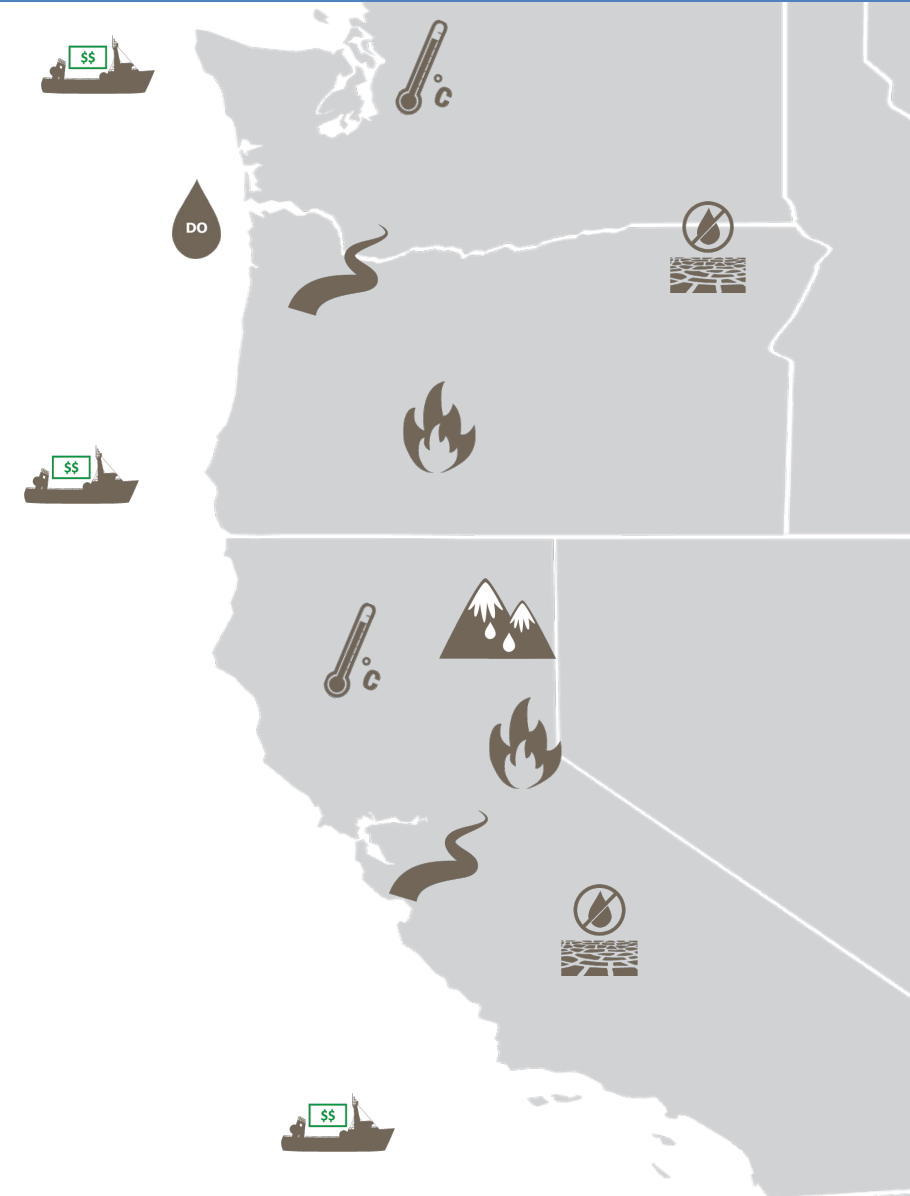
Hypoxia

Widespread near-bottom hypoxia off OR/WA May-October

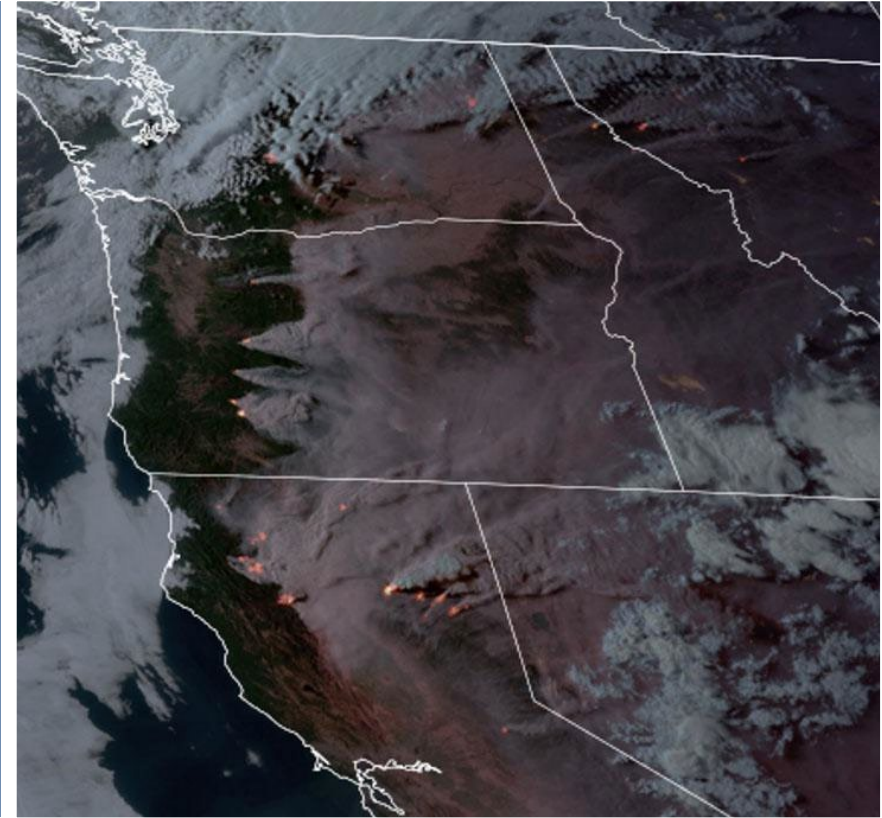
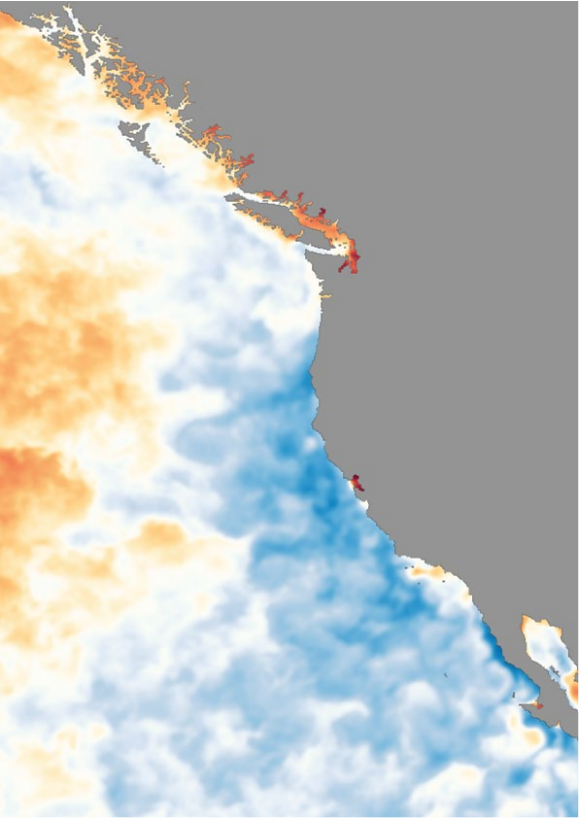


Fishery Landings

Landings continued to decline in 2021 for several target groups (though revenue improved for many)

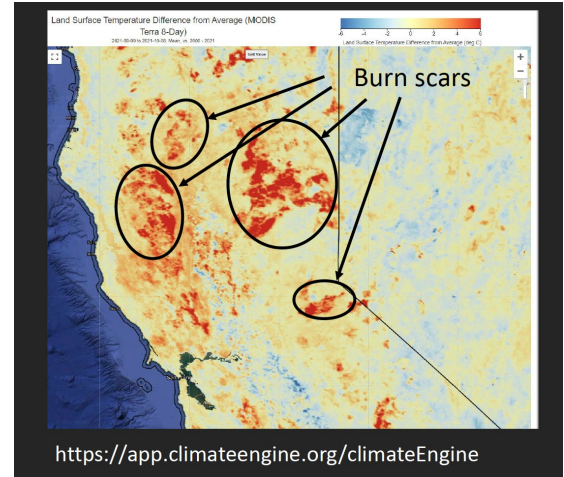
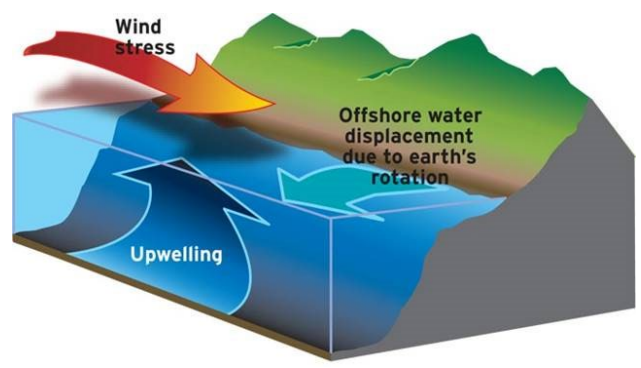
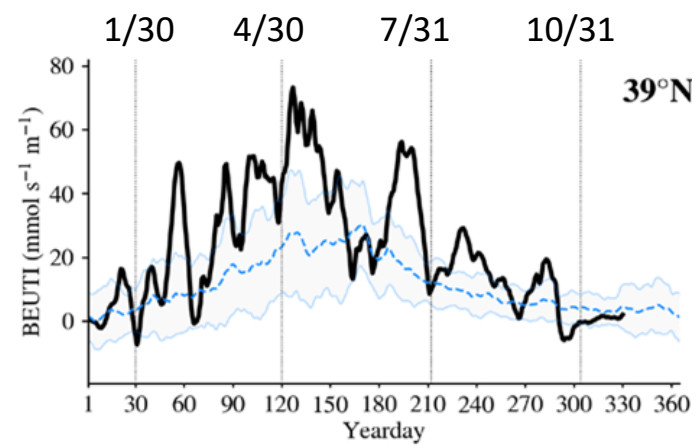
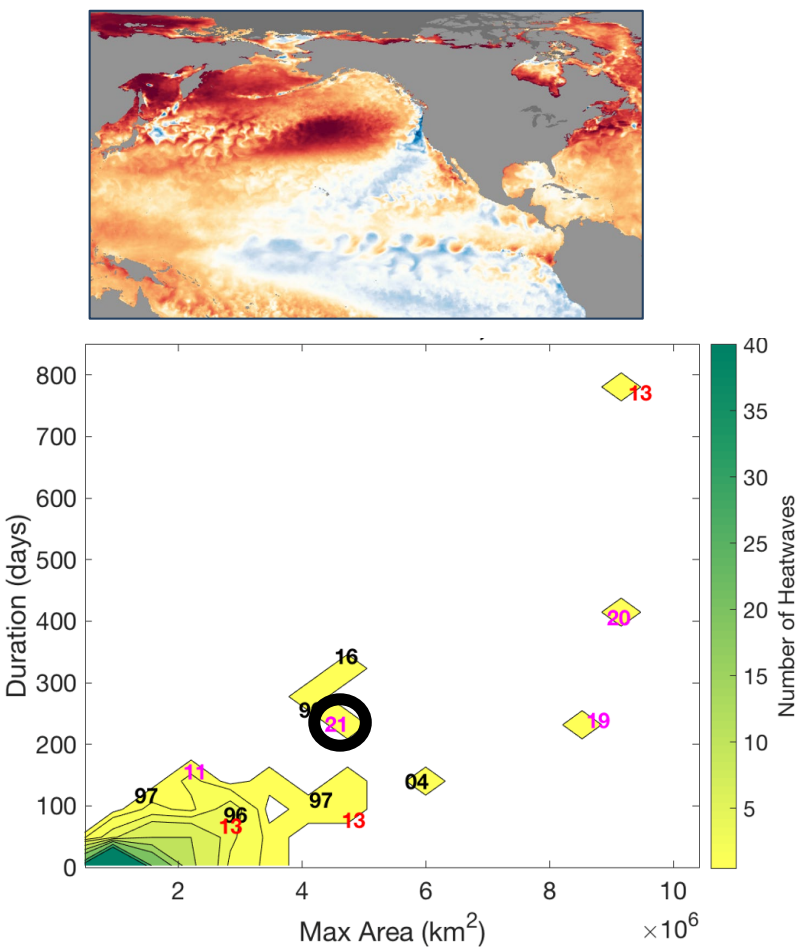


Physical Conditions

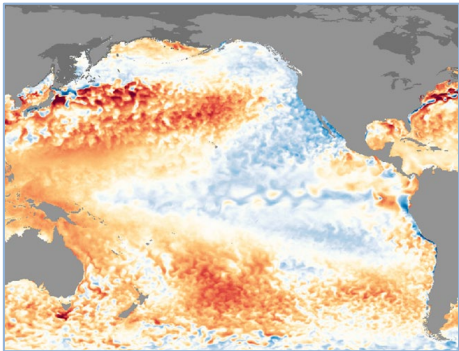


Physically, 2021 was a tale of three regimes

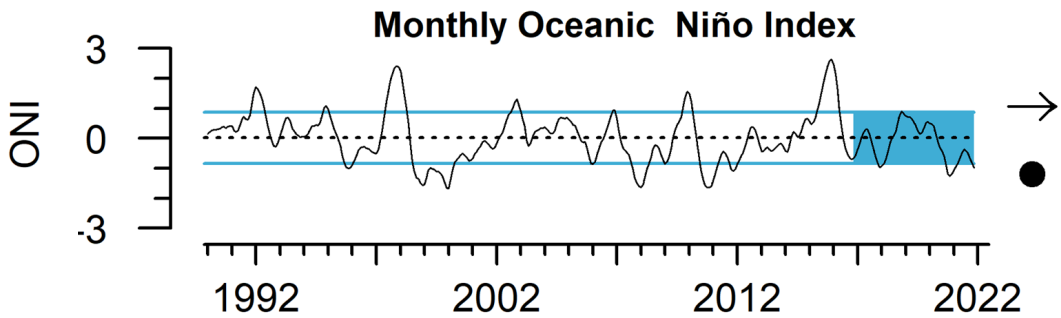
- The open ocean had a “top 10” marine heatwave in both size and duration
- The California Current experienced record upwelling in May that created a large region of cool habitat
- The terrestrial tale was hot, dry and full of fires as drought continued



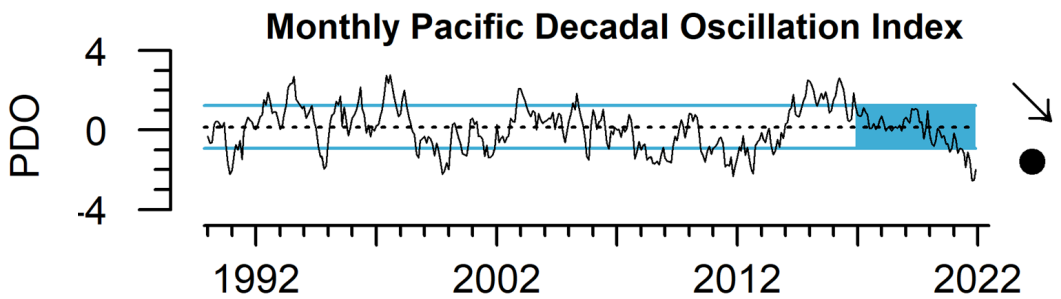
Basin-scale climate indices signaled cool, productive conditions for CCE in 2021



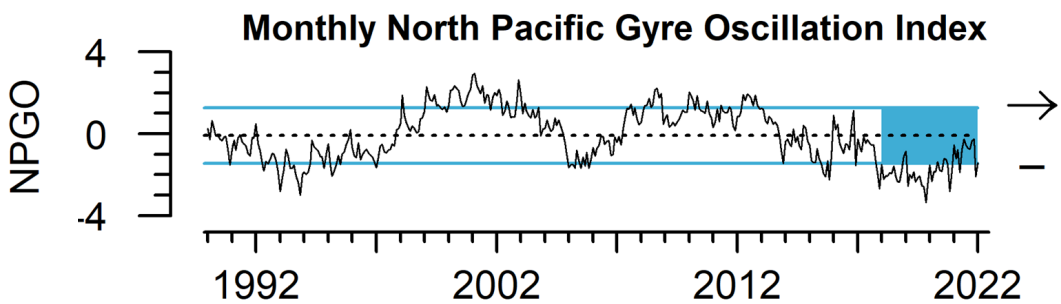
NOAA SST anomalies
March 22-28, 2021



- *Oceanic Niño Index remained in La Niña conditions*
- *This generally favors higher productivity in the CCE*
 - 77% chance of La Niña persisting through spring 2022



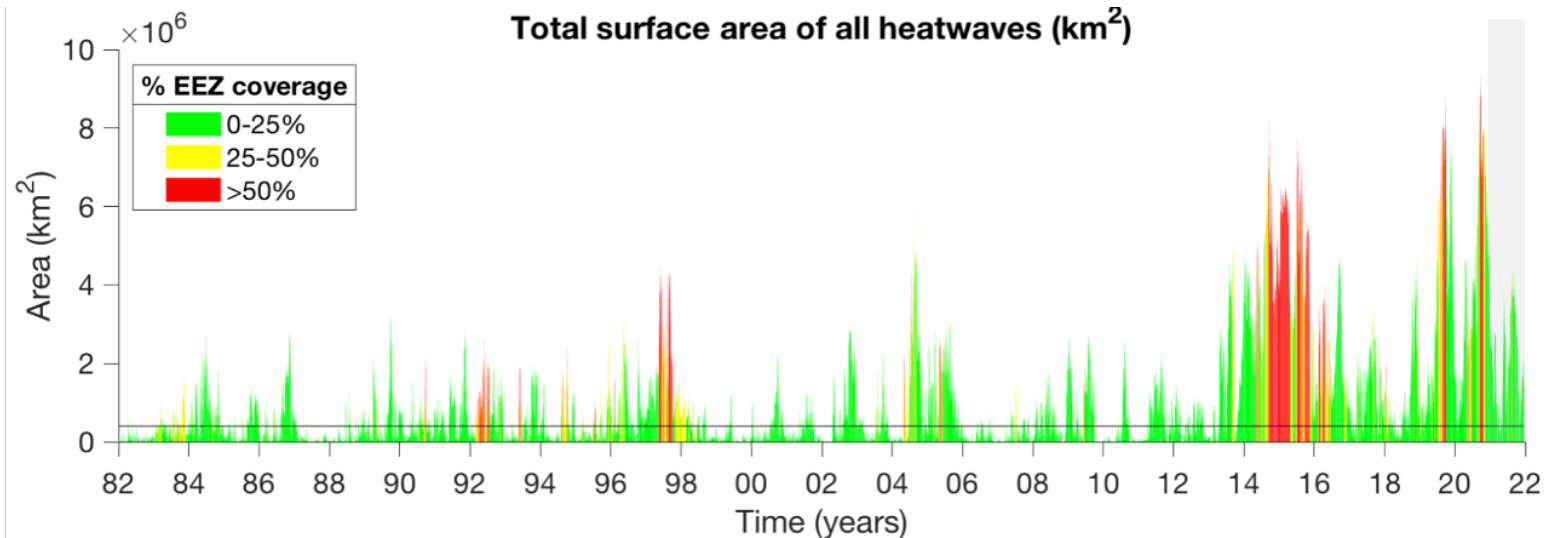
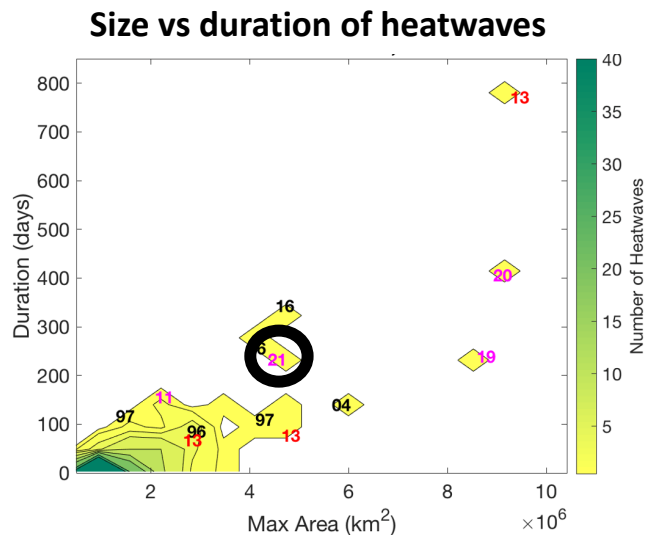
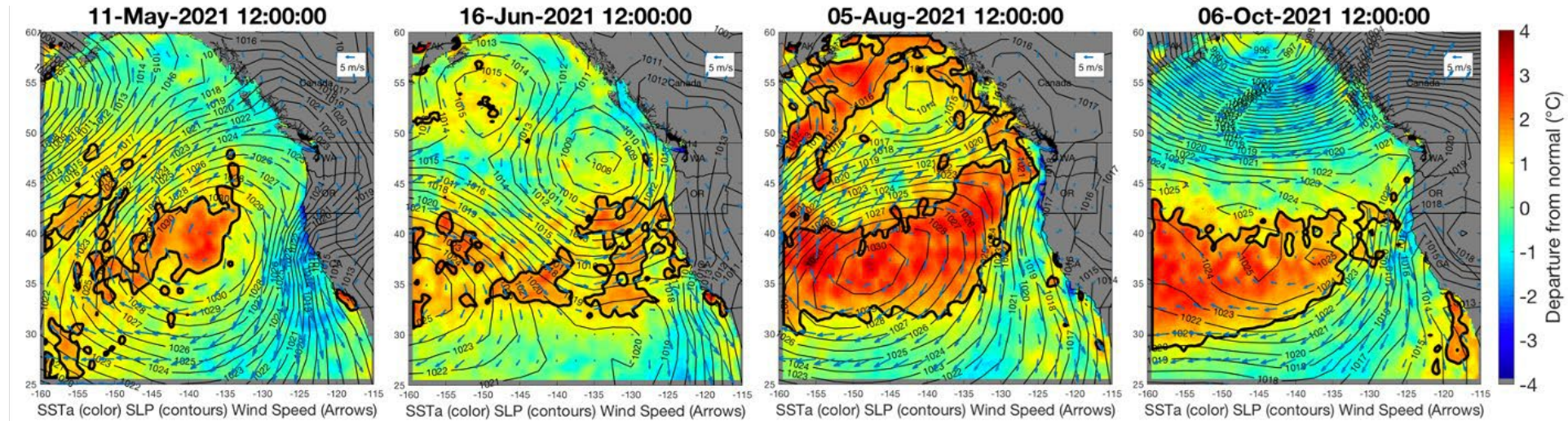
- *Pacific Decadal Oscillation (PDO) became increasingly negative*
- *Indicates cooler SST and favors higher productivity in the CCE*



- *North Pacific Gyre Oscillation (NPGO) returned to more neutral conditions*
 - NPGO indicates circulation conditions
 - Positive NPGO favors higher circulation and productivity in the CCE

Another large marine heatwave, which mostly stayed offshore

- *The 2021 event lasted from May to December, 6th longest*
- *Stayed offshore for most of 2021*
- *Briefly reached parts of coast in June*
- *At its peak, it was the 7th largest MHW on record*

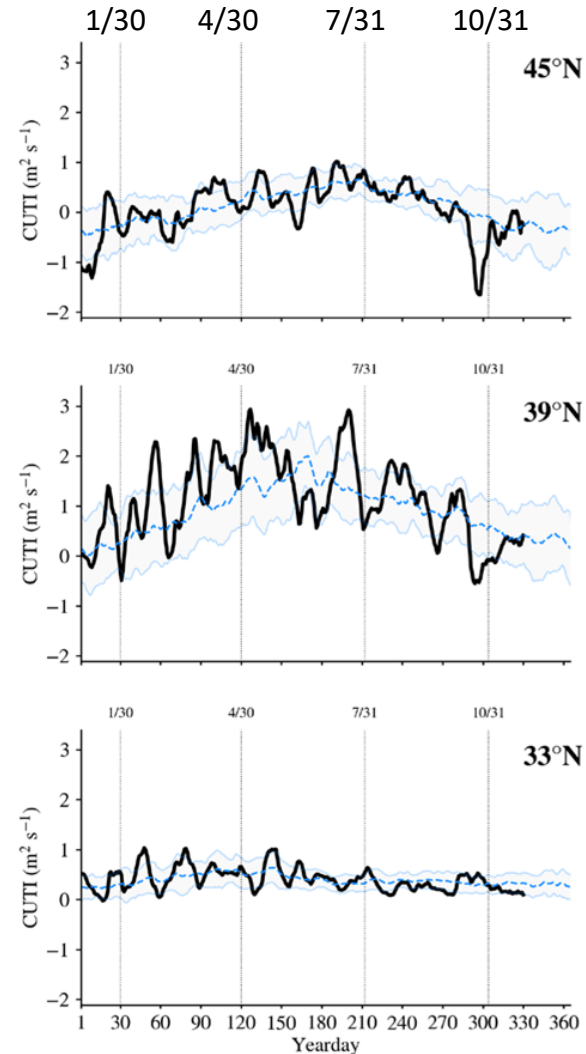




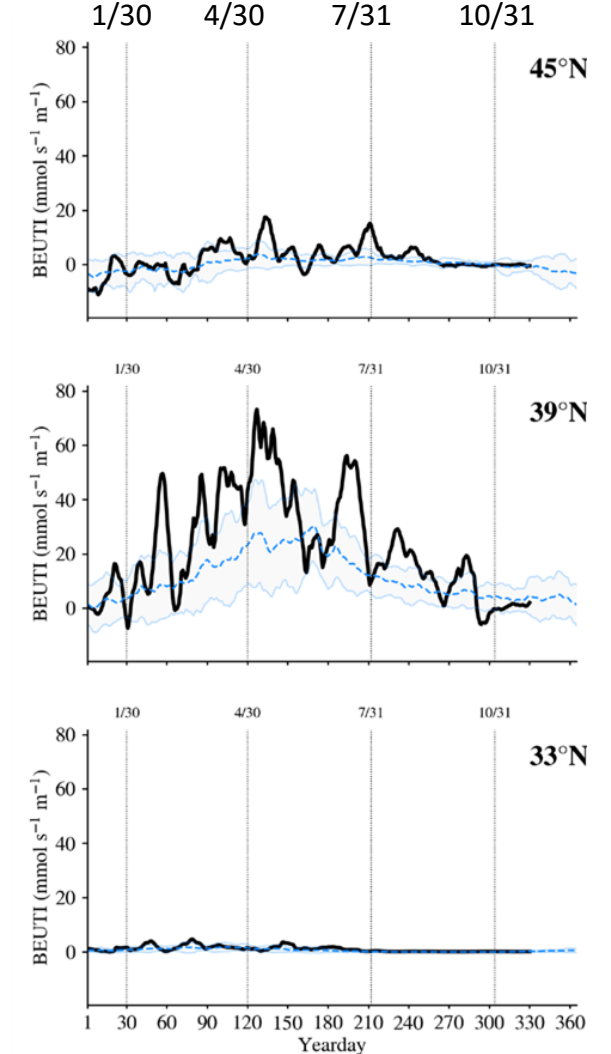
Upwelling in 2021 was strong, which favors productivity

- *Strong winter upwelling “preconditioned” the system*
- *Pronounced sawtooth cycle of upwelling and relaxation events in spring and summer*
- *Upwelling of nitrate in May 2021 was the strongest on record*
- *Upwelling strength and nitrate flux greatest by far in central region (39° N)*

Coastal Upwelling Transport Index (CUTI): water flux



Biologically Effective Upwelling Transport Index (BEUTI): nitrate flux



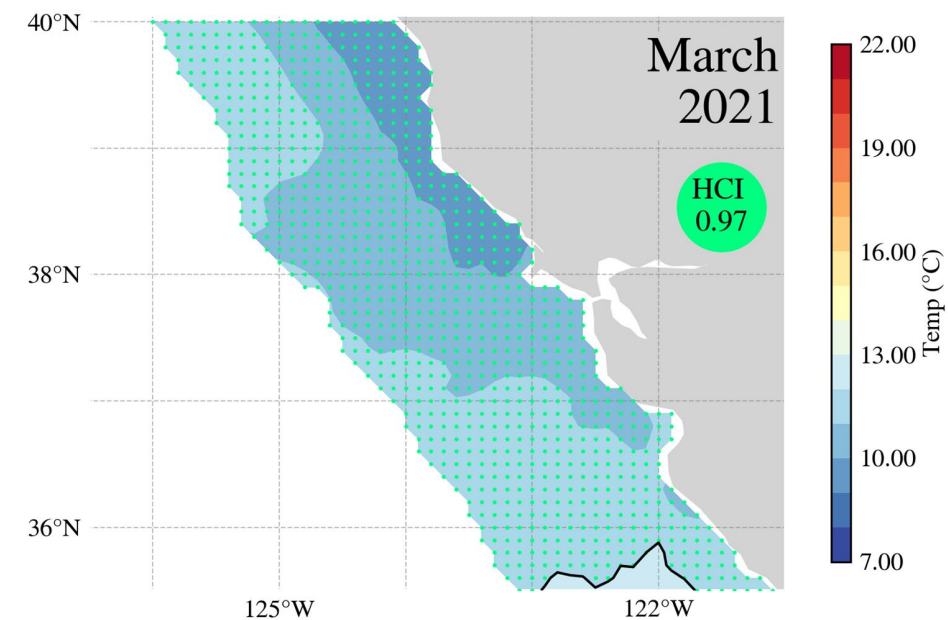
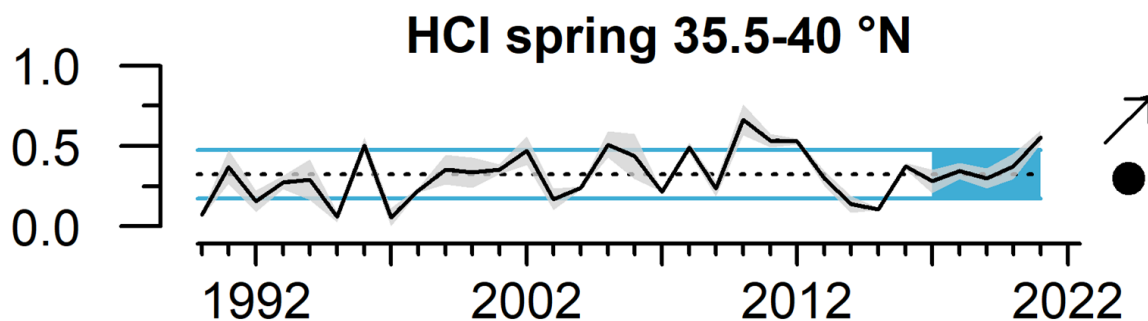
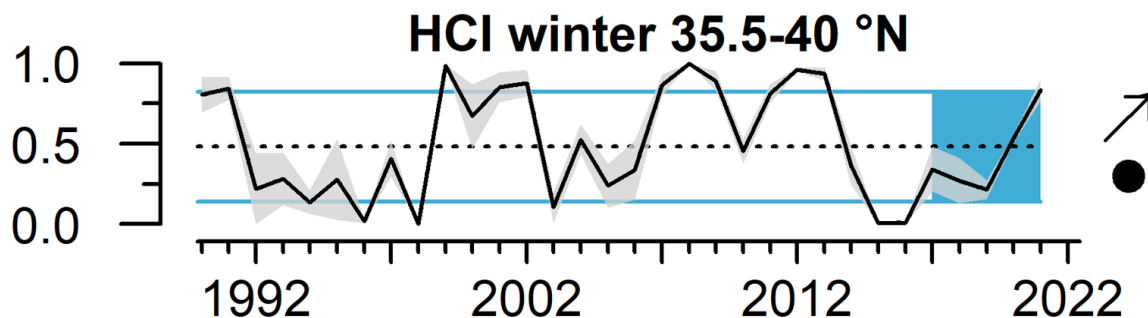


Cool coastal habitat has expanded

The Habitat Compression Index (HCI) is a measure of the balance of cool coastal water and warm oceanic water at the near surface, from the coast out to 150 km

- *HCI has been increasing (cool habitat has expanded) in the peak upwelling region*
- *This follows the low HCI associated with the 2013-2016 MHW*
- *HCI is now calculated for four reaches covering the whole US west coast*

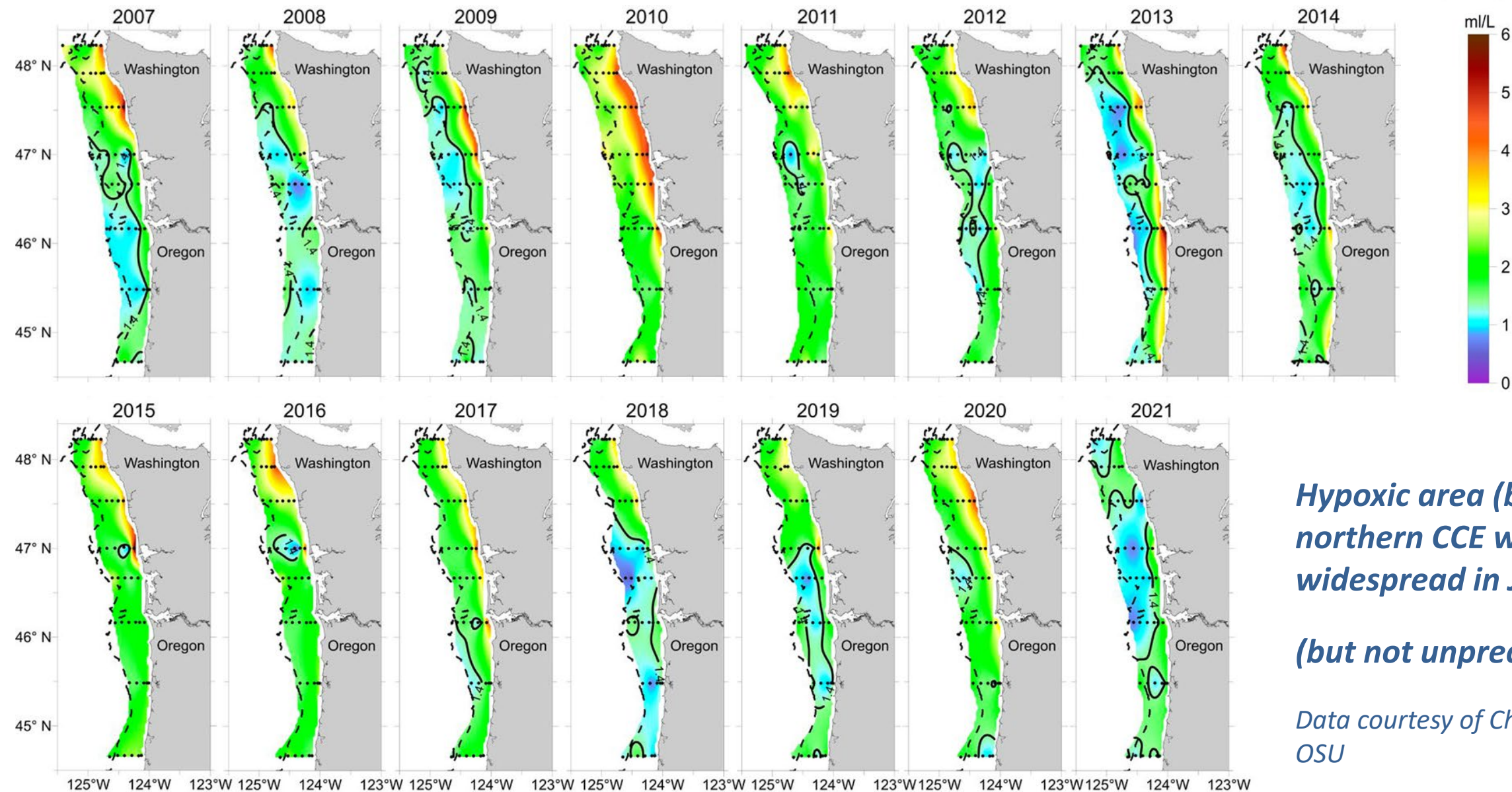
HCI (fraction of coastal area below monthly threshold)



HCI color based on standard deviation (SD) and mean (MN) of all values over 1980-01 to 2021-03

Low Compression (HCI > 1SD)

Dissolved oxygen: low in shelf waters in the north



Hypoxic area (blue) in northern CCE was widespread in June 2021

(but not unprecedented)

Data courtesy of Cheryl Morgan, OSU



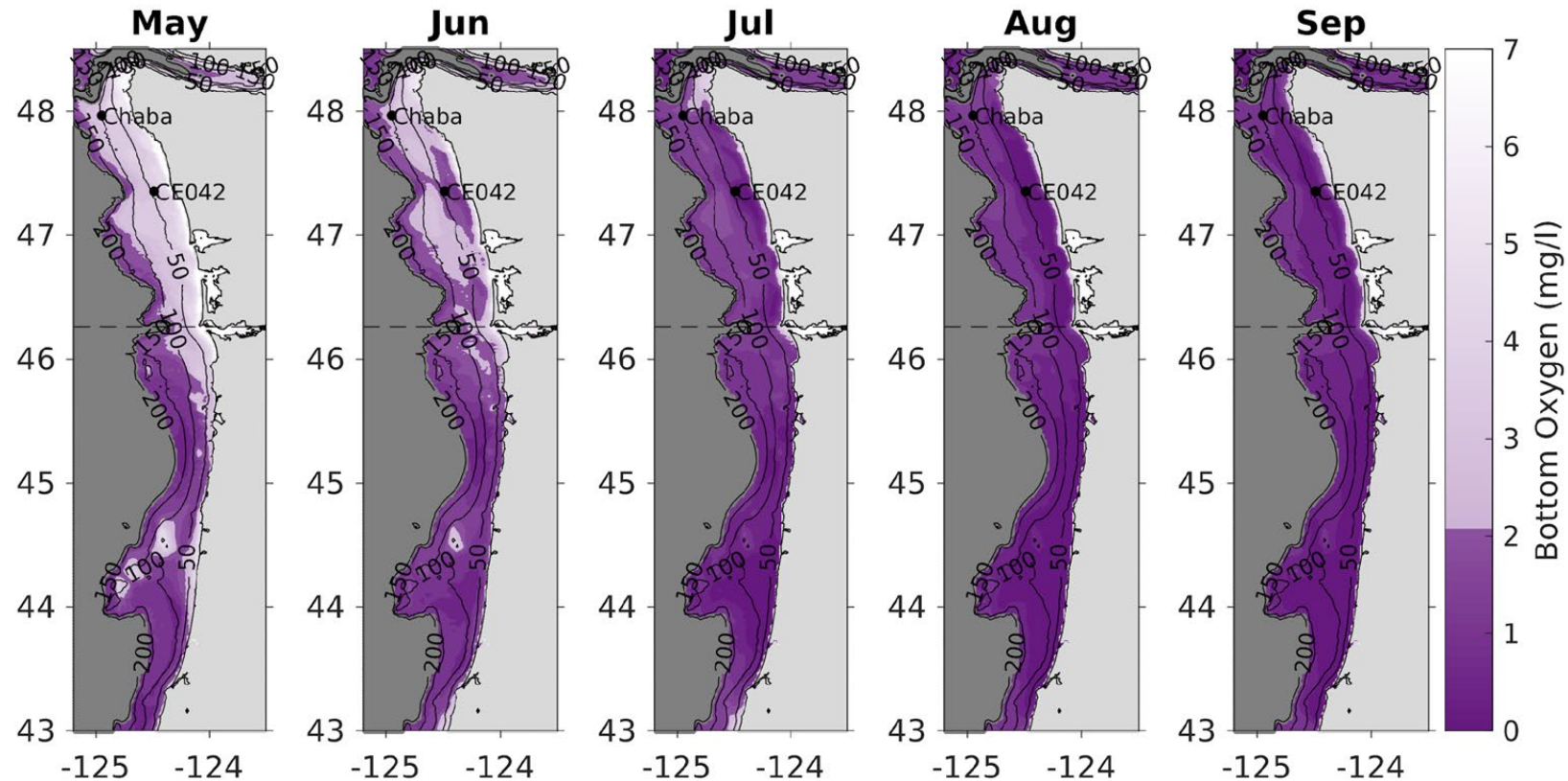
J-SCOPE predicts widespread hypoxia in 2022 off WA, OR

J-SCOPE model generates seasonal forecasts of physical and biological conditions off WA, OR

2022 dissolved oxygen forecast:

- *Below-average DO on WA and OR shelves early in the upwelling season*
 - Closer to average later in summer
- *Hypoxia widespread off Oregon and patches of Washington by June, all of shelf in this region by July*
 - Earlier than average for hypoxia
 - High uncertainty in the forecast ensemble
- *Ocean acidification prediction shows a similar temporal trend as the DO*

Benthic dissolved oxygen forecast, 2022



courtesy Dr. Samantha Siedlecki, University of Connecticut
www.nanoos.org/products/j-scope/forecasts.php

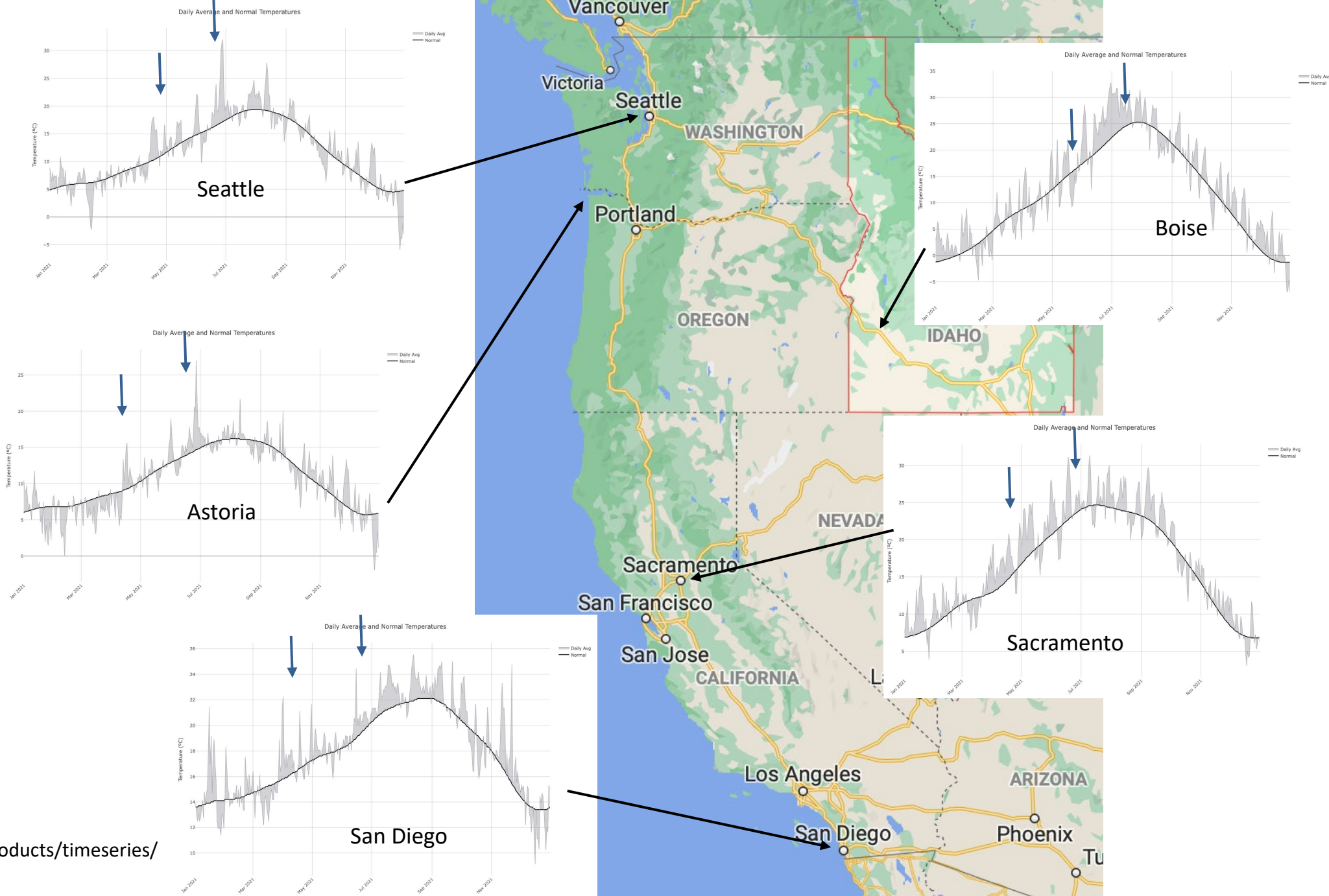
NOTE: see www.oregonocean.info for an OA video

Selected daily air temperatures;
it was hot! (5°C bars)

The black line is the
smoothed average
temperature and
the shading is
showing daily
positive (warm) and
negative (cool)
deviation from the
mean.

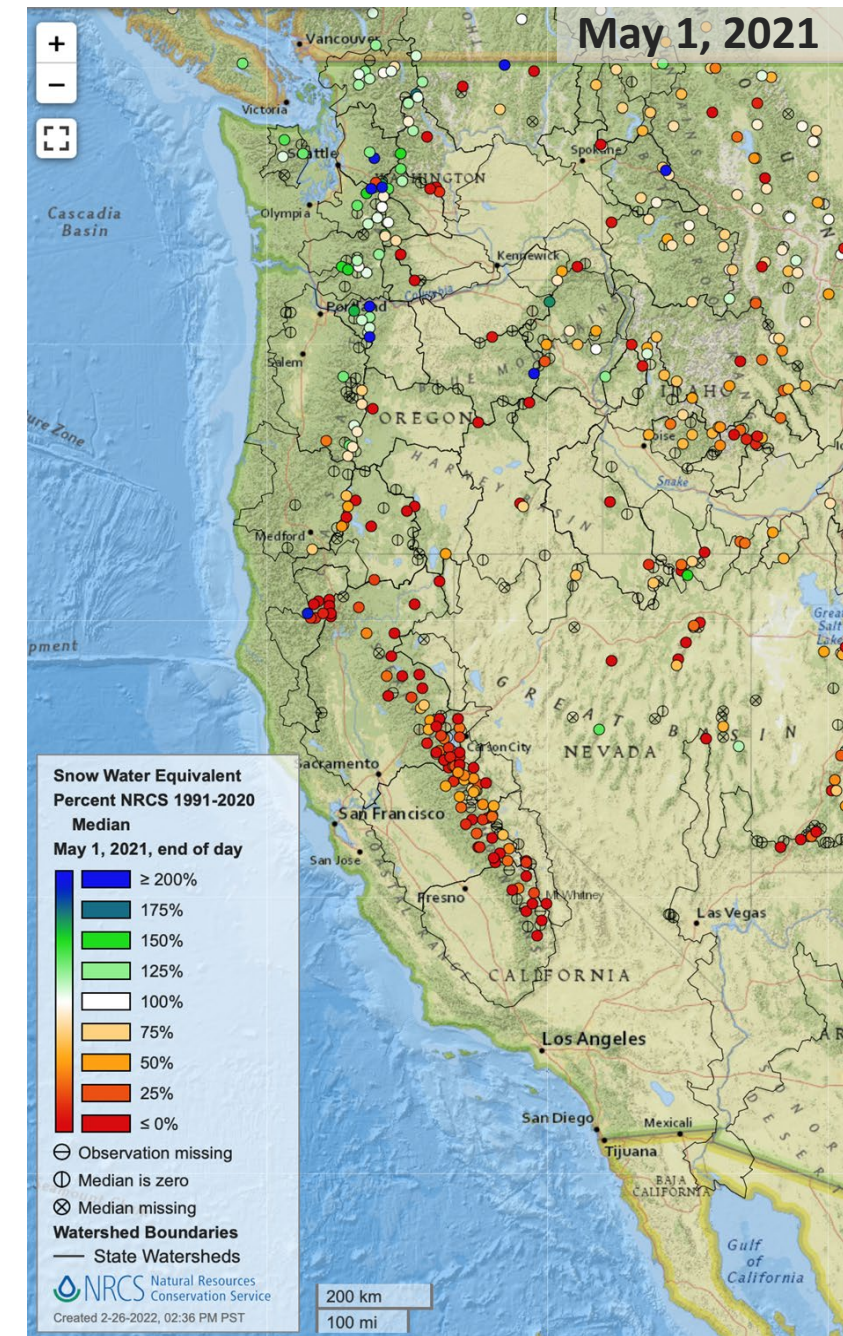
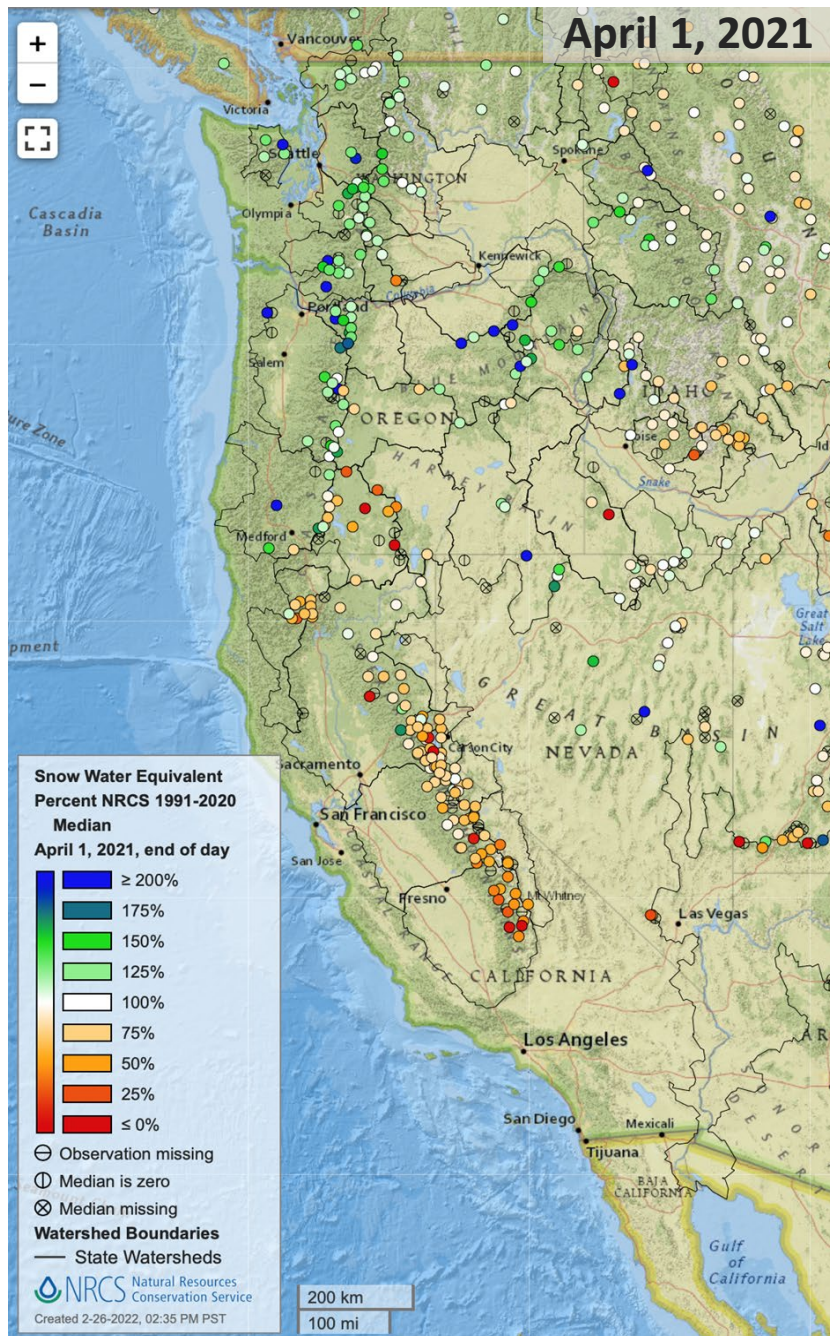
vertical arrows
are aimed at
April and June

<https://www.cpc.ncep.noaa.gov/products/timeseries/>



Snow Water Equivalent in 2021: 1 April and 1 May

- The very warm April conditions caused record rates of snow melt in the first and third weeks*





2016

Drought and fires

Three views of
Lake Oroville
(Feather River)

April 2021



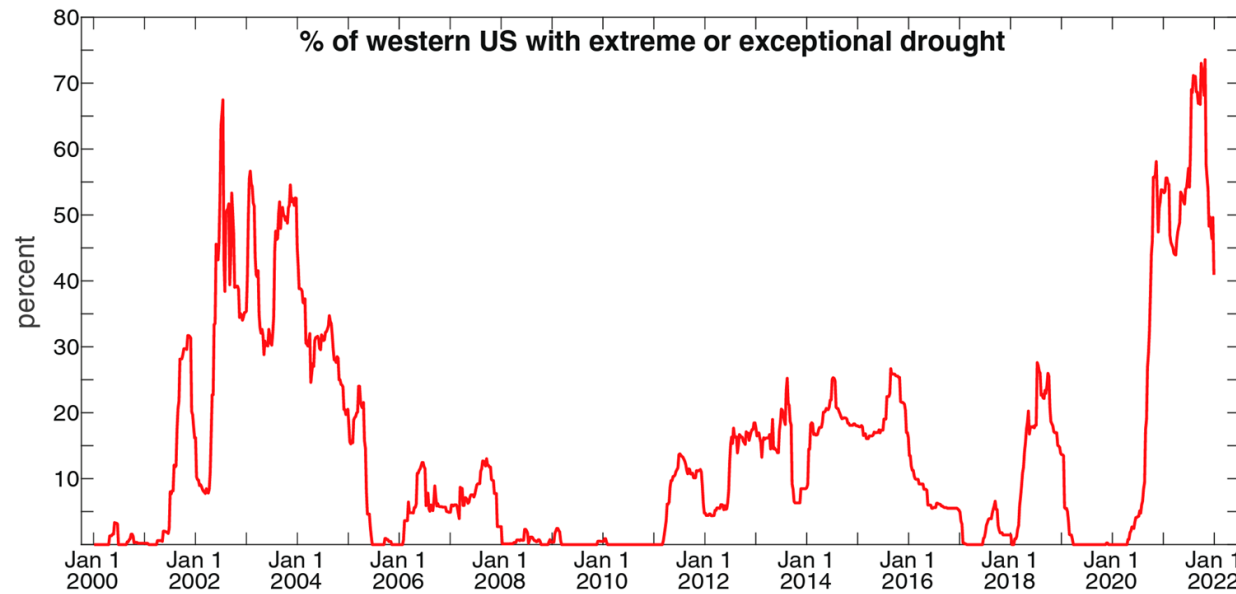
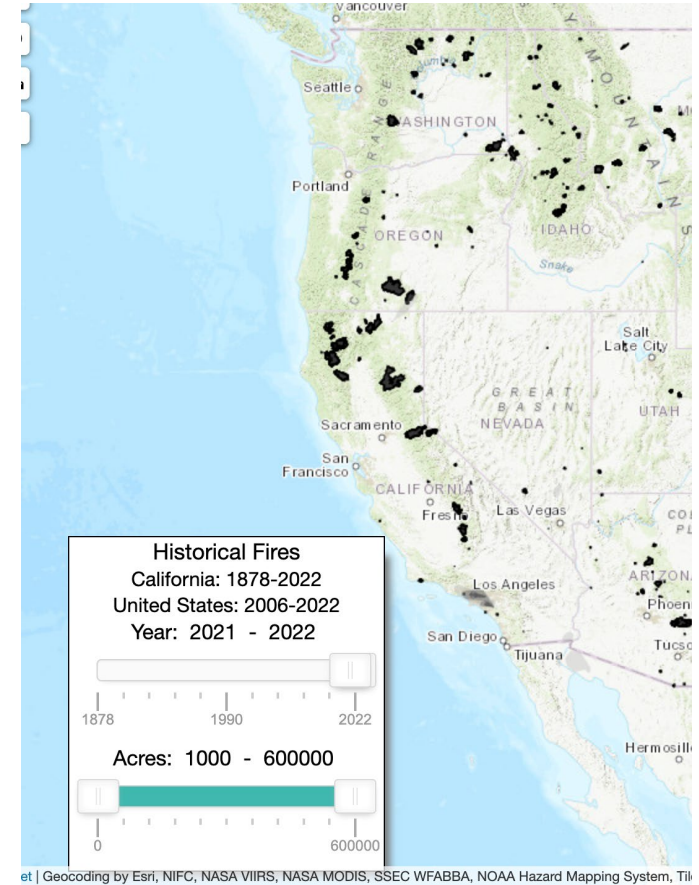
Fall 2021

Remember Feb 2017?



2021 Wildfires

<https://firemap.sdsc.edu/>

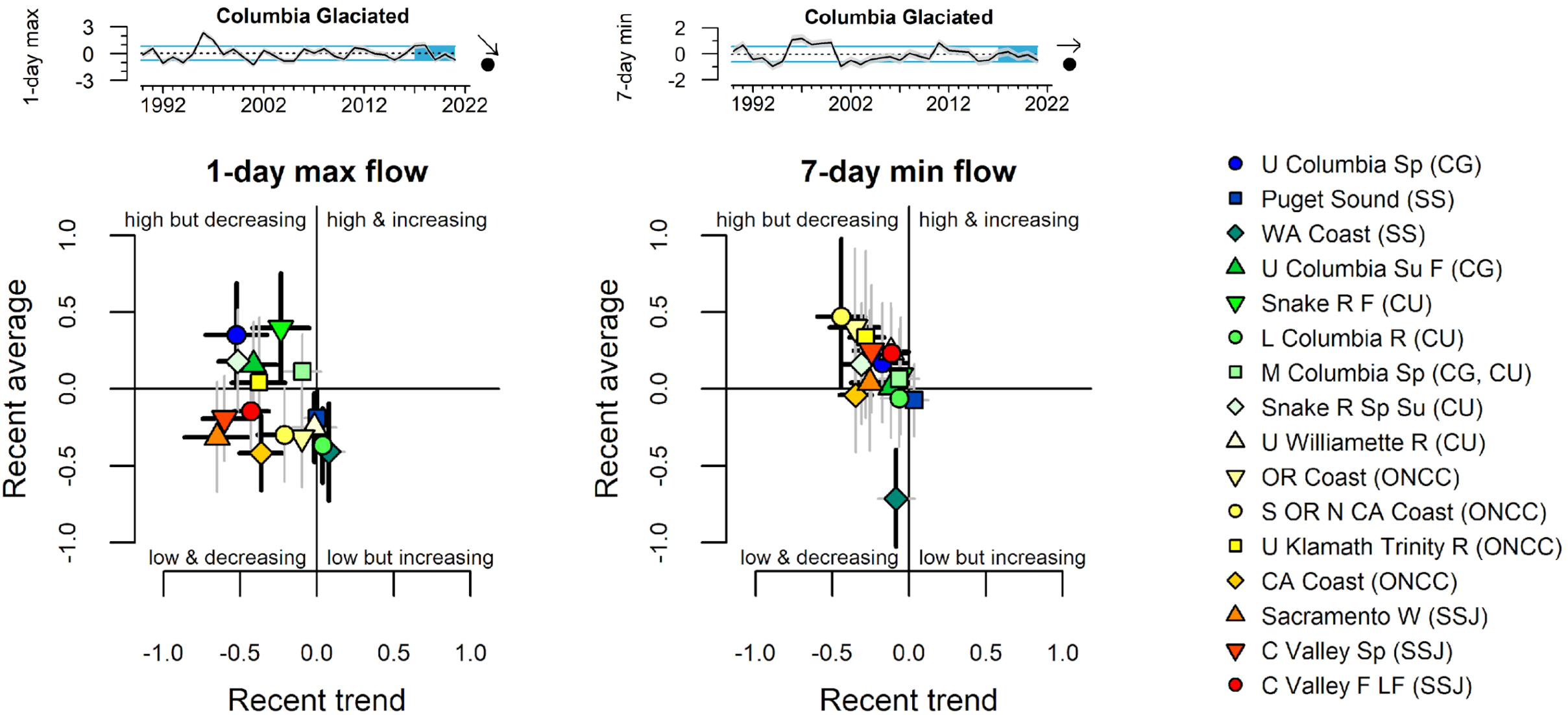


Extended Data Fig. 4 | Extreme and exceptional drought in the western United States (US). Weekly percentage of western continental United States (west of 103°W) classified by the United States Drought Monitor (USDM) as under extreme or exceptional drought from January 1, 2000 to December 28, 2021. Calculations were made from weekly shapefiles of USDM drought classifications, available at <https://droughtmonitor.unl.edu/DmData/GISData.aspx> as of January 9, 2022. The USDM is developed by the National Drought Mitigation Center (NDMC), the U.S. Department of Agriculture (USDA) and the National Oceanic and Atmospheric Administration (NOAA).

Williams, et al, 2022.

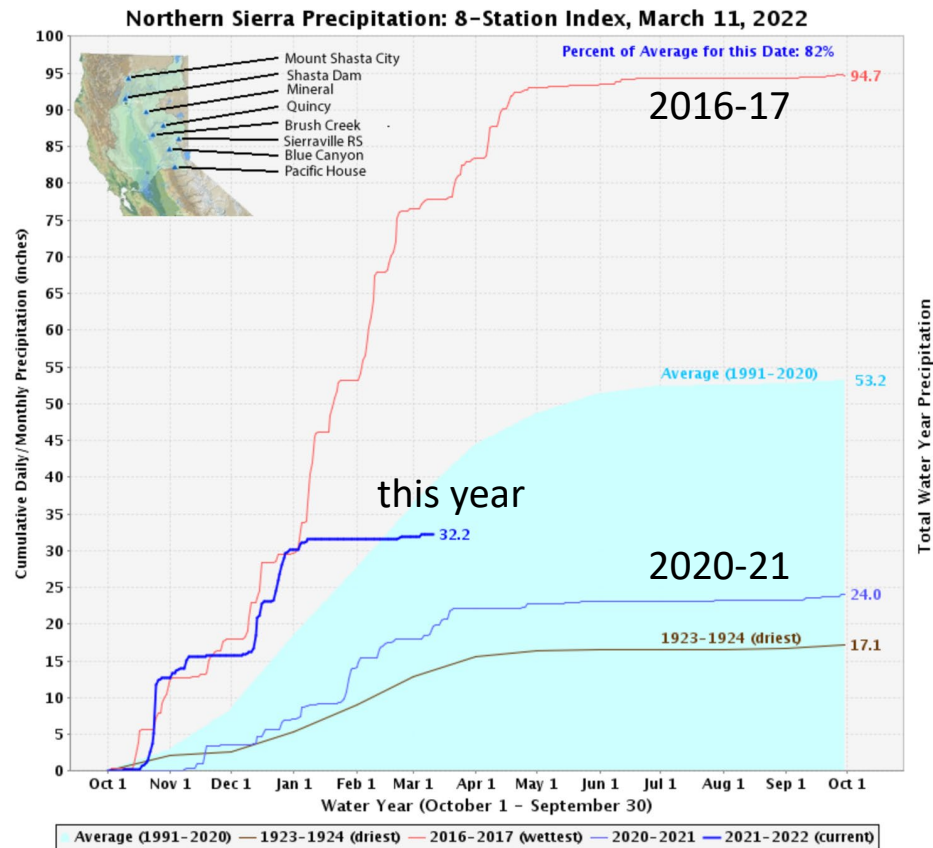
<https://doi.org/10.1038/s41558-022-01290-z>

The five-year trends in maximum and minimum stream flows have declined for many Chinook ESUs

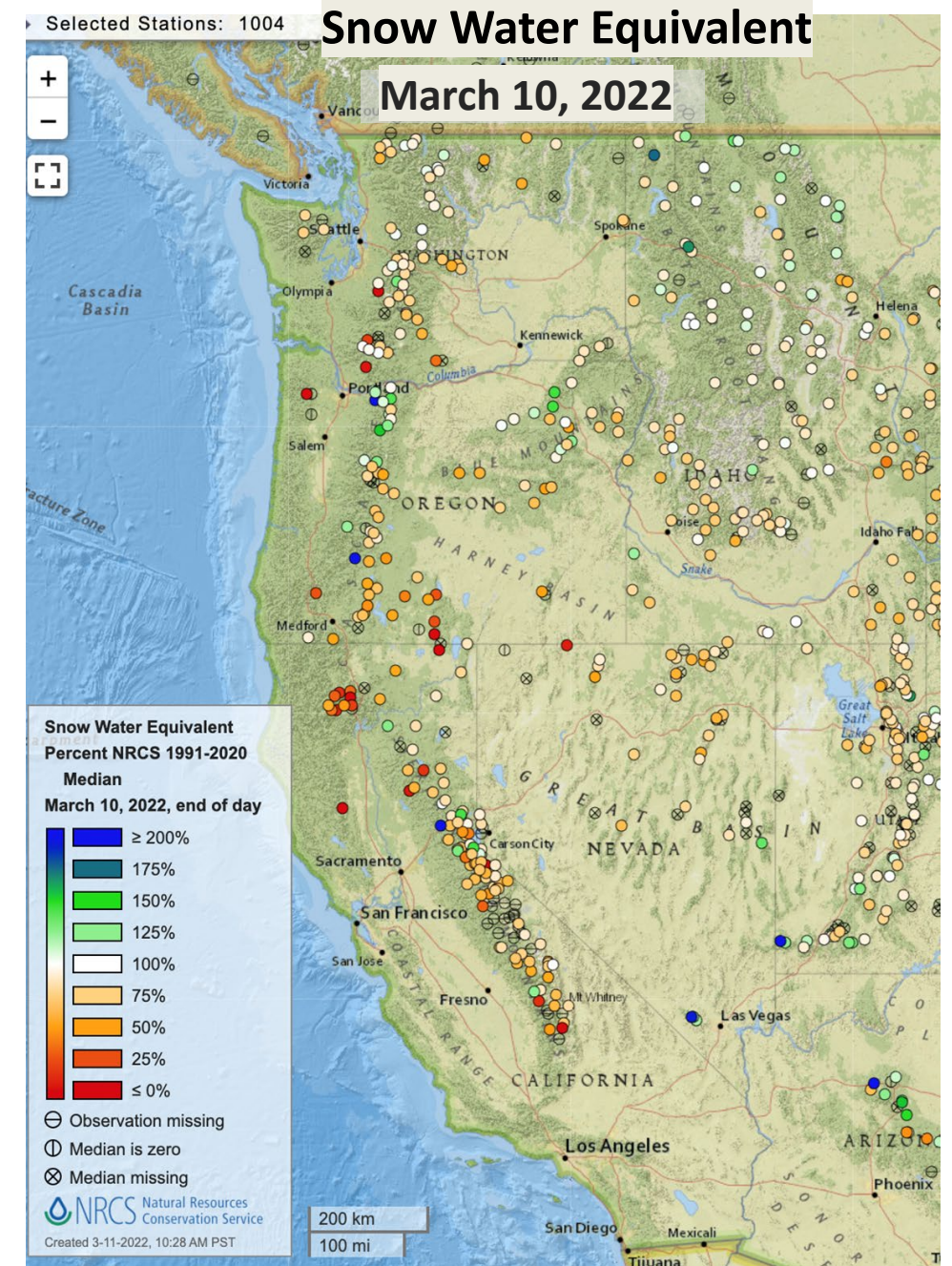


Precipitation as of March 10, 2022

- Two storm periods, October and December
- The October precipitation increased ground moisture
- December precipitation brought SWE to normal
- It's been dry since early January (down to <90%)!
- Official 2022 measure will be made on April 1st

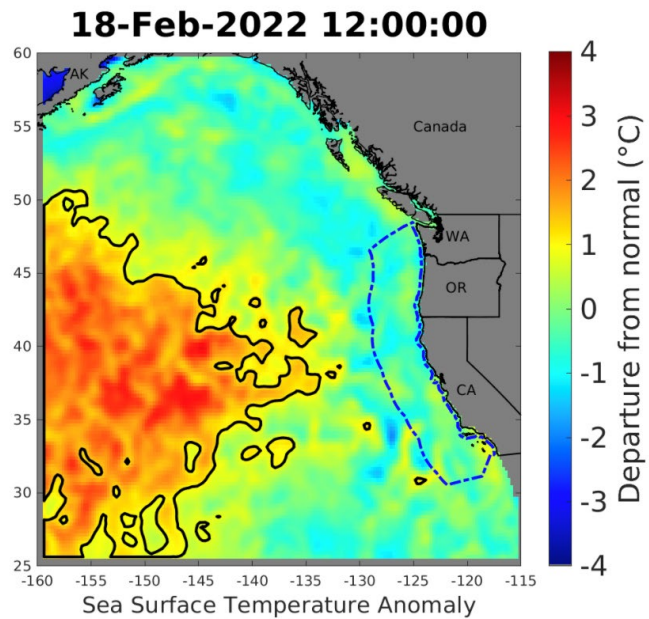


<https://cdec.water.ca.gov/precipapp/get8SIPrecipIndex.action>



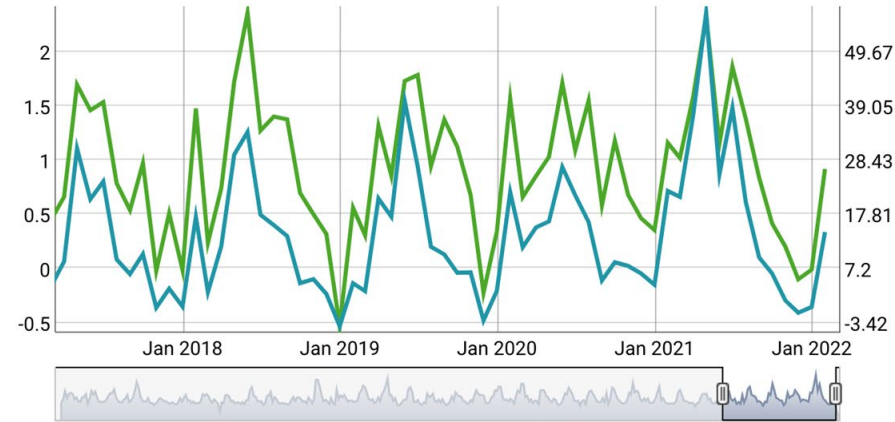
<https://www.nrcs.usda.gov/wps/portal/home/quicklinks>

What “tale” is developing in Spring 2022?



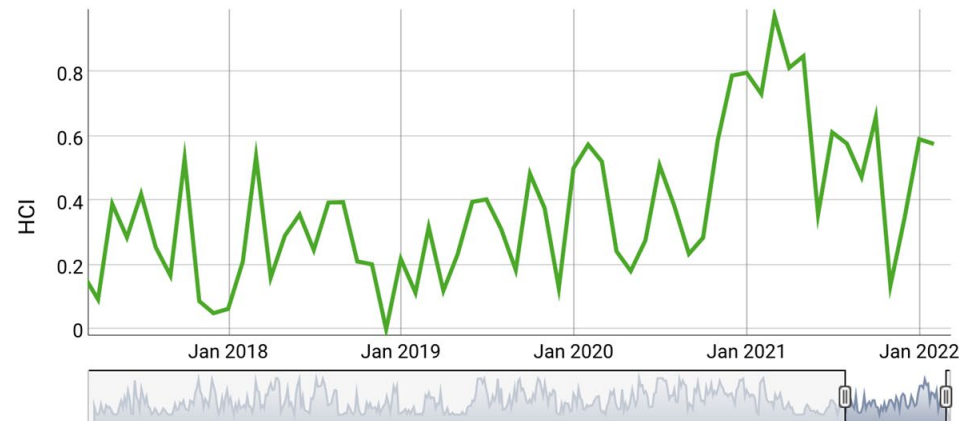
Upwelling Index

- Coastal Upwelling Transport Index (39N) ($\text{m}^2 \text{s}^{-1}$)
- Biologically Effective Upwelling Transport Index (39N) ($\text{mmol s}^{-1} \text{m}^{-1}$)

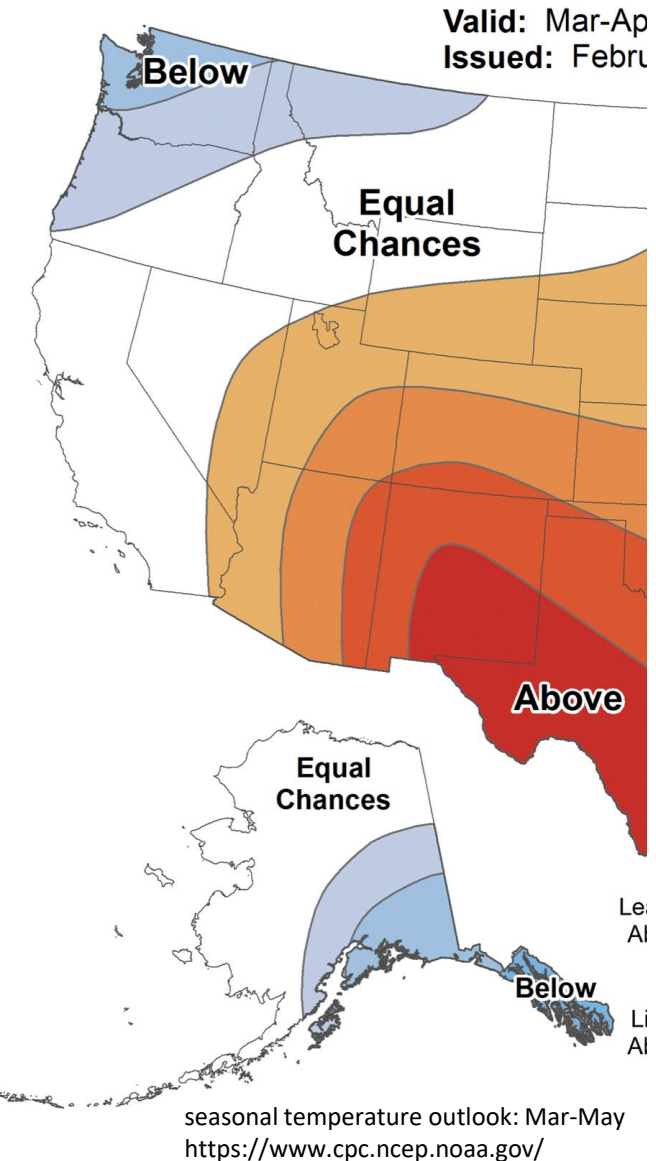


Habitat Compression

- Habitat Compression Index (fraction below monthly threshold)



March - May temperature outlook



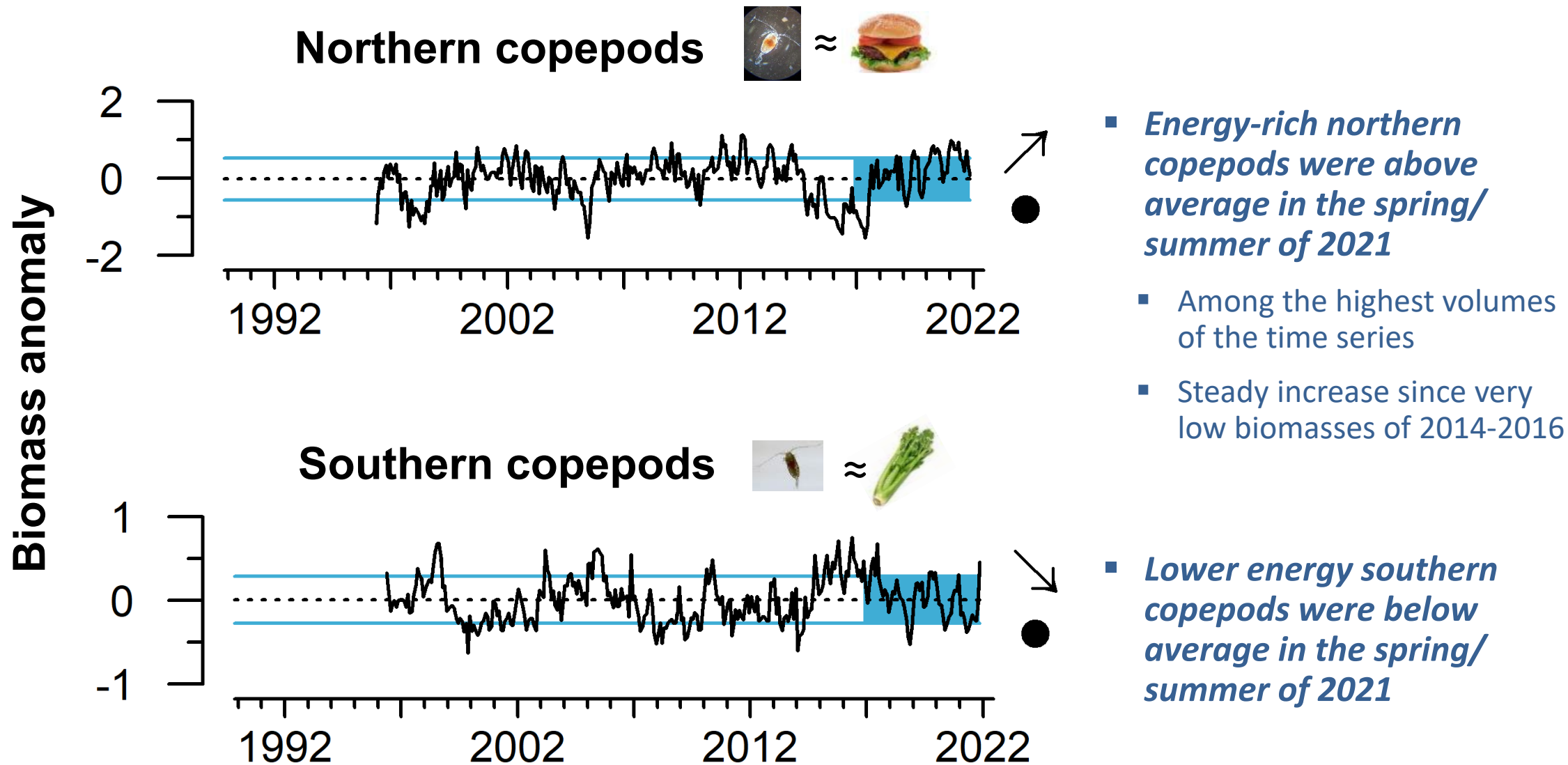


Ecological indicators





Copepods off Newport: 2021 was one of the best years ever



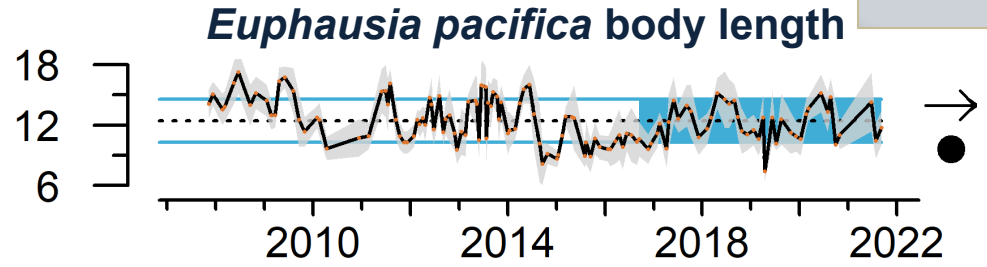


Krill: mixed signals in 2021

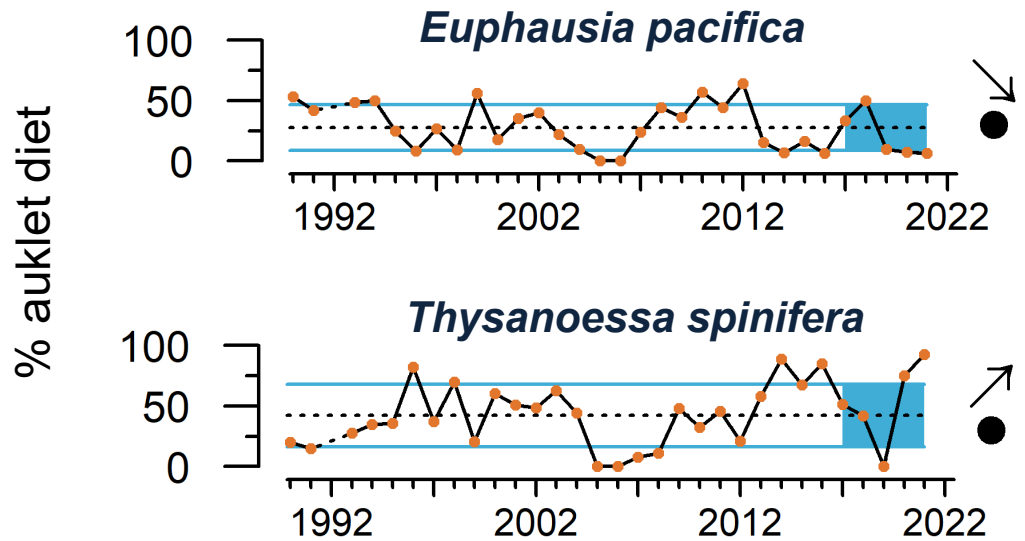
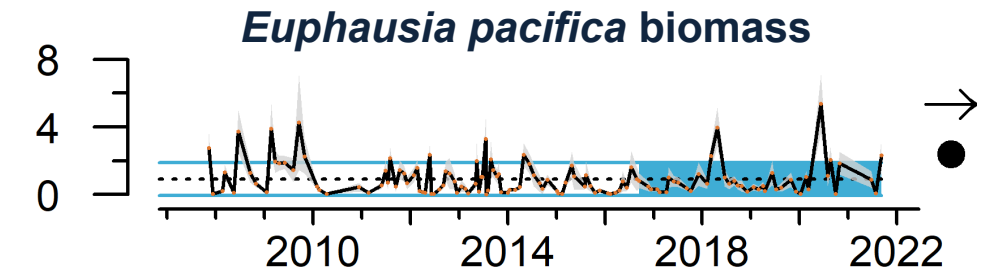
- *Krill length off Trinidad Head was above average in spring and summer*
- *Biomass: average, down from the large catches in 2020*
- Large catches reported from Newport Line
- Below-average catches of krill in Monterey Bay and further south



Length (mm)



g C m⁻²

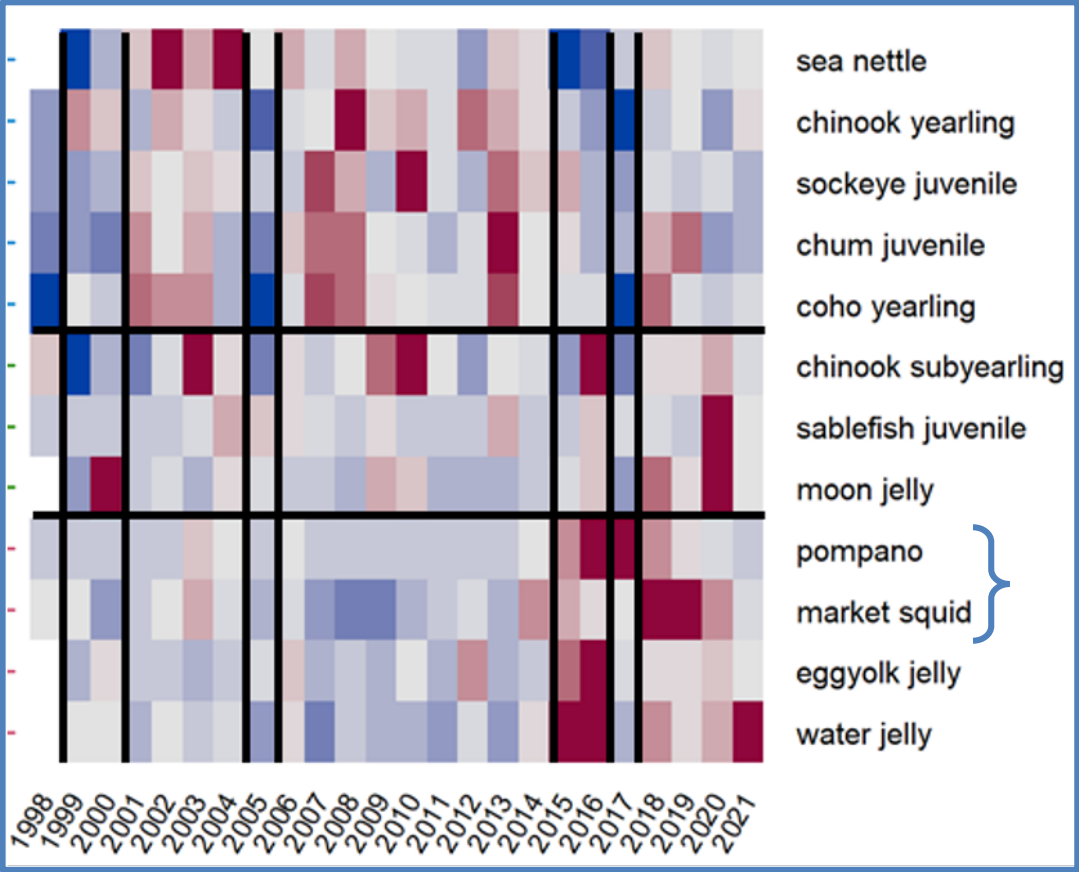
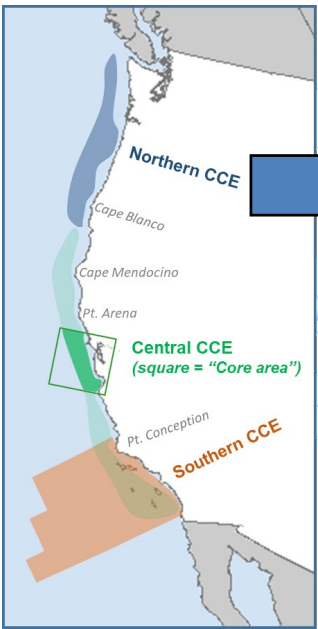


- *Krill increasing in Cassin's auklet diets at SE Farallon Island*
- Krill also increased in albacore diets

Regional pelagic communities

(No serious COVID impacts on regional forage surveys in 2021)

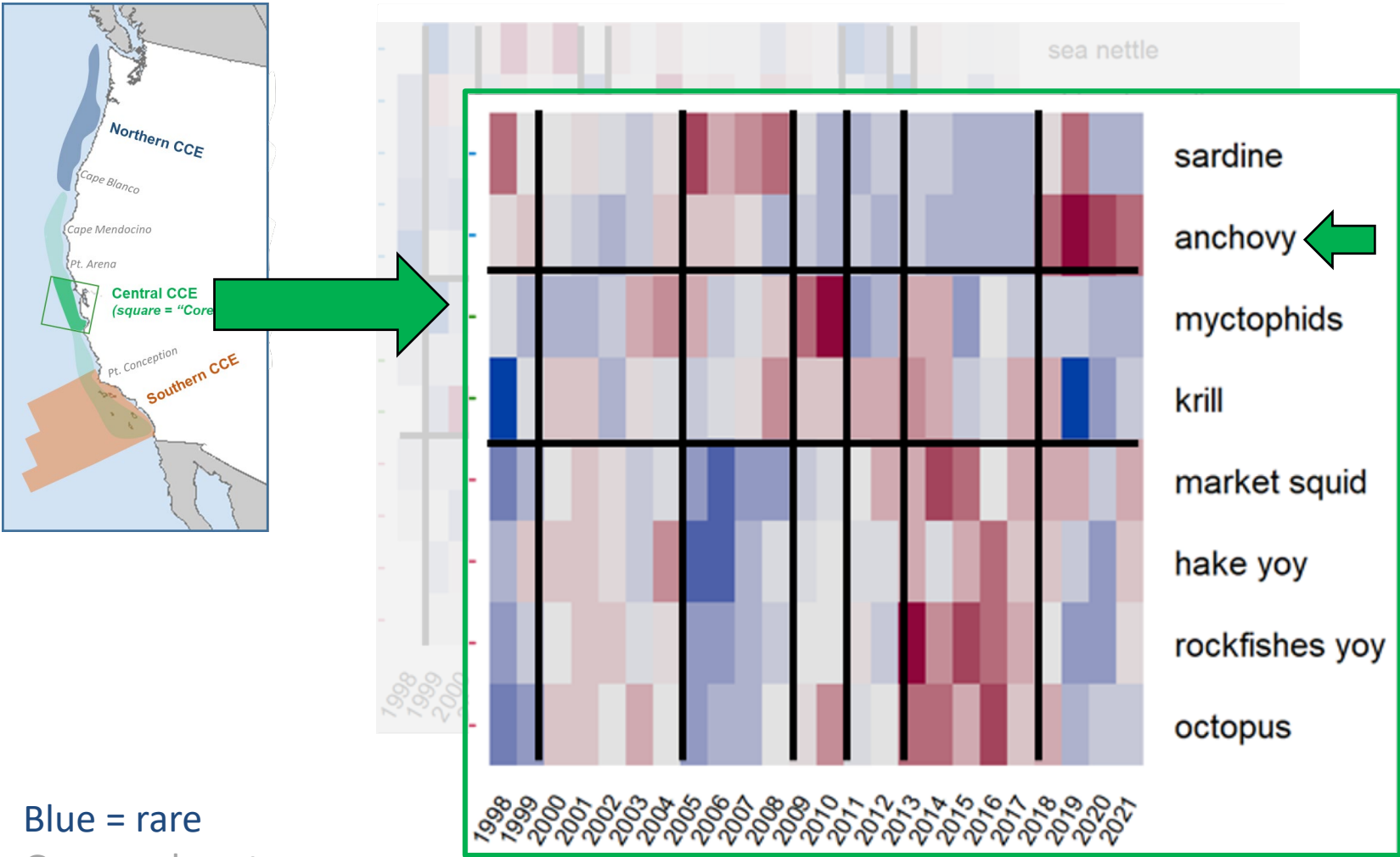
- Northern assemblage clustering has been fairly consistent since 2018
 - Though several “warm” taxa have declined



Blue = rare
Grays = close to average
Red = abundant

Regional pelagic communities

(No serious COVID impacts on regional forage surveys in 2021)

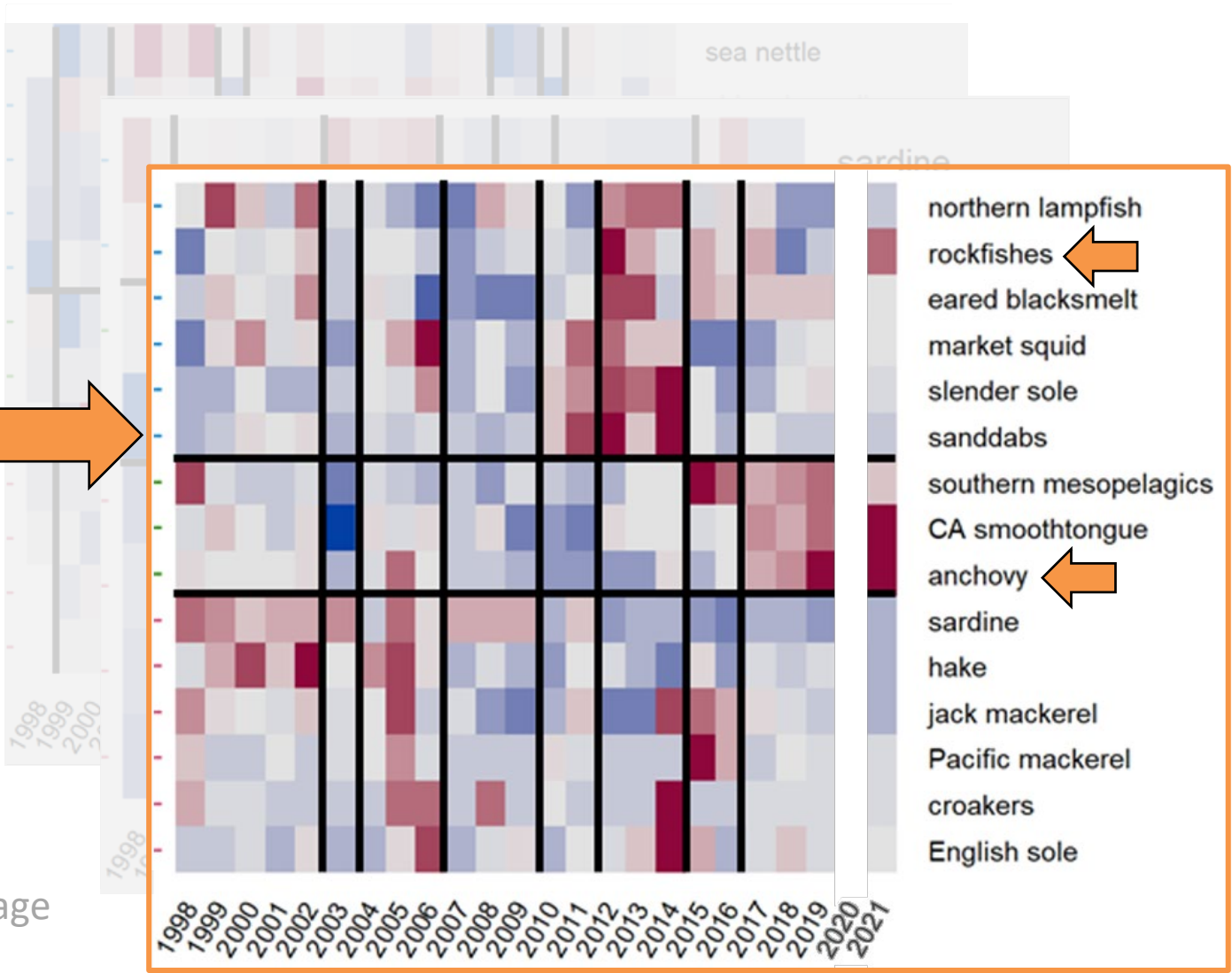
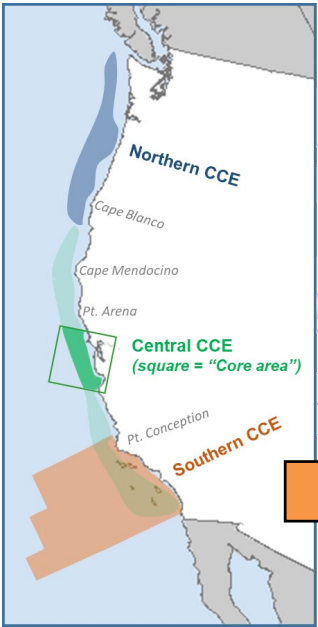


Blue = rare
Grays = close to average
Red = abundant

- *Northern assemblage clustering has been fairly consistent since 2018*
 - Though several “warm” taxa have declined
- *Central assemblage also consistent since 2018, dominated by anchovy*
 - ~Avg YOY groundfishes, market squid in 2021

Regional pelagic communities

(No serious COVID impacts on regional forage surveys in 2021)



Blue = rare
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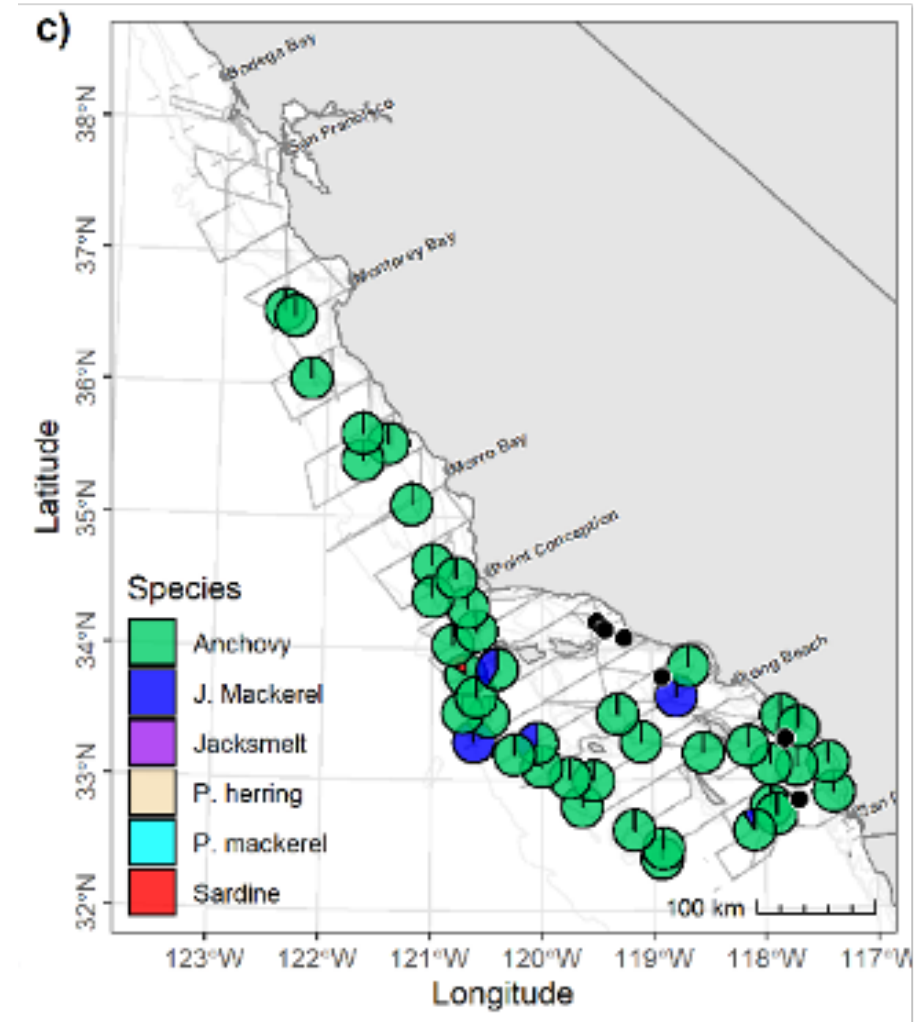
- *Northern assemblage clustering has been fairly consistent since 2018*
 - Though several “warm” taxa have declined
- *Central assemblage also consistent since 2018, dominated by anchovy*
 - ~Avg YOY groundfishes, market squid in 2021
- *Southern larval assemblage consistent since 2017, also dominated by anchovy*
 - Larval rockfish above average in 2021
 - No data in 2020



Abundant anchovy in spring CPS survey, and in HMS diets

- *Spring 2021 cruise from US/Mexico boundary to San Francisco Bay*
- *Anchovy dominated trawl catches and egg counts*
- *Based on acoustic estimates, anchovy biomass has increased 68% since 2019, due in part to strong year classes in 2019 and 2020*
- Anchovy also common in diets of albacore, swordfish and bluefin tuna

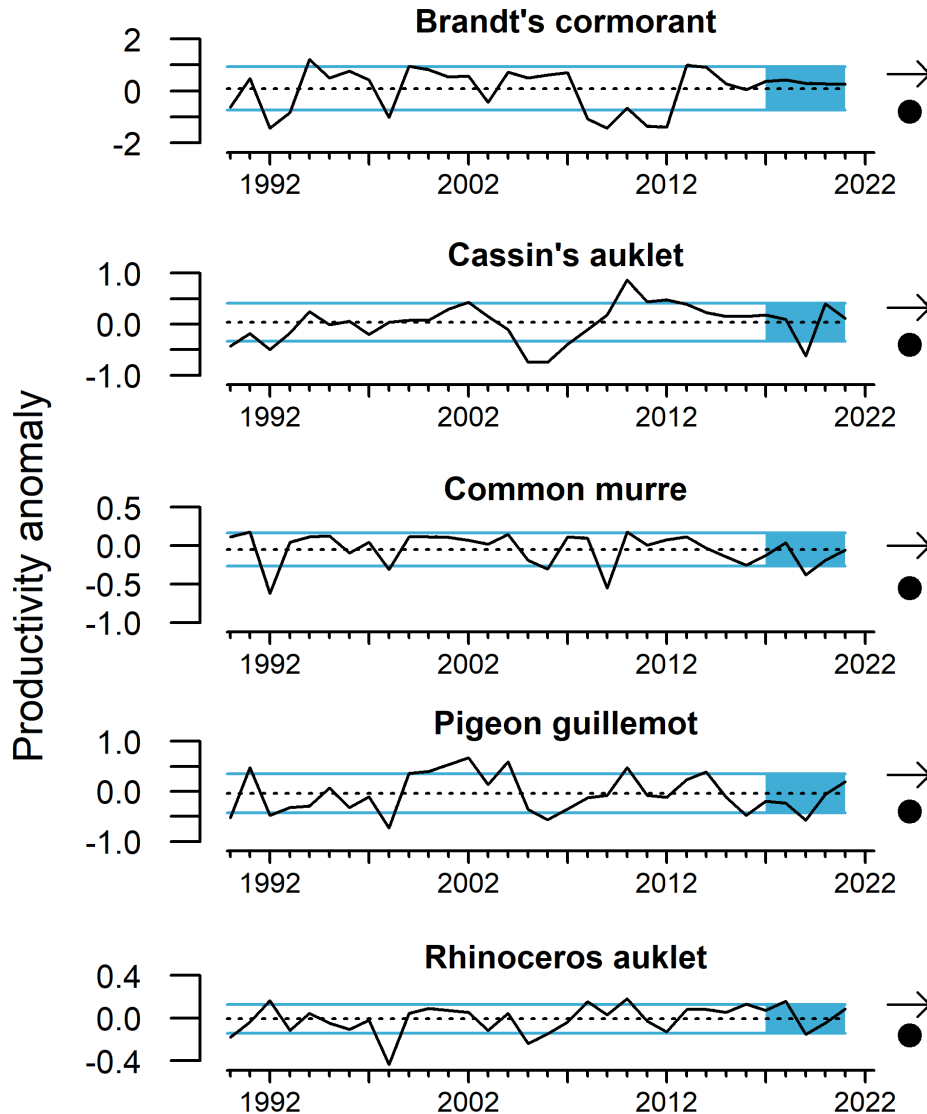
Spring CPS survey trawl catch composition



Seabird productivity was generally good



Fledgling production at SE Farallon Island, CA

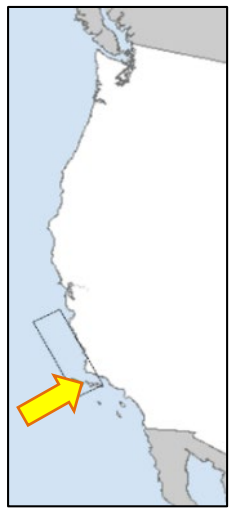


- ***Fledgling production for five key species at SE Farallon Island was average or above average***
 - Implies good delivery of prey to nests
 - Abundant anchovies in piscivore diets (murres, guillemots, rhinoceros auklets)
- ***Fledgling production also average to above-average for common murres and cormorants at Yaquina Head, OR***
- ***No apparent mass mortalities (“wrecks”) on beaches in 2021***

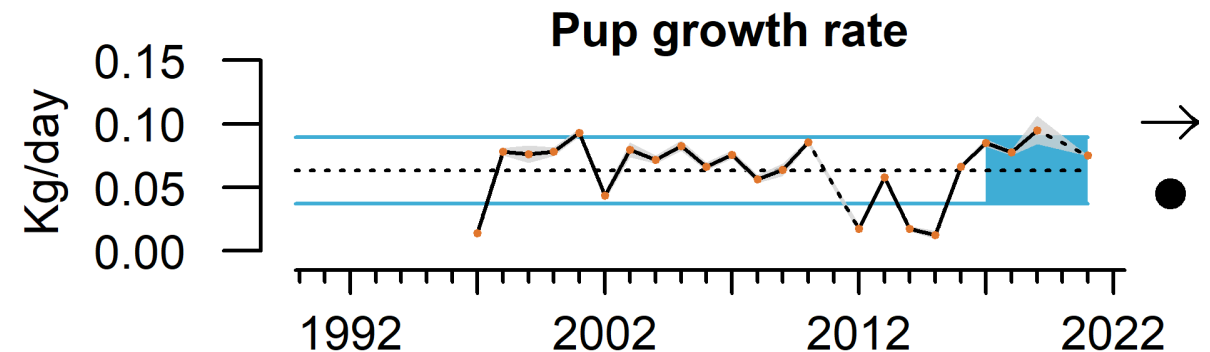
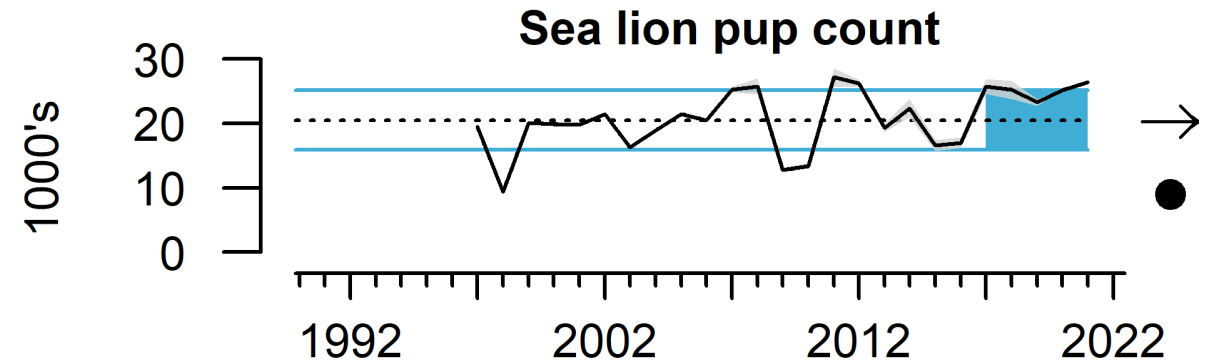
Sea lion pups suggest good feeding conditions off central / southern California

San Miguel Island California sea lion colony (arrow on map)

Maternal feeding grounds in rectangle on map



- **High pup count for the fifth consecutive cohort**
 - Implies good feeding conditions for gestating mothers, October 2020-June 2021
- **Pup growth from September 2021-February 2022 was average to above-average**
 - Implies good overwinter feeding conditions
- Consistent with high abundance of anchovy in this area in recent years



Very good conditions for early marine salmon in 2021

Stoplight table of indicators related to Chinook counts at Bonneville, coho returns to Oregon coast systems



		Smolt year									
ECOSYSTEM INDICATORS		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CLIMATE & ATMOSPHERIC	PDO (SUM; Dec-Mar)	Green	Yellow	Yellow	Red	Red	Red	Yellow	Red	Yellow	Green
	PDO (SUM; May-Sep)	Green	Yellow	Red	Red	Red	Red	Yellow	Red	Yellow	Green
	ONI (AVG; Jan-Jun)	Green	Yellow	Yellow	Red	Red	Yellow	Green	Red	Red	Green
LOCAL PHYSICAL	SST NDBC Buoys (°C; May-Sep)	Yellow	Red	Red	Red	Red	Yellow	Red	Red	Yellow	Green
	Upper 20 m T (°C; Nov-Mar)	Green	Yellow	Green	Red	Red	Red	Yellow	Red	Green	Green
	Upper 20 m T (°C; May-Sep)	Green	Red	Red	Red	Yellow	Yellow	Yellow	Red	Red	Green
	Deep Temp (°C; May-Sep)	Green	Yellow	Red	Red	Yellow	Red	Red	Red	Red	Green
	Deep Salinity (May-Sept)	Yellow	Yellow	Red	Red	Yellow	Yellow	Green	Yellow	Red	Green
LOCAL BIOLOGICAL	Copepod richness	Green	Green	Yellow	Red	Red	Red	Yellow	Yellow	Green	Green
	N copepod biomass	Green	Green	Green	Red	Red	Red	Yellow	Green	Green	Green
	S copepod biomass	Yellow	Green	Yellow	Red	Red	Red	Yellow	Yellow	Yellow	Green
	Biological transition	Yellow	Green	Green	Red	Red	Red	Yellow	Yellow	Green	Yellow
	Nearshore Ichthyoplankton	Green	Yellow	Red	Yellow	Red	Yellow	Yellow	Red	Green	Green
	Nearshore & offshore Ichthyoplankton	Green	Green	Yellow	Red	Red	Red	Red	Red	Red	Yellow
	Chinook salmon juvenile catch	Green	Green	Yellow	Yellow	Red	Red	Yellow	Yellow	Red	Yellow
	Coho salmon juvenile catch	Red	Green	Yellow	Yellow	Yellow	Red	Green	Yellow	Yellow	Yellow

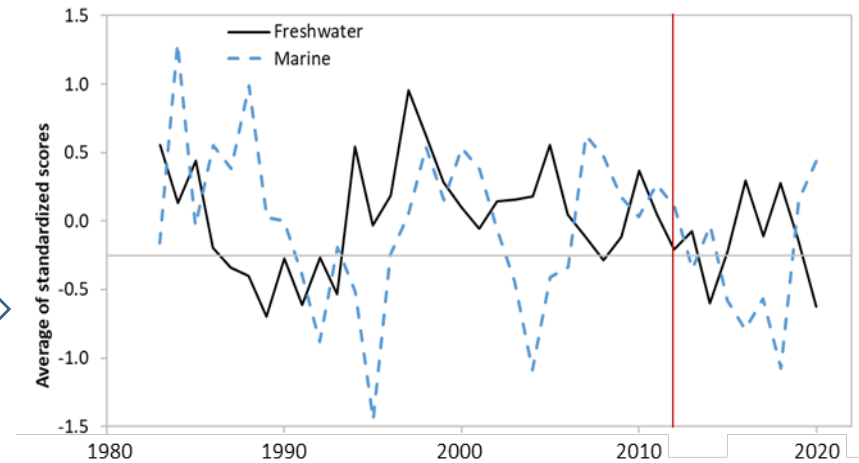
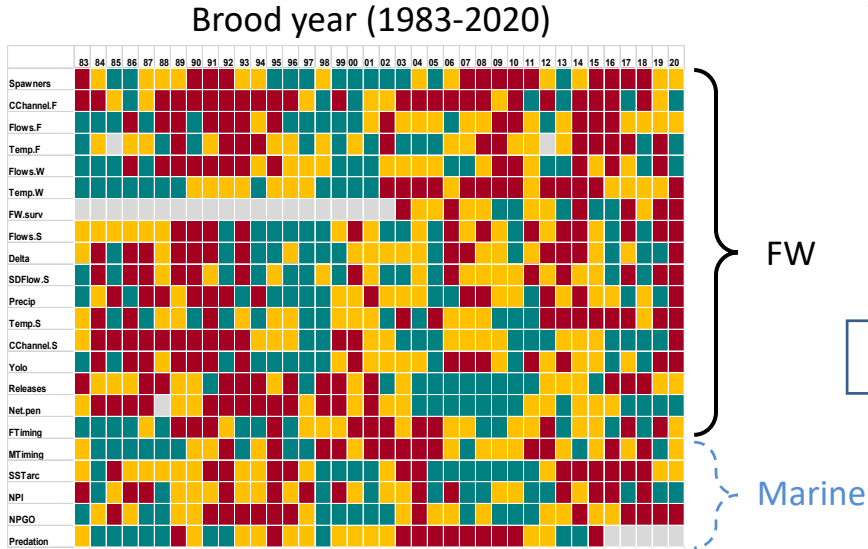
- Indicators of conditions in the northern CCE by smolt year
 - Green: top third of all years (1998-2021)
 - Yellow: middle third
 - Red: bottom third
- 2021 marine conditions among best observed; consistent with good returns of coho in 2022*
- Smolt year 2020 consistent with average returns of Chinook to Columbia Basin in 2022*

Chinook salmon to BVL in 2022  Coho salmon to Oregon in 2022 

Expanded “stoplight” tables for Sacramento and Klamath fall Chinook

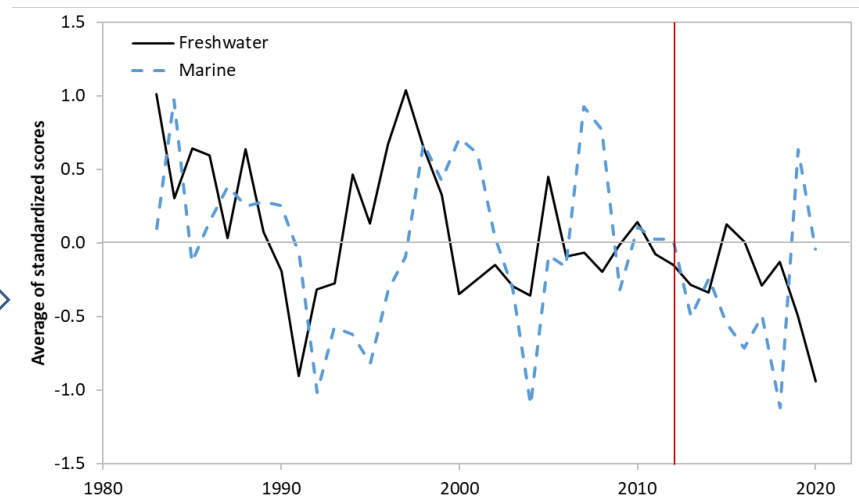
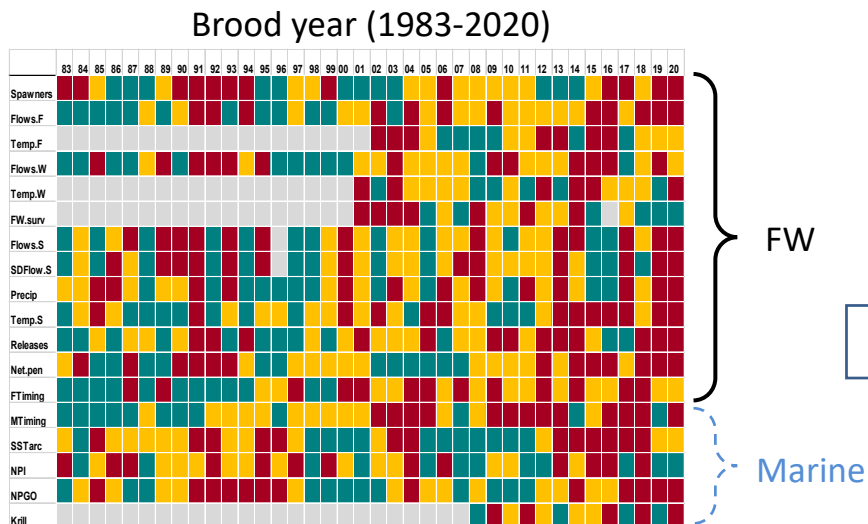
Developed in light of rebuilding plans for these two populations; feature freshwater, marine and hatchery indicators

Sacramento Fall Chinook



- Time series: avg freshwater and marine indicator scores for each cohort (brood year)
- ***Marine indicators: poor for 2018 cohorts, better for 2019 and 2020***

Klamath Fall Chinook



- *Freshwater indicators: poor for 2020 cohorts*
- Thiamine deficiency may be an issue for Sac River fish, due to anchovy consumption



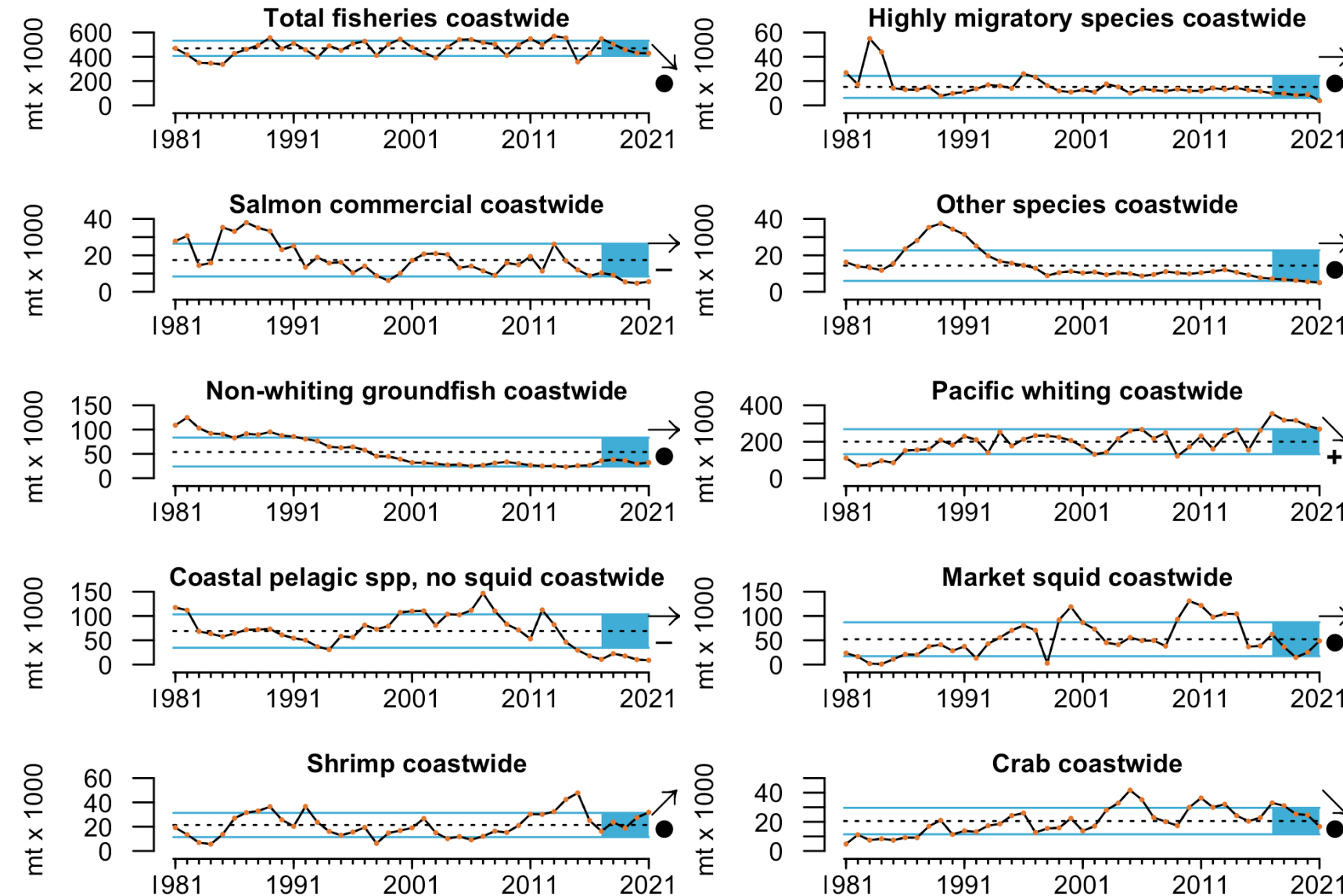
Human activities and wellbeing



John Pohl, NOAA

Fishery landings through 2021*

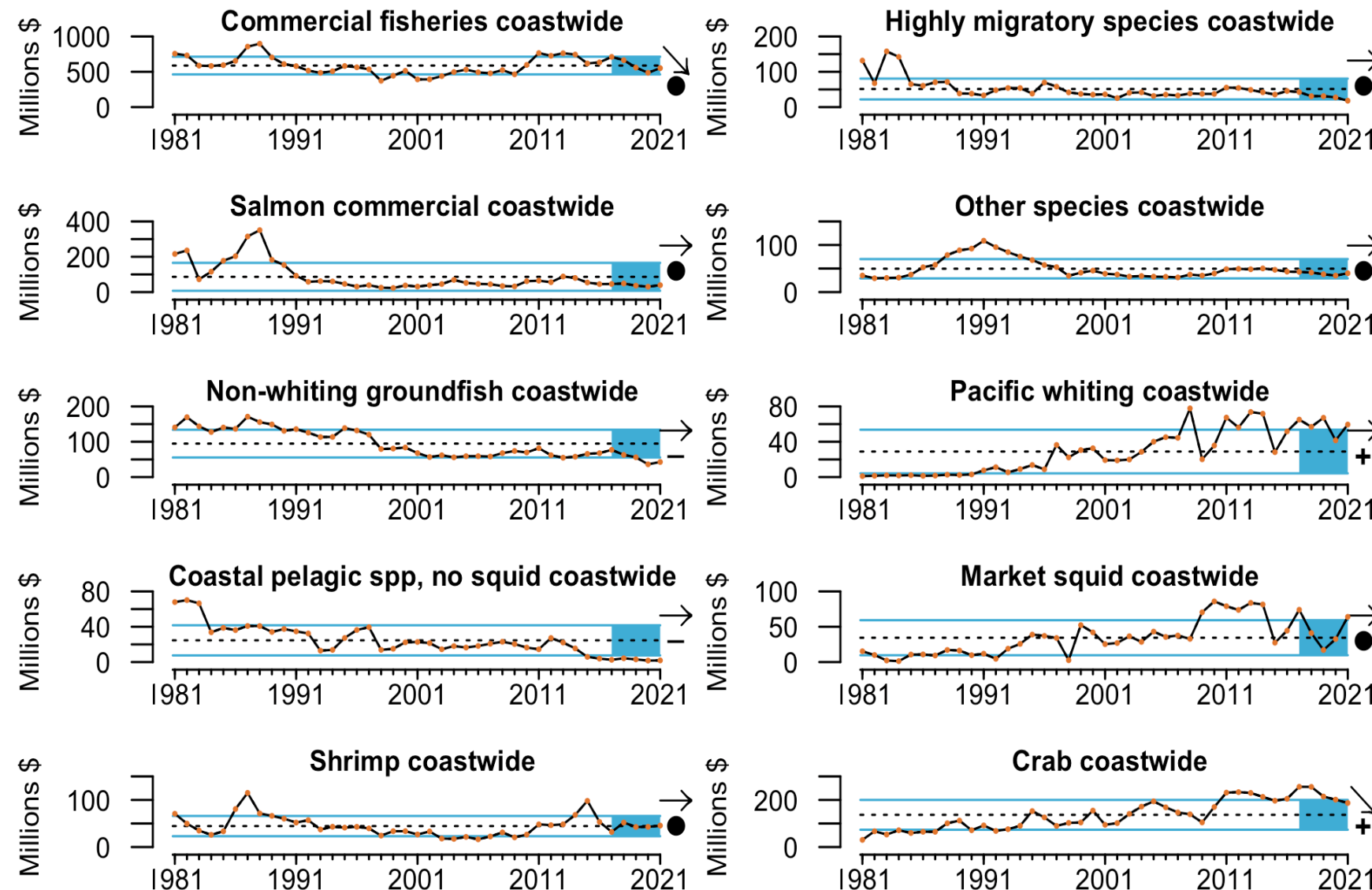
*updated from the values in our Briefing Book report



- ****Total landings down <1% in 2021 compared to 2020***
- ***Declines in some fisheries:***
 - HMS (-57%)
 - *Crab (-32%)
 - CPS (-13%)
 - *Other spp (-10%)
 - Whiting (-6%)
- ***Increases in some:***
 - Squid (+94%)
 - *Salmon (+18%)
 - Shrimp (+16%)
 - Non-whiting groundfish (+9%)
- ***Rec landings below average in 2021 (but, data incomplete)***

Fishery revenue through 2021*

*updated from the values in our Briefing Book report



- ***Total revenue up 13% in 2021 relative to 2020**

- Just below the 30-year average

- ***Revenue up in several fisheries in 2021 over 2020**

- Market squid (+96%)
- Whiting (+43%)
- *Salmon (+29%)
- Non-whiting groundfish (+19%)
- Other species (+15%)
- *CPS (+11%)
- Shrimp (+6%)

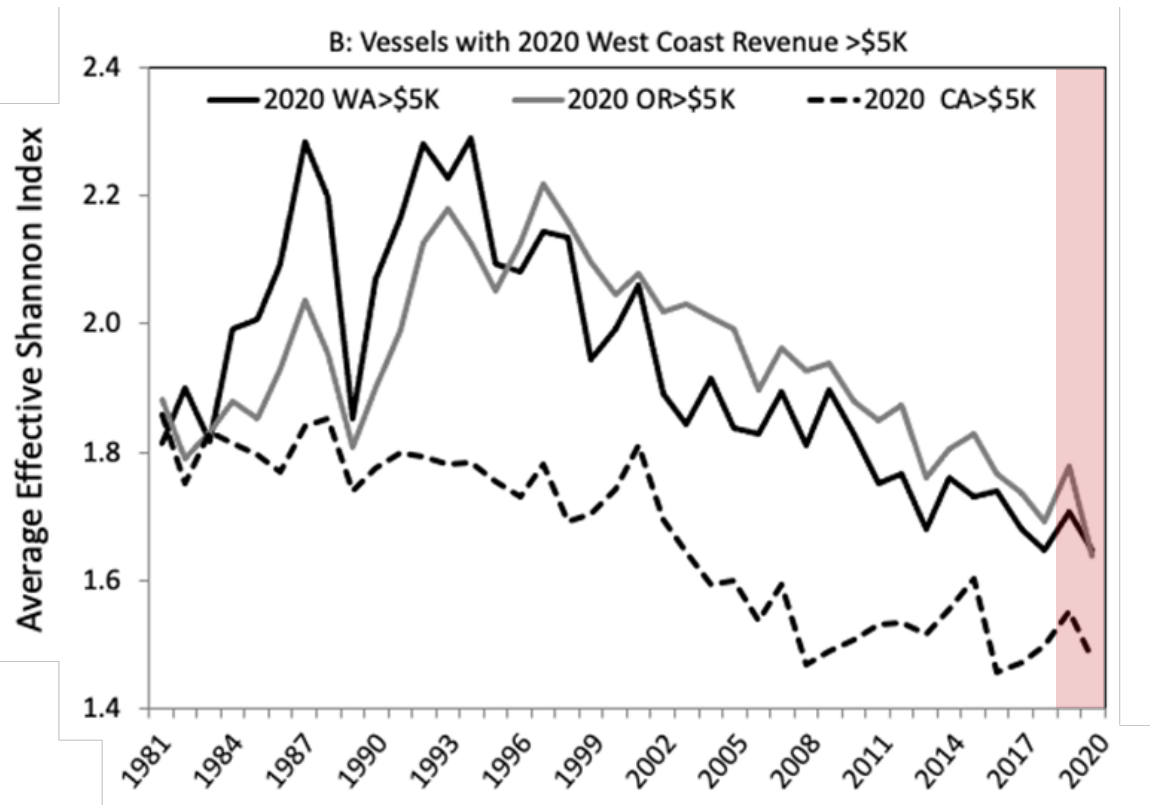
- ***Some decreases in 2021**

- HMS (-34%)
- *Crab (-7%)

Fishery revenue diversification and concentration

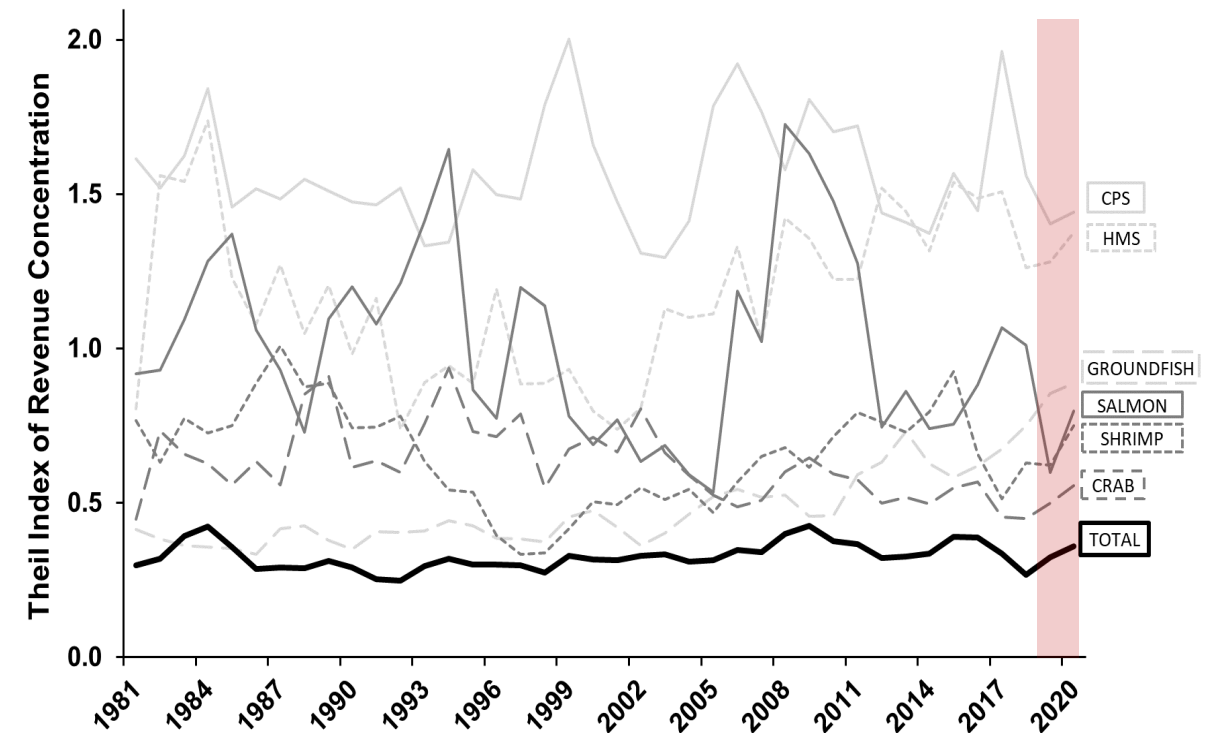
Revenue diversification:

- Average declined in all states in 2020, remains low relative to time series
- Declines in 2020 in many ports as well



Revenue concentration:

- Slight increases in geographic concentration of commercial revenue in all fisheries in 2020

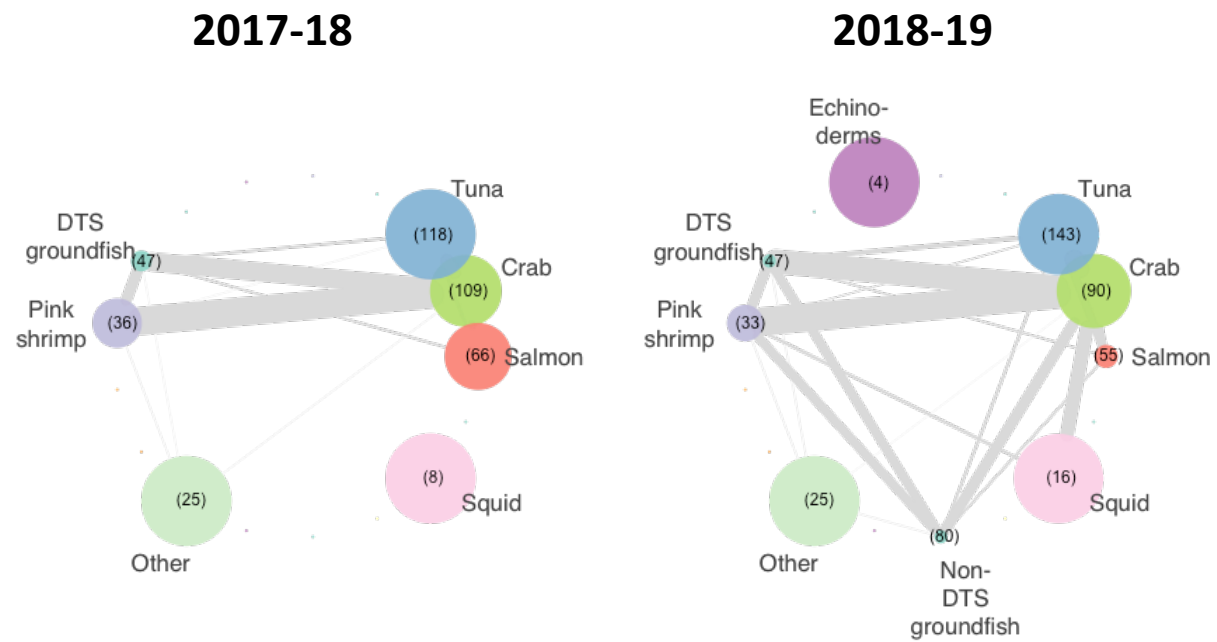


Fishery participation networks

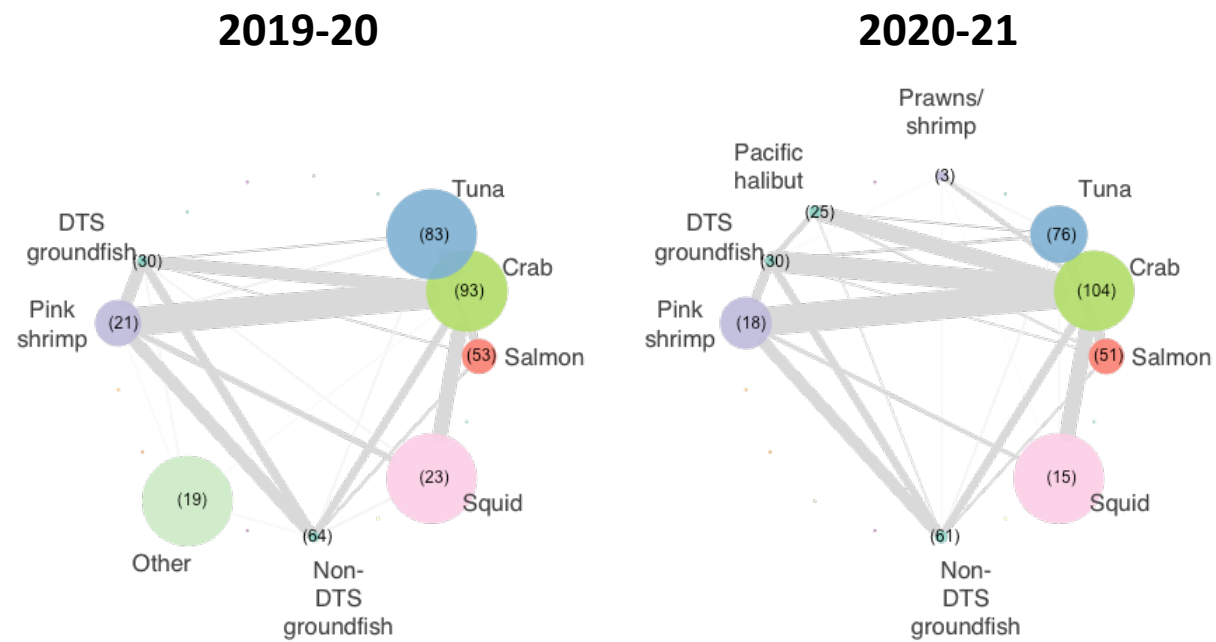
Nodes represent fisheries and revenue levels

Edges (lines connecting fisheries) represent vessel participation and revenue in both fisheries

Coos Bay participation networks just before COVID:



Coos Bay participation networks during COVID:

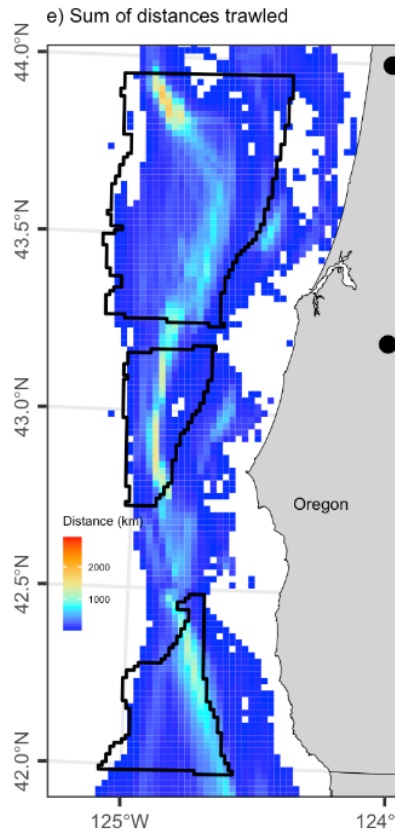


Groundfish bottom trawling activity and wind energy

Federally managed limited entry/catch share bottom trawl fleet

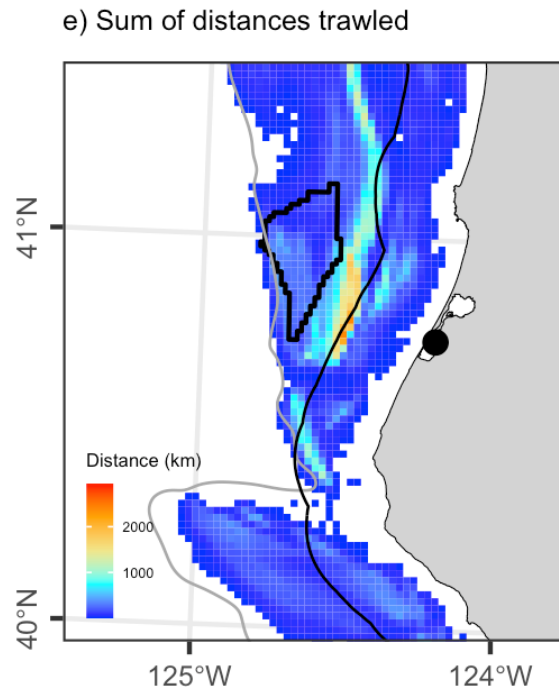
Sum of distance trawled in 2019 (most recent year of data; non-confidential)

Oregon



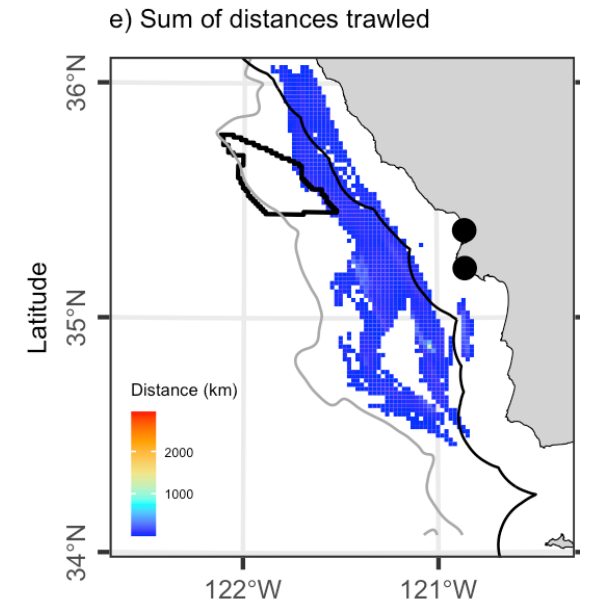
- Bands of greatest activity within the call areas*

Humboldt



- Band of greatest activity just shoreward of WEA*

Morro Bay



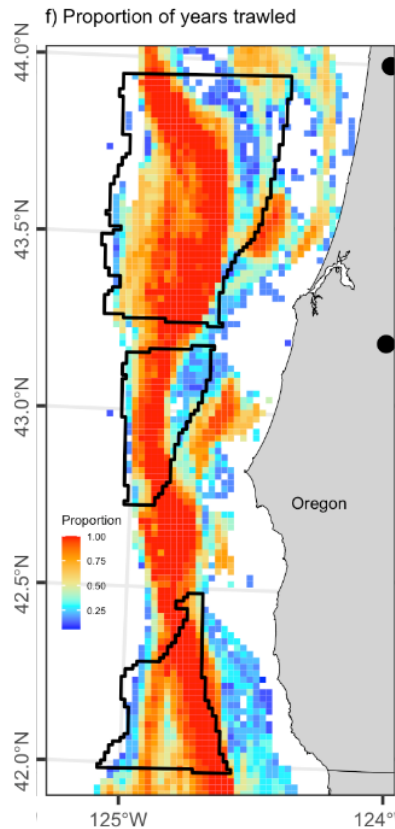
- Low trawl activity, almost all shoreward of WEA*

Groundfish bottom trawling activity and wind energy

Federally managed limited entry/catch share bottom trawl fleet

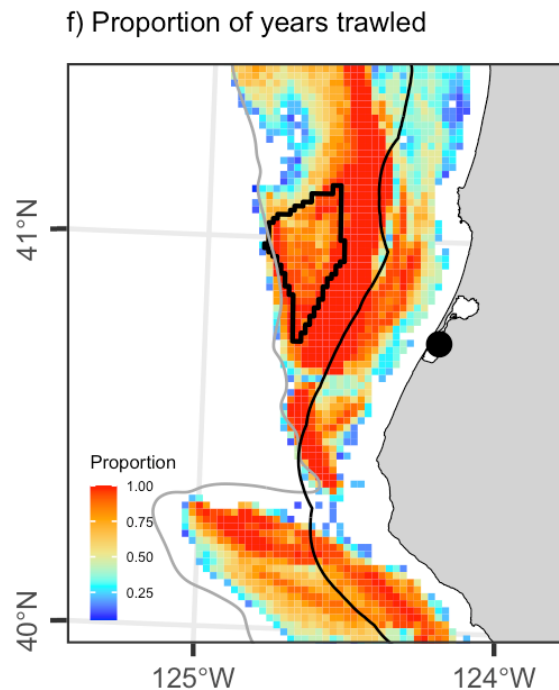
Proportion of years each cell was trawled, 2002-2019

Oregon



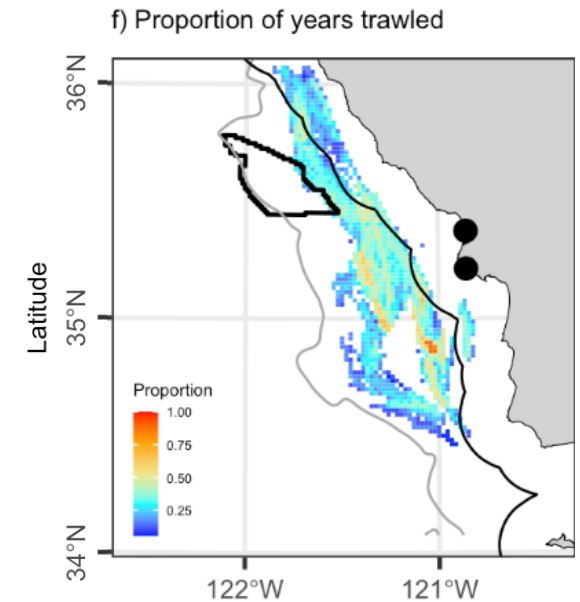
- *Much of the call areas see activity nearly every year*

Humboldt



- *Much of WEA and area shoreward of WEA see activity nearly every year*

Morro Bay



- *Outside call area, most cells trawled <50% of years*

Conclusions



Matthew Savoca

2021 was a Tale of Three Systems

- Large, strong marine heatwave offshore
- Strong upwelling and cool, productive water supported good feeding conditions in much of the California Current
- Heat, drought, fires on land
- La Niña conditions and widespread drought conditions are anticipated to continue at least through spring 2022
- Some rebounds in fishing revenues in 2021, following the very difficult year of 2020



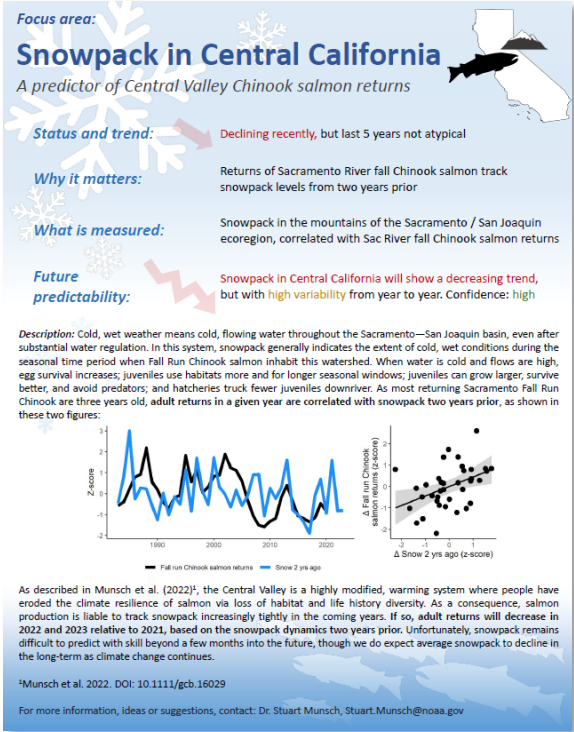
Summary and synthesis

- It is challenging to translate these extremes and “natural experiments” into species and fisheries responses
- Climate change is intensifying this challenge

Summary and synthesis

- It is challenging to translate these extremes and “natural experiments” into species and fisheries responses
- Climate change is intensifying this challenge
- Our “Climate Change Appendix” conversation starter

Index	Description	Nowcast/ hindcast	Seasonal Forecast	Decadal Forecast	Climate Projection
“Type I”	Very well sampled, most dynamics understood (example: some physical indices)				
“Type II”	Well sampled, some dynamics understood, impacts of long-term change can be estimated (examples: some biological and biogeochemical indices)				
“Type III”	Not well sampled, dynamics less well understood (examples: hydrology, many biological and fisheries indices)				



Thank you



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