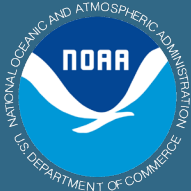


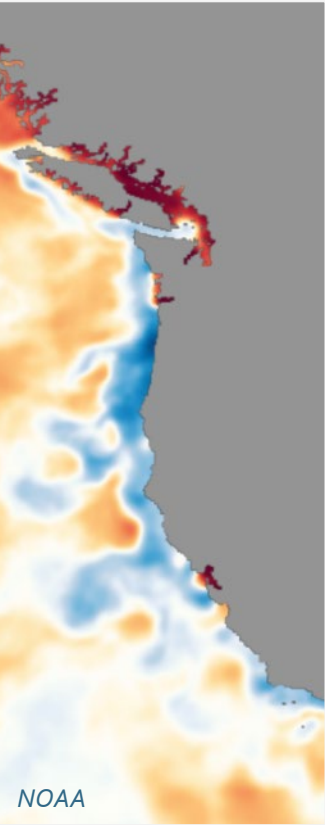
# 2020-21 California Current Ecosystem Status Report

NOAA California Current IEA Team

Presented to the Pacific Fishery Management Council  
March 10, 2021



Angela Klemmedson



- **The COVID-19 pandemic heavily impacted West Coast research efforts**
- **Two large-scale climate indices in 2020 trended toward increased productivity**
  - Along the equator, weak El Niño conditions transitioned to La Niña conditions in summer 2020
  - Positive PDO transitioned to negative PDO, which favors higher productivity in the CCE
  - We continued to observe a strongly negative NPGO, which often dampens productivity
  - The second largest marine heat wave emerged in May, reached a maximum in October and lasted into 2021
- **Regional climate and oceanography indicators were also mixed**
  - Strong winter upwelling preceded an average to above-average upwelling season, good nutrient supply
  - Coastal habitat expanded, returning to neutral conditions\*
  - However, the system experienced low snowpack, drought and catastrophic fires in 2020

# Summary #2



- **Many ecological indicators suggest a productive system**
  - Abundant lipid-rich copepods off Newport; improved signals for krill biomass
  - Still a lot of anchovy off CA
  - Above-average abundance of CA sea lion pup births
  - Above-average production of young at key seabird colonies
  - *Interpret these indicators with extra care due to sharply reduced sampling effort*
- **Signs of concern**
  - Pyrosomes (warm-water tunicates) remained abundant, especially off California
  - Mixed or below-average “stoplight” outlooks for returns of multiple salmon stocks
- **Landings and revenue were down for most fisheries in 2020**

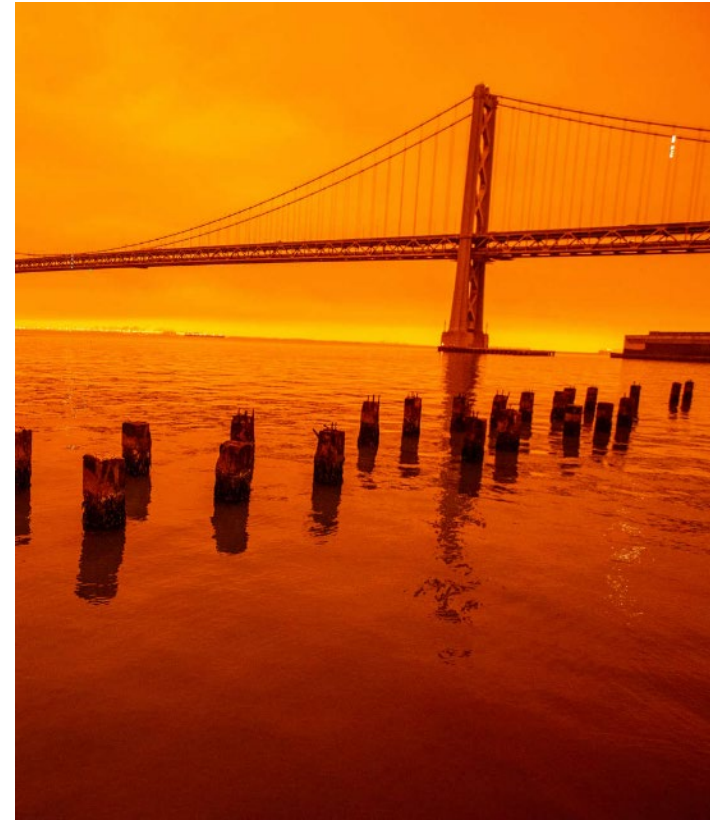
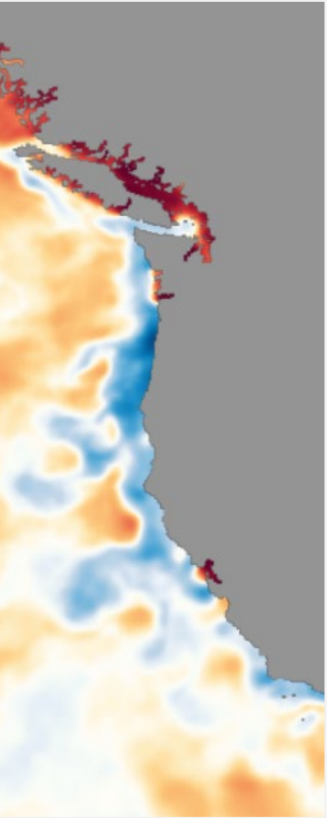
# COVID-19 “stress test”



- **Impacts on fisheries monitoring and assessment**
  - Cancellation of research cruises on NOAA white ships and some charter vessels
  - Removal of NOAA personnel from academic and charter vessels
  - Delayed processing: many samples stored in freezers awaiting the reopening of laboratories
  - Cancellation of field work such as on-site sea lion surveys and salmon river surveys
- **Commercial Impacts**
  - Drops in landings and revenue due to reductions in restaurant and export markets
  - Some outbreaks on vessels, in processing plants, and in fishing-dependent communities
  - Increased operating costs to implement safety measures
  - Revenue losses in the charter sector
  - Concurrent stresses like wildfires, harmful algal blooms
  - Some relief via the CARES Act and other measures

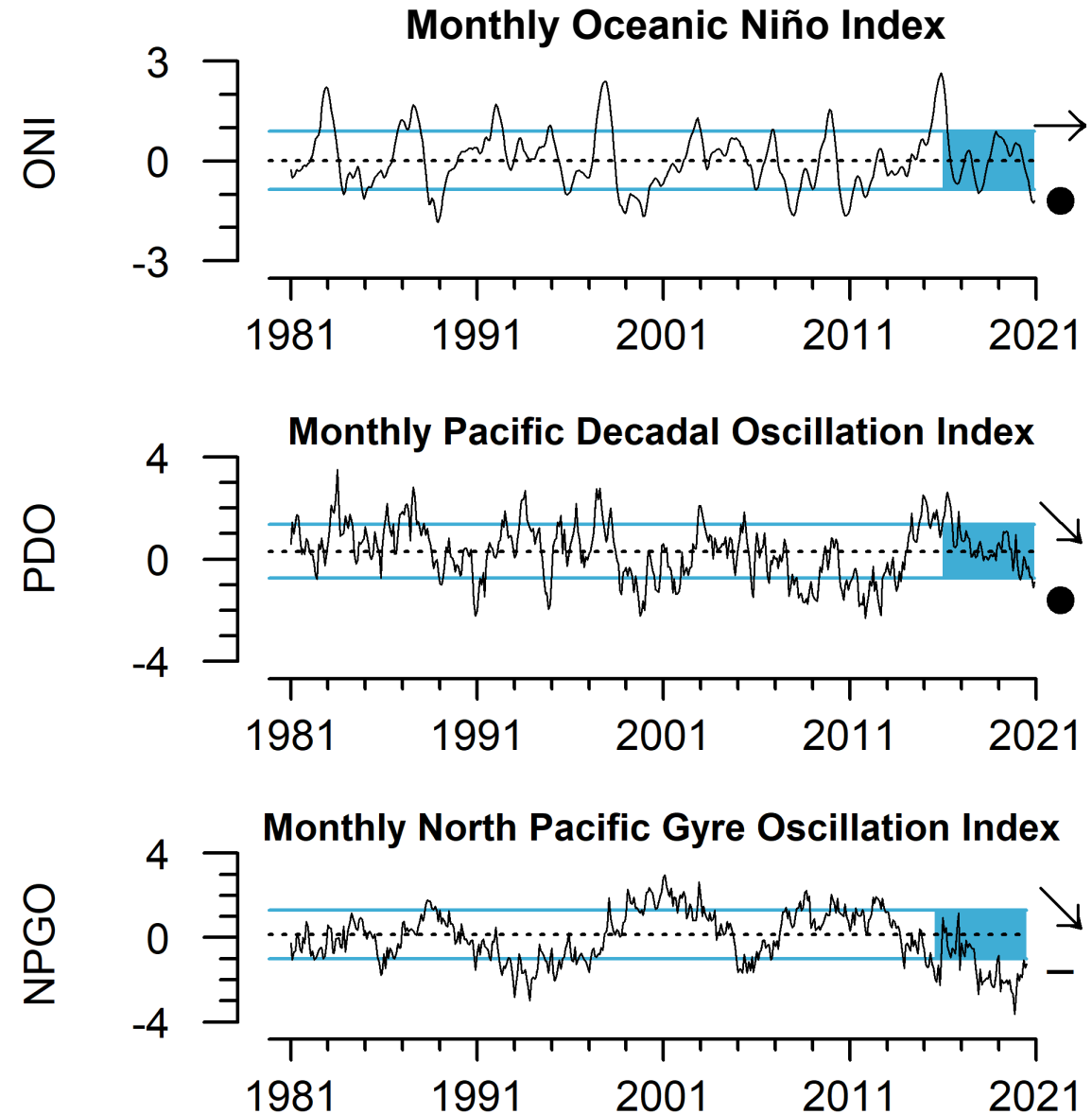
# Physical Conditions

*early upwelling  
marine heatwave stays offshore  
cool ocean, drought, fires*



# Basin-scale climate: two key indices shifted in 2020

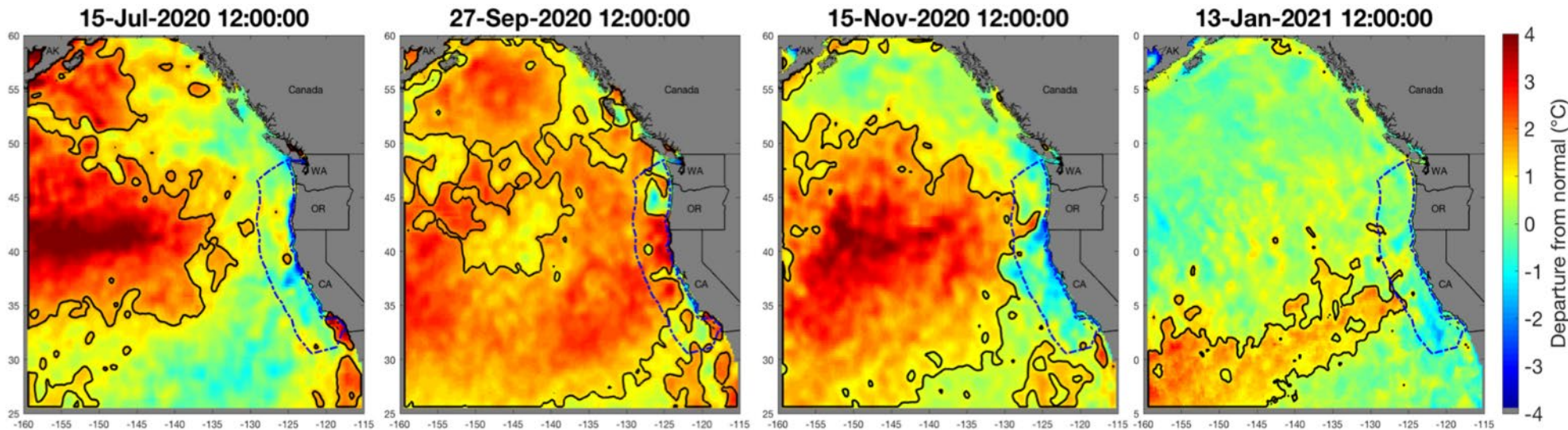
- *Oceanic Niño Index (ONI) shifted to La Niña conditions, which generally favor higher productivity in the CCE*
  - 60% chance of La Niña persisting through spring 2021
- *Pacific Decadal Oscillation (PDO) became increasingly negative, which indicates a cooler ocean and favors higher productivity in the CCE*
  - Values this negative last seen in 2012
- *North Pacific Gyre Oscillation (NPGO) remained strongly negative, which indicates lower water transport in the CCE, and favors lower productivity*
  - Lowest NPGO values of the time series



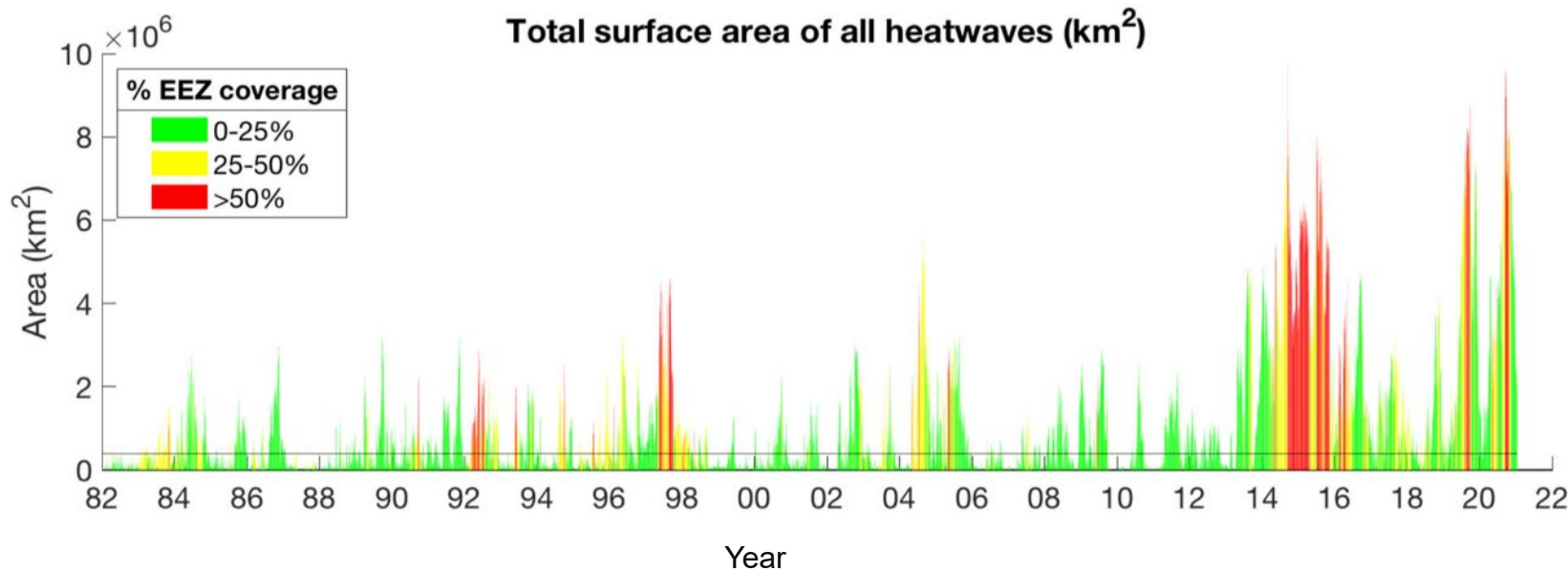


# 2020 experienced the 2<sup>nd</sup> largest marine heat wave, but it mostly stayed offshore

- 2020 event has lasted from May 2020 to February 2021
- Briefly reached coast September, then weakened
- Too early to estimate possible impacts to the CCE



- The US EEZ is outlined in the temperature maps
- Color coding is the % intrusion of warm oceanic water into the Exclusive Economic Zone (EEZ) – 200 nautical miles from shore





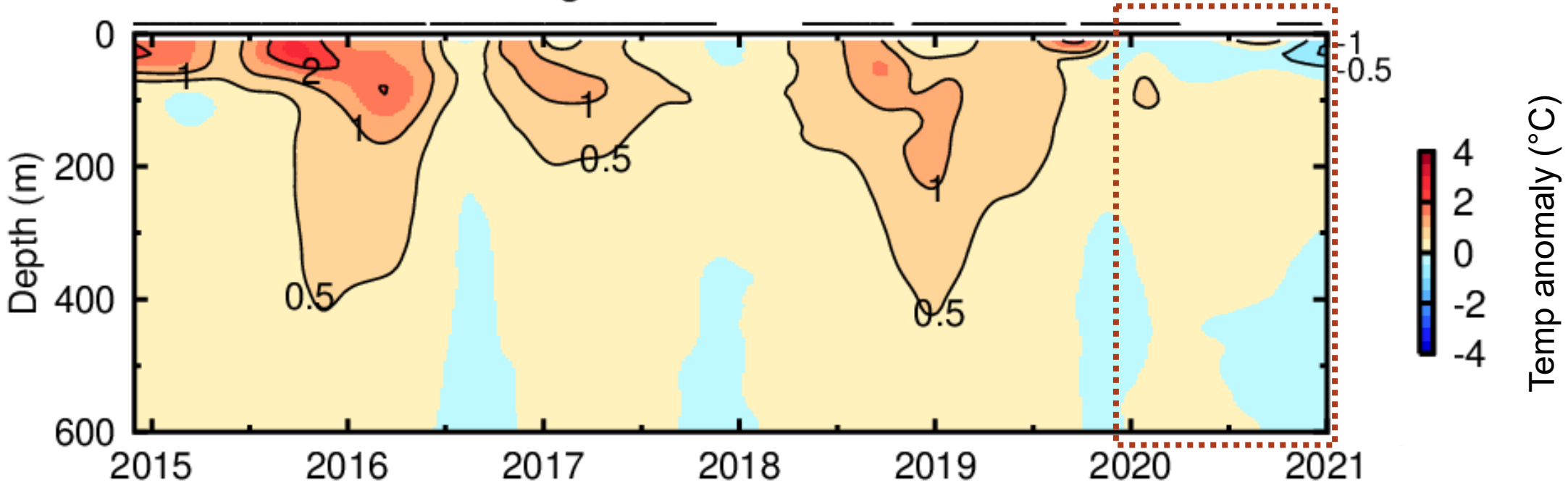
# 2020 subsurface temperatures cooling in the north, not the south

Temperature anomalies at depth off Trinidad Head, northern California, collected by autonomous glider

*Trinidad glider clearly shows:*

- *2013-2016 Blob and El Niño, followed by 2019 marine heat wave*
- *2020 inshore cooling and return to “neutral” conditions\**

Trinidad Head temperature anomaly  
averaged over inshore 200 km





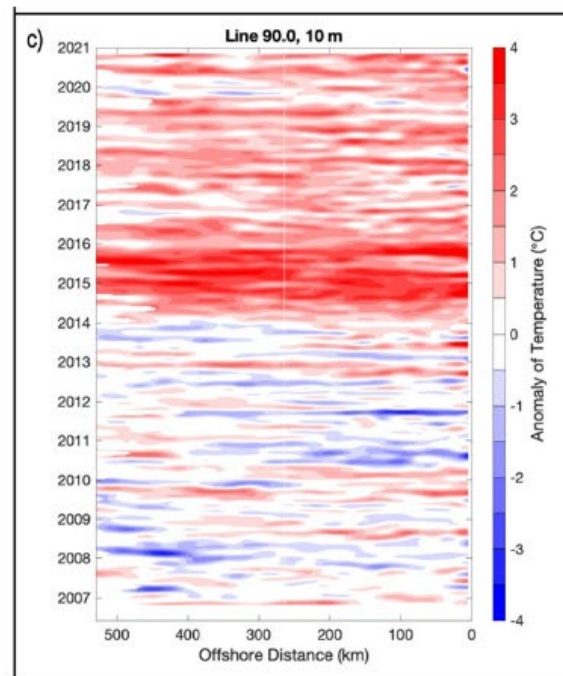
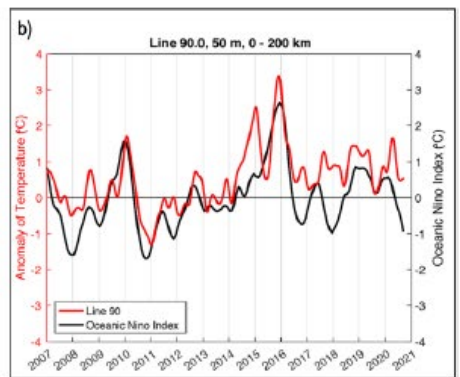
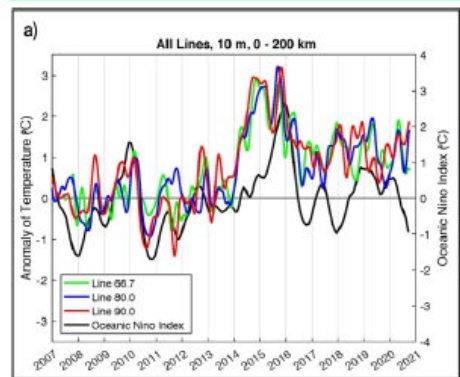


# 2020 subsurface temperatures cooling in the north, not the south

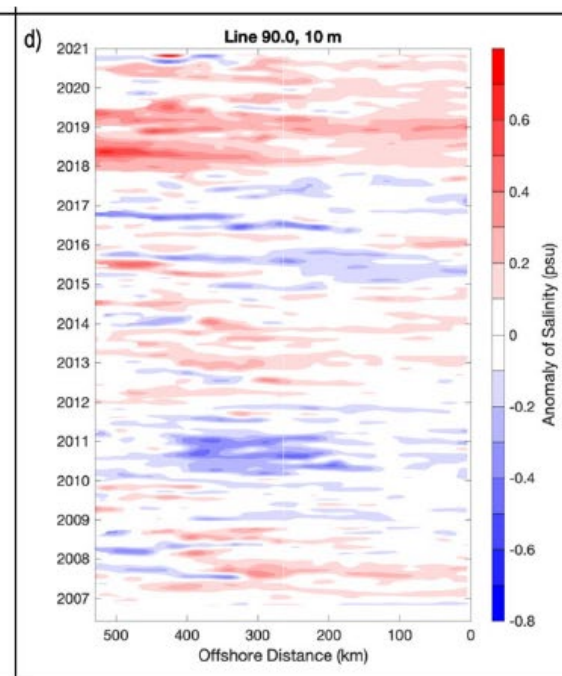
## California Underwater Glider Network



- California glider network shows the El Niño correlation up to 2015, then the decorrelation*
- Line 90 in SoCal reveals the warm conditions since 2015*
- The salinity anomaly shows 2018-2019 had some of the highest salinity values seen in the SoCal region*



Temperature @ 10 m



Salinity @ 10 m

DOI: 10.21238/S8SPRAY7292

Rudnick, SIO

Rudnick et al., 2017; Ren and Rudnick, 2021

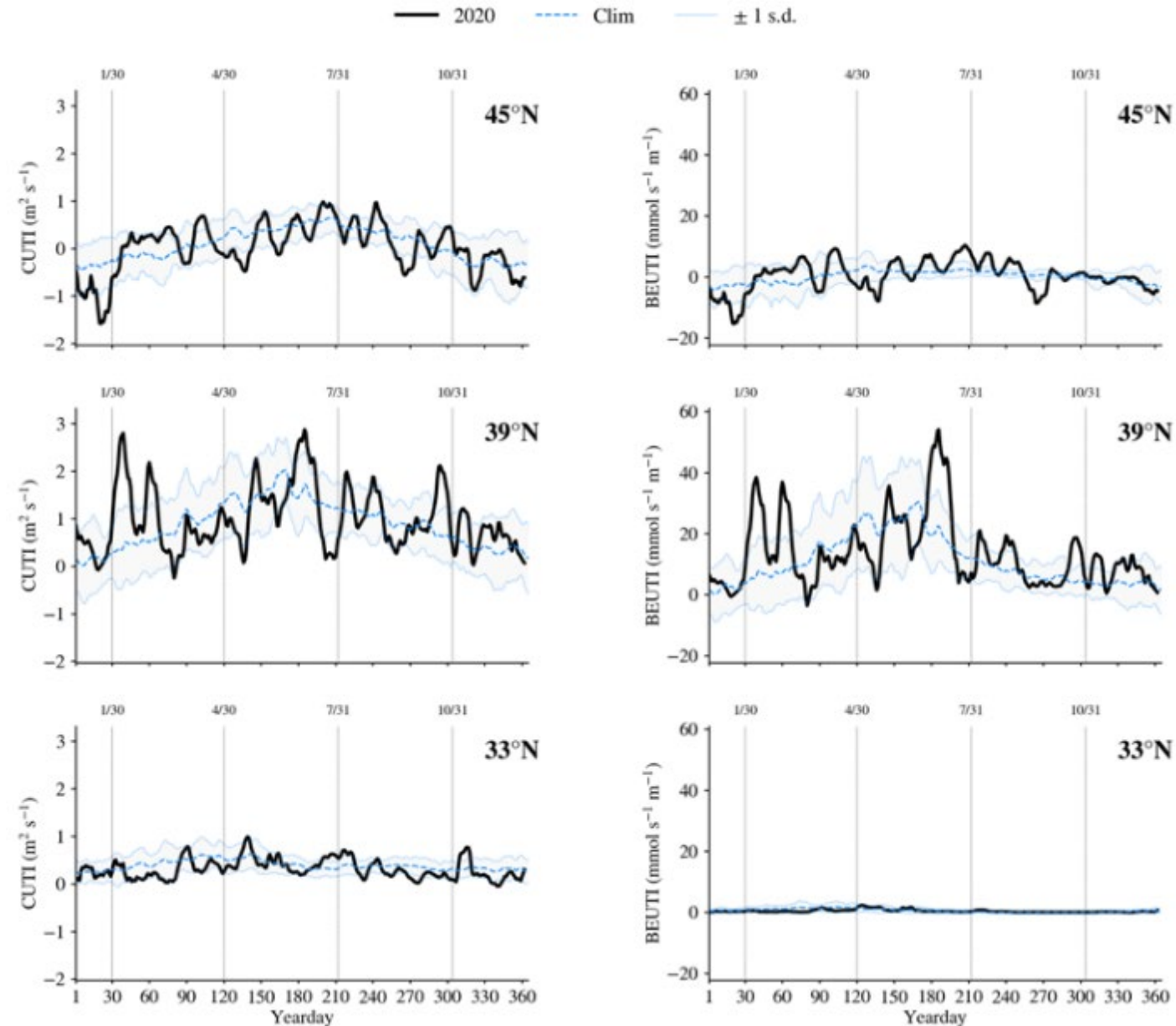


# Upwelling in 2020 was above average; favors productivity

Coastal Upwelling Transport Index (CUTI): water flux

Biologically Effective Upwelling Transport Index (BEUTI): nitrate flux

- *North and Central: Strong 2020 winter upwelling, pronounced upwelling/relaxation sawtooth cycle in spring and summer*
- *South: average/below average in spring and summer 2020*
- Upwelling strength and nitrate flux greatest by far in central region

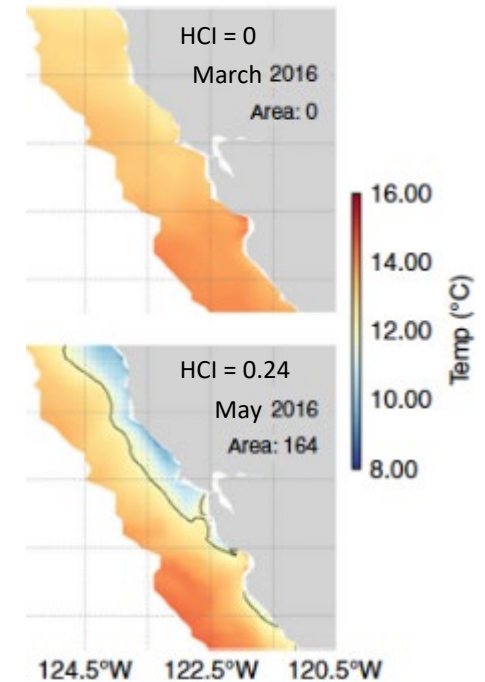




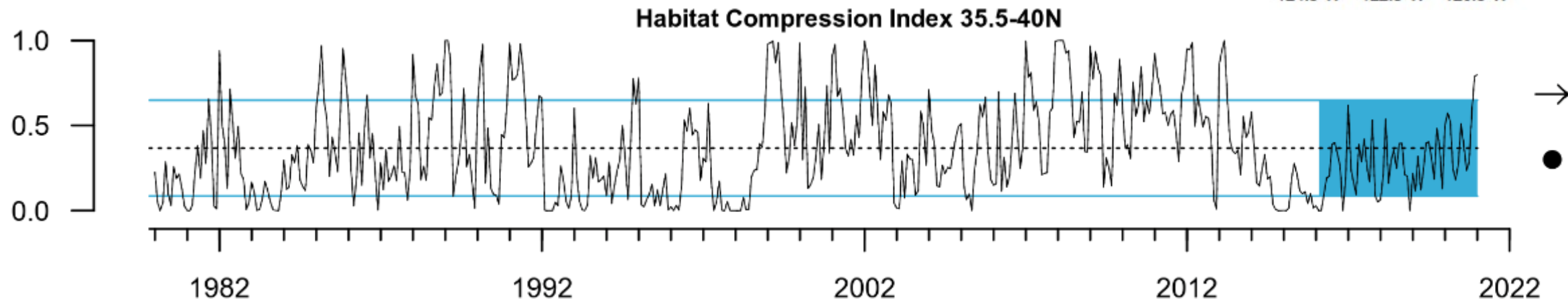
# Cool coastal habitat expanded

- The coastal Habitat Compression Index (HCI) is a measure of the balance of cold, upwelled water (HCI = 1) and warm, oceanic water (HCI = 0) at the near surface from the coast out to 150 km
- Intense compression (low HCI) can intensify ecological interactions (Santora et al. 2020)

- *Following the low HCI correlated with the 2013-2016 MHW, the HCI has been increasing for the last three years*
  - Increase = expansion of cool near-surface habitat area



HCI (fraction of coastal area below monthly threshold)



The HCI index has been expanded to four regions that cover the whole coast: WA/OR, OR/CA, cen CA and so CA

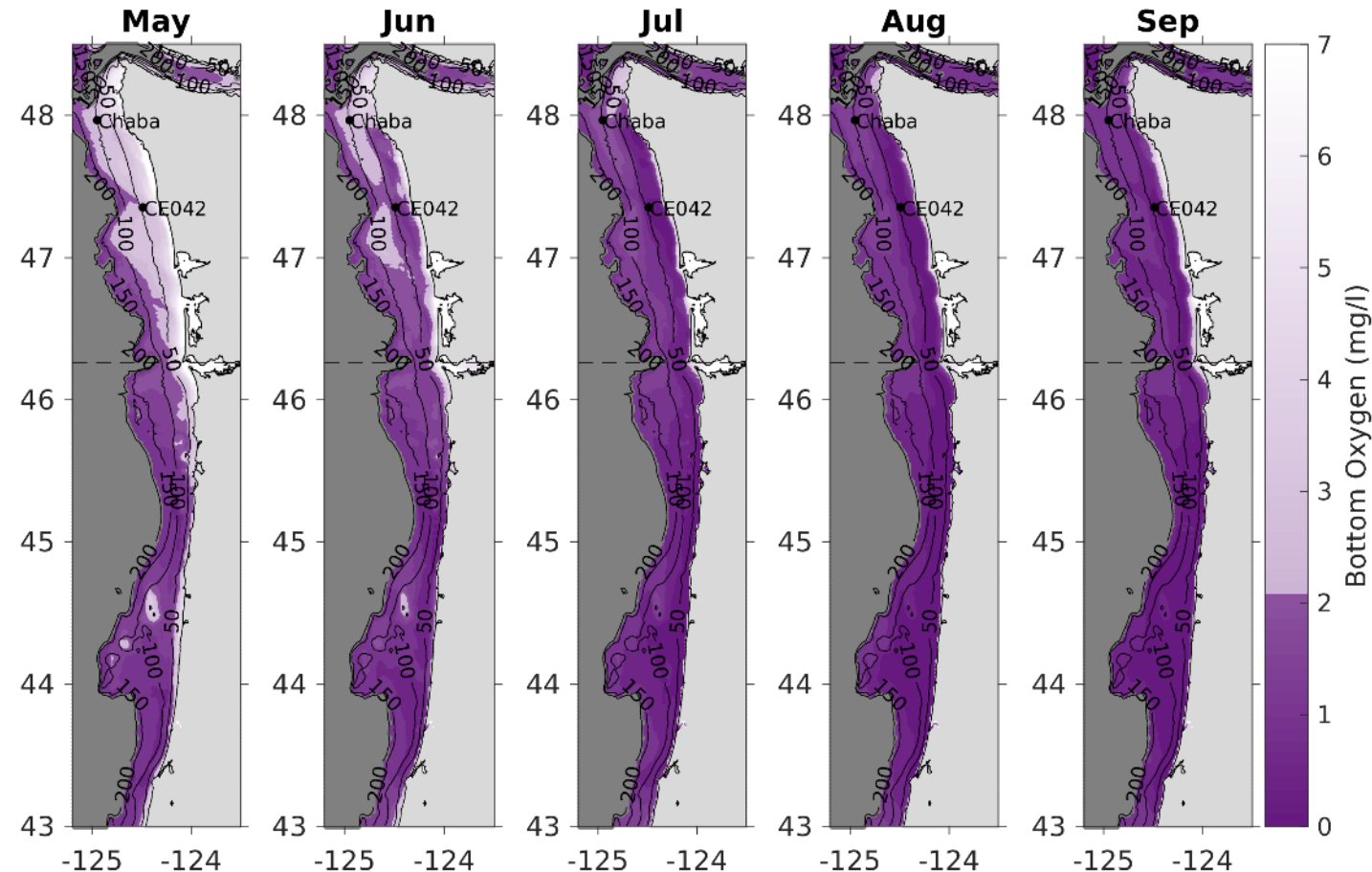


# J-SCOPE forecasts of ocean conditions off WA, OR

- J-SCOPE model system forecasts physical and biological conditions off WA, OR from Jan-Sept each year

- **2021 dissolved oxygen forecast:**
  - *Below average DO on WA and OR shelves early in the upwelling season*
  - *Hypoxia widespread off Oregon by May-June, will spread to Washington by July*
    - Earlier than average for hypoxia
  - *High uncertainty for hypoxia forecast*

## Benthic dissolved oxygen forecast, 2021



courtesy Dr. Samantha Siedlecki, University of Connecticut

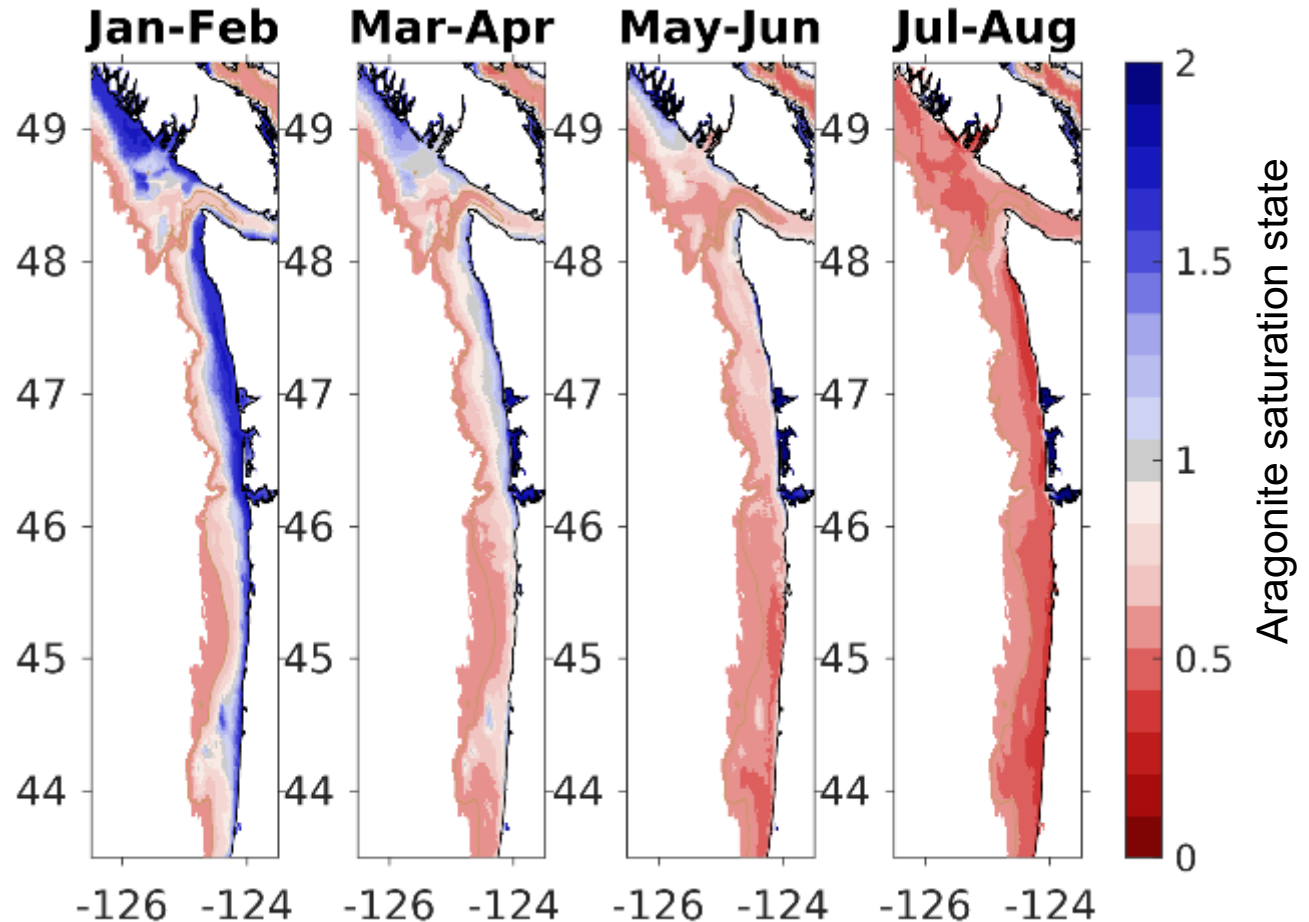




# J-SCOPE forecasts of ocean conditions off WA, OR

- J-SCOPE model system forecasts physical and biological conditions off WA, OR from Jan-Sept each year
- **2021 ocean acidification forecast:**
  - *Aragonite on the shelf near the seafloor is expected to be corrosive (<1.0) in the spring and summer upwelling season*
  - *Exception: shallow nearshore shelf off Washington, March-June*
  - Surface waters expected to be supersaturated (non-corrosive) throughout the season (not shown)

## Benthic aragonite saturation forecast, 2021

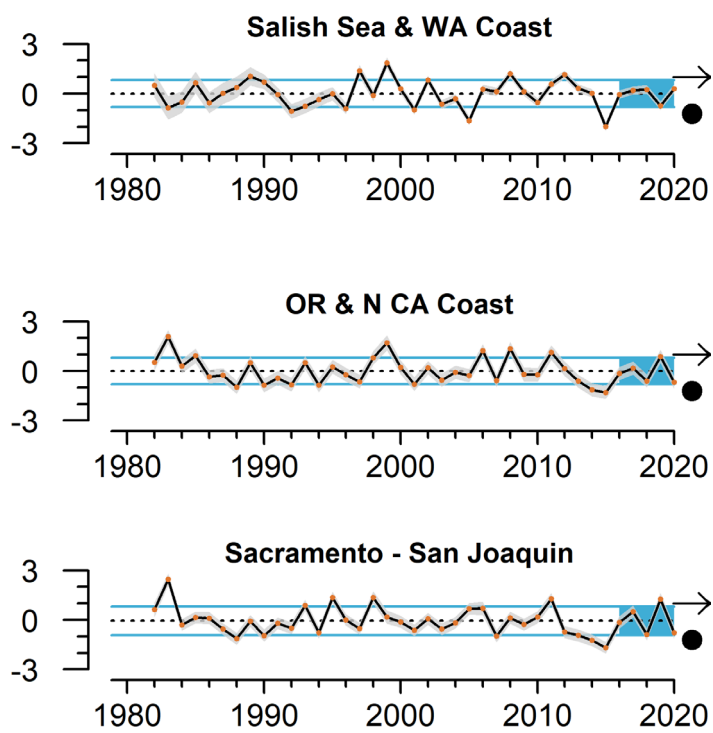


courtesy Dr. Samantha Siedlecki, University of Connecticut

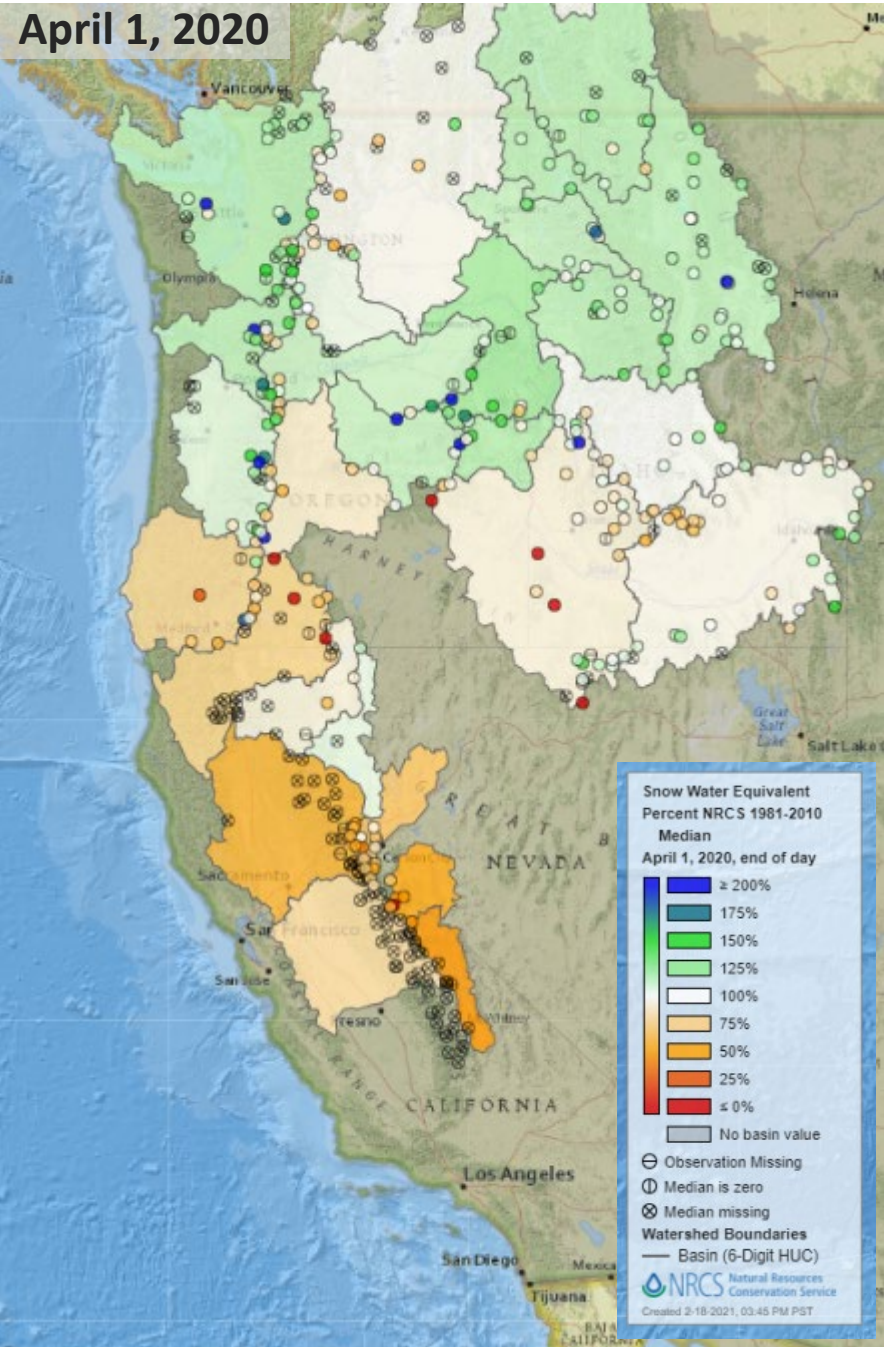


# Snow Water Equivalent in 2020: slightly above average in much of the north, below average in central & south

SWE anomaly



■ *This regional SWE pattern was generally reflected in stream flows in 2020*



# Snowpack as of March 7, 2021

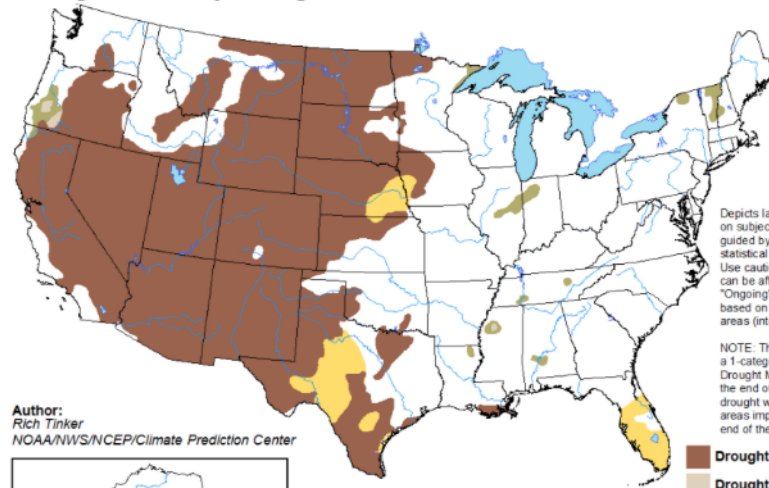
- *Pattern to date is similar to 2020*
- *California: mostly below the median of 1981-2010*
- *Oregon & Idaho: mixed*
- *Washington: mostly above median and higher than last year*
  - Official 2021 measure will be made on April 1<sup>st</sup>

## Monthly U.S. Drought Outlook

The latest monthly drought outlook from the [Climate Prediction Center](#)

### U.S. Monthly Drought Outlook Drought Tendency During the Valid Period

Valid for March 2021  
Released February 28, 2021



Author:  
Rich Tinker  
NOAA/NWS/NCEP/Climate Prediction Center

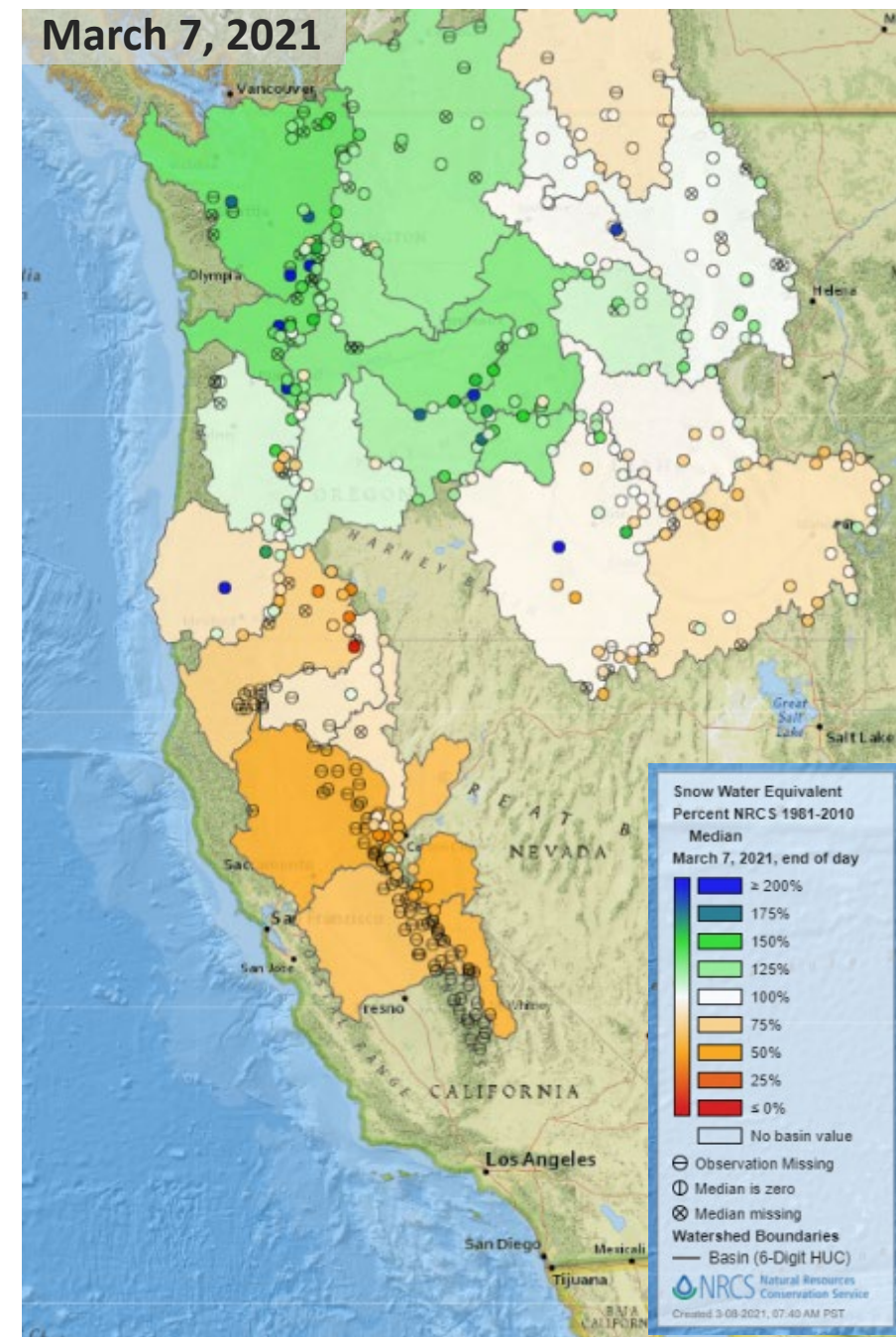
Depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts. Use caution for applications that can be affected by short lived events. "Ongoing" drought areas are based on the U.S. Drought Monitor areas (intensities of D1 to D4).

NOTE: The tan areas imply at least a 1-category improvement in the Drought Monitor intensity levels by the end of the period, although drought will remain. The green areas imply drought removal by the end of the period (D0 or none).

- Drought persists
- Drought remains but improves
- Drought removal likely
- Drought development likely

<http://go.usa.gov/3eZGd>

March 7, 2021



Snow Water Equivalent  
Percent NRCS 1981-2010  
Median  
March 7, 2021, end of day

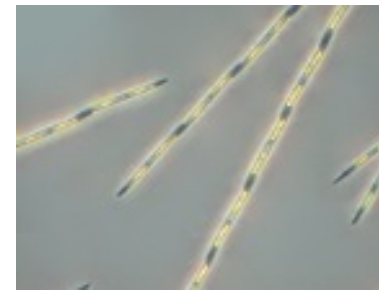
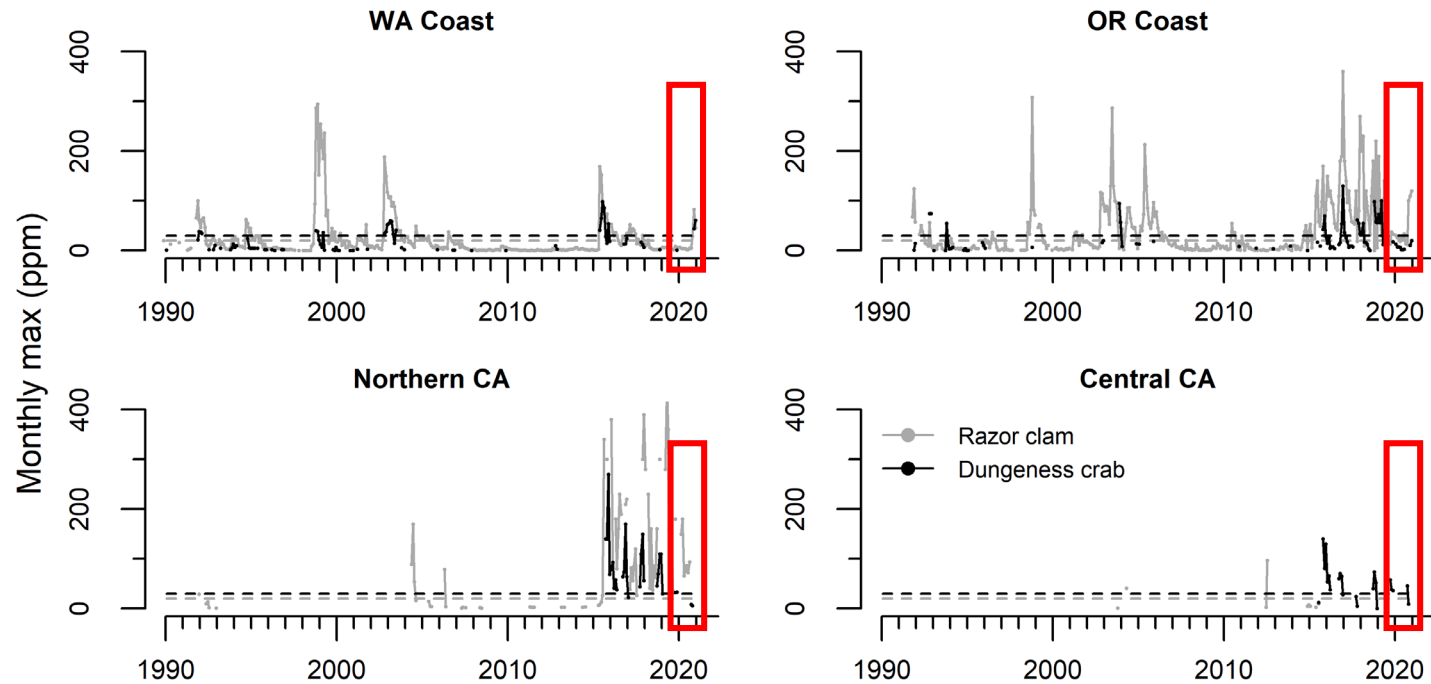
- $\geq 200\%$
- 175%
- 150%
- 125%
- 100%
- 75%
- 50%
- 25%
- $\leq 0\%$
- No basin value
- ⊖ Observation Missing
- ⊕ Median is zero
- ⊗ Median missing
- Watershed Boundaries
- Basin (6-Digit HUC)
- NRCS Natural Resources Conservation Service
- Created: 3-08-2021, 07:40 AM PST

## Nat'l Weather Service Drought Monitor from February 28, 2021

- Moderate to extreme drought persists for most of California, Oregon
- Abnormally dry for much of Idaho
- Washington mostly normal



# Harmful algal blooms and Red Tide



- *Razor clam harvests shortened (WA, OR) or closed (CA) due to domoic acid*
- *Dungeness crab (WA, OR) and rock crab (CA) harvests shortened due to domoic acid*
  - Crab seasons also affected by meat quality and entanglement mitigation

- *“Red tide” in southern California caused by intense spring bloom of dinoflagellate *Lingulodinium polyedra**

- Localized fish and invertebrate kills from oxygen depletion
- Respiratory irritation from release of yessotoxin
- Bioluminescence



Credit: Mike Latz, SIO



# Ecological responses, Part I

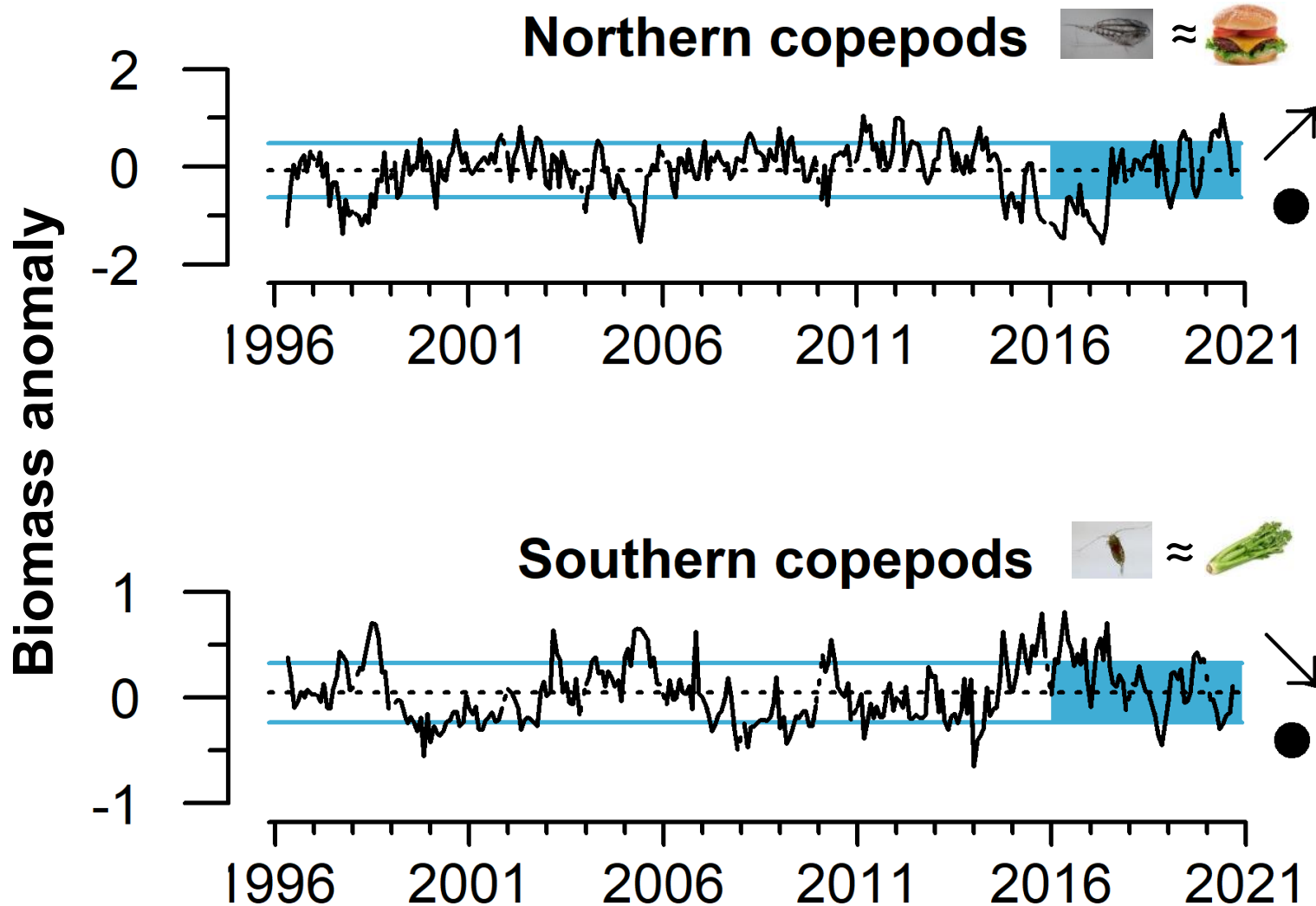
*plankton! anchovies!*  
*happy pups and baby birds!*  
*interpret with care!*



Matthew Savoca



# Copepods off Newport: 2020 was one of the best years ever



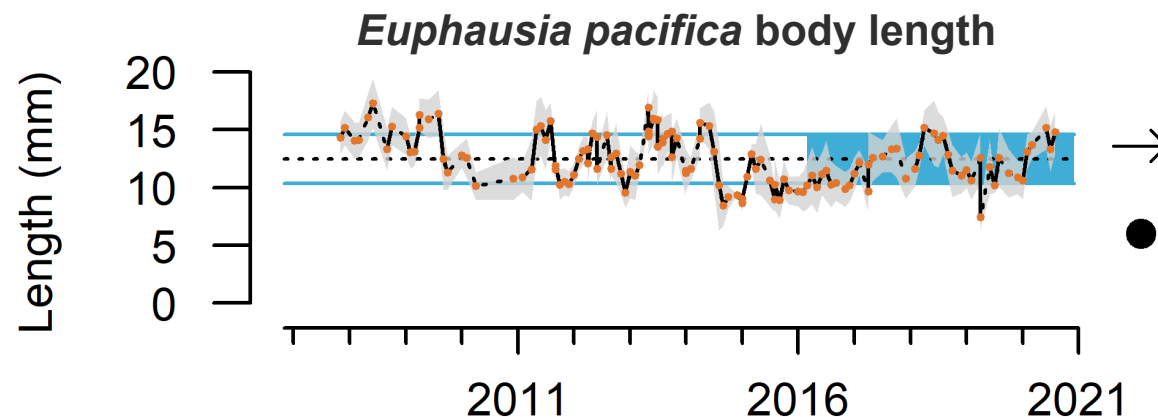
- *Energy-rich northern copepods were above average in the spring/summer of 2020*
- Steady increase since very low biomasses of 2014-2016
- *Lower energy southern copepods were average to below-average in 2020*



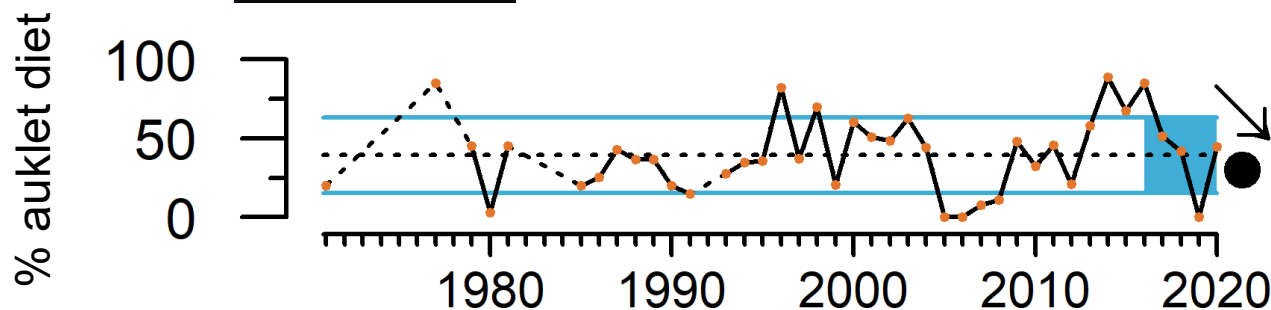
# Krill: a data-poor year, but some good signs



- *Most surveys that catch krill were cancelled or sharply reduced*
- *Krill body length was above average off Trinidad Head in 2020*
  - And, large krill catches anecdotally reported from Newport Line



*Thysanoessa spinifera* in  
Cassin's auklet diets



- *Krill returned to Cassin's auklet diets at SE Farallon Island in 2020*



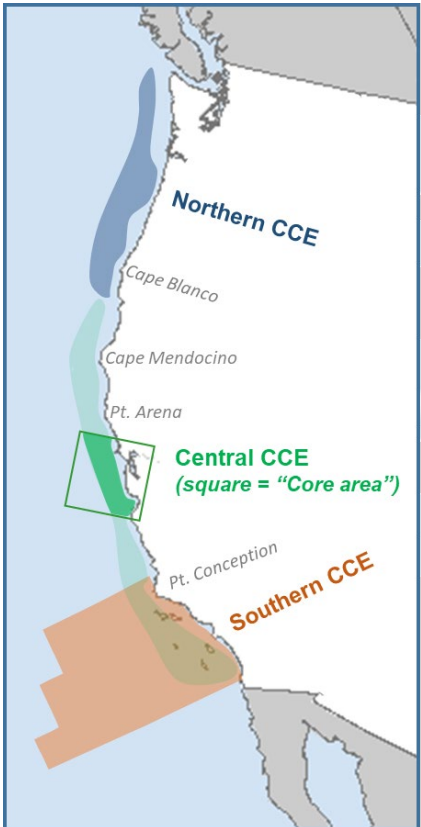
# Regional pelagic community surveys: **interpret with care**

Northern CCE: normal stations surveyed, but delayed sample processing

Central CCE: only ¼ of stations in “Core area” sampled in 2020; approach reviewed by SSC-ES

Southern CCE: spring survey cancelled, winter data analyzed; approach reviewed by SSC-ES

Coastwide CPS survey: cancelled



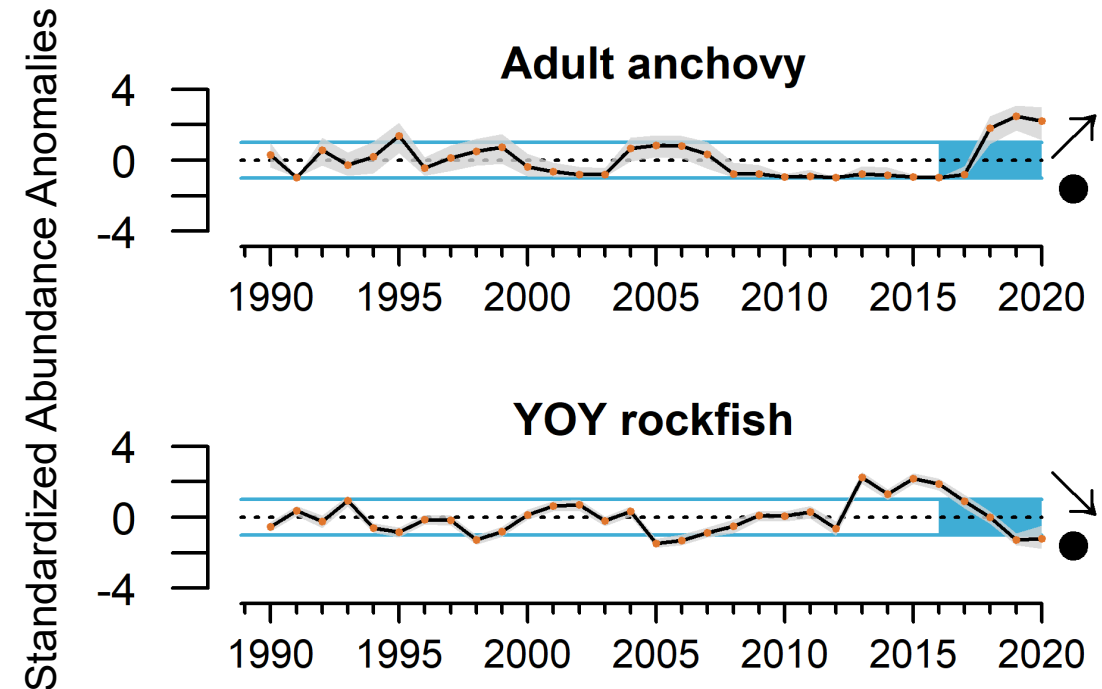
**Central (right) and South (not shown):**

- **Anchovy remained abundant**
- **Age-0 rockfish remained below average**

**Other results of note (not shown):**

- YOY sablefish abundant in the **North**
- Market squid abundant in **North**
- Pyrosomes still abundant in the **Central**

## Catch anomalies from “**Core area**” of Central forage survey

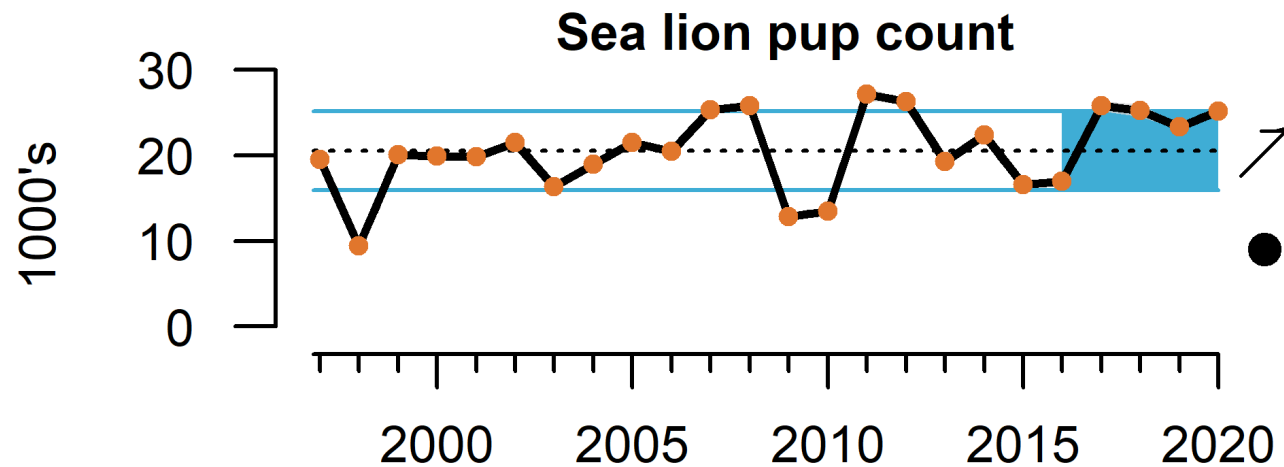


# Sea lion pups suggest good feeding conditions off central / southern California

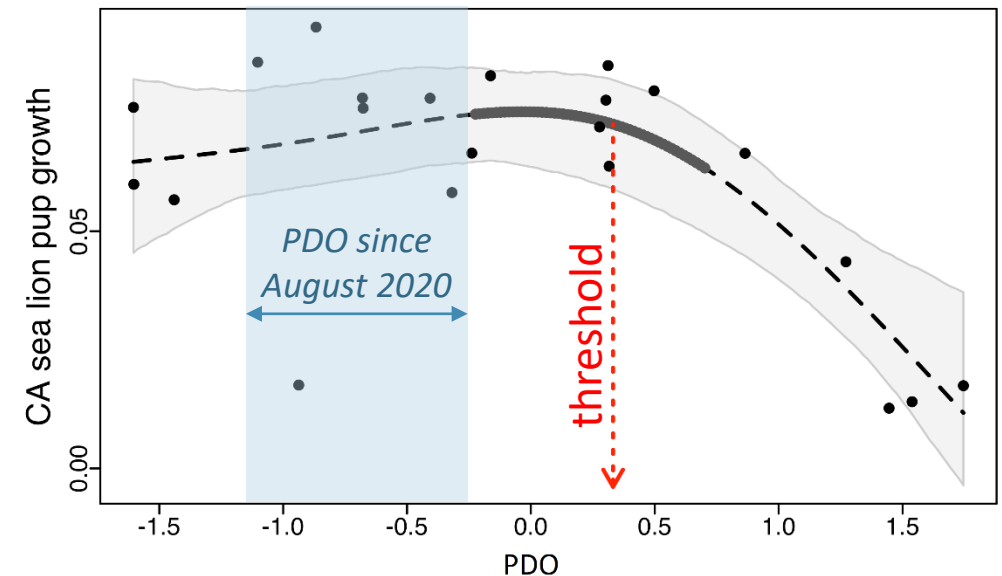


- San Miguel Island California sea lion colony (arrow on map)
- Maternal feeding grounds in rectangle on map

- **2020: high pup count for the fourth consecutive cohort**
  - Good feeding conditions for gestating mothers, October 2019-June 2020

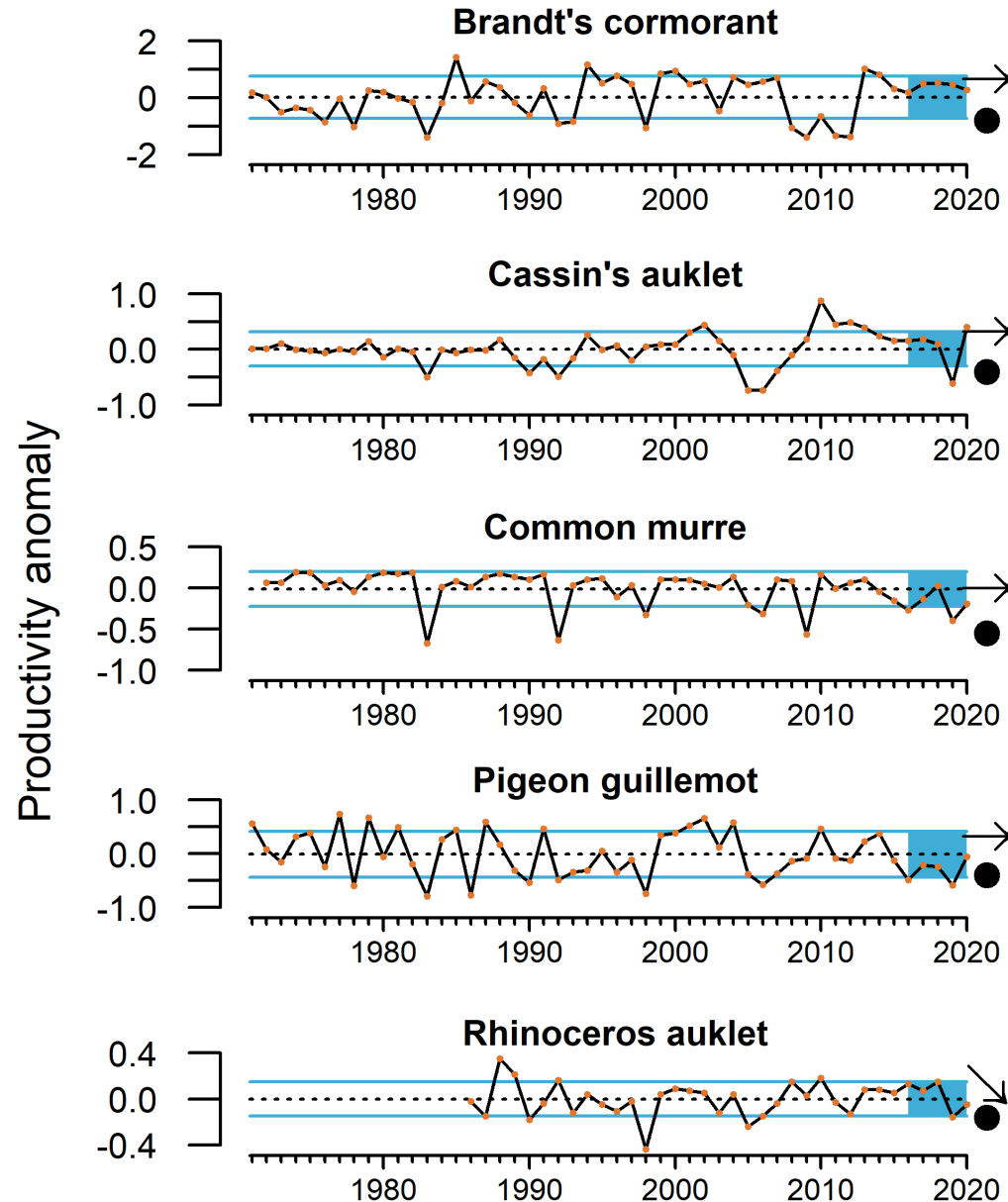


- **No pup growth data, due to COVID**
  - However, since the 2020 cohort was born, PDO has been negative, and well below the threshold where pup growth drops off





# Some rebounds in seabird fledgling production

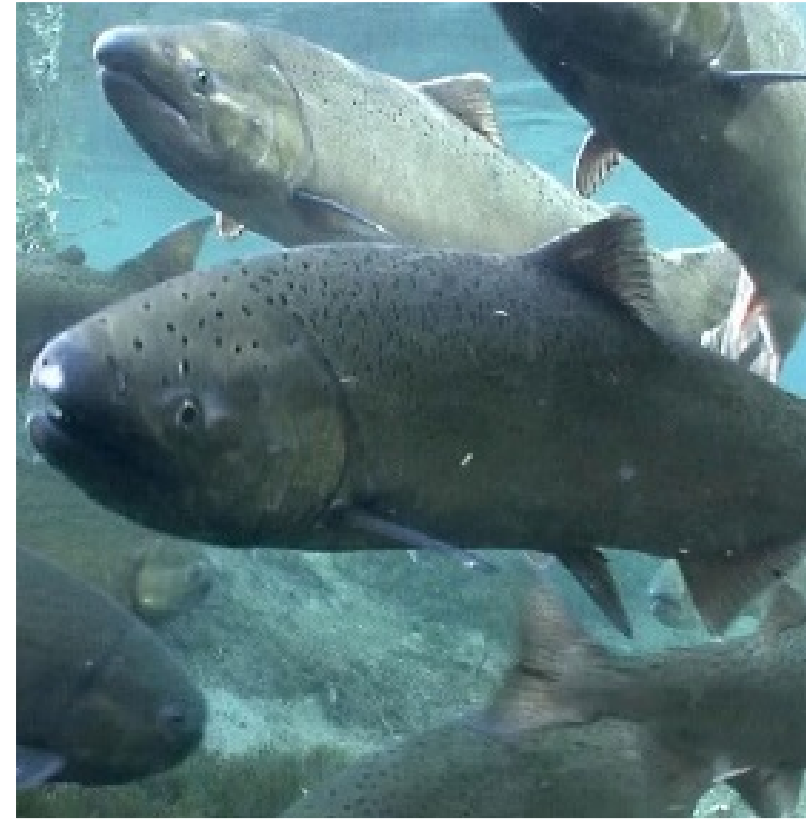


- *Fledgling production for several species at SE Farallon Island was greater in 2020 than 2019*
  - Implies good delivery of prey to nests, across a range of feeding strategies
  - Abundant anchovies in piscivore diets
  - Average or above-average production for cormorants at Yaquina Head, OR
- *No apparent mass mortalities (“wrecks”) on beaches in 2020*

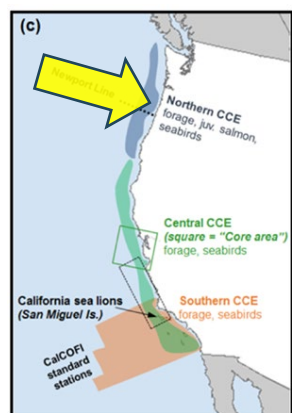


## Ecological responses, Part II

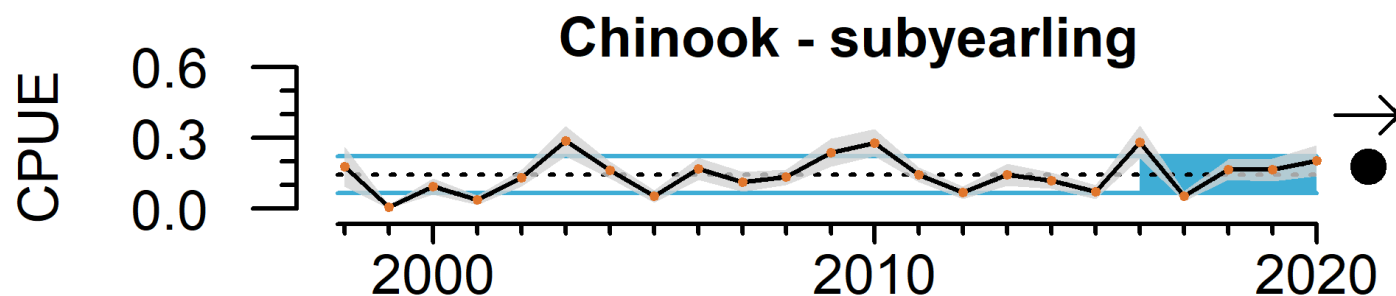
*mixed salmon signals  
from surveys and stoplight charts  
(plus, some news of whales)*



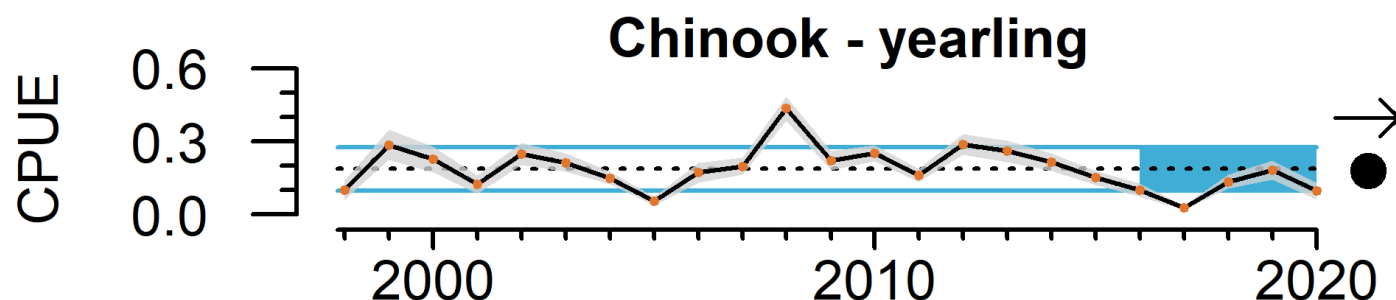




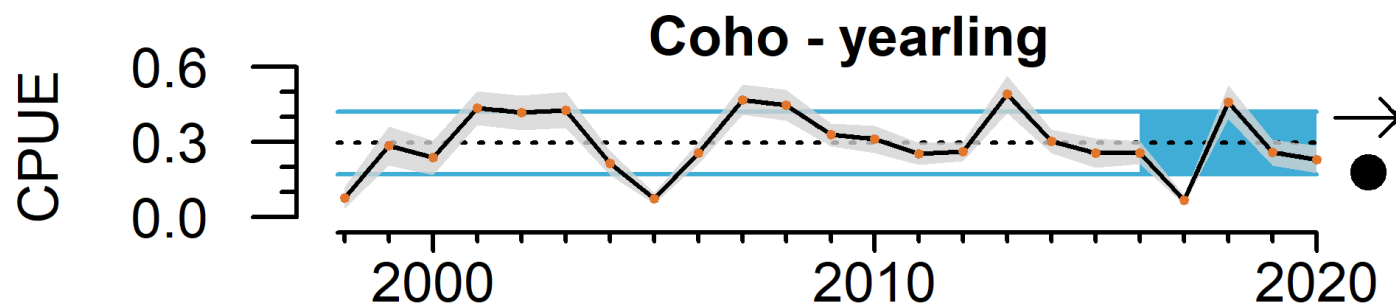
# Juvenile salmon catches off Washington and Oregon were mixed



- *Subyearling Chinook: about 1 s.d. above average*



- *Yearling Chinook: about 1 s.d. below average*



- *Yearling coho: close to average*

# “Stoplight” table for salmon returns to WA/OR in 2021: a mixed outlook



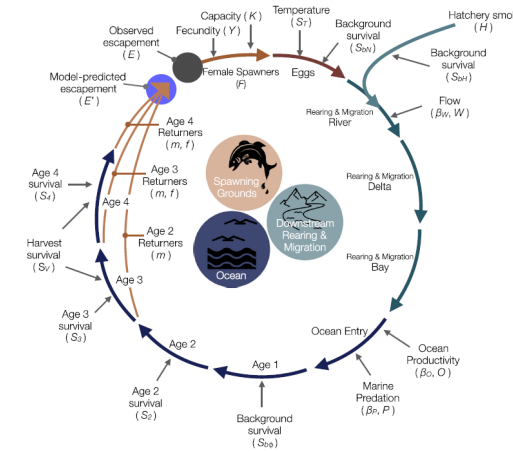
Chinook counts at Bonneville, coho returns to OPI area

Scale of indicators	Smolt year				Adult return outlook	
	2017	2018	2019	2020	Coho, 2021	Chinook, 2021
<b>Basin-scale</b>						
PDO (May-Sept)	Yellow/square	Yellow/square	Red/diamond	Yellow/square	Yellow/square	Red/diamond
ONI (Jan-Jun)	Yellow/square	Green/circle	Red/diamond	Red/diamond	Red/diamond	Red/diamond
<b>Local and regional</b>						
SST anomalies	Yellow/square	Yellow/square	Red/diamond	Yellow/square	Yellow/square	Red/diamond
Deep water temp	Red/diamond	Red/diamond	Red/diamond	Red/diamond	Red/diamond	Red/diamond
Deep water salinity	Yellow/square	Green/circle	Yellow/square	Red/diamond	Red/diamond	Yellow/square
Copepod biodiversity	Red/diamond	Yellow/square	Yellow/square	Green/circle	Green/circle	Yellow/square
Northern copepod anomaly	Red/diamond	Yellow/square	Green/circle	Green/circle	Green/circle	Green/circle
Biological spring transition	Red/diamond	Red/diamond	Yellow/square	Green/circle	Green/circle	Yellow/square
Winter ichthyoplankton biomass	Yellow/square	Yellow/square	Red/diamond	Green/circle	Green/circle	Red/diamond
Winter ichthyoplankton community	Red/diamond	Red/diamond	Red/diamond	Yellow/square	Yellow/square	Red/diamond
Juvenile Chinook catch (Jun)	Red/diamond	Yellow/square	Yellow/square	Yellow/square	Yellow/square	Yellow/square
Juvenile coho catch (Jun)	Red/diamond	Green/circle	Yellow/square	Yellow/square	Yellow/square	Yellow/square

- Indicators of conditions for recent smolt years in the northern CCE
- Color = rank of all years
  - Green/circle: top third
  - Yellow/square: middle third
  - Red/diamond: bottom third
- Consistent with below-average returns of Chinook to Columbia Basin*
- Mixed signals for returns of coho to OPI area*

# “Stoplight” table for natural origin Central Valley fall Chinook: mixed signals for 2021 returns

- Links ecosystem drivers to key stages in a life cycle model for naturally produced Sacramento/San Joaquin fall Chinook (Friedman et al. 2019)
- *Conditions were mixed for the dominant year class (2018) that will return in 2021*
  - Mixed conditions also for age-5 and jacks; poor conditions for age-4



Natural spawning escapement (year <i>t</i> )	Egg incubation temperature (Oct-Dec, year <i>t</i> )	Median flow (Feb, year <i>t</i> +1)	Seabird marine predation index (year <i>t</i> +1)	Chinook age in fall 2021
2016: 56,000	11.8°	48,200 cfs	Near average	5
2017: 18,000	11.8°	5,525 cfs	Near average	4
2018: 72,000	11.7°	21,700 cfs	Near average	3
2019: 120,400	11.2°	6,030 cfs	Near average	2

## Expanded “stoplight” tables for Sacramento and Klamath fall Chinook

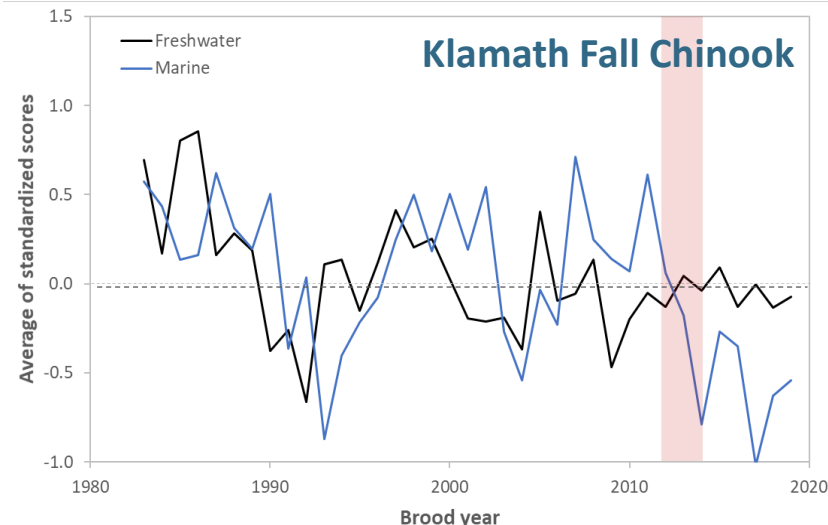
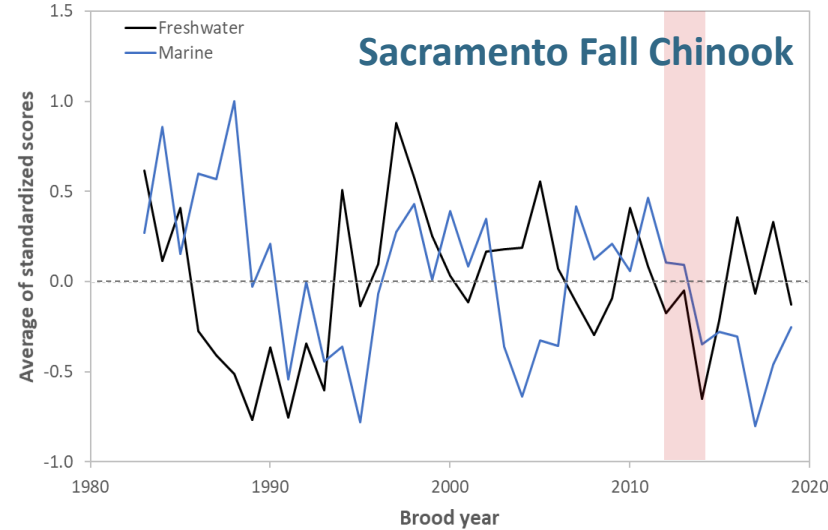
- Developed by the HC and STT in light of the rebuilding plans for these two overfished populations
- Building on other “stoplight” efforts, with freshwater, marine and hatchery-related indicator suites

## Sacramento Fall Chinook

[illegible]

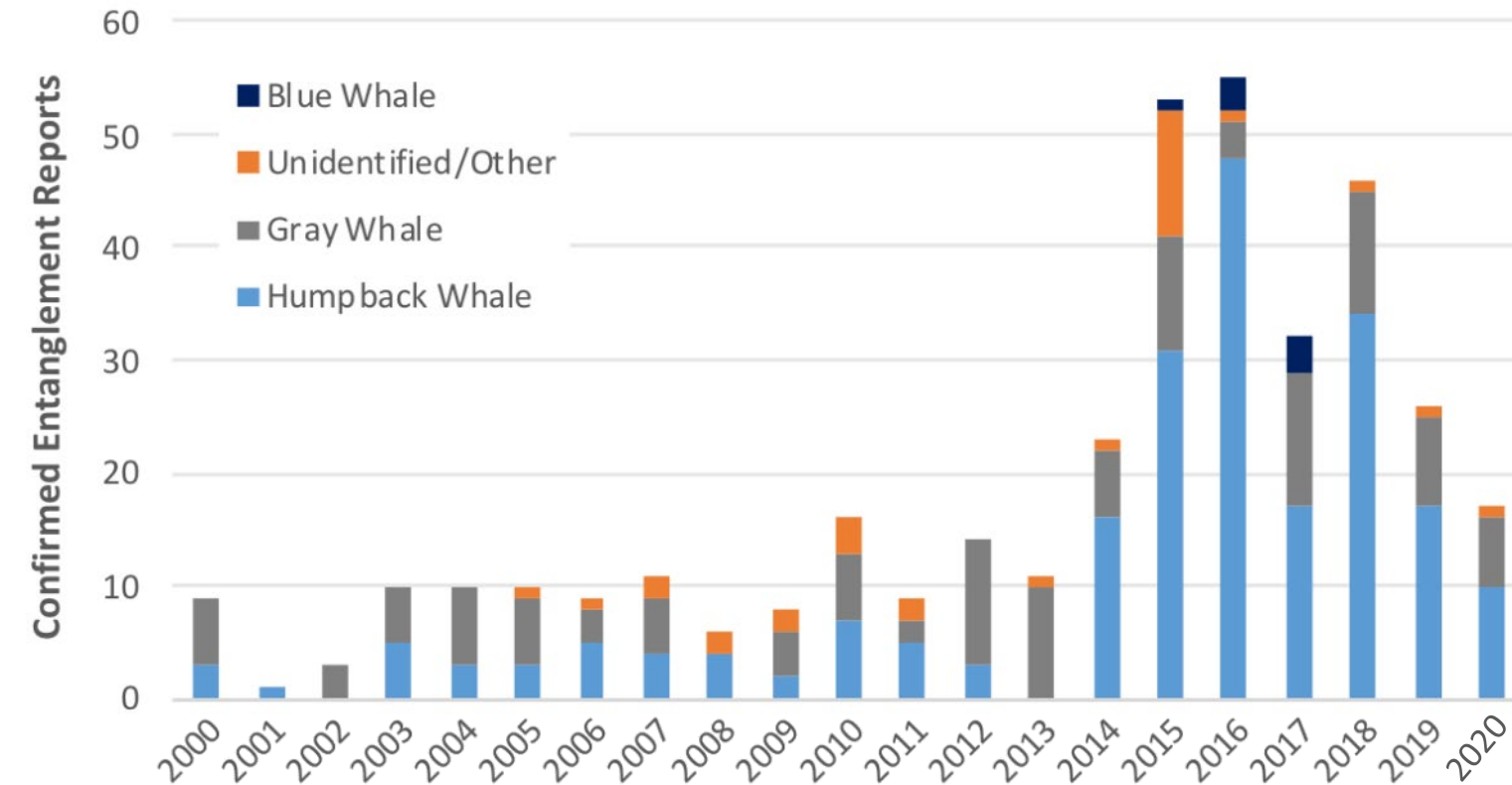
## Klamath Fall Chinook

Year	Sex	Freshwater conditions										Marine conditions					
		Adult spawners		Incubation		Freshwater residence		Saltwater release		Marine residence		Marine residence					
		Spawning	Incubation	Residence	Residence	Residence	Residence	Residence	Residence	Residence	Residence	Residence	Residence				
1984	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA				
1985	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1986	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1987	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1988	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1989	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1990	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1991	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1992	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1993	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1994	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1995	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1996	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1997	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1998	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
1999	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2000	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2001	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2002	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2003	0.40	0.13	NA	0.38	NA	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2004	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2005	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2006	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2007	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2008	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2009	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2010	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2011	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2012	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2013	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2014	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2015	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2016	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2017	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2018	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2019	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				
2020	0.40	0.13	0.19	0.20	0.31	0.00 - 0.00	0.21	0.42	0.19	0.70	0.71	0.71	0.71				



- First-cut analysis: summary plots of annual average indicator scores
- *Recent averages of marine-based indicators have declined for both populations and have been poor since the rebuilding plan (shaded)*
- *Freshwater-based indicator rankings have been near time-series averages in recent years*

# Whale entanglement reports dropped in 2020, with many possible contributing factors



- ***17 confirmed reports in 2020; down from 2015-2018***
  - May reflect precautionary mgmt actions, or shortened seasons due to HABs
  - May also reflect decrease in observation/documentation capability, due to COVID
- ***Most entanglements: humpbacks***
- ***ID'd gear: commercial Dungeness crab, commercial spot prawn, and gillnet***
  - No sablefish gear reported

courtesy Mr. Dan Lawson, NMFS West Coast Region





# Human activities and wellbeing



# Landings and ex-vessel revenue down in 2020\*

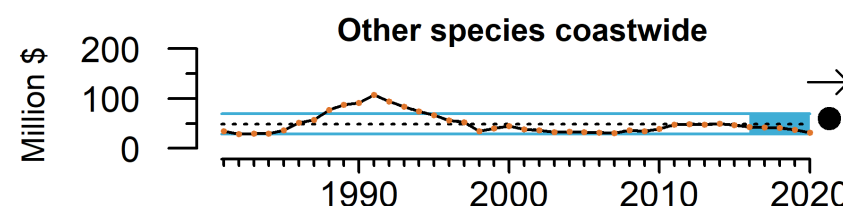
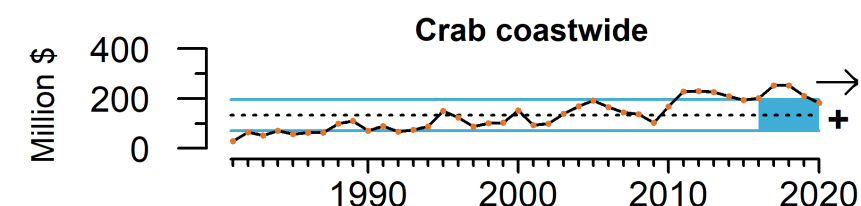
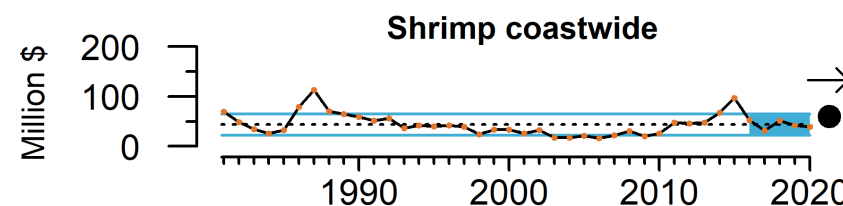
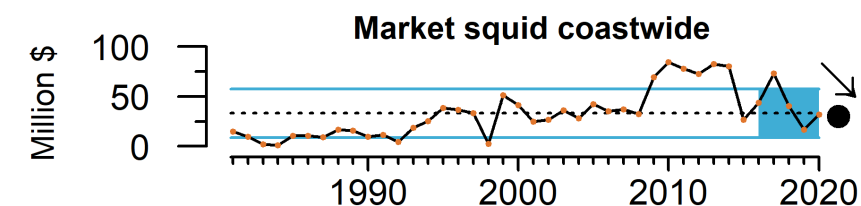
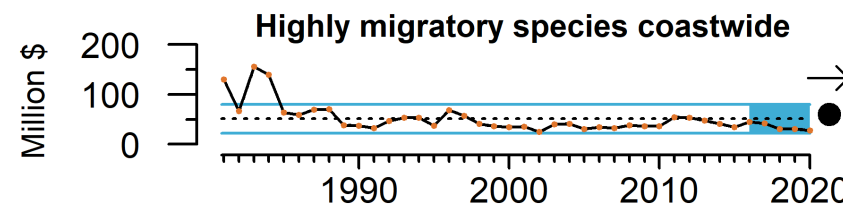
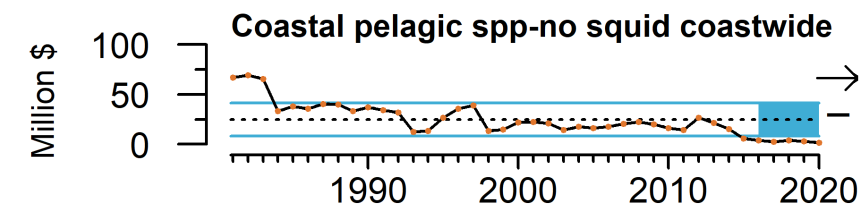
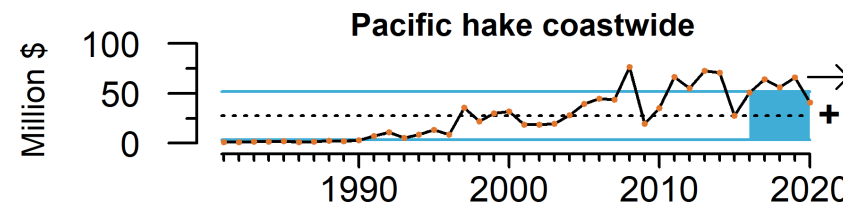
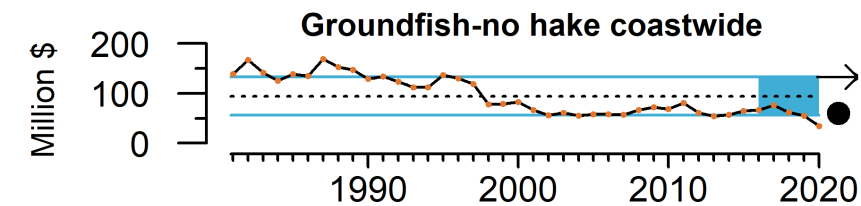
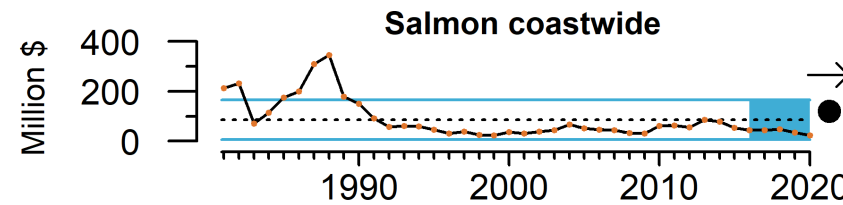
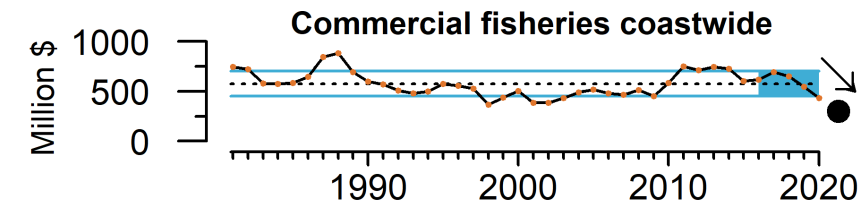
\*Based on available data, >90% complete

- Landings down 7% relative to 2019
- Revenue (left) down by 21%

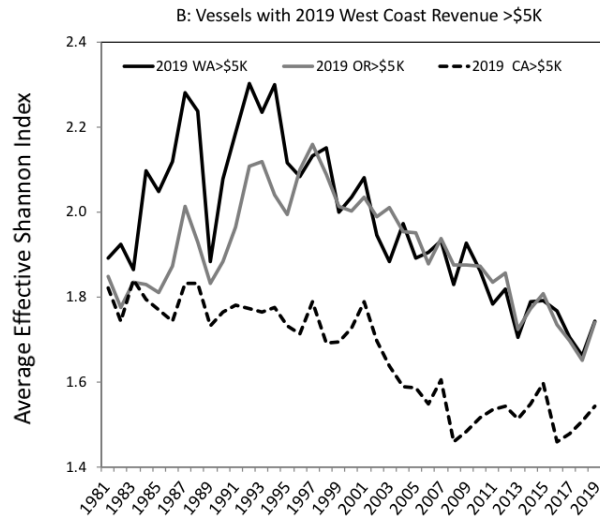
- Revenue down in most fisheries from 2019

- CPS finfish (-45%)
- Whiting (hake) (-38%)
- Non-whiting groundfish (-36%)
- Salmon (-32%)
- Other species (-14%)
- Crab (-13%)
- HMS (-10%)
- Shrimp (-6%)

- One increase in 2020
- Market squid (+91%)



# Revenue diversification and concentration

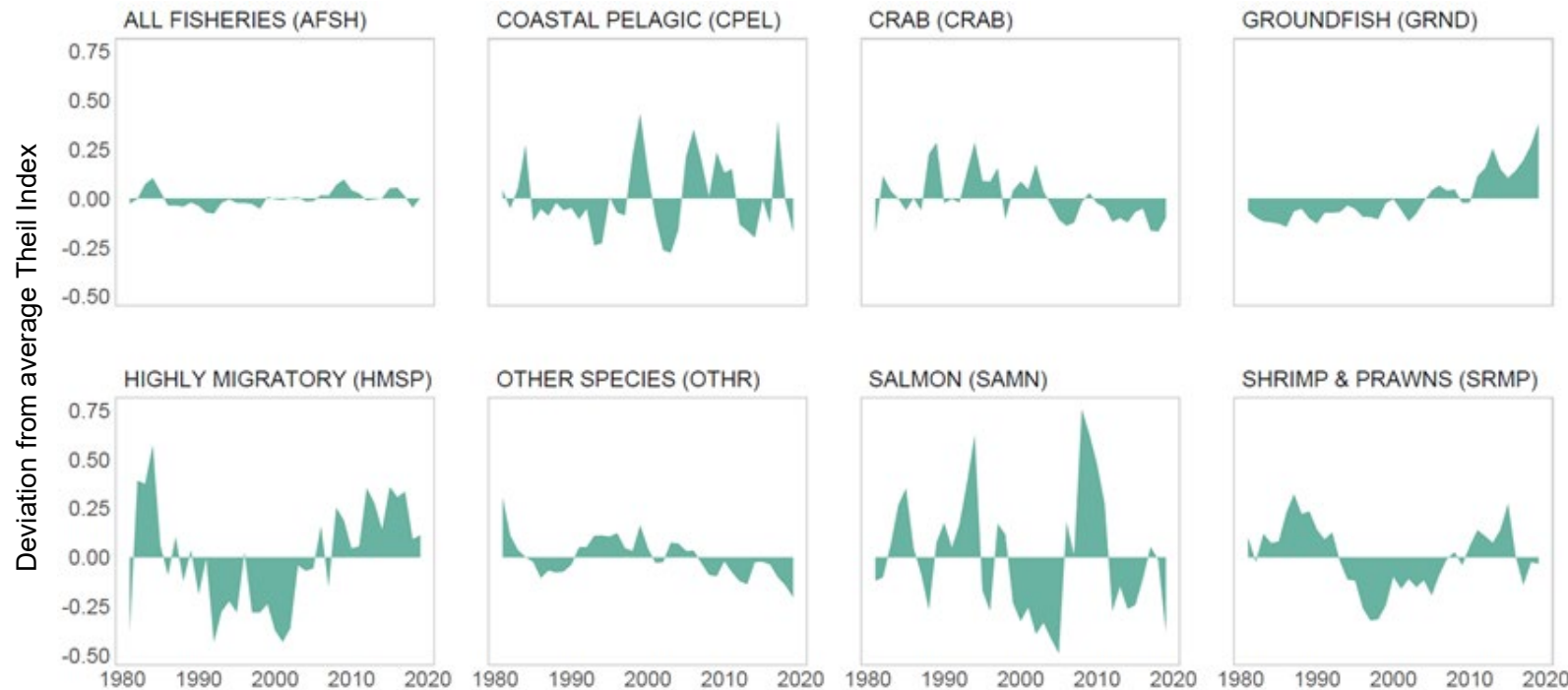


## Revenue diversification:

- Average increased slightly in all states in 2019
- But, remains low relative to time series since 1981

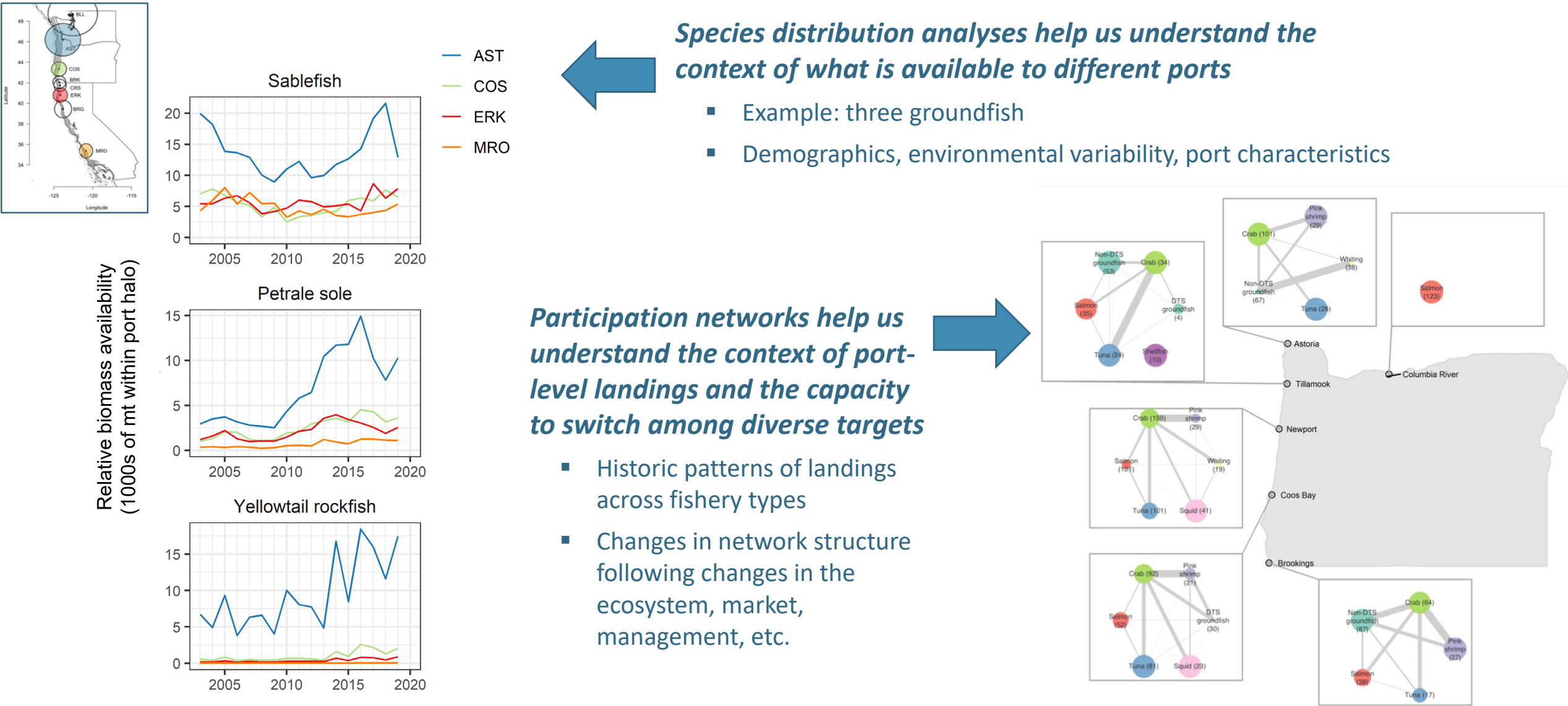
## Revenue concentration: updated analysis, using the Theil Index

- Increasing score = revenue more concentrated in certain port groups
- *Some fisheries have clear trends*
  - Groundfish and HMS: more concentration, but different patterns over time
  - Crab and Other: more equitable
  - CPS, salmon: volatility



# Species distributions and participation networks

Just like species or food webs, fisheries operate in a broader ecosystem context







# Conclusions

*cooler conditions  
sampled indices rebound  
COVID disruption*





- **In 2020, much of the CCE cooled and returned to average conditions for the first time in over five years**
  - Upwelling was stronger than in recent years, keeping a large MHW offshore until fall
  - The system still has plenty of stored heat, so there is potential for heatwave reemergence
- **Many trophic levels seemed to experience good feeding conditions, although reduced sampling effort means greater uncertainty**
  - Complementary indicators (e.g., seabirds) provide some reassurance
  - Lagging negative effects from the past several years may affect some salmon returns
- **Landings and revenue were down for most fisheries in 2020**

# Thank you

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