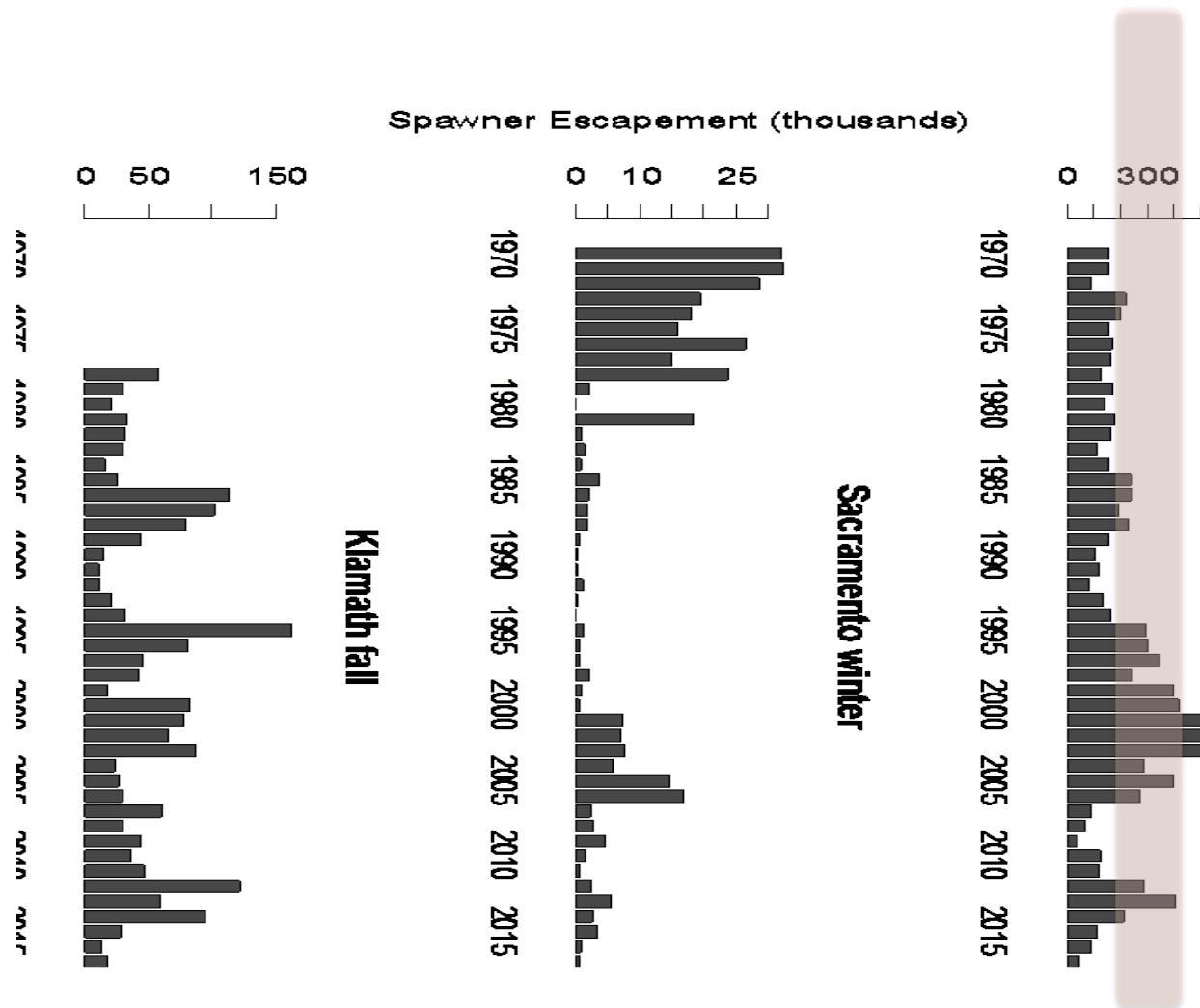


## California Chinook salmon escapements very poor in 2015, 2016, and 2017

Climate-driven  
declines in stream and  
ocean productivity  
have likely been major  
contributors



# Climate and California salmon 2014-present

**Freshwater**: California's hot drought from 2012-2016 had extensive negative impacts on salmon

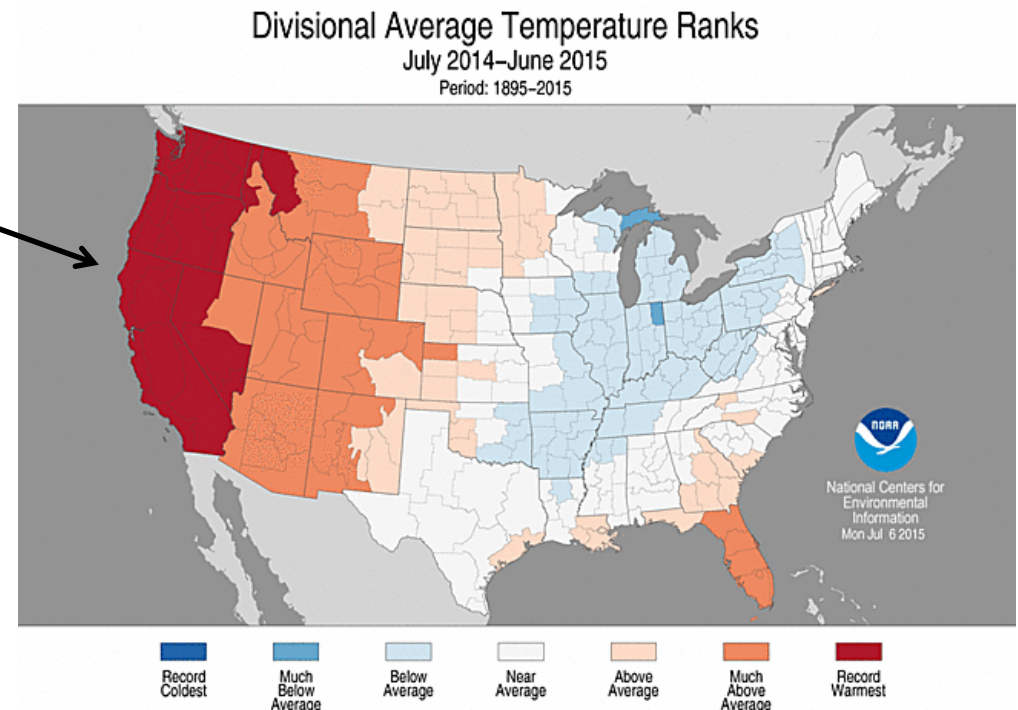
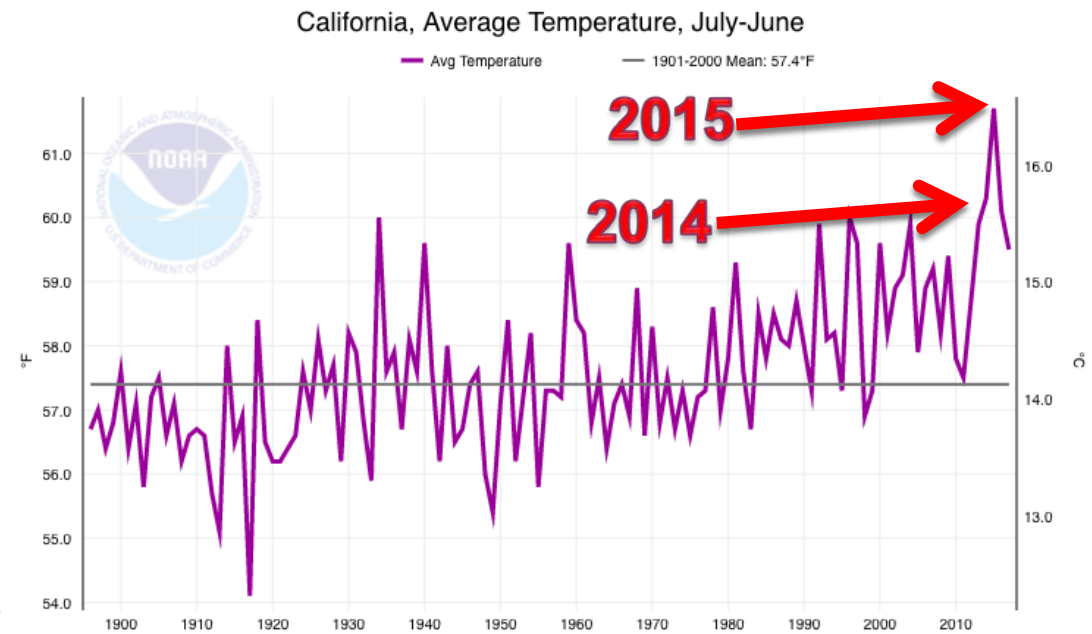
- record-low winter-run egg-to-fry survival rates in 2014-15
- high water temperature and exceptionally high disease and infection rates in Klamath salmon in 2014-15
- JSATS data showed very low outmigration survivals in 2013-14-15-16; much higher outmigration survivals in 2017

**Ocean**: record-warm ocean temperatures/subtropical conditions in 2014-2015 had extensive negative impacts

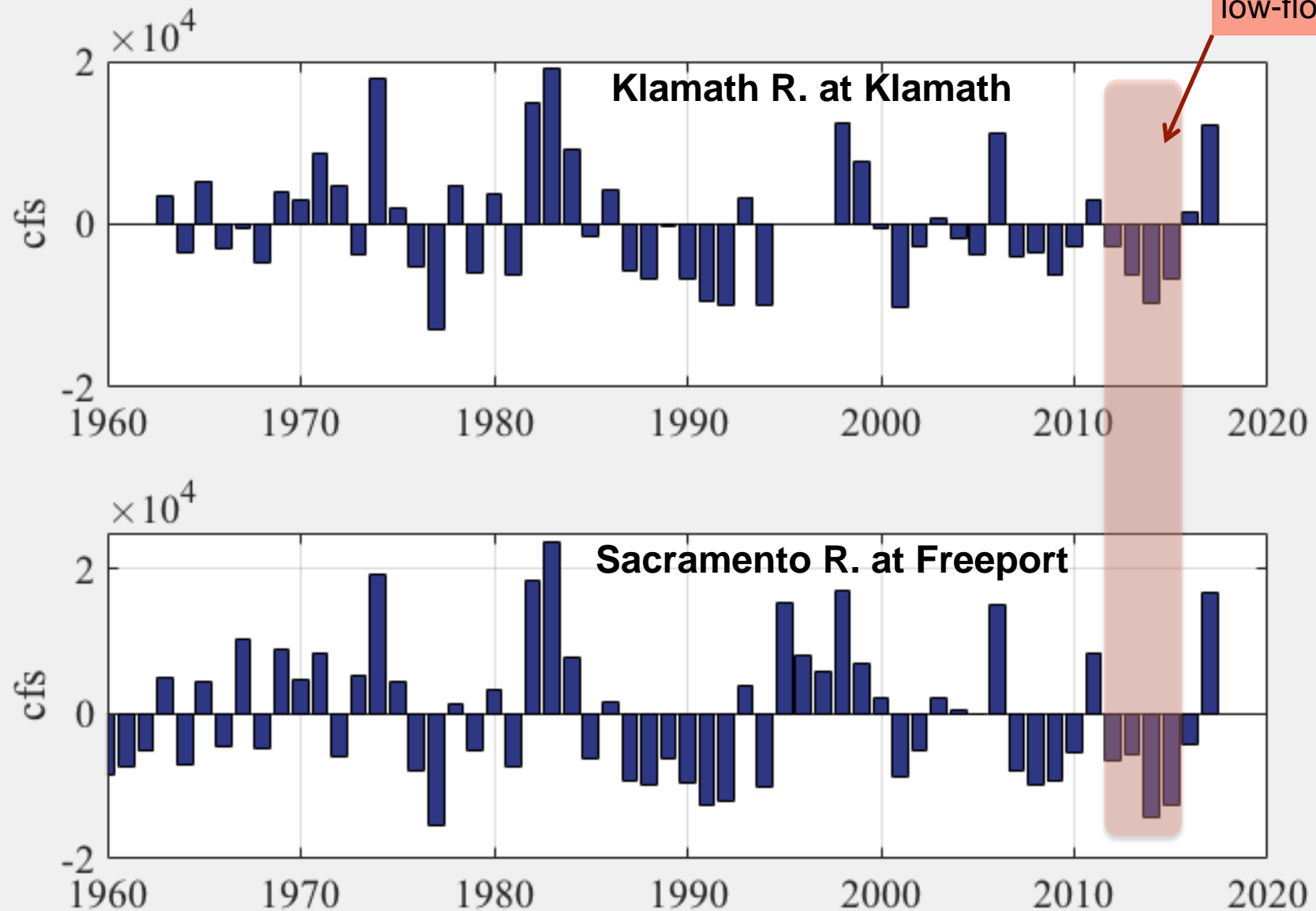
- Ocean indicators point to strong sub-tropical influences on West Coast marine life in 2014-15 coast-wide; recovery to more productive conditions south of Mendocino in 2016-17

# 2014-17: exceptionally warm years for California

- Surface air temperature record for July 2014-June 2015 was almost off the charts, ~ 1 °C warmer than the previous record
- 2015 Western Snow Drought came with record high temperatures for the entire west coast
- The “hot drought” was amplified ~30% by high temperatures
- 2016 and 2017 a bit cooler than 2014

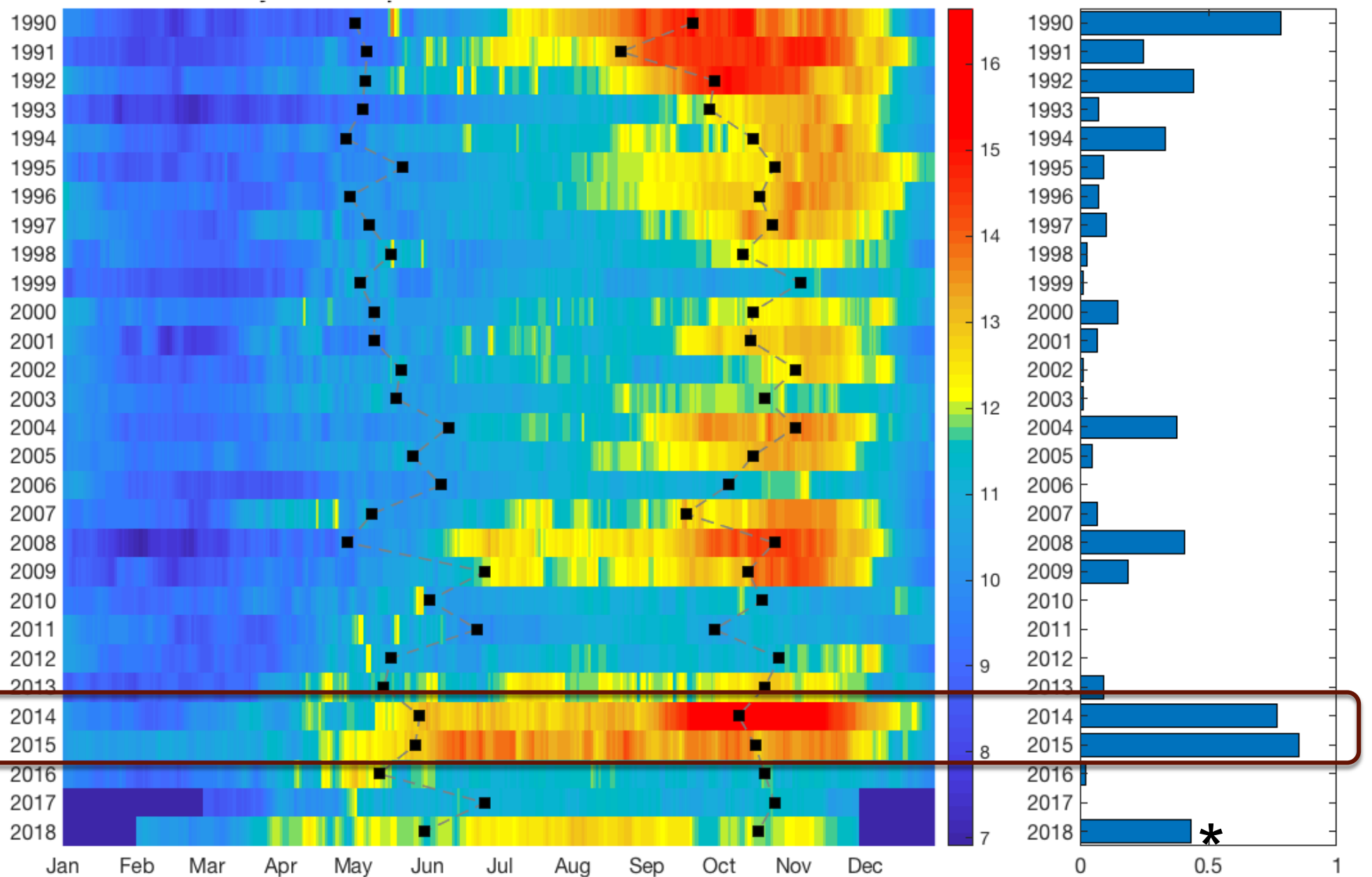


# Water year streamflow anomalies in the Klamath and Sacramento Rivers

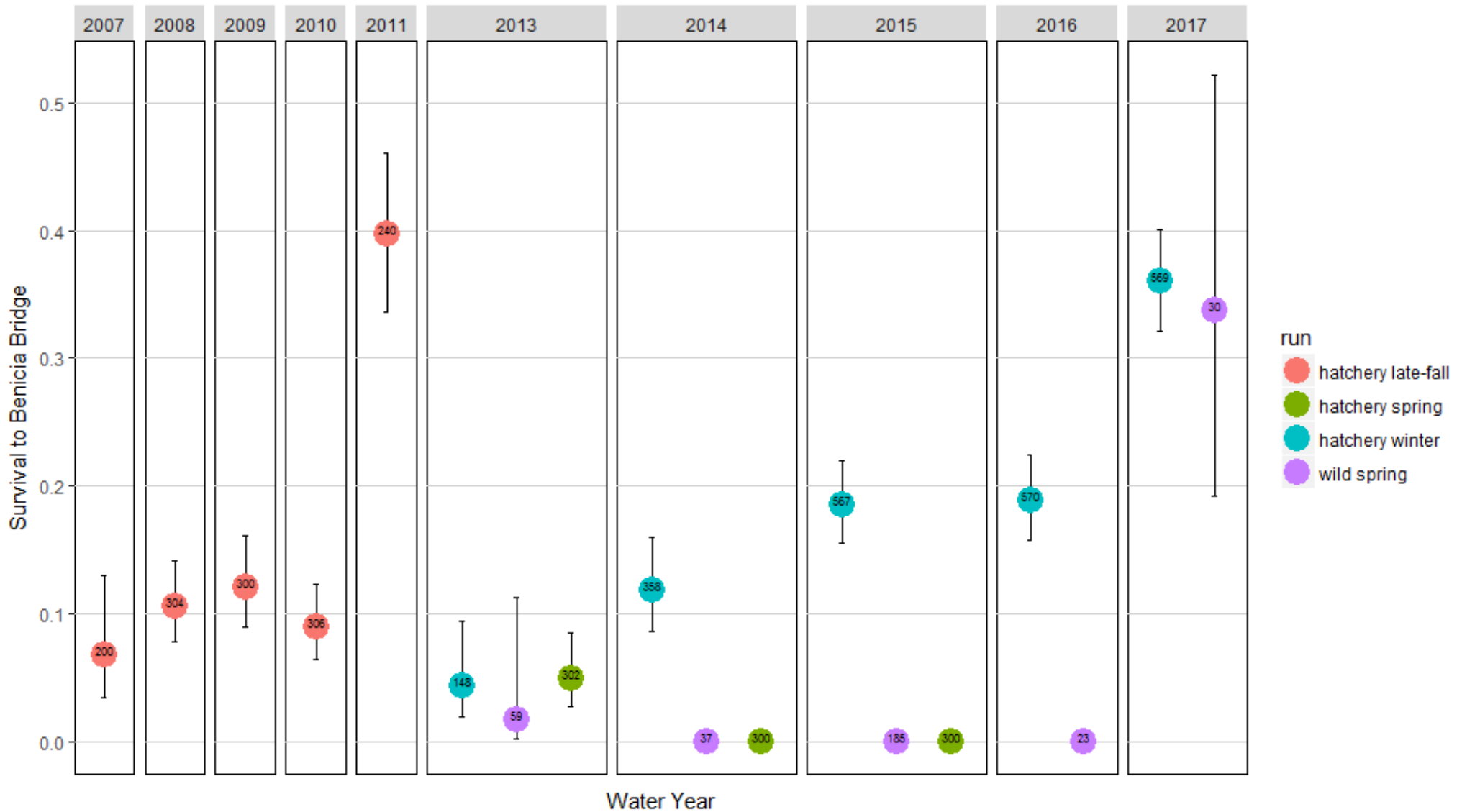


# Daily mean water temperatures in winter-run Chinook salmon spawning habitat between Keswick Dam and Clear Creek

\* Values for 2018 based on projected reservoir operations provided by the USBR.



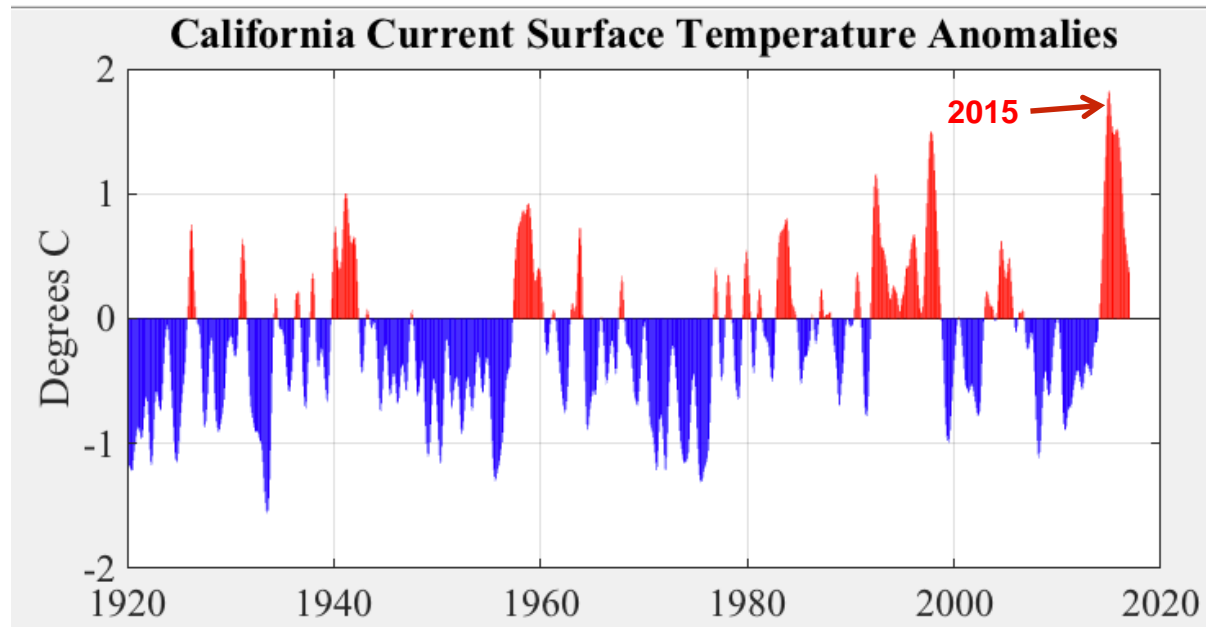
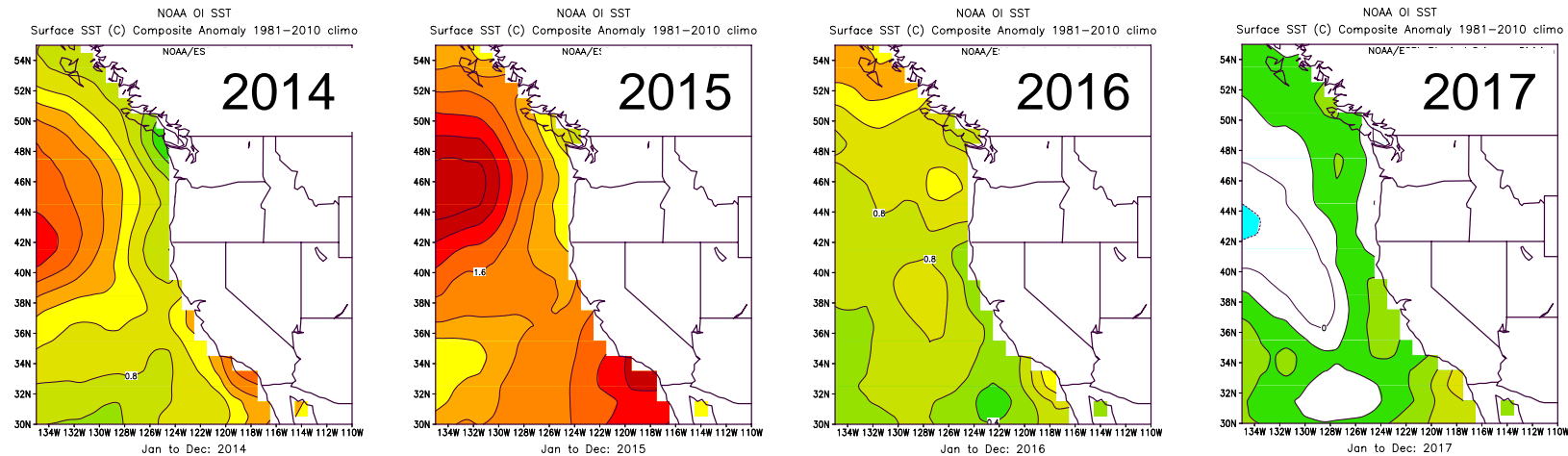
# Smolt Outmigration Survival Rates to Benicia from JSATs



## **How bad were ocean conditions for CA salmon from 2014-2017?**

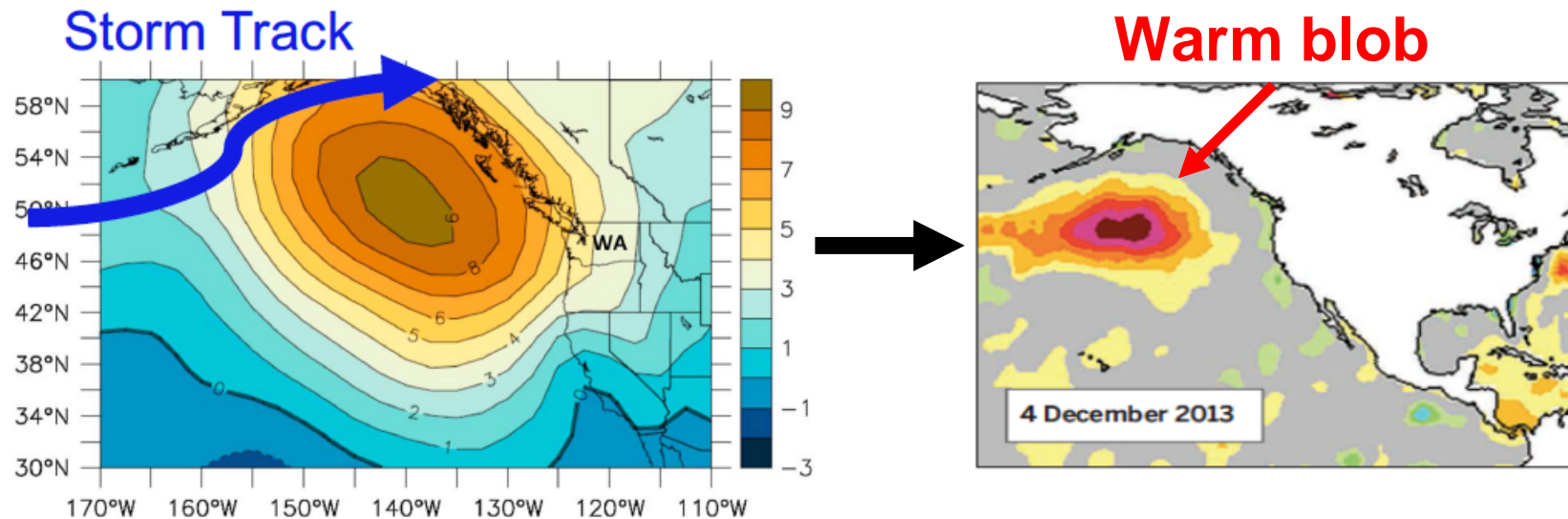
- Mostly really bad!
- Record high CCS temperatures: 2015 was the warmest year on record, 2014-2016 the warmest 3 year average
- Poor growth/survival conditions for CA salmon and many other top predators (sea lions, sea birds)
- Affected salmon abundance and fisheries 2016-2017, and will likely affect abundance through at least 2018
- High temperatures were caused by “the blob”, weak winds, and the extreme tropical El Niño in 2015-16

# Ocean temperatures from 2014-2017

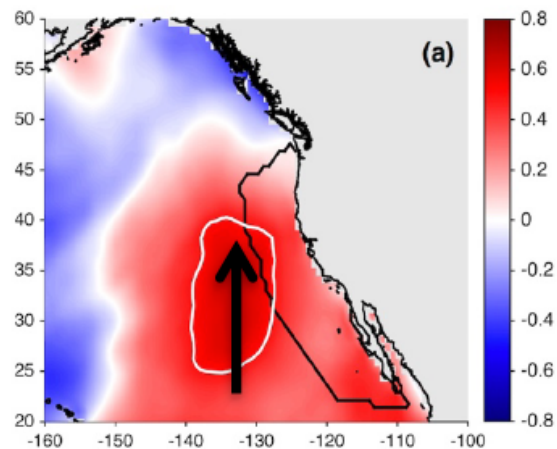




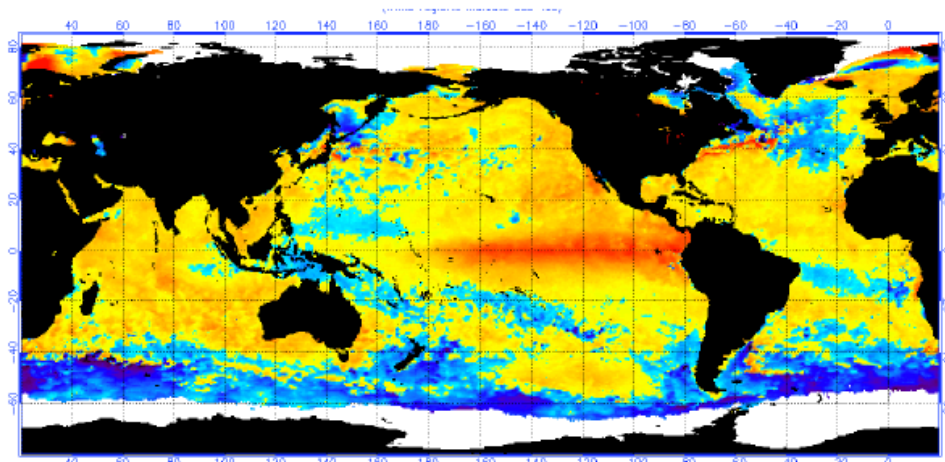
# What caused the recent extreme ocean temperatures?



High pressure ridge → Reduced storm-driven mixing → Warm Gulf of Alaska



+ Anomalous winds  
off US west coast



+ One of the strongest El Niños on record

# Biological Impacts

## Warming Pacific Makes for Increasingly Weird Ocean Life

A "blob" of warm water that's partly to blame for dead birds and stranded sea lions in the Pacific may share a cause with Boston's snows and California's drought.



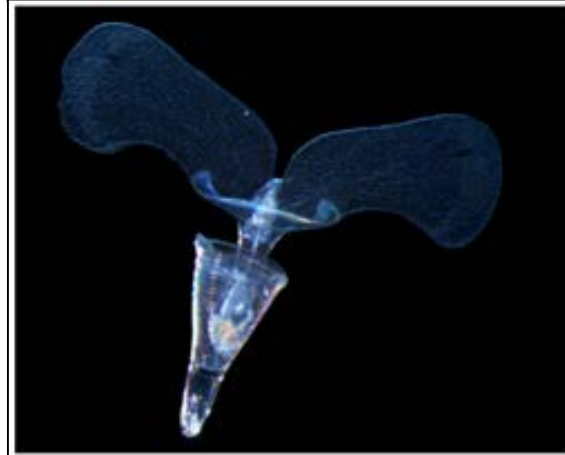
### Mysterious Sea Lion Die-Off Strikes Again on California Coast

Tiny sea lion pups are washing up on beaches in unusually high numbers—for the third winter in a row.

## Experts puzzled as 30 whales stranded in 'unusual mortality event' in Alaska

Scientists 'very concerned' and suspect toxic algae, though NOAA concedes 'bottom line is we don't know what's causing deaths'

## Unusual warm ocean conditions off California, West Coast bringing odd species



## Huge Toxic Algal Bloom Shuts Down West Coast Fisheries

## Pacific Ocean 'blob' draws scrutiny of researchers

A huge swath of unusually warm water that has spread to the normally cool Pacific has grown to the size of the entire ocean temperature anomaly on record, researchers now say, profoundly affecting climate and marine life from Baja California to Alaska.

## Record Algae Bloom Laced With Toxins is Flourishing in "The Blob" — and Spreading in the North Pacific

## Unusual species in Alaska waters indicate parts of Pacific warming dramatically

## The Gulf of Alaska is unusually warm, and weird fish are showing up



In this Aug. 29 photo, a 7-foot ocean sunfish rarely seen in Washington waters washed ashore on a beach near Ilwaco, Wash., with June Mohler, a biological technician working as an interpretative assistant. (AP Photo/Cape Disappointment State Park, Eric Wall)

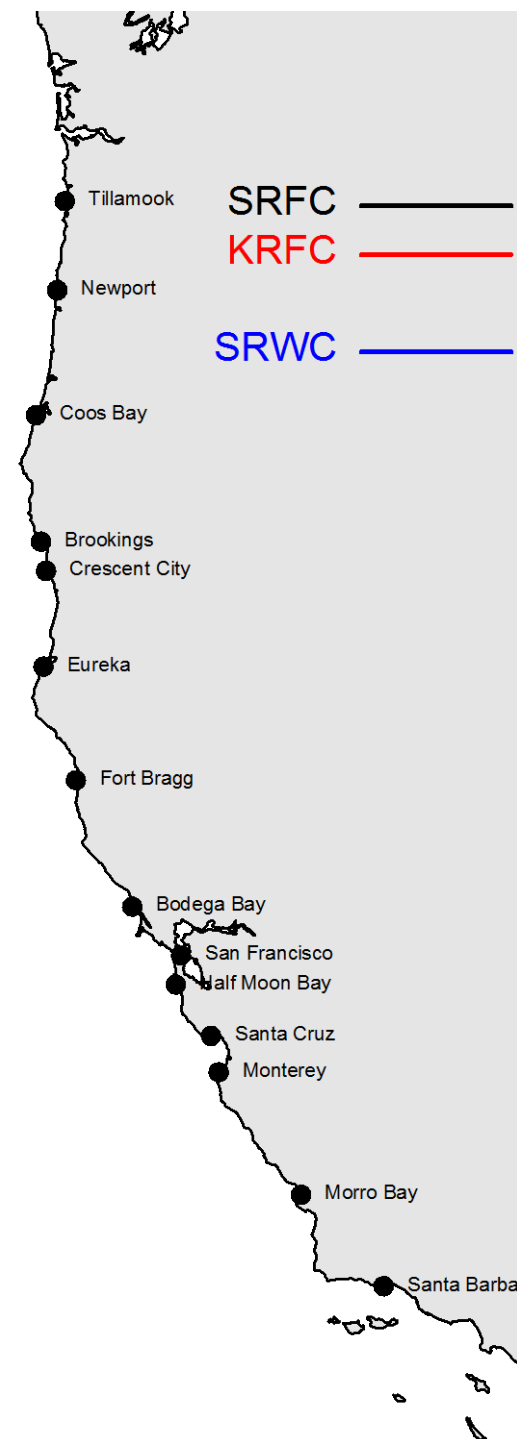
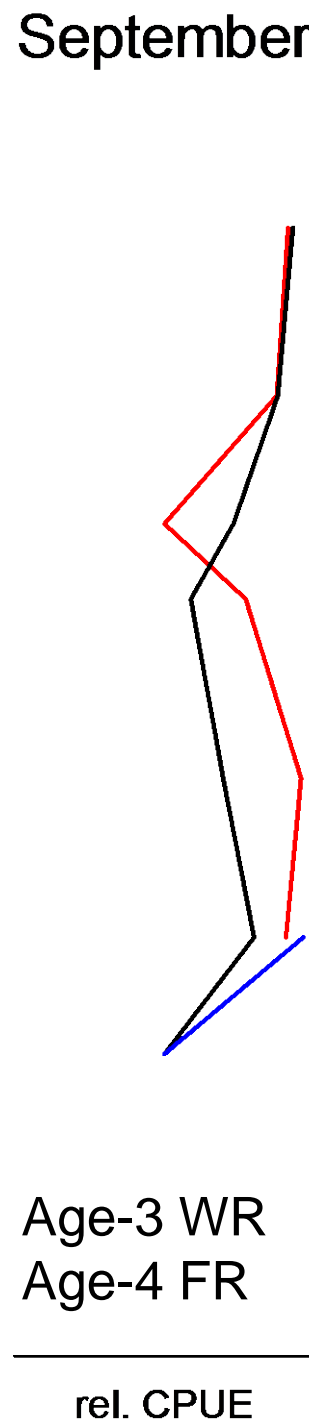
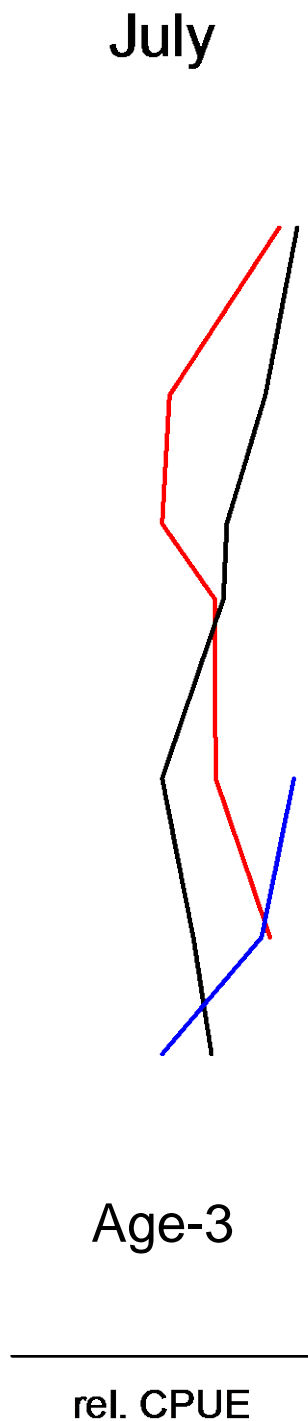
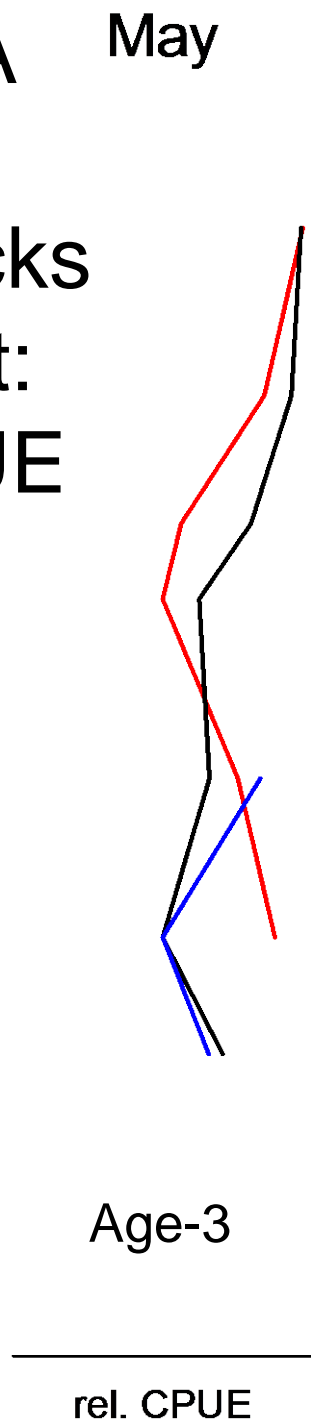


## Why are so many whales dying on California's shores?

# Where CA Chinook salmon stocks are caught: ocean CPUE

Sacramento R. stocks based on sport fishery recoveries

Klamath stocks based on commercial fisheries

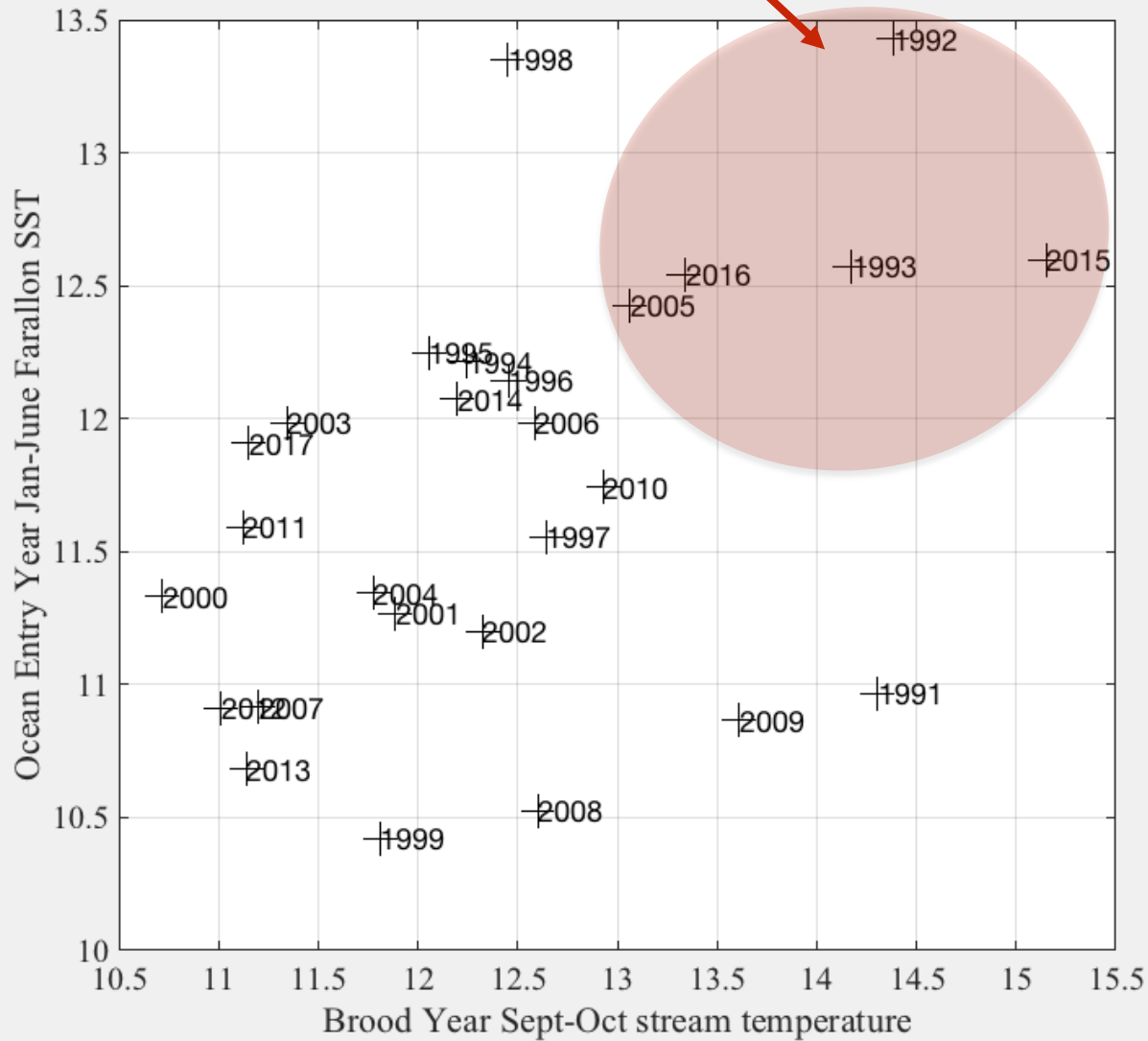


# Spring 2017 ocean conditions from the State of the CCS report: Northern CCS still unproductive, while Central/Southern CCS were near normal

Indicator	Basin	Northern CCS	Central CCS	Southern CCS
ONI	Average			
PDO	Above average			
NPGO	Near average			
NPH	Below average			
Upwelling		Below average	Average	Above average
Cumulative upwelling		Average	Below average	Average
SST		Above average	Average	Average
Chlorophyll		Below average	Average	Average
Harmful algal blooms		No	No	Yes
Copepods		Southern derived and rich	-	-
Forage		Off-shore and southern derived assemblage	Typical assemblage	Typical assemblage along with increased anchovy abundances.
Salmon survival		Below average juvenile abundance at sea	<i>Ecosystem indicators related to salmon suggest average</i>	-
Seabird productivity (2016)		Reproductive failures	Below/near average	-
Seabird at-sea abundance		Well below average	<i>Below/near average</i>	Well above average
Sea lions (2016)		Signs of recovery after the 2013 Unusual Mortality Event		
Whales		Humpback whales distributed shoreward		



Especially bad combinations of extreme warm stream temperature and ocean temperature for the same brood year



- This plot shows brood year stream temperature between Keswick and Clear Creek for Sept-Oct against January—June ocean entry year SST at the Farallon Islands
- Year labels indicate ocean entry years (Brood Year+1)
- Note the relative lack of extreme Sept-Oct stream temperatures after 1993 (TCD was installed in 1996-97), **until 2014/15**
- **These data suggest that brood years 1991, 1992, and 2014 experienced the 3 worst combined stream/ocean temperature conditions for Central Valley salmon going back to 1990 (when our RAFT-based stream temperature record begins)**

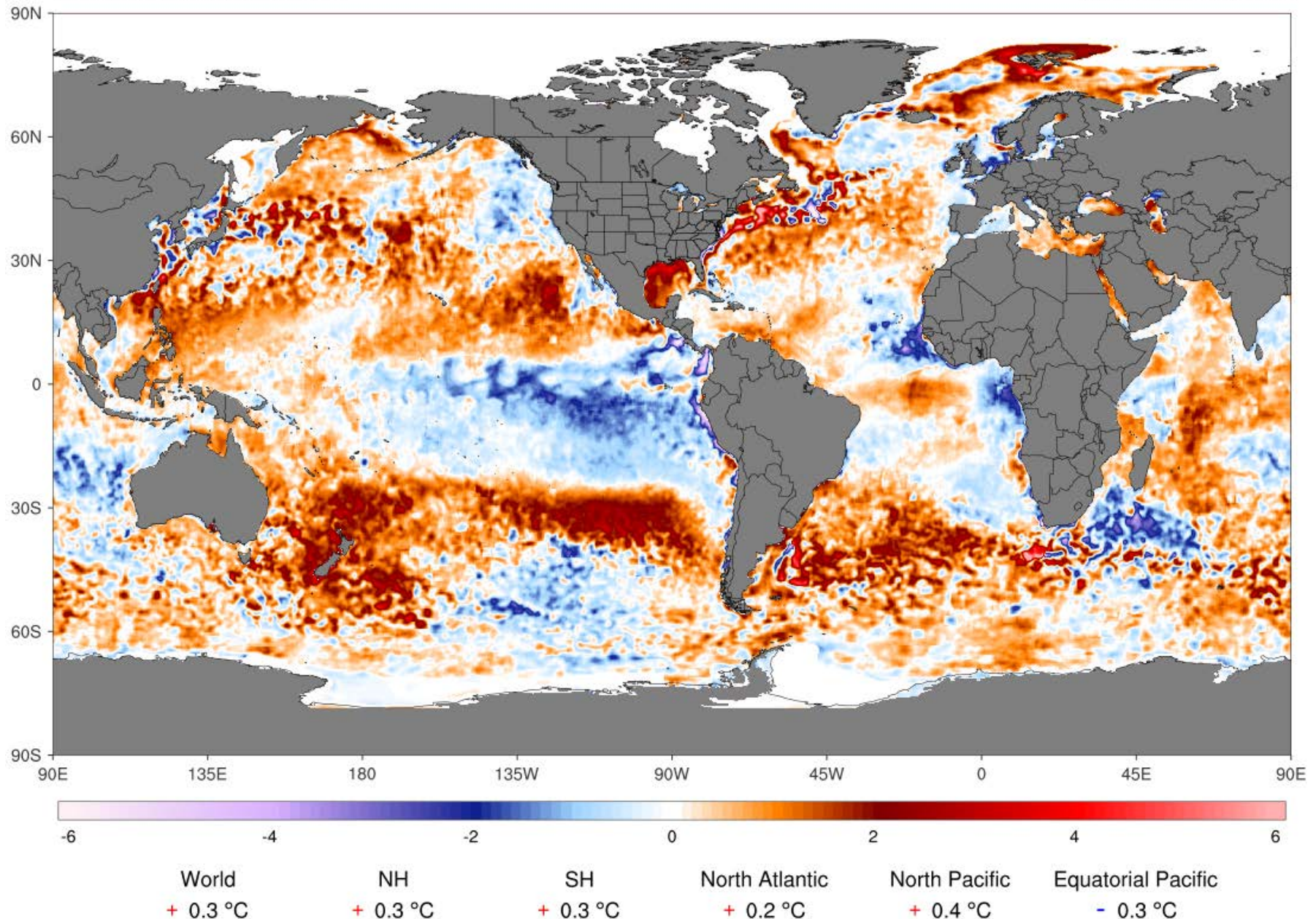
# A climate timeline for California's salmon

2013	2014	2015	2016	2017	2018
Yr 2 CA drought, carryover storage	Year 3 CA drought, record heat	West Coast "snow drought" record heat	Near average precip and snowpack but warm w/an early melt	A very wet year with abundant snowpack; refill reservoirs	Extremely warm/dry/low snow; good carryover storage
Cold productive NE Pacific	NEP in transition from good to bad	Record warm SSTs, ecosystem stress	A still warm unproductive NEP, but not as extreme	good productivity south of Mendocino	Near normal SSTs; no info on productivity yet
BY 2013 Chinook	Smolt migration	Ocean year 2	Ocean year 3, most return	Ocean year 4	
	BY 2014 Chinook	Smolt migration	Ocean year 2	Ocean year 3, most return	Ocean year 4
		BY2015 Chinook	Smolt migration	Ocean Year 2	Ocean year 3 Most return

Tropical La Niña has been fading, while persistently strong and cold north winds in late February brought West Coast ocean temperatures back to normal

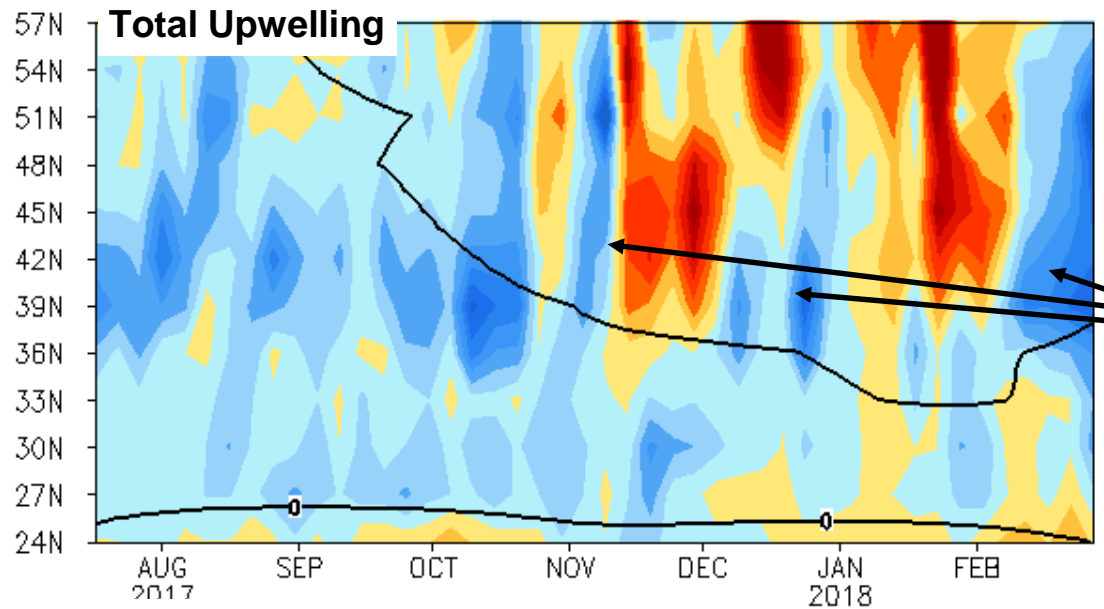
ClimateReanalyzer.org  
University of Maine | Climate Change Institute

OISST 1-day Avg SST Anomaly (°C) [1971-2000 base]  
Monday, Mar 05, 2018

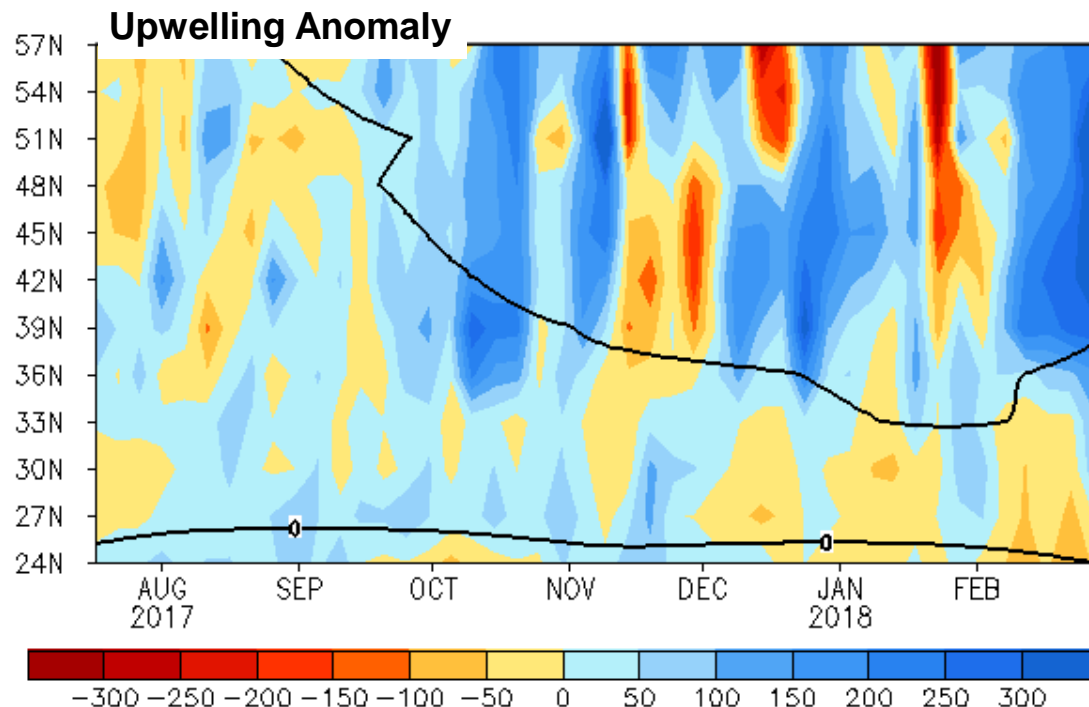




**Pentad Coastal Upwelling for West Coast North America**  
(m<sup>3</sup>/s/100m coastline)



- Fall 2017-Winter 2018 “downwelling” was very weak and intermittent (persistent high pressure ridge blocked storms that come with intense south winds)
- Frequent periods of upwelling along the US West Coast in October, December, and February



- Note the prevalence of blue shading in the upwelling anomaly plot going back to September 2017 – fall/winter downwelling has been weak, while fall/winter upwelling has been unusually strong and frequent



The latest climate model forecasts for North Pacific ocean temperatures are extraordinary: many models are predicting a rapid warming for much of the North Pacific in spring/summer 2018

### North American Multi-model ensemble SST forecast for May-June-July 2018

