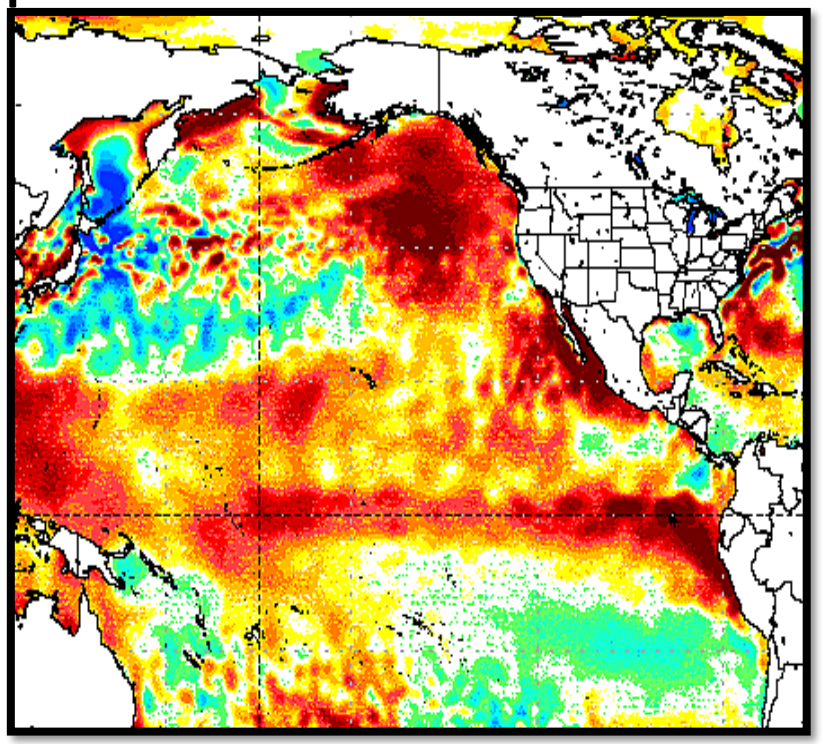
# The saga continues:
# recent ocean conditions and biological response in the NE Pacific Ocean

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Northwest Fisheries Science Center
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# Today's talk

Latest stoplight table

Physical conditions across the North Pacific

- The blob, El Niños, La Niñas, recent SSTs

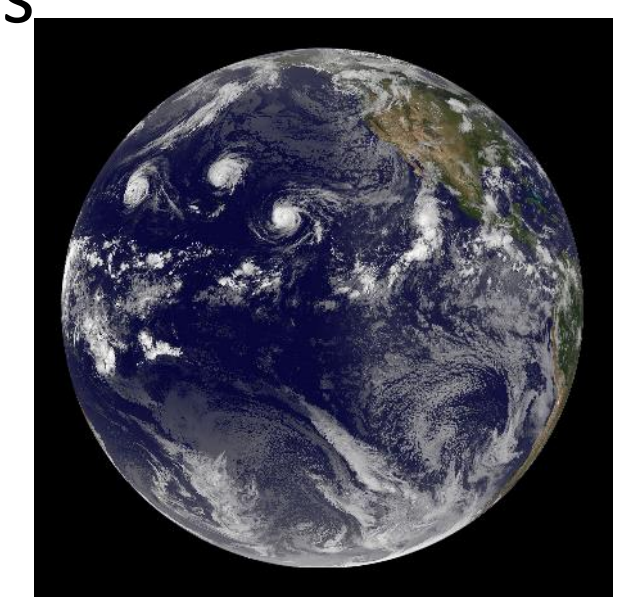
Salmon marine distributions

Biological response to physical conditions

Forecasts

- El Niño-Southern Oscillation (ENSO)
- Sea surface temperatures (SSTs)

Summary



# Bill Peterson's stoplight table

## Salmon ocean entry year

| | *Ecosystem Indicators* | *1998* | *1999* | *2000* | *2001* | *2002* | *2003* | *2004* | *2005* | *2006* | *2007* | *2008* | *2009* | *2010* | *2011* | *2012* | *2013* | *2014* | *2015* | *2016* | *2017* | *2018* | *2019* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ocean basin | PDO (Sum Dec-March) | 19 | 6 | 3 | 13 | 7 | 21 | 12 | 17 | 14 | 9 | 5 | 1 | 16 | 4 | 2 | 8 | 10 | 22 | 20 | 18 | 11 | 15 |
| | PDO (Sum May-Sept) | 10 | 4 | 6 | 5 | 11 | 17 | 16 | 18 | 12 | 14 | 2 | 9 | 7 | 3 | 1 | 8 | 20 | 22 | 21 | 15 | 13 | 19 |
| | ONI (Average Jan-June) | 21 | 1 | 1 | 7 | 14 | 16 | 15 | 17 | 9 | 12 | 3 | 11 | 18 | 4 | 6 | 8 | 10 | 19 | 22 | 13 | 5 | 20 |
| Physical | SST NDBC buoys (°C; May-Sept) | 17 | 6 | 8 | 4 | 5 | 11 | 22 | 12 | 2 | 14 | 1 | 10 | 3 | 7 | 9 | 16 | 20 | 19 | 18 | 13 | 15 | 21 |
| | Upper 20 m T (°C; Nov-Mar) | 21 | 11 | 8 | 10 | 6 | 15 | 16 | 13 | 12 | 5 | 1 | 9 | 18 | 4 | 3 | 7 | 2 | 22 | 20 | 19 | 14 | 17 |
| | Upper 20 m T (°C; May-Sept) | 16 | 11 | 13 | 4 | 1 | 3 | 22 | 19 | 8 | 10 | 2 | 5 | 17 | 7 | 6 | 18 | 20 | 9 | 14 | 12 | 15 | 21 |
| | Deep temperature (°C; May-Sept) | 22 | 6 | 8 | 4 | 1 | 10 | 12 | 16 | 11 | 5 | 2 | 7 | 14 | 9 | 3 | 15 | 21 | 19 | 13 | 18 | 20 | 17 |
| | Deep salinity (May-Sept) | 21 | 3 | 11 | 4 | 5 | 18 | 19 | 12 | 7 | 1 | 2 | 16 | 20 | 15 | 14 | 13 | 22 | 17 | 9 | 8 | 6 | 10 |
| Biological | Copepod richness anom. (no. species; May-Sept) | 20 | 2 | 1 | 7 | 6 | 15 | 14 | 19 | 16 | 10 | 8 | 9 | 18 | 4 | 5 | 3 | 11 | 21 | 22 | 17 | 13 | 12 |
| | N. copepod biomass anom. (mg C $m^{-3}$; May-Sept) | 20 | 15 | 11 | 12 | 4 | 17 | 14 | 21 | 16 | 13 | 7 | 10 | 9 | 1 | 3 | 5 | 6 | 18 | 22 | 19 | 8 | 2 |
| | S. copepod biomass anom. (mg C $m^{-3}$; May-Sept) | 22 | 2 | 5 | 4 | 3 | 15 | 16 | 21 | 14 | 10 | 1 | 7 | 17 | 9 | 8 | 6 | 11 | 19 | 20 | 18 | 13 | 12 |
| | Biological transition (day of year) | 19 | 11 | 6 | 7 | 8 | 15 | 12 | 20 | 14 | 3 | 1 | 2 | 17 | 4 | 9 | 5 | 10 | 21 | 21 | 18 | 13 | 15 |
| | Nearshore Ichthyoplankton (mg C 1,000 $m^{-3}$; Jan-Mar) | 17 | 3 | 11 | 6 | 1 | 21 | 22 | 15 | 8 | 17 | 3 | 13 | 2 | 7 | 5 | 10 | 19 | 14 | 15 | 12 | 9 | 20 |
| | Nearshore & offshore Ichthyoplankton community index (PCO axis 1 scores; Jan-Mar) | 11 | 6 | 5 | 9 | 8 | 13 | 16 | 20 | 1 | 14 | 3 | 12 | 15 | 4 | 2 | 7 | 10 | 18 | 21 | 22 | 17 | 19 |
| | Chinook salmon juvenile catches (no. $km^{-1}$; June) | 20 | 4 | 5 | 17 | 8 | 12 | 18 | 21 | 13 | 11 | 1 | 6 | 7 | 16 | 2 | 3 | 10 | 14 | 19 | 22 | 15 | 9 |
| | Coho salmon juvenile catches (no. $km^{-1}$; June) | 20 | 8 | 14 | 6 | 7 | 3 | 17 | 21 | 18 | 4 | 5 | 10 | 11 | 16 | 19 | 1 | 13 | 9 | 15 | 22 | 2 | 12 |
| | Mean of ranks | 18.5 | 6.2 | 7.3 | 7.4 | 5.9 | 13.9 | 16.4 | 17.6 | 10.9 | 9.5 | 2.9 | 8.6 | 13.1 | 7.1 | 6.1 | 8.3 | 13.4 | 17.7 | 18.3 | 16.6 | 11.8 | 15.1 |
| | Rank of the mean rank | 22 | 4 | 6 | 7 | 2 | 15 | 17 | 19 | 11 | 10 | 1 | 9 | 13 | 5 | 3 | 8 | 14 | 20 | 21 | 18 | 12 | 16 |

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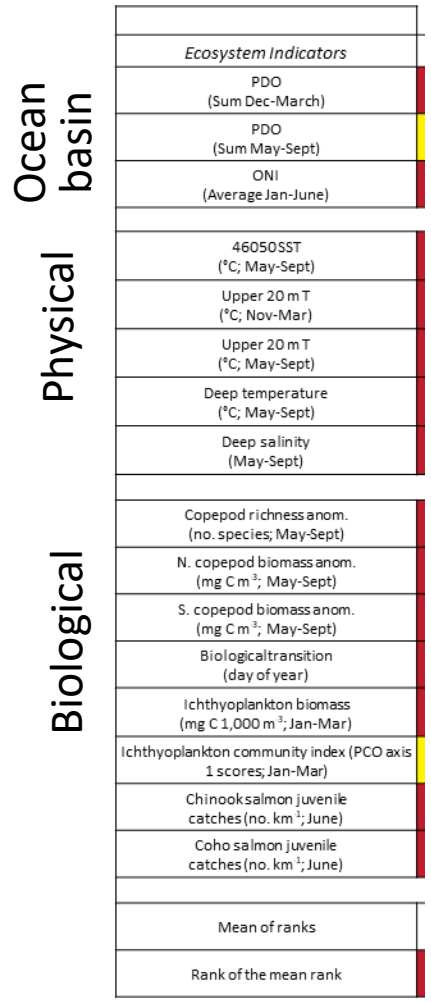
# What promotes rapid growth & survival?




## Indicators

Ocean-basin scale
Seasonal PDO
=NE Pacific SST
El Niño index

Physical indicators
Seasonal sea surface temp Deep temps & salinity

Biological
Copepods (zooplankton)
Ichthyolankton (=salmon food)
Juvenile salmon catches

## "Good" conditions

**Cold** water along West Coast before/after spring outmigration, no El Niño

**Cold** & salty water off Newport, OR)

Lots of lipid-rich copepods & good salmon prey, early onset of upwelling, lots of juvenile salmon in June

# Bill Peterson's stoplight table

Salmon ocean entry year

1997/98 El Niño

Good

Bad

Good

| | Ecosystem Indicators | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ocean basin | (Sum | | 6 | | | 7 | 21 | 12 | 17 | 14 | 9 | 5 | 1 | 16 | 4 | 2 | 8 | 10 | 22 | 20 | 18 | 11 | 15 |
| | (Sum | | 4 | | | 11 | | | 18 | 12 | 14 | 2 | | | | 1 | 8 | 20 | 22 | 21 | 15 | 13 | 19 |
| | (Avera | | 1 | 1 | 7 | 14 | | | 17 | 9 | 12 | 3 | | | | 6 | 8 | 10 | 19 | 22 | 13 | 5 | 20 |
| Physical | SST NDBC buoys (°C; May-Sept) | 17 | 6 | 8 | 4 | 5 | 11 | 22 | 12 | 2 | 14 | 1 | 10 | 3 | 7 | 9 | 16 | 20 | 19 | 18 | 13 | 15 | 21 |
| | Upper 20 m T (°C; Nov-Mar) | 21 | 11 | 8 | 10 | 6 | 15 | 16 | 13 | 12 | 5 | 1 | 9 | 18 | 4 | 3 | 7 | 2 | 22 | 20 | 19 | 14 | 17 |
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| | Deep temperature (°C; May-Sept) | 22 | 6 | 8 | 4 | 1 | 10 | 12 | 16 | 11 | 5 | 2 | 7 | 14 | 9 | 3 | 15 | 21 | 19 | 13 | 18 | 20 | 17 |
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| Biological | Copepod richness anom. (no. species; May-Sept) | 20 | 2 | 1 | 7 | 6 | 15 | 14 | 19 | 16 | 10 | 8 | 9 | 18 | 4 | 5 | 3 | 11 | 21 | 22 | 17 | 13 | 12 |
| | N. copepod biomass anom. (mg C $m^{-3}$; May-Sept) | 20 | 15 | 11 | 12 | 4 | 17 | 14 | 21 | 16 | 13 | 7 | 10 | 9 | 1 | 3 | 5 | 6 | 18 | 22 | 19 | 8 | 2 |
| | S. copepod biomass anom. (mg C $m^{-3}$; May-Sept) | 22 | 2 | 5 | 4 | 3 | 15 | 16 | 21 | 14 | 10 | 1 | 7 | 17 | 9 | 8 | 6 | 11 | 19 | 20 | 18 | 13 | 12 |
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Salmon ocean entry year

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Blob and after effects

Marine heat wave

**Bottom line: 5+ years of unfavorable ocean conditions, no obvious end in sight**

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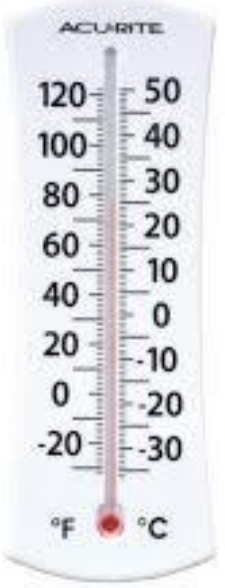
# Physical conditions across the North Pacific

Drivers of physical conditions

- Formation of the blob
- El Niño and La Niñas

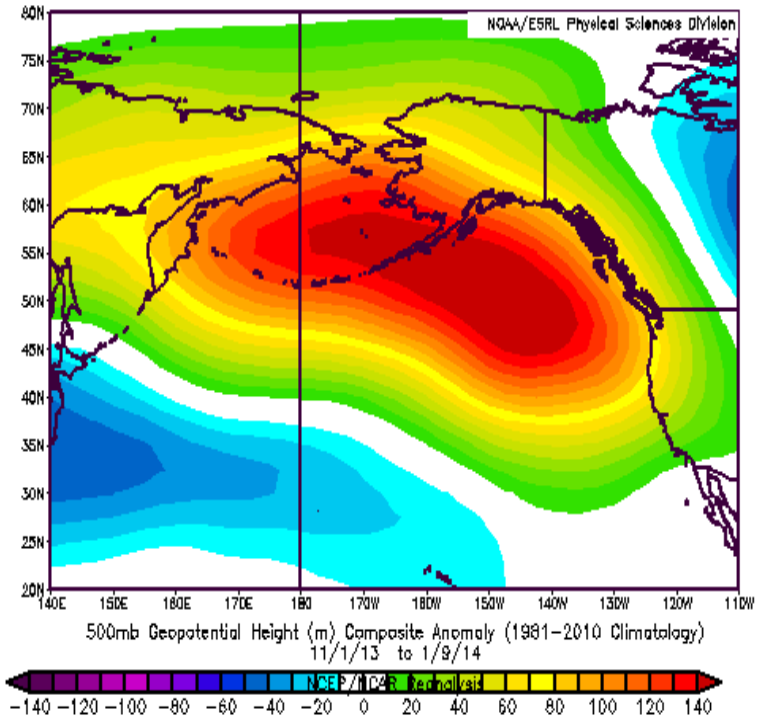
Recent sea surface temperature (SST) anomalies



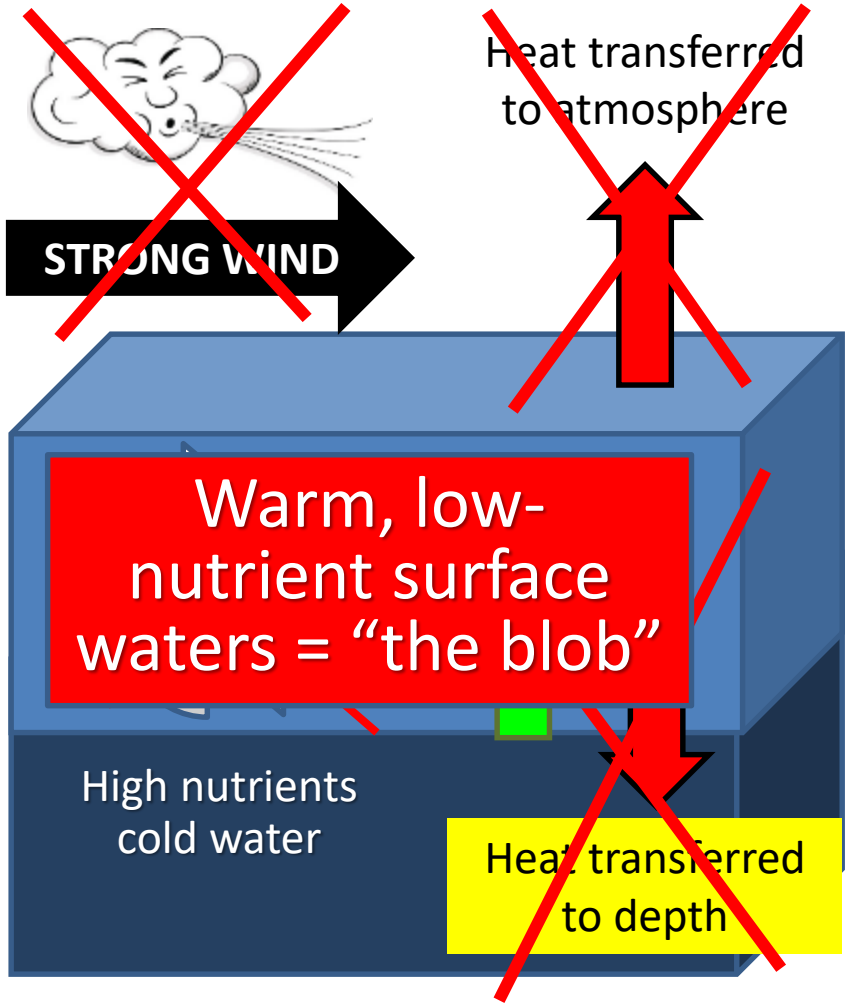
# How the blob formed (Winter 2013/14)

Unusually stationary high pressure over the North Pacific blocked storms, which limited vertical mixing

**Ridiculously resilient ridge**

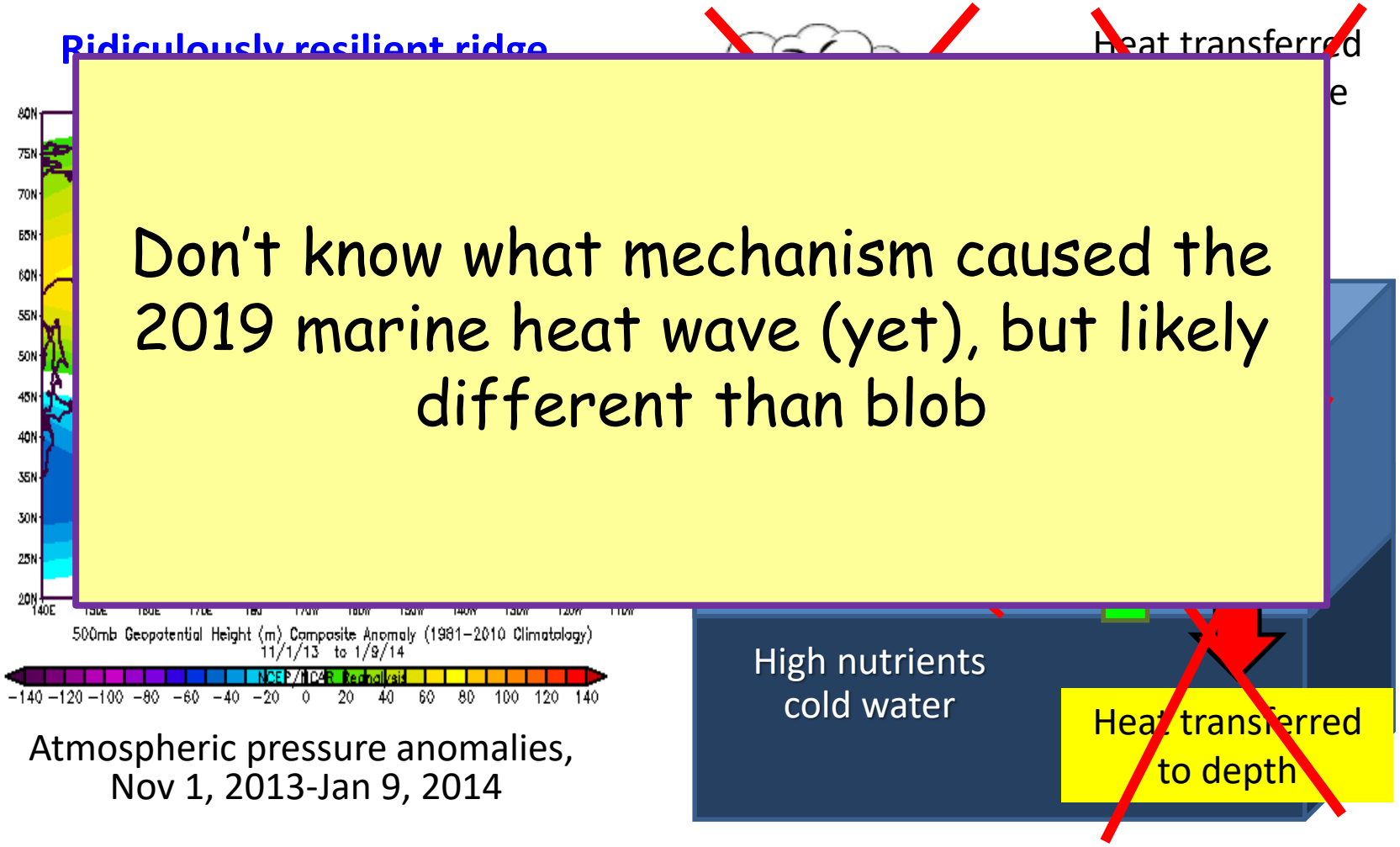



Atmospheric pressure anomalies, Nov 1, 2013-Jan 9, 2014



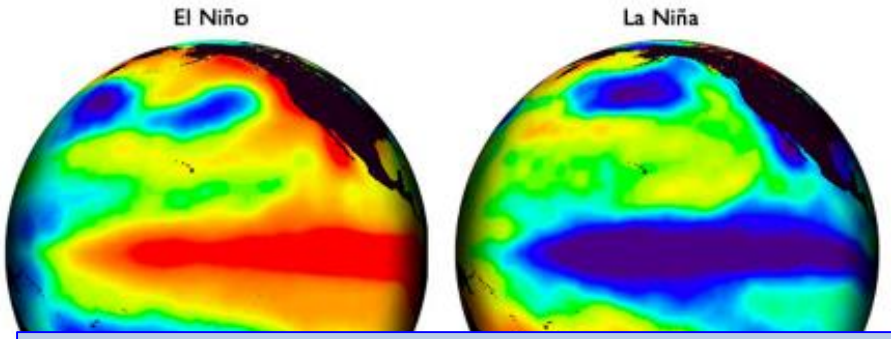
# How the blob formed (Winter 2013/14)

Unusually stationary high pressure over the North Pacific blocked storms, which limited vertical mixing




Atmospheric pressure anomalies, Nov 1, 2013-Jan 9, 2014

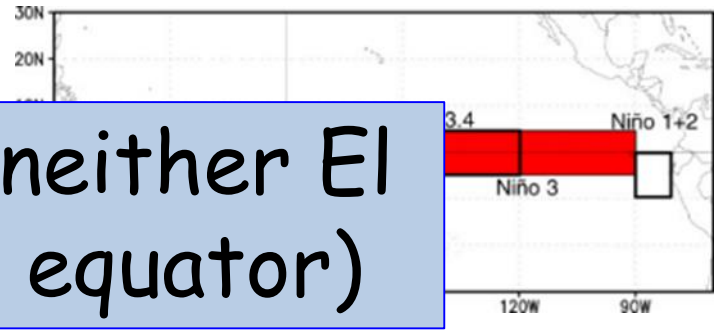
# El Niños and La Niñas: Tropical phenomena that impact global weather



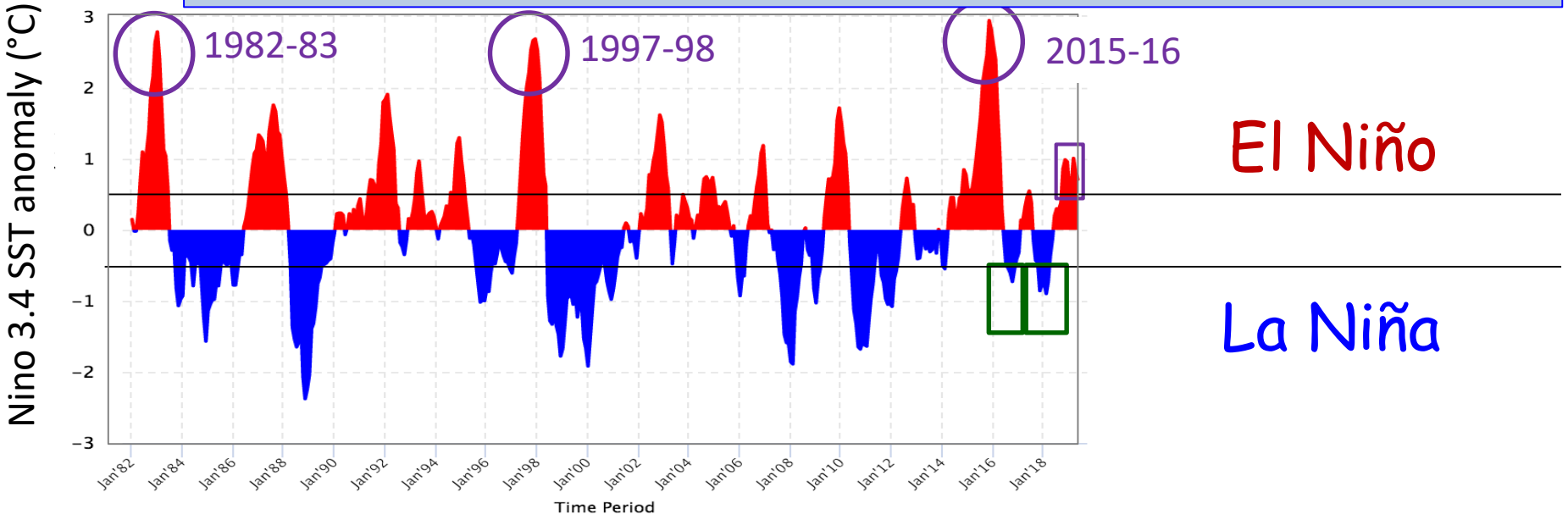

Measured as 5 consecutive 3-month SST anomalies in the Niño 3.4 area:

El Niños > +0.5°C

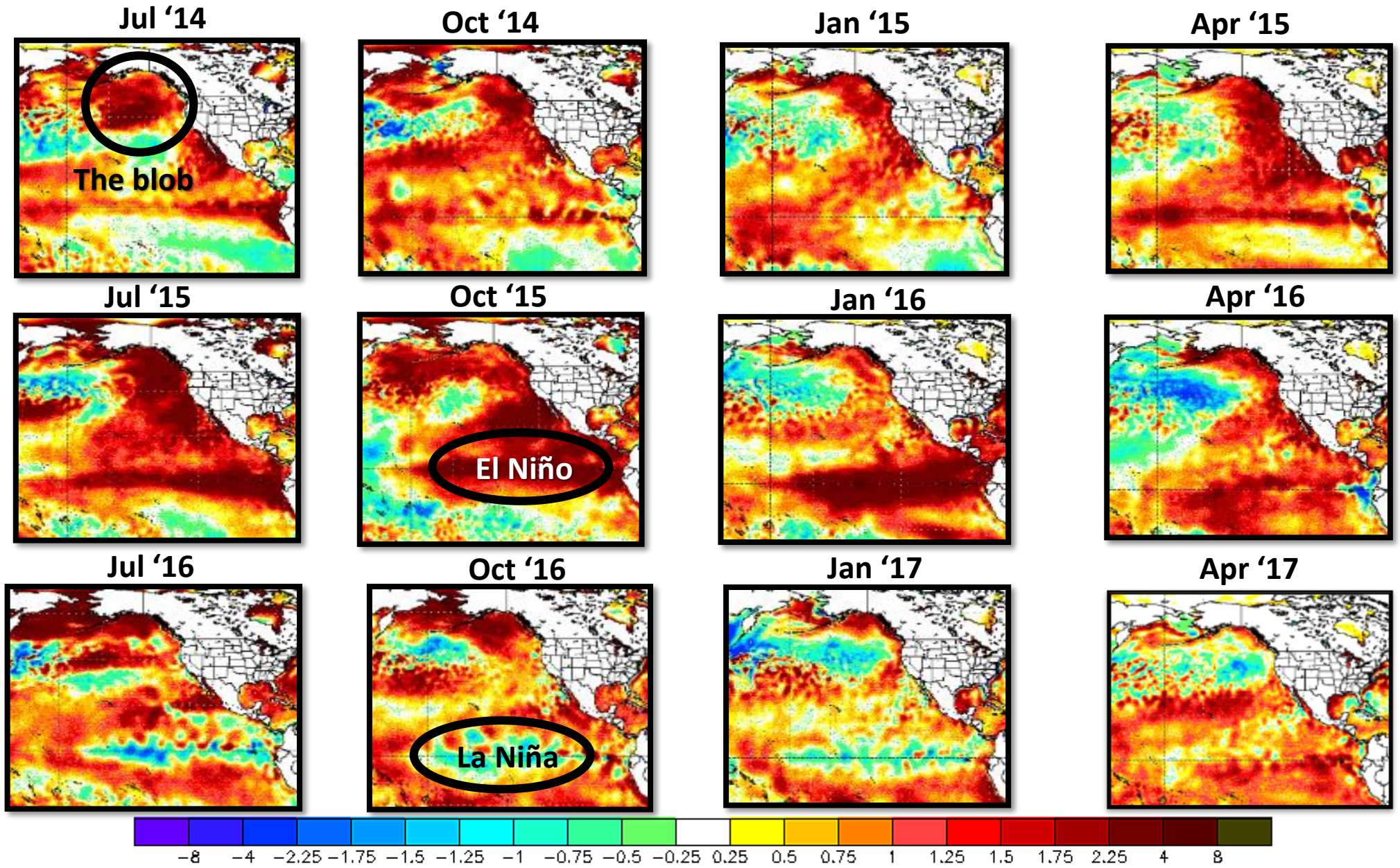
La Niñas < -0.5°C




**Current conditions: neutral (neither El Niño nor La Niña present at equator)**

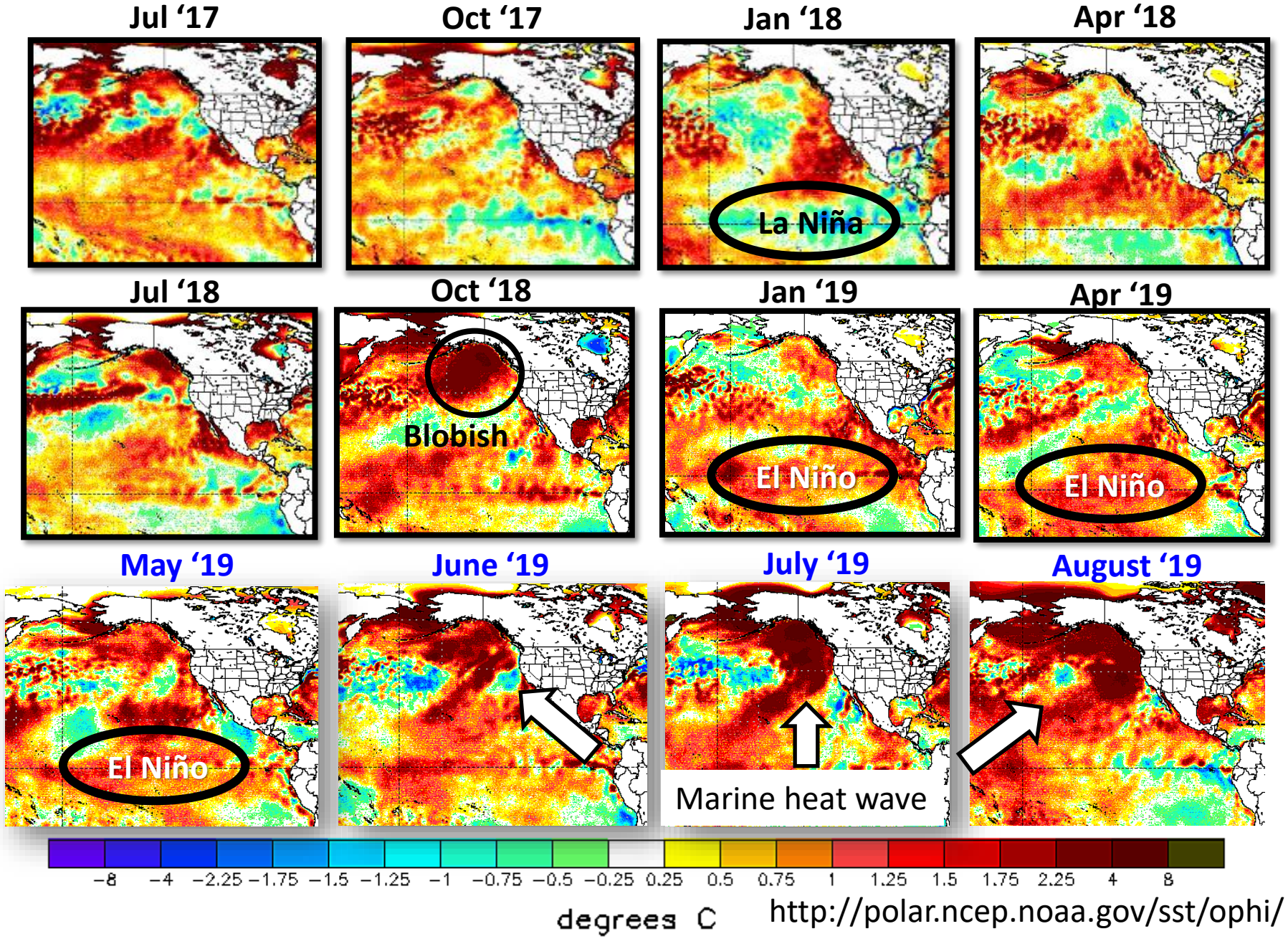


# North Pacific surface temperature anomalies




http://polar.ncep.noaa.gov/sst/ophi/

# North Pacific surface temperature anomalies

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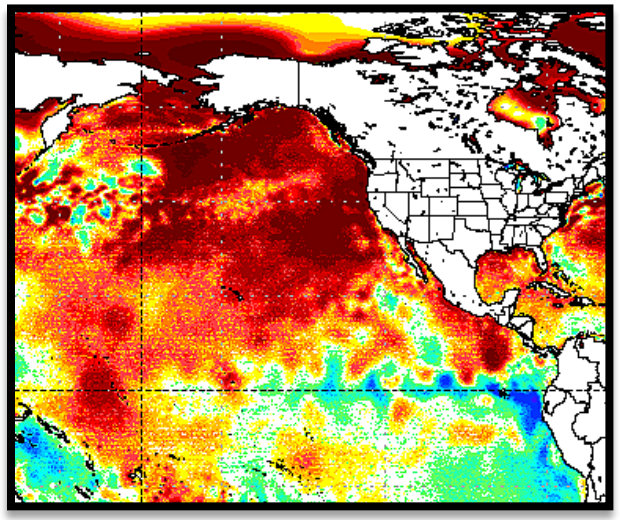
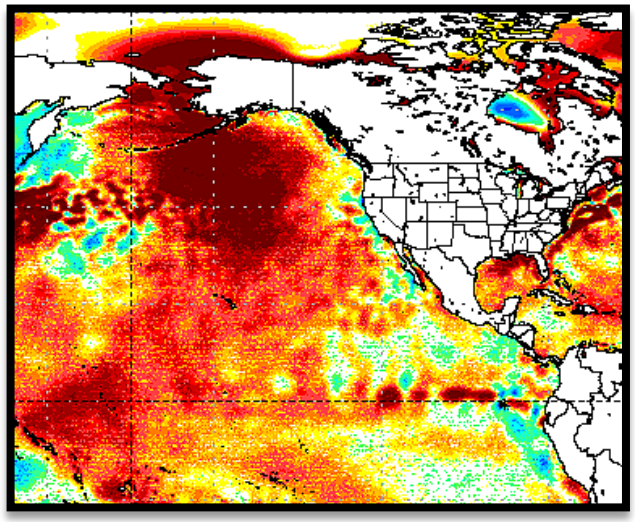
# North Pacific surface temperature anomalies

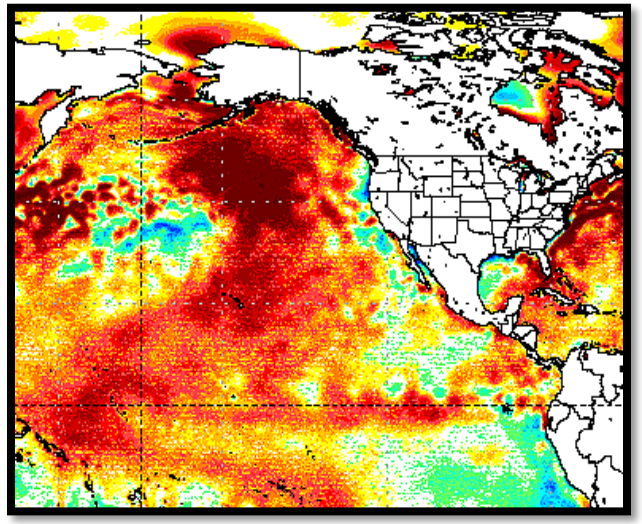
**Sept ‘19**

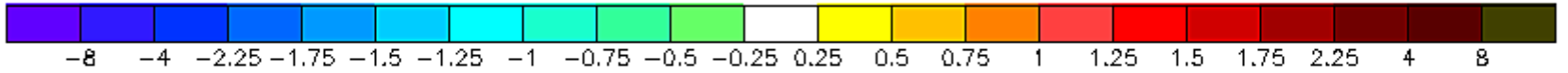


**Oct ‘19**



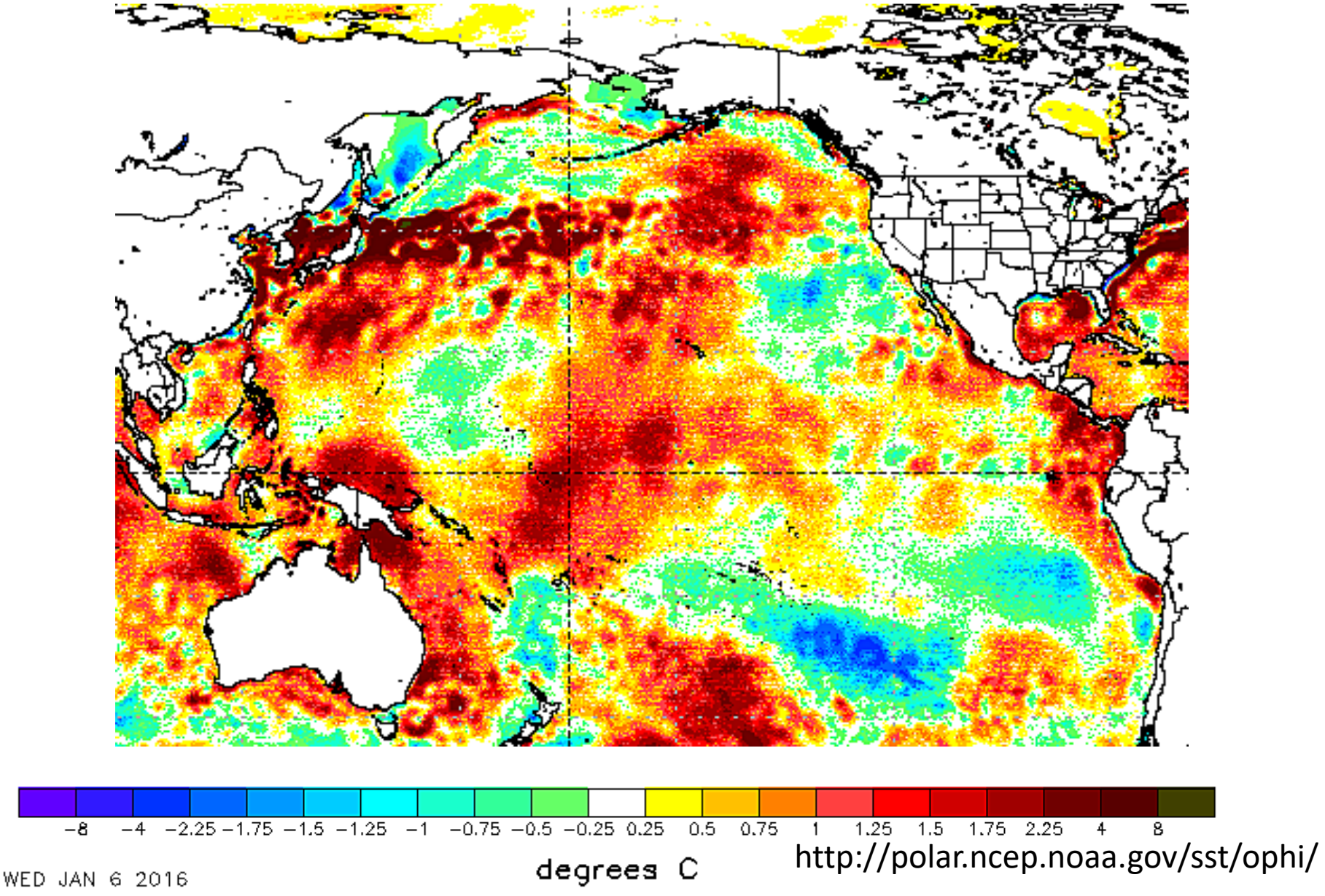
**Nov ‘19**






http://polar.ncep.noaa.gov/sst/ophi/

# SST anomalies, 13 January 2020




http://polar.ncep.noaa.gov/sst/ophi/

# Salmon marine distributions

Where salmon go in the ocean determines the conditions they encounter:

- Physical condition (temp, salinity)
- Prey, competitor, and predator abundances

which influences

- Growth potential
- Decisions to mature
- Ultimately survival

Knowing where salmon are at any time is the 1st step to understanding their marine ecology

# First summer in the ocean: 3 patterns for NW salmon

Pattern 1: Rapid north-wards movement on shelf to Gulf of Alaska

Which: Spring Chinook, chum, sockeye, some coho


Pattern 2: Remain in local waters

Which: Fall Chinook, some coho


Pattern 3: Move rapidly offshore

Which: Steelhead

# First summer in the ocean: 3 patterns for NW salmon

Pattern 1: Rapid north-wards movement on shelf to Gulf of Alaska

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Pattern 2: Remain in local waters

Which: Fall Chinook, some coho

Pattern 3: Move rapidly offshore

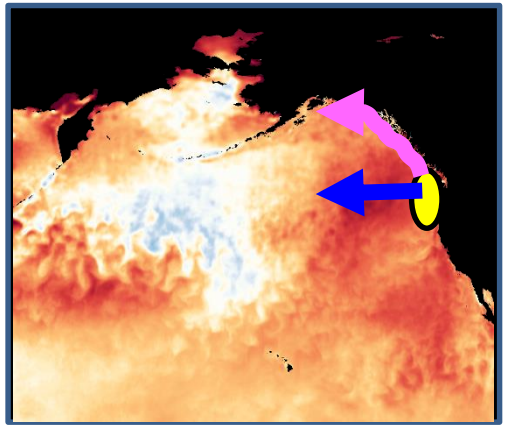
Which: Steelhead


**This early period is when most marine mortality occurs**

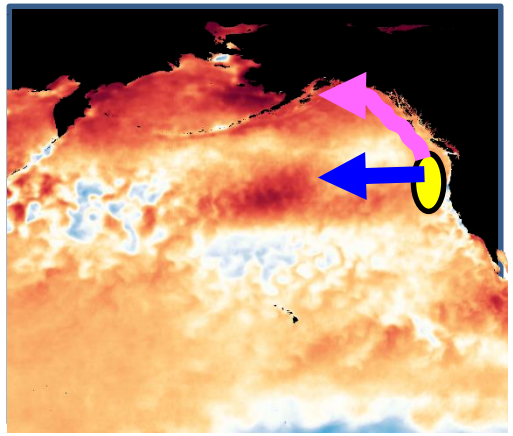
# Initial ocean migrations of Northwest salmon in recent Julys

(shading = monthly sea surface temperature anomalies)

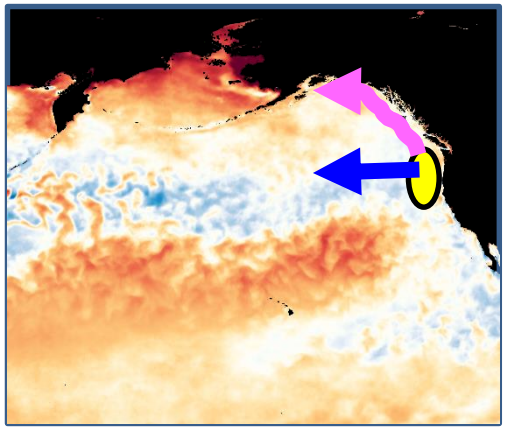
**July 2015**



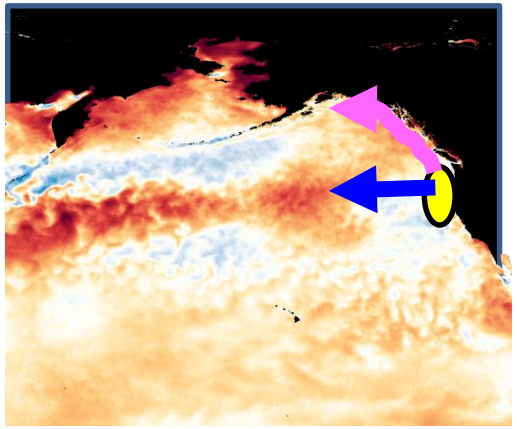
**July 2016**



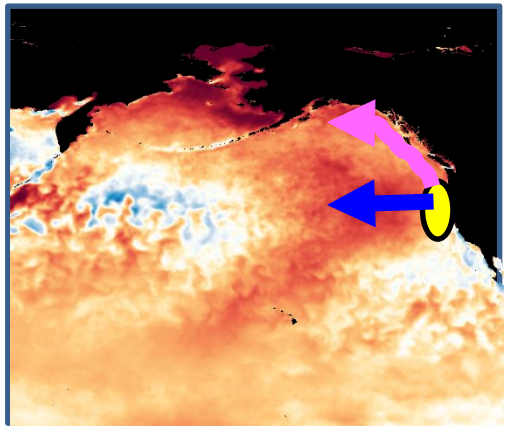
**July 2017**



**July 2018**



**July 2019**



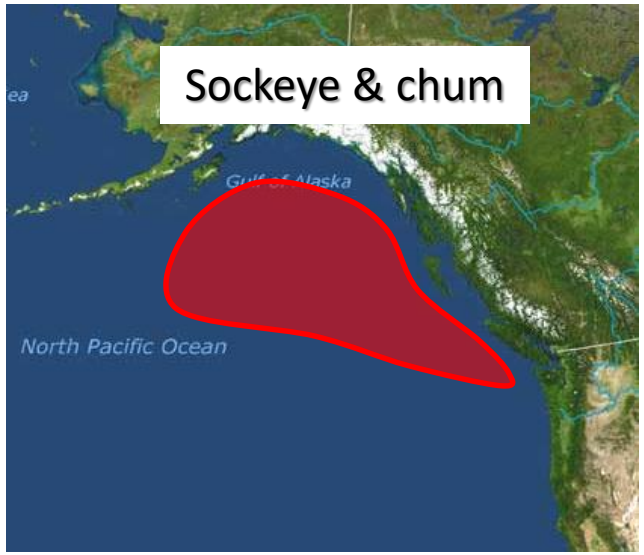
Spring Chinook, sockeye

Steelhead

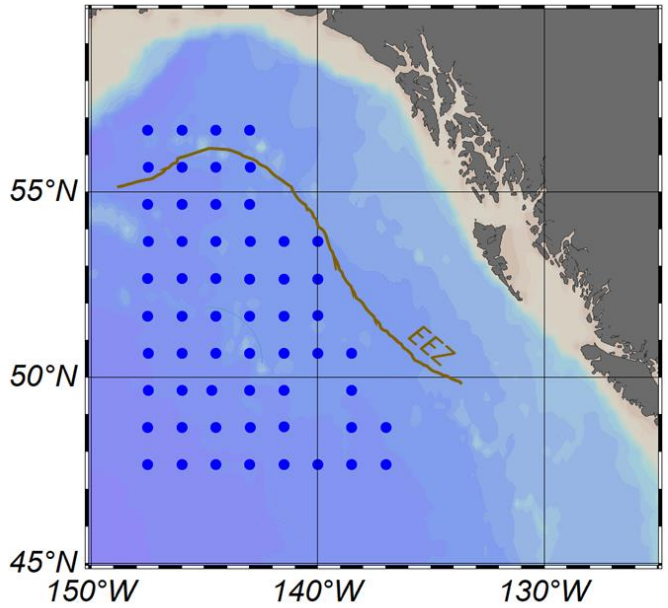
Fall Chinook, coho

# NW high seas distributions



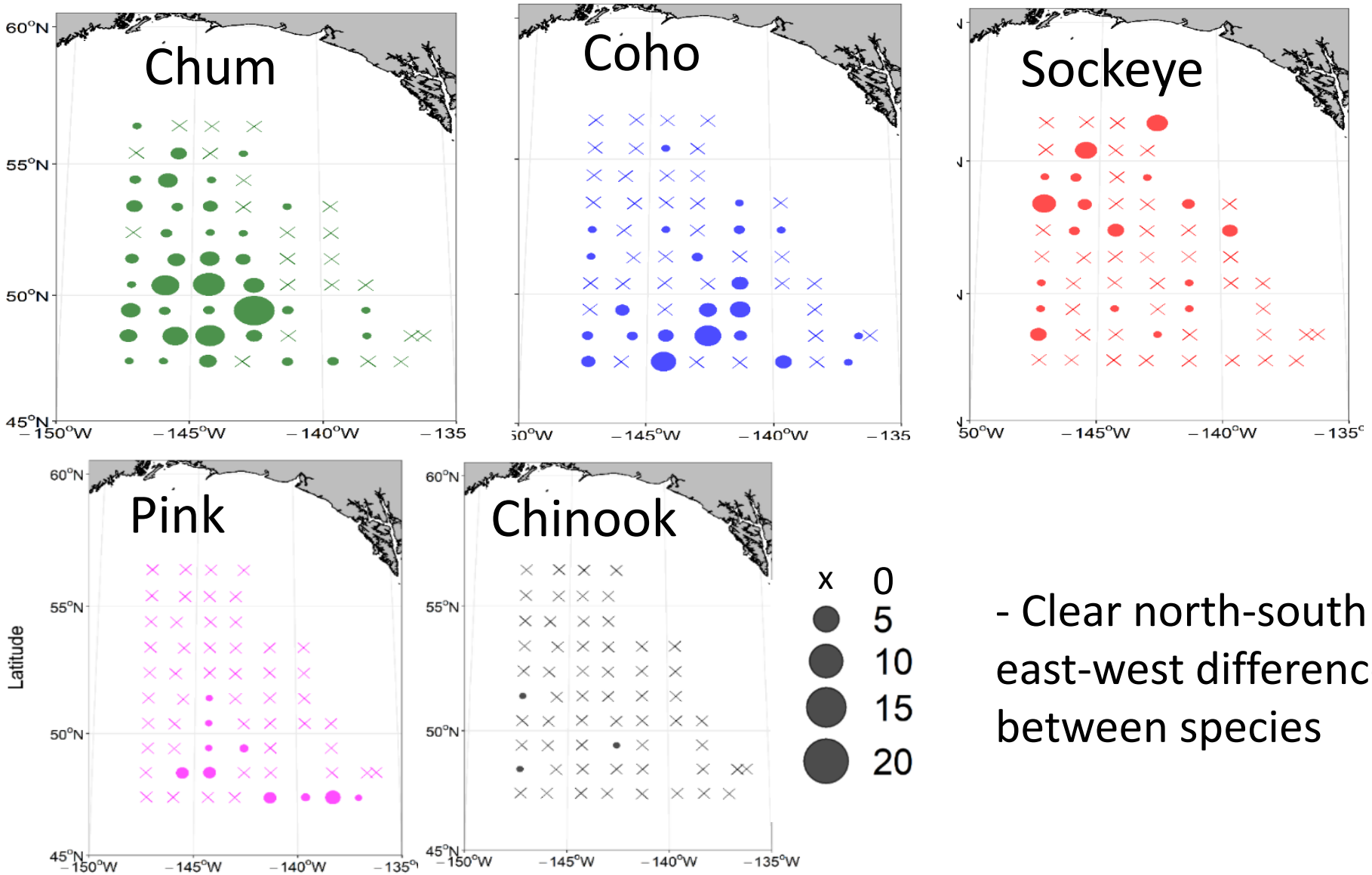



# Winter 2019 expedition to Gulf of Alaska



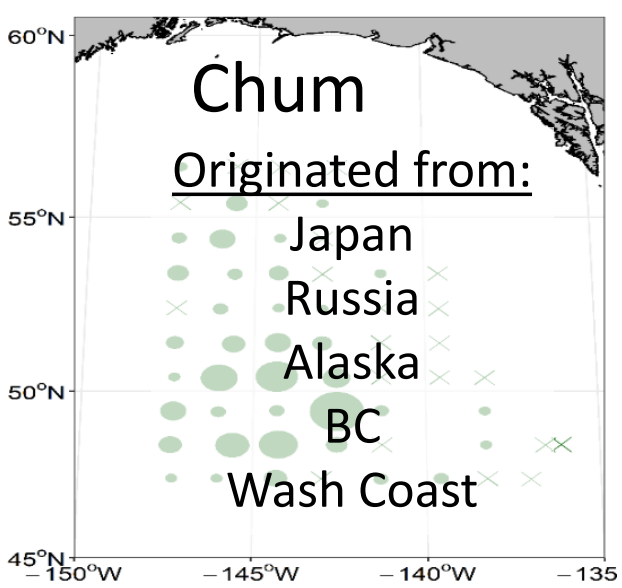


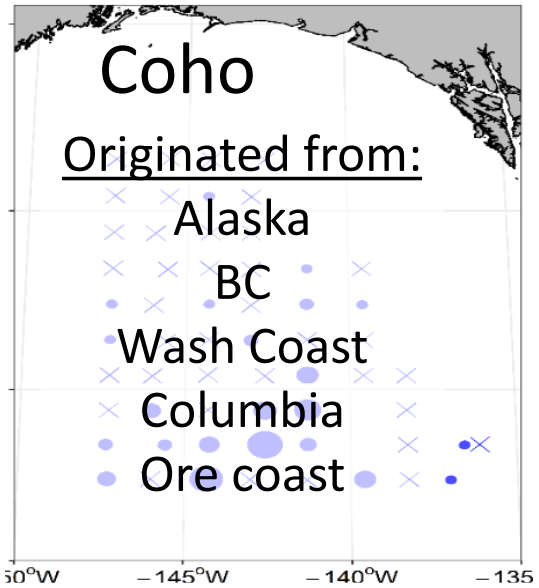
# Winter 2019 Salmon distributions

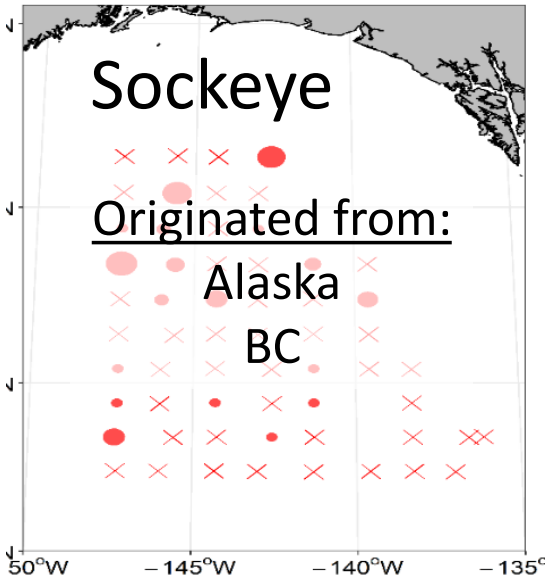


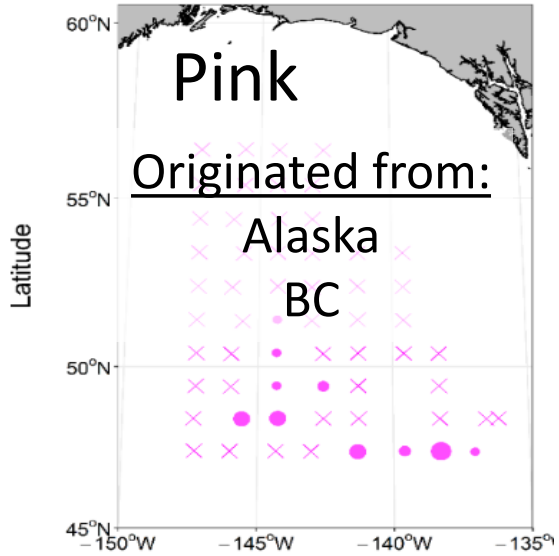

- Clear north-south and east-west differences between species

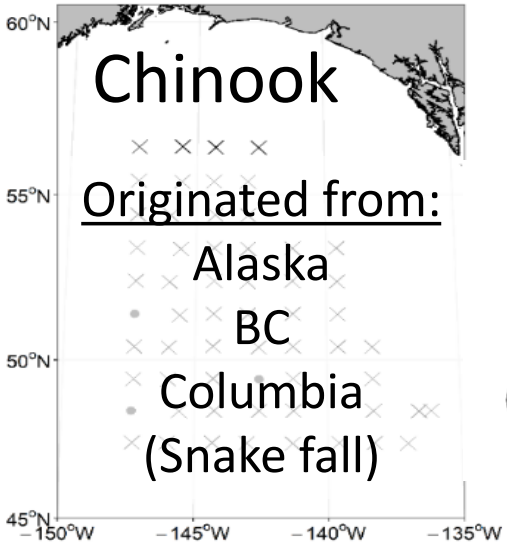
# Winter 2019 Salmon distributions

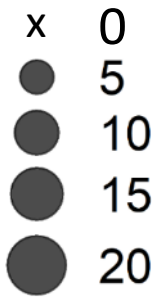



- Clear north-south and east-west differences between species

# 1. Adults returning to the NW: 3 general migration patterns

Pattern 1: Southwards movement along shelf

Which: Fall Chinook, Chum (?), sockeye (?)


Pattern 2: Northwards along CA & OR Coasts (CR-S); southward off BC coast (WA cst-N)

Which: Coho


Pattern 3: Move rapidly onshore (or unknown)

Which: Steelhead, Spring Chinook

# Biological response to physical conditions

Pyrosomes caught in a 5 minute tow off the Washington coast, May 2018

<u>Highlights</u>

- Extremes across the N Pacific
- Observations from juvenile salmon surveys (JSOES study)
- Adult salmon returns, AK to CA

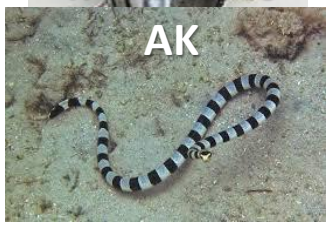
# Extreme biological response to warm oceans

## 2015

Tropicals In Oregon



Species range extensions from CA to AK



Dramatic changes to food webs

Domoic acid closes crab and clam fisheries AK-CA

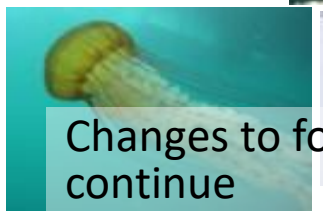
Young Chinook & coho in ocean very skinny

## 2016

Squid fishery in Oregon!

Red pelagic crabs in Newport!

Anchovies invade the Salish Sea

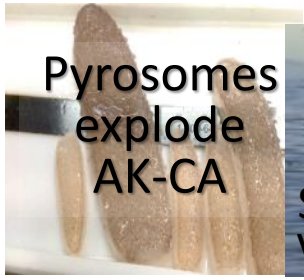


Changes to food webs continue

Crab and clam fishery closures

## 2017

High Pacific lamprey counts at Bonneville Dam



Pyrosomes explode AK-CA

Swordfish off Vancouver Is.

Extremely low Pacific cod abundance in Gulf of Alaska

Crab and clam fishery closures

# Extremes across the N Pacific

## 2018

Zooplankton returning to "normal"

Pyrosomes thick in spring, gone by fall

Big hypoxia event caused crab die-offs

Huge squid fishery in Oregon!


Some warm water fish still around

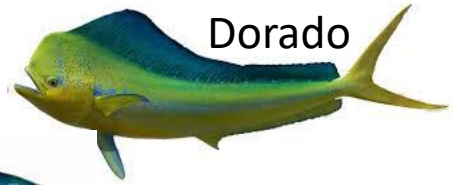
Continuing crab and/or razor clam fisheries closures due to domoic acid

## 2019

Squid boats in Newport, big squid fishery


**They're back**! Invasion of subtropical fishes on West Coast

Striped marlin



Dorado

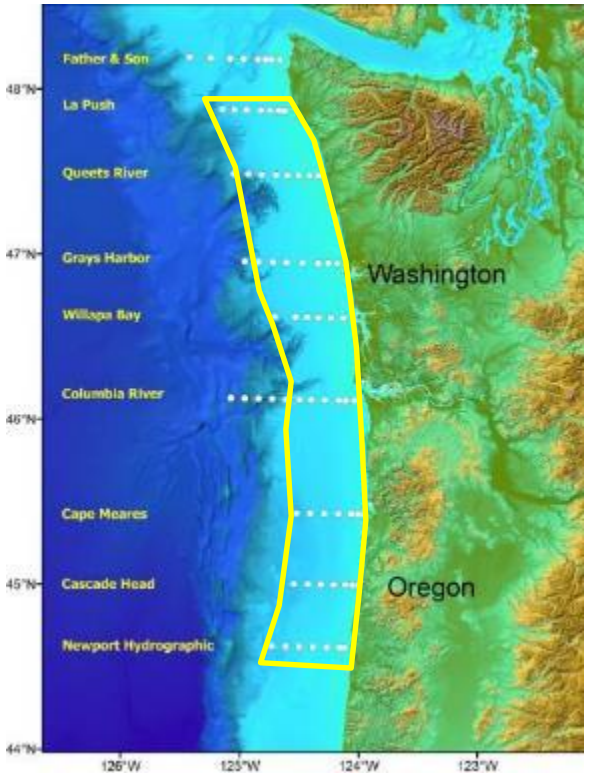
Yellowtail Jack

Zooplankton "normal"

Domoic acid still present in Oregon & N California

# Juvenile Salmon Surveys

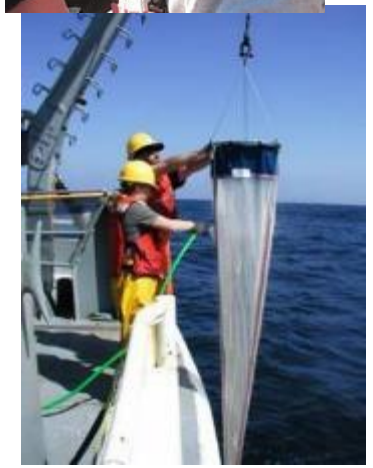
- Document distribution and condition of juvenile salmon off OR/WA coasts
- 1998 – present (also 1981 – 85)
- Sampling fish community, hydrography, plankton
- Funded by BPA




Pearcy

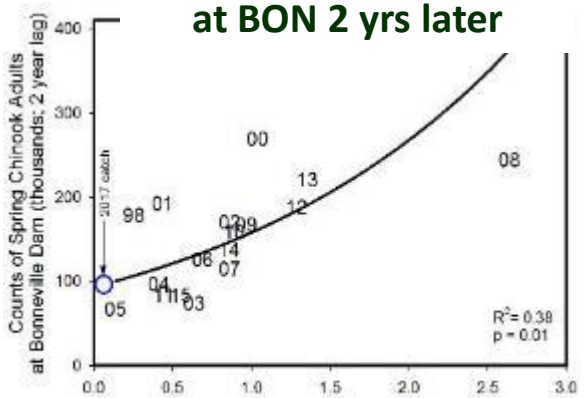
Fisher

Emmett



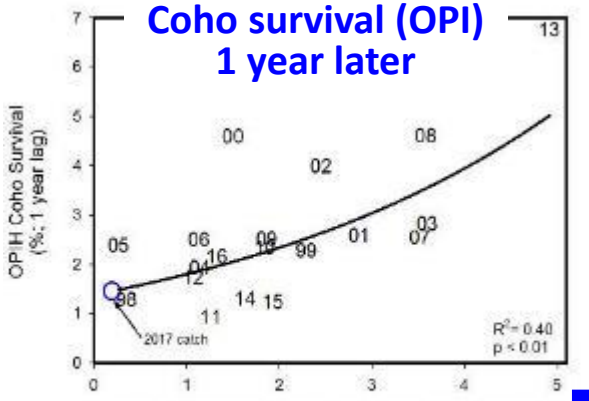
# Extremely low juvenile salmon abundances in 2017 resulted in poor coho returns in 2018 & poor spring Chinook in 2019

**Spring Chinook counts at BON 2 yrs later**




Juvenile Chinook in surveys

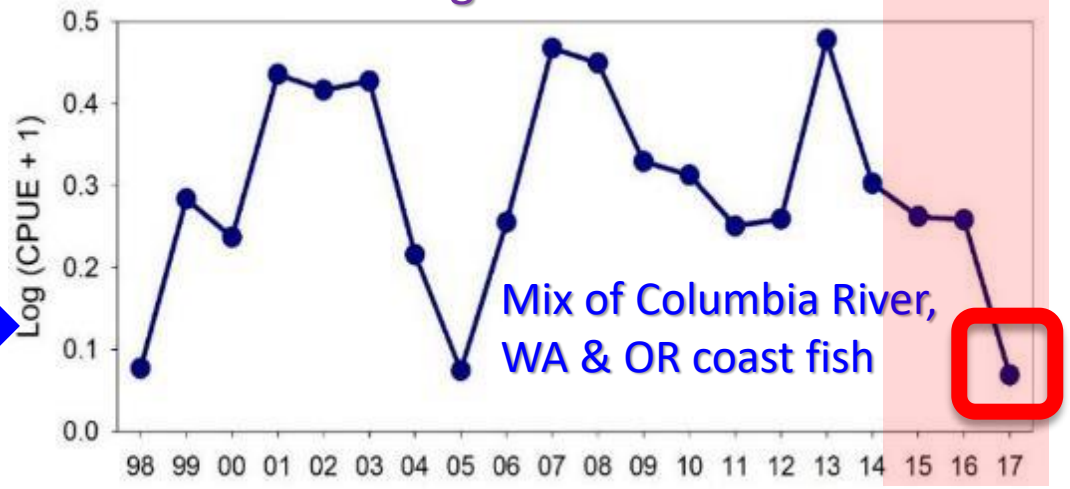
**Coho survival (OPI) 1 year later**



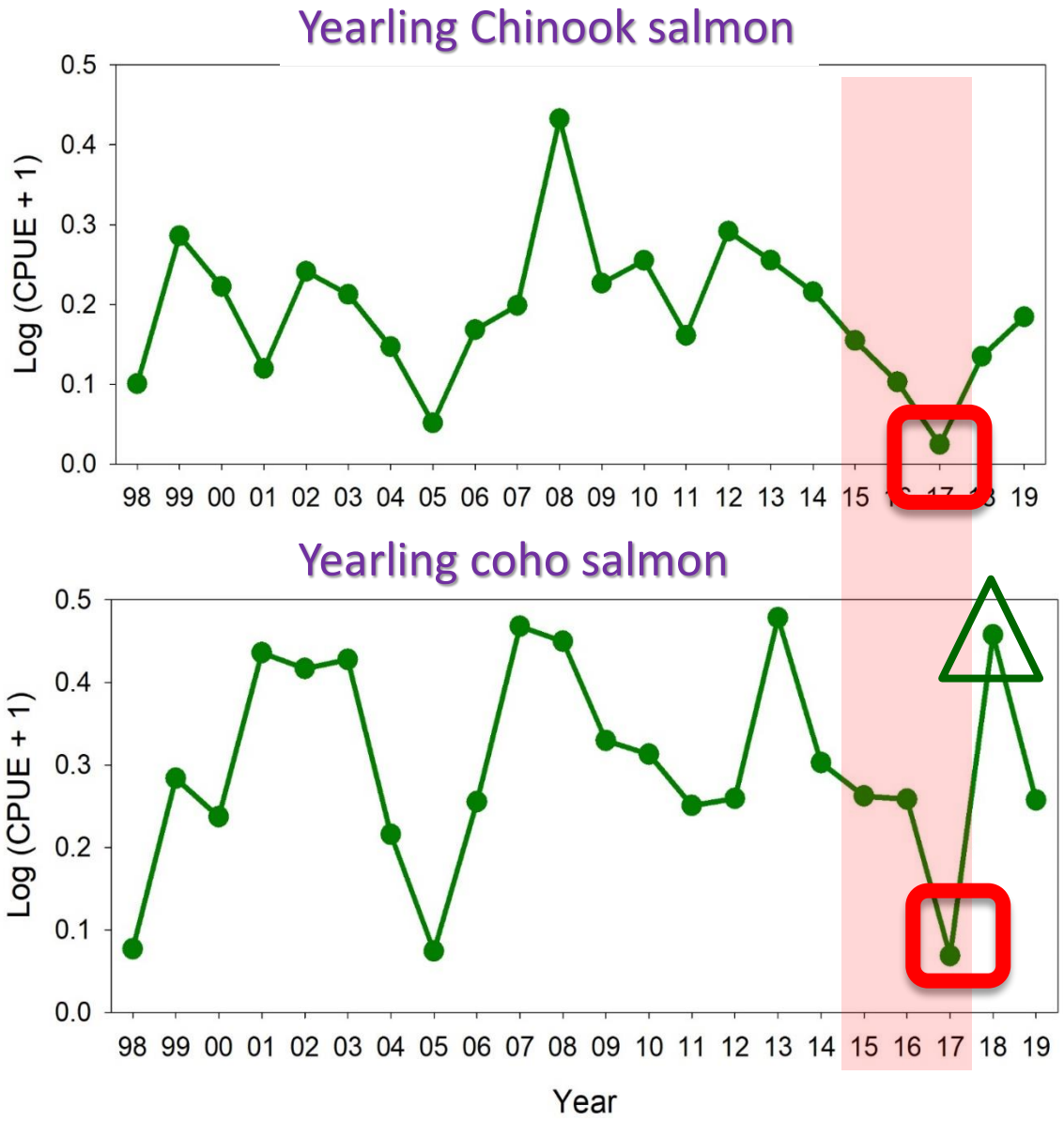

Juvenile coho in surveys

Yearling Chinook salmon

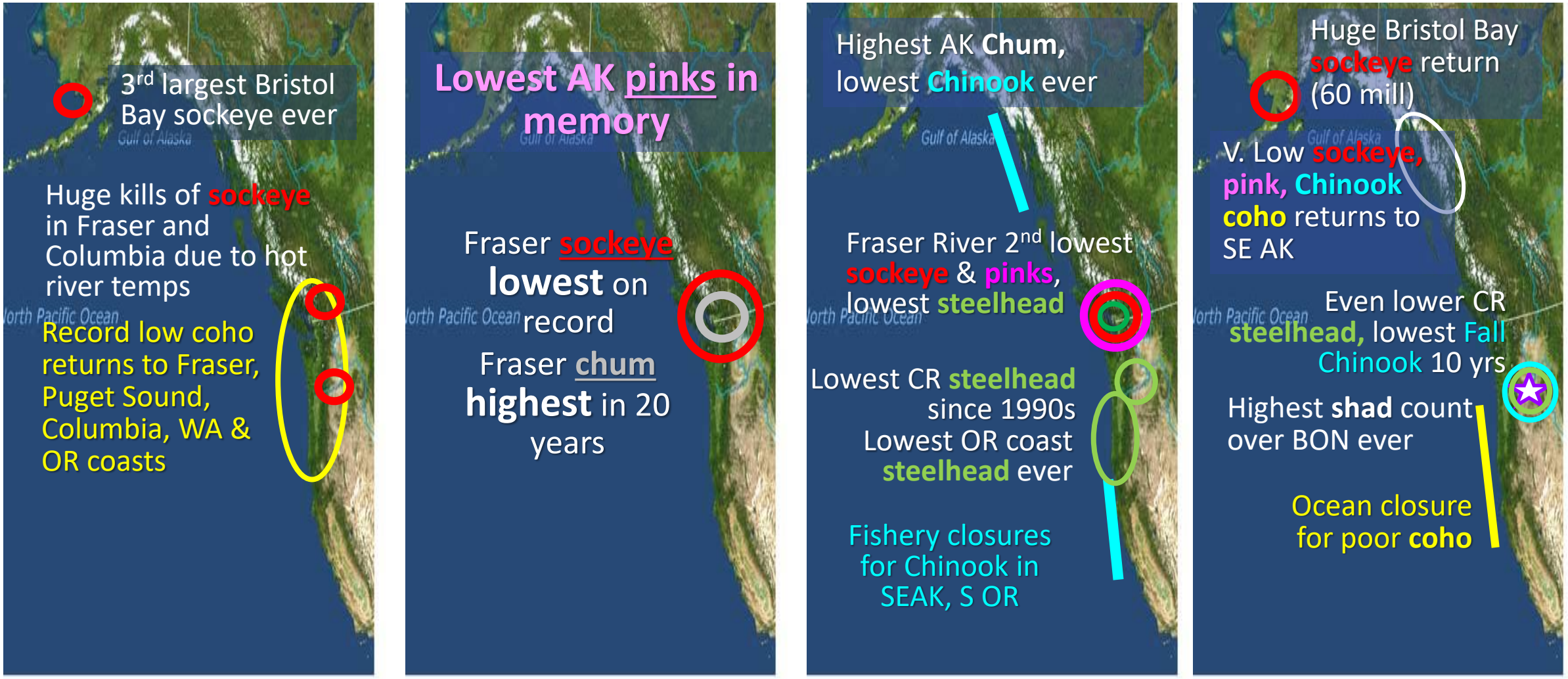

Yearling coho salmon



# Juvenile salmon catches in 2018 and 2019 suggested a large coho return in 2019, “normal” in 2020 for both



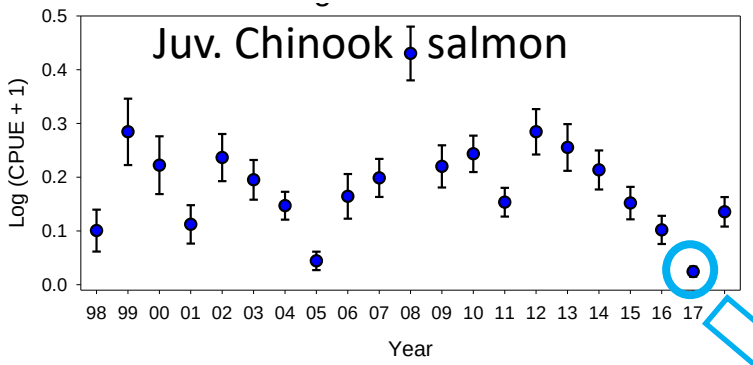
# Unusual adult salmon observations

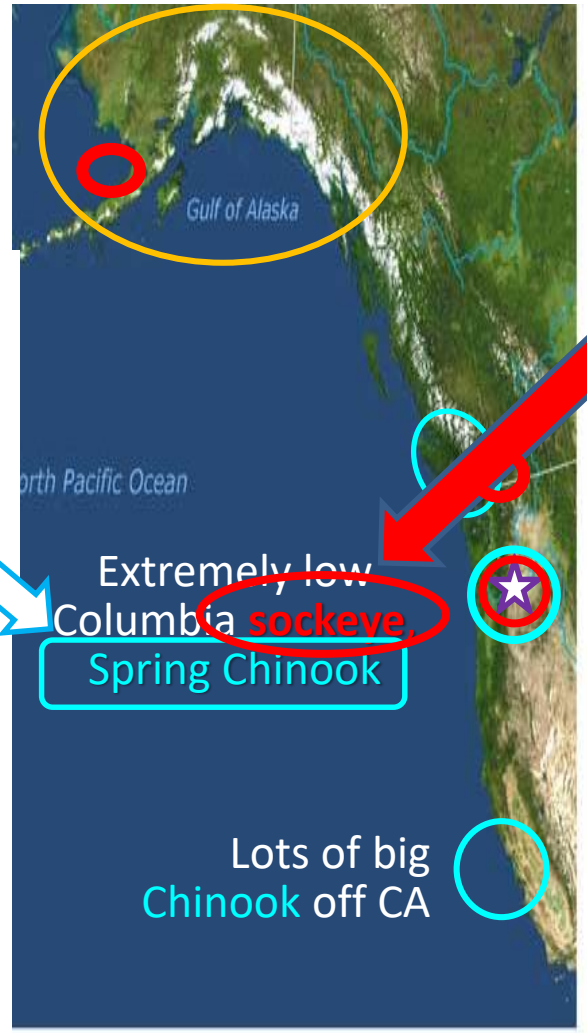


# Unusual adult salmon observations

## 2019

4th largest Bristol Bay sockeye return ever (56 mill)




Salmon kills in Alaska due to hot river temps

Offspring of fish killed in 2015 due to high river temps

S. BC closed to Chinook fishing to protect expected extremely low Fraser returns.
Lowest Fraser River sockeye return ever

Even higher shad count across Bonneville Dam (7.5 million)

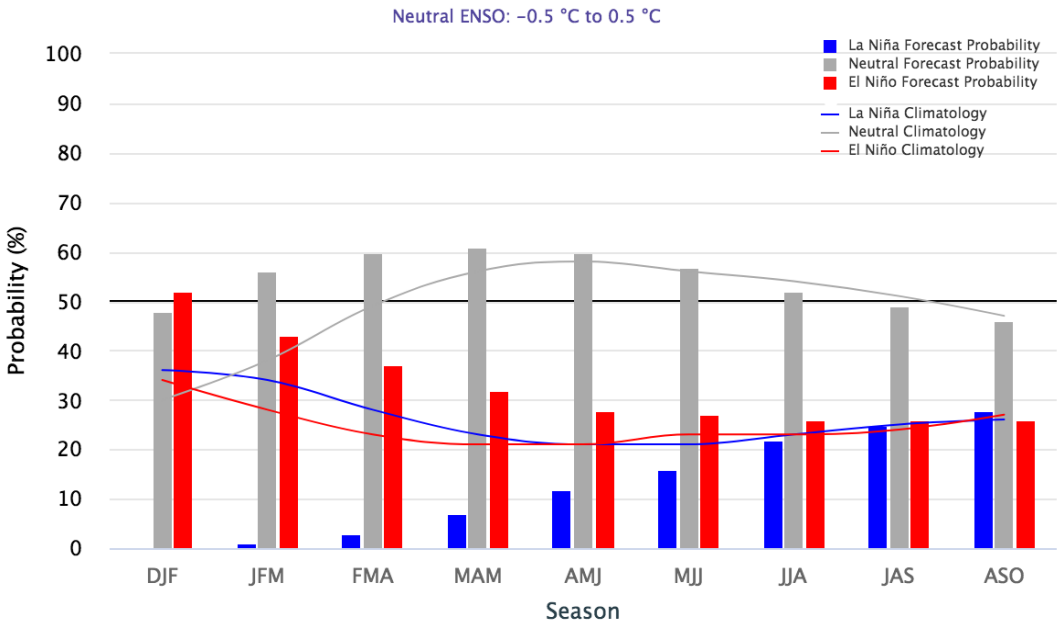
# Forecasts

- El Niño
- SST forecasts

# ENSO: Recent Evolution, Current Status and Predictions

**13 January 2020**
**ENSO-neutral conditions are present**

**A majority of models favor ENSO-neutral through the Northern Hemisphere summer 2020.**



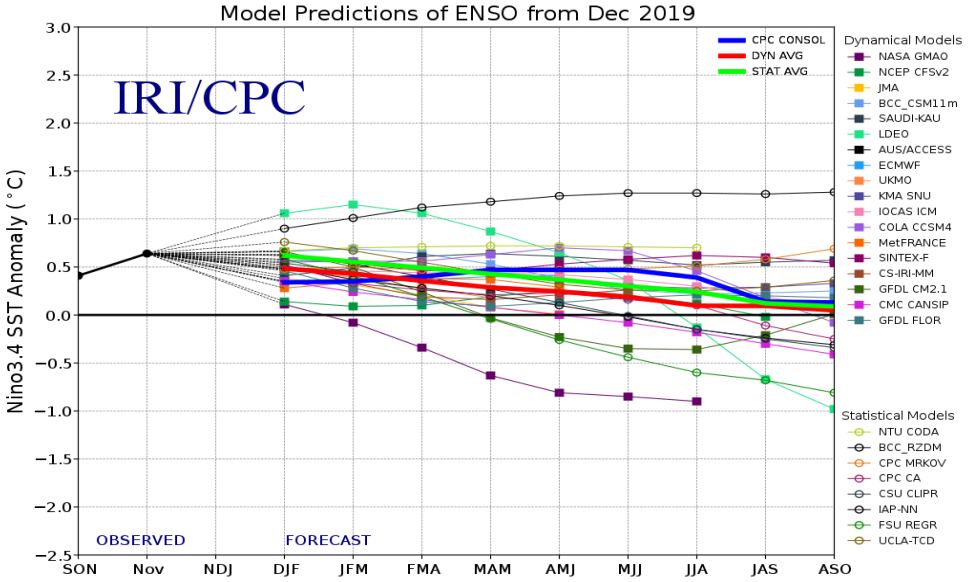




Figure provided by the International Research Institute (IRI) for Climate and Society (updated 19 December 2019).

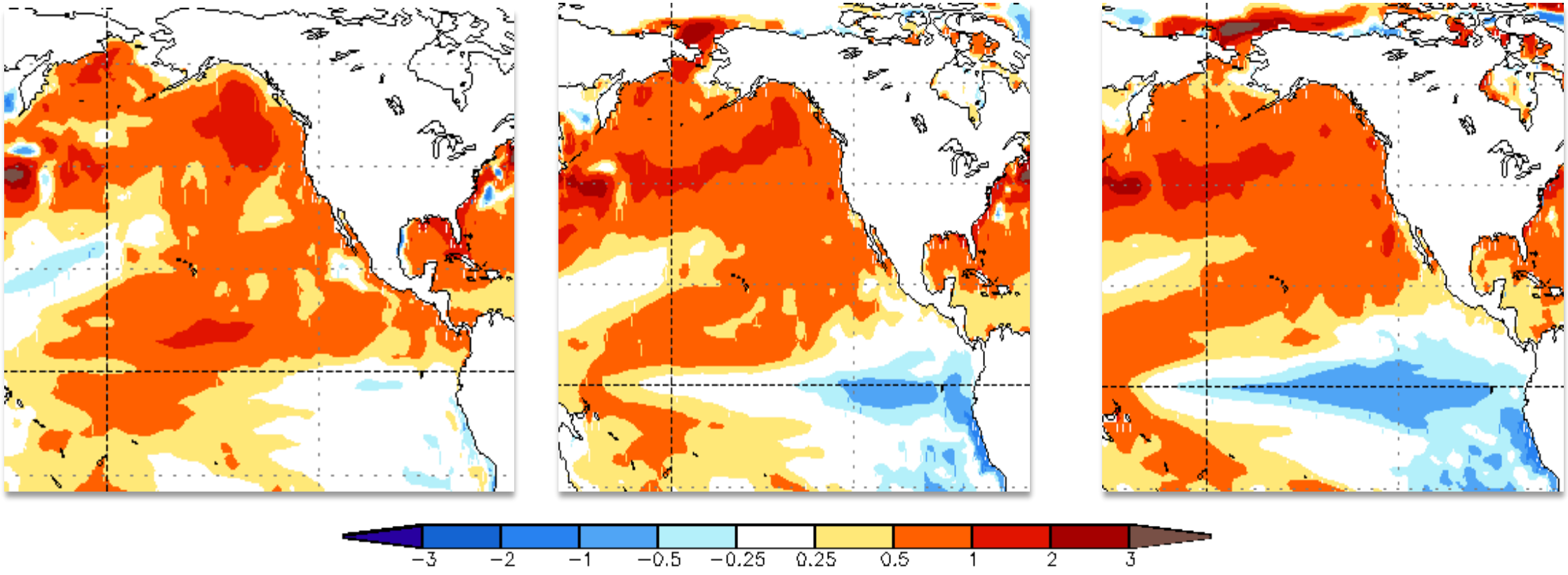
# Forecast SST anomalies

NOAA Climate prediction Center coupled forecast model 2

Mar-Apr-May 2020

May-Jun-Jul 2020

Jul-Aug-Sep 2020




http://www.cpc.ncep.noaa.gov/products/CFSv2/CFSv2seasonal.shtml

# Summary

- Warm ocean waters present since 2014 still continue across large parts of the North Pacific Ocean
- Biological response to warm ocean has been huge
  - Effects observed at all levels of marine ecosystem
  - Expect biological effects of warm ocean conditions will continue for several years (e.g., salmon returns, hake increase)
- Last summer's marine heat wave and predicted above average N Pacific waters this spring/summer are unlikely to be favorable for cold water species (e.g., salmon, crab).

- **What's next?!**


Questions?