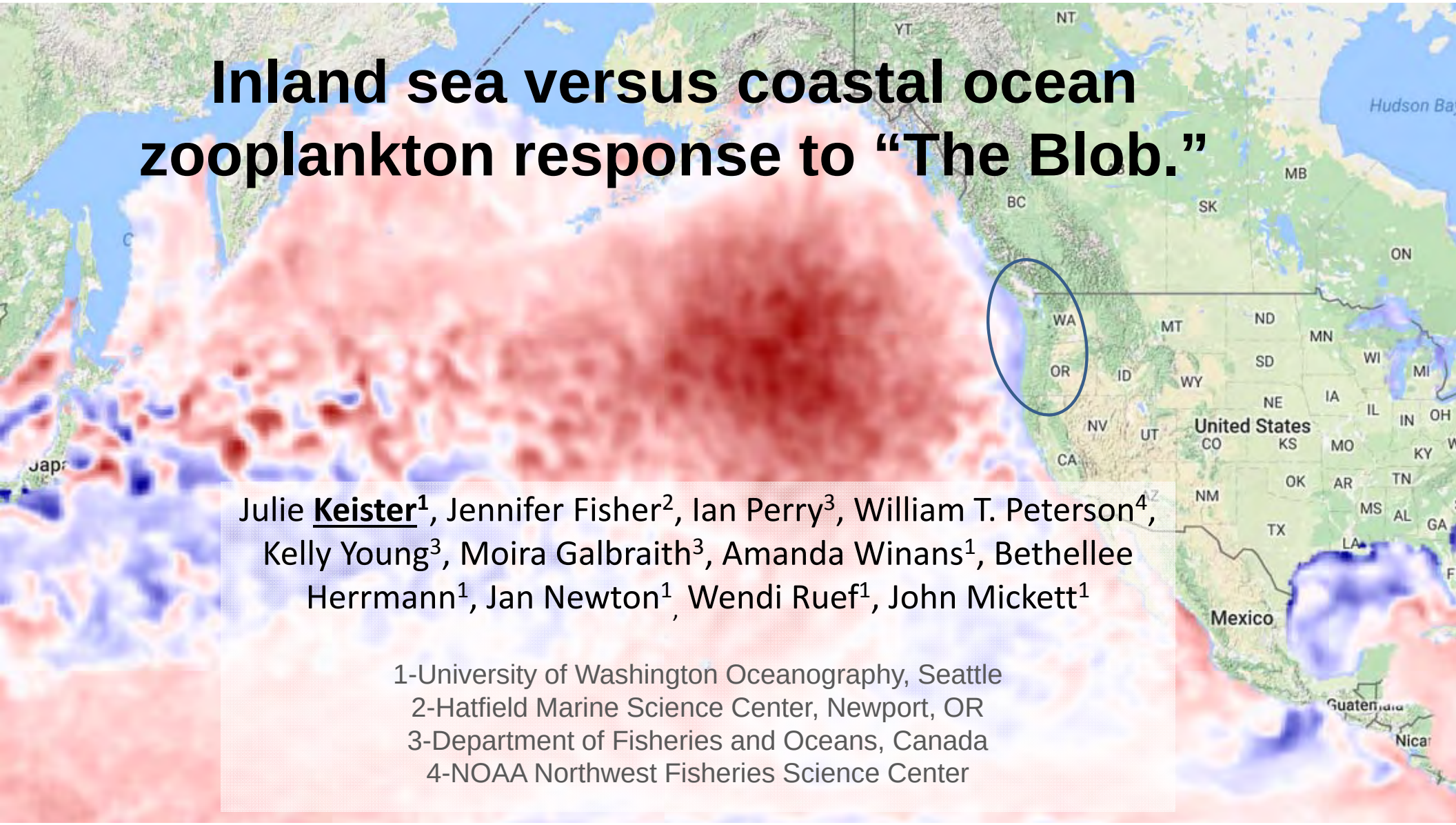
Inland sea versus coastal ocean zooplankton response to “The Blob.”



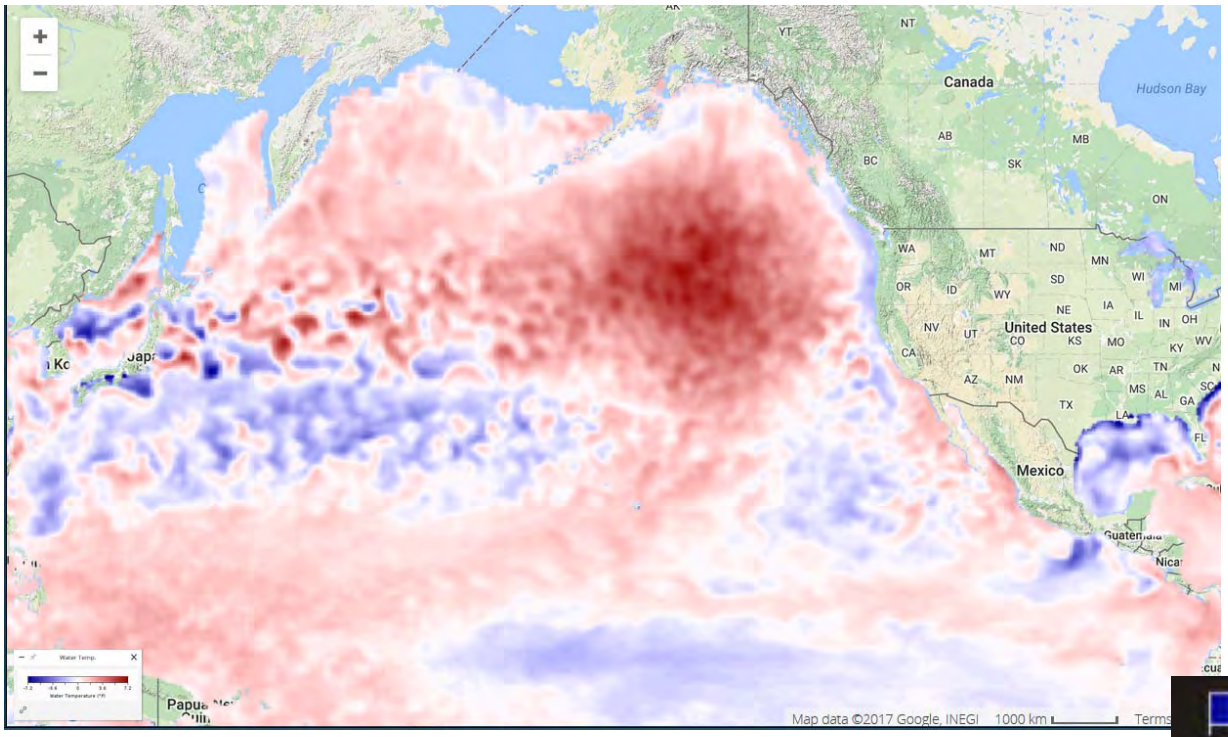
Julie **Keister**[1], Jennifer Fisher[2], Ian Perry[3], William T. Peterson[4], Kelly Young[3], Moira Galbraith[3], Amanda Winans[1], Bethellee Herrmann[1], Jan Newton[1], Wendi Ruef[1], John Mickett[1]

1-University of Washington Oceanography, Seattle
2-Hatfield Marine Science Center, Newport, OR
3-Department of Fisheries and Oceans, Canada
4-NOAA Northwest Fisheries Science Center

Record high temperatures occurred during the Pacific Warm Anomaly, a.k.a. “The Blob”

January 2014

Developed offshore during winter 2013-14

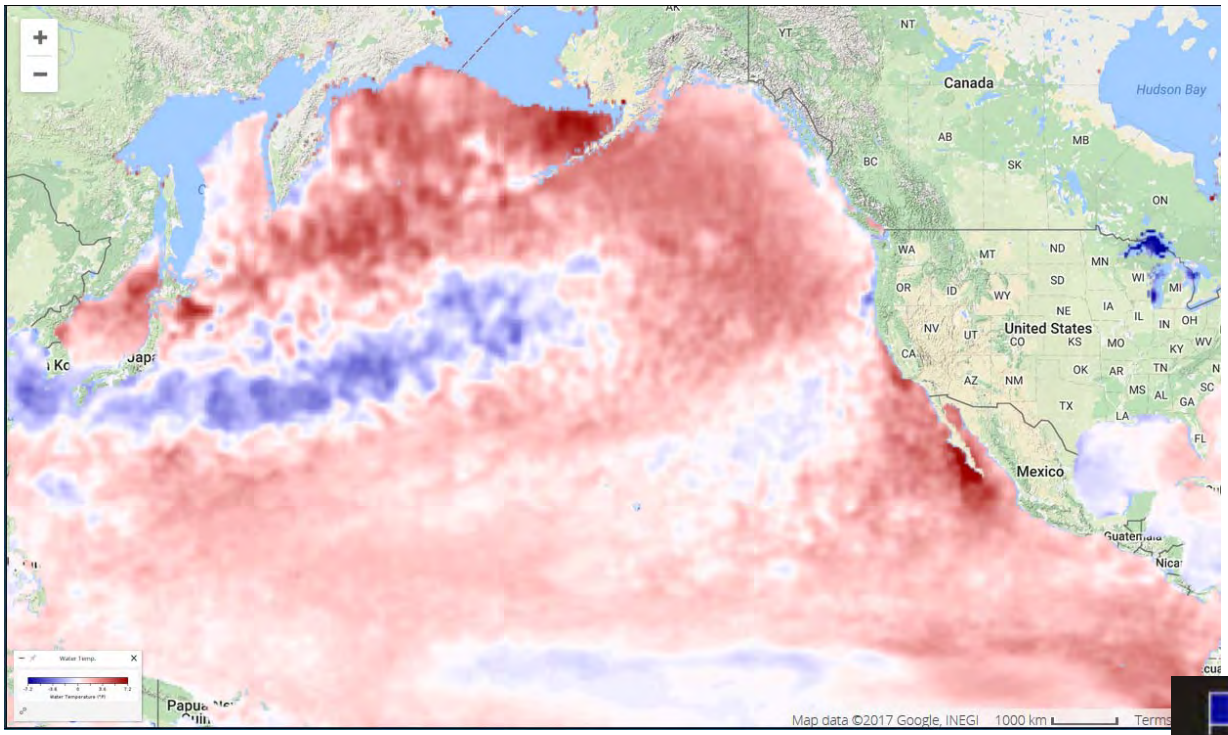


SST anomalies

NANOOS Visualization System:
http://www.nanoos.org/

Summer 2014 – Warm water held offshore by upwelling in summer 2014

July 2014

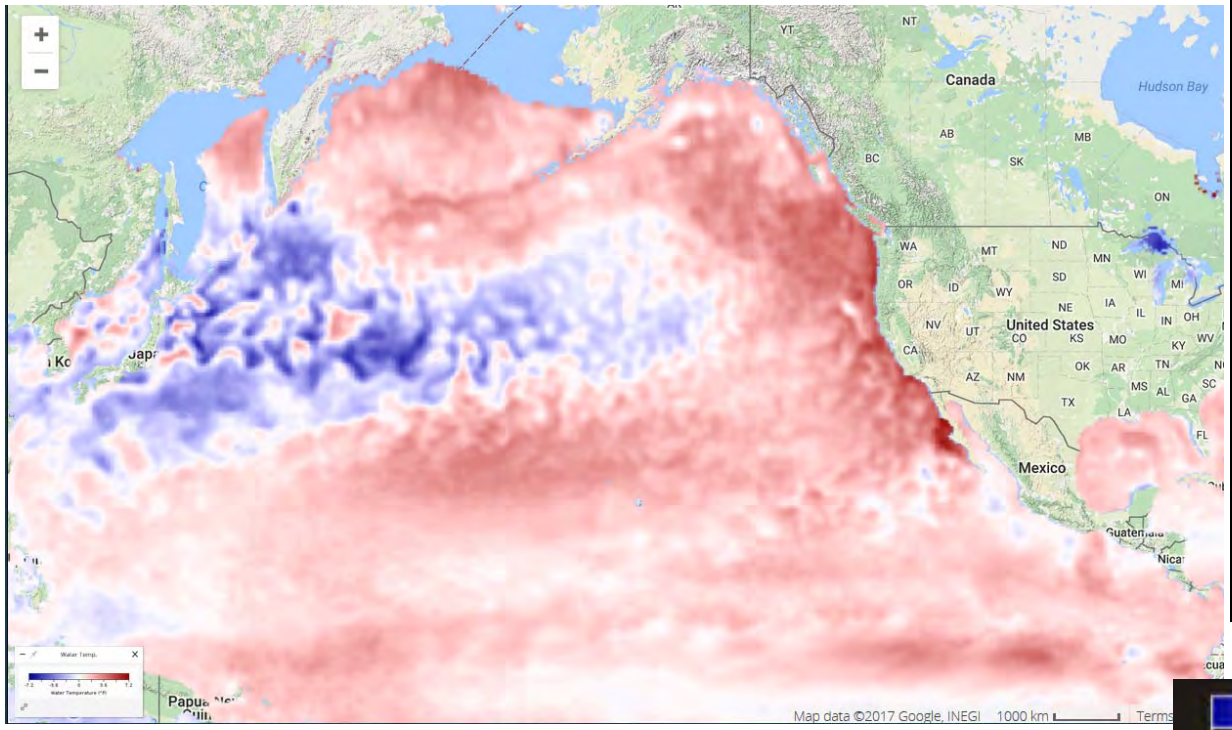


SST anomalies

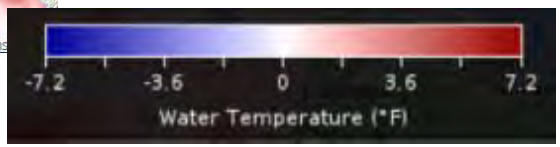
NANOOS Visualization System:
http://www.nanoos.org/

Dramatically advected onto shelf in Fall 2014 with shift to downwelling.

October 2014

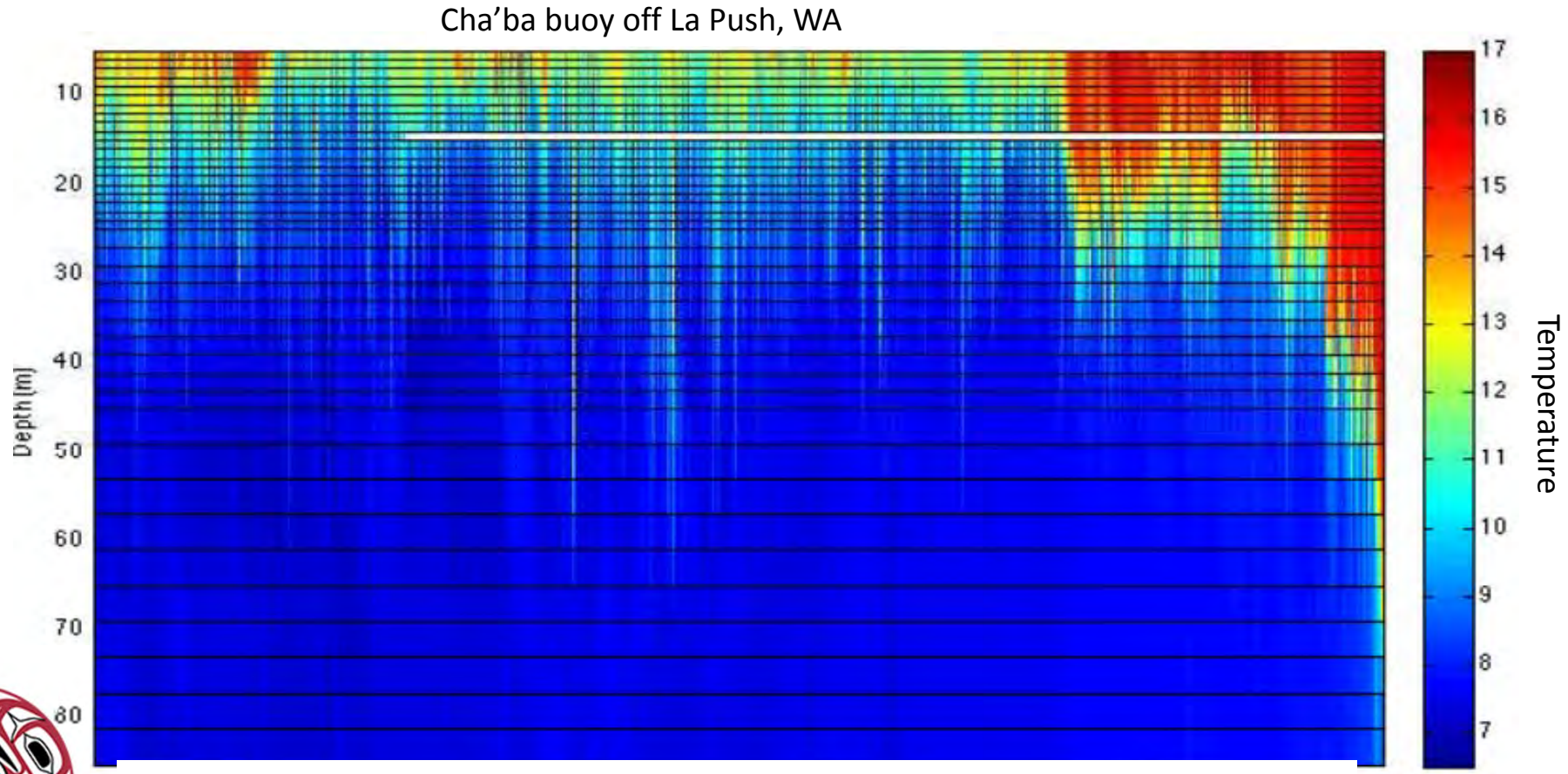


SST anomalies

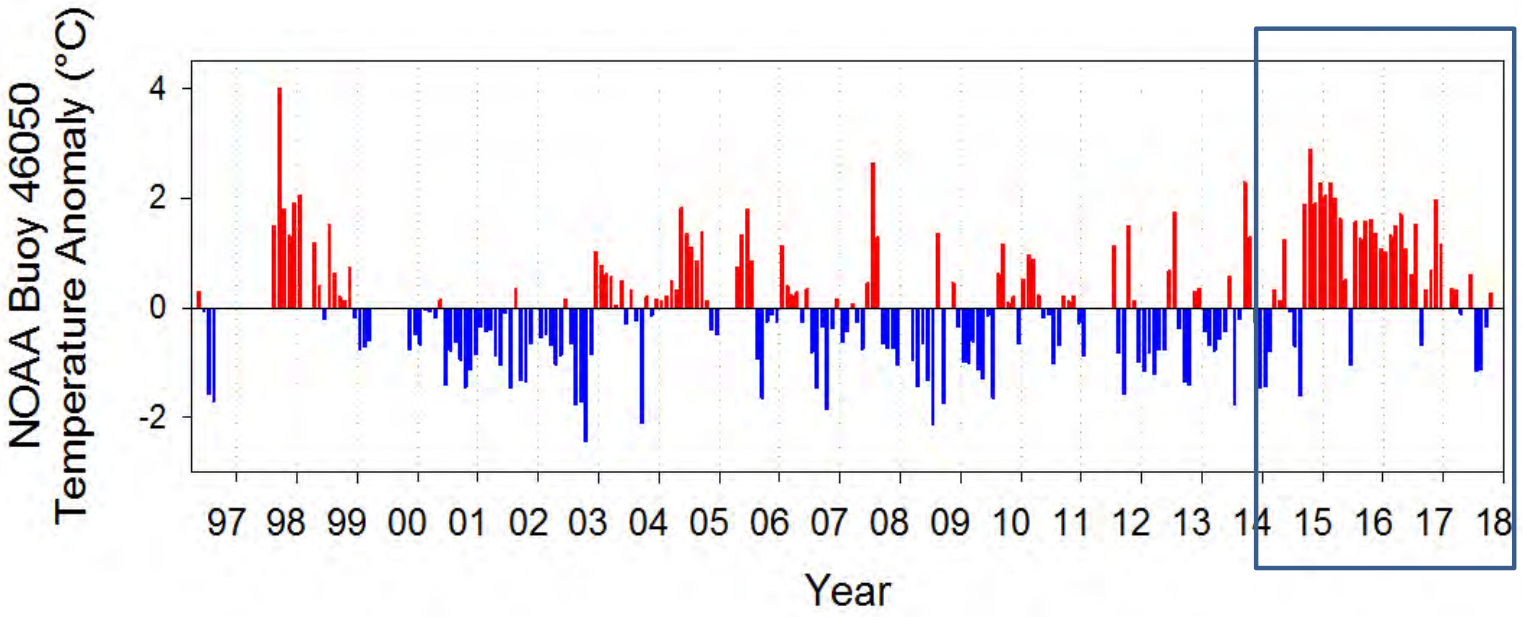


NANOOS Visualization System:
http://www.nanoos.org/

Very warm water at >50 m depth on shelf in October.



Oregon coast temperatures remained high Fall 2014 through Fall 2016:



Reported biological impacts during the Blob:

- Unprecedented copepod species richness off Oregon
  (Peterson et al. 2017; Jacobson yesterday)
- Unprecedented negative cold-water copepod anomalies
- Near-record positive warm-water copepod anomalies
- Extremely low juvenile/adult euphausiid biomass

- Massive Cassin's auklet die offs
  (J. Parrish)
- Extremely low salmon returns
- Abandoned and starved sea lion pups
- Unprecedented, wide-spread toxic *Pseudo-nitzschia* bloom
  (Du et al. 2016)

How was this big anomaly reflected in inland sea systems?

Were responses coherent throughout the region?

Nutrients

↓

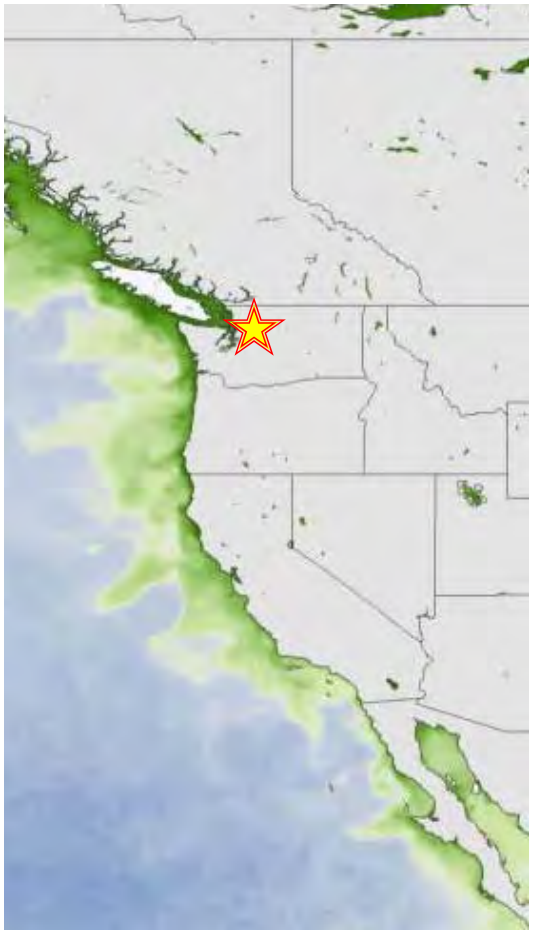
Chlorophyll

↓

Zooplankton

↓

Salmon

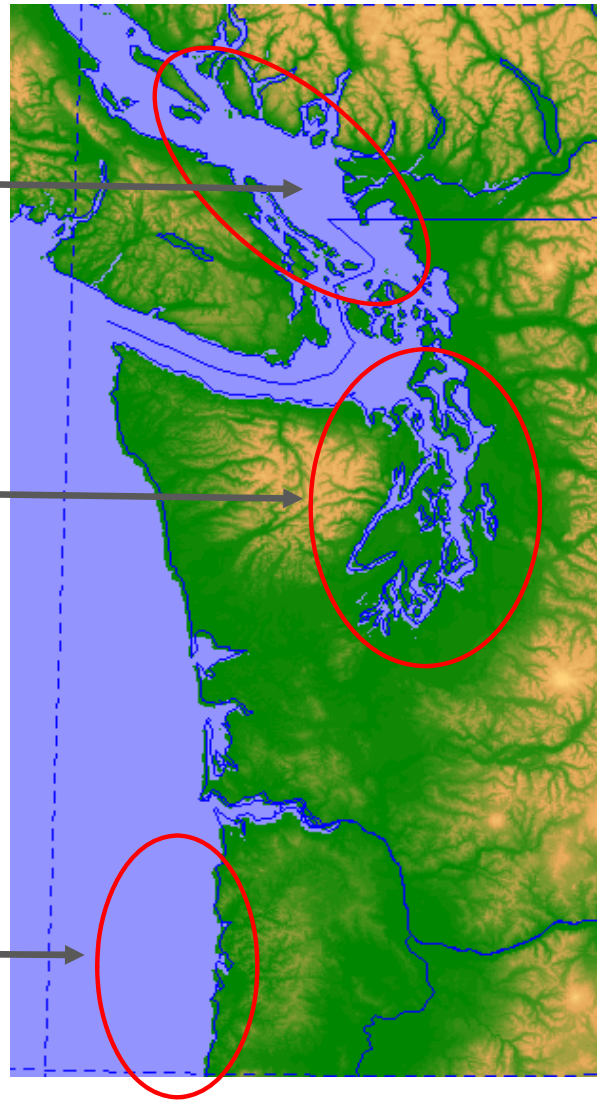


Zooplankton time series:

Strait of Georgia:
Inland Fjord
1995-present
DFO Canada (D. Mackas, I. Perry, et al.)
- 300 m average depth

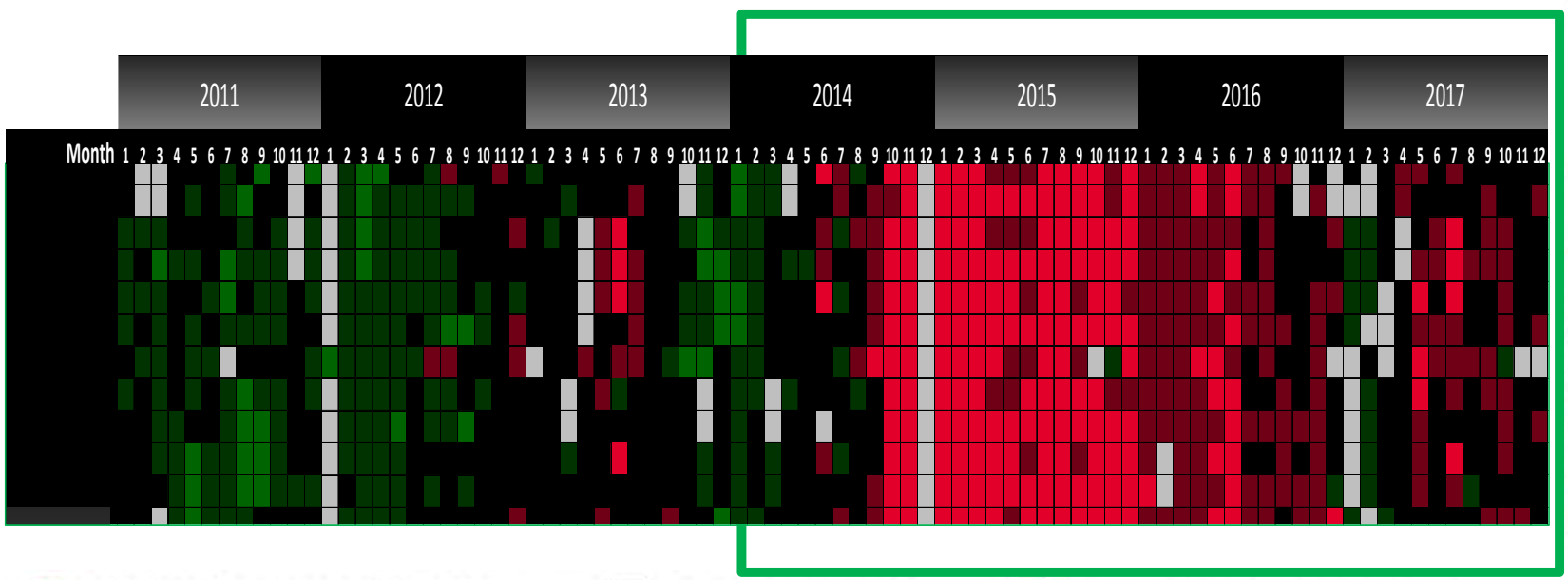
Puget Sound:
Inland Fjord
2014-present (zooplankton, J. Keister et al.)
1997-present (hydrography, King Count)
Collaborative program
- 200 m average depth

Newport Line:
Continental shelf upwelling system
1996-present
NOAA NWFSC (W. Peterson et al.)
- 65 m depth



Puget Sound: Water column heat content anomalies

DEPARTMENT OF ECOLOGY
State of Washington

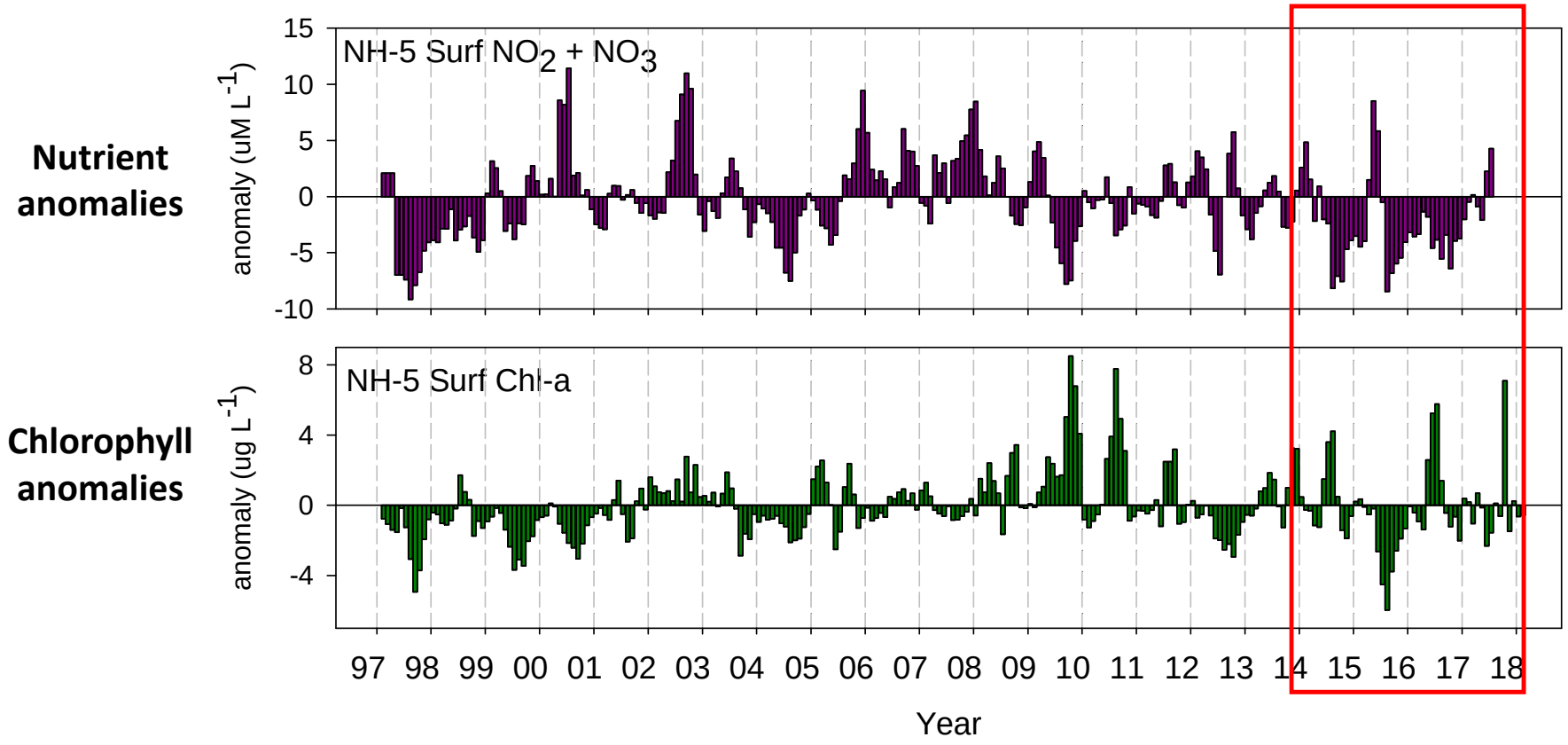


= higher than expected (> *IQR)
= higher than previous measurements
= expected (= *IQR)
= no data
= lower than expected (< *IQR)
= lower than previous measurements

*IQR = Interquartile Range (25th – 75th percentiles); **n = 17**

Oregon coast – Nutrient and Chlorophyll anomalies

Relative to 1997-2018 mean

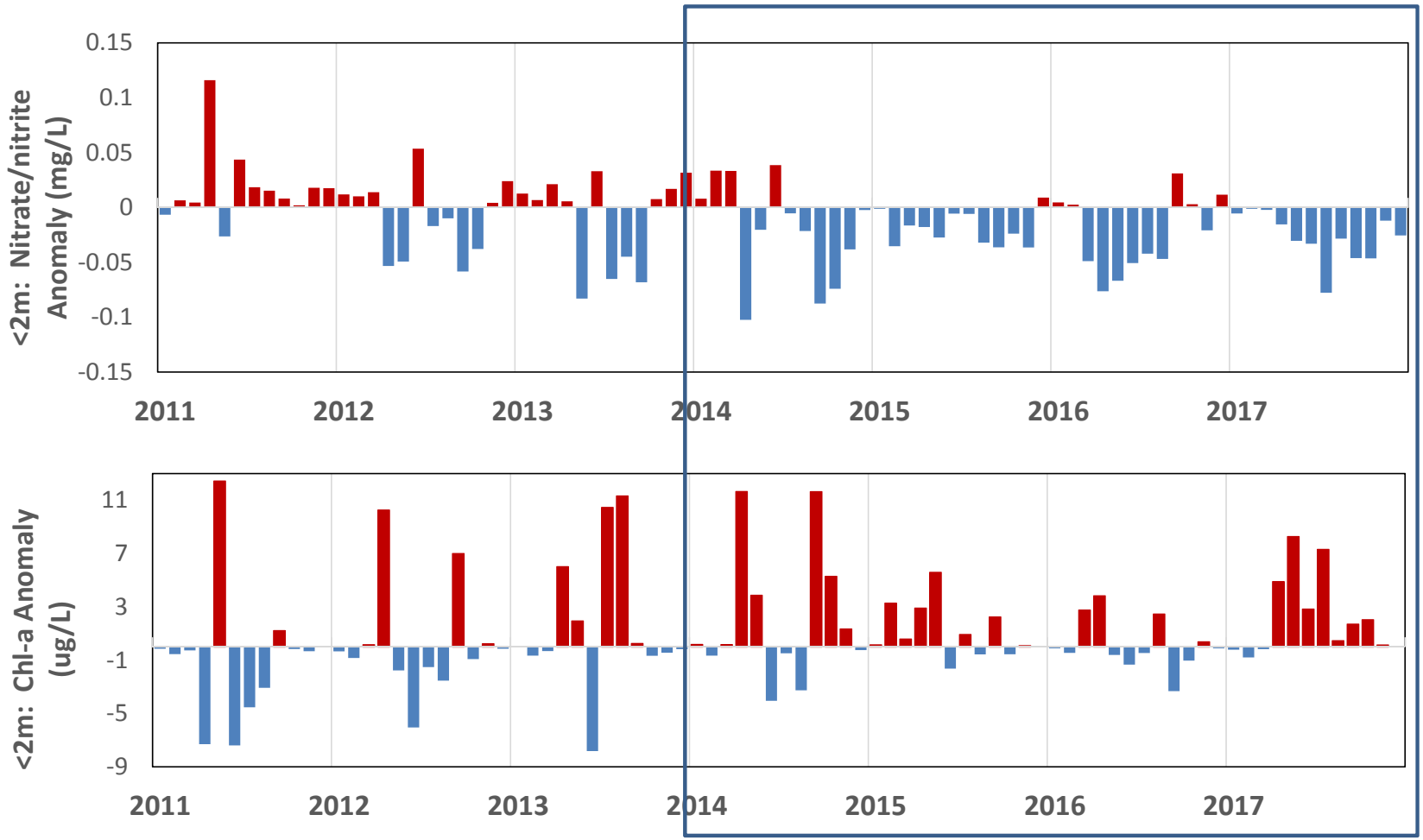


Puget Sound – Nutrient and Chlorophyll anomalies

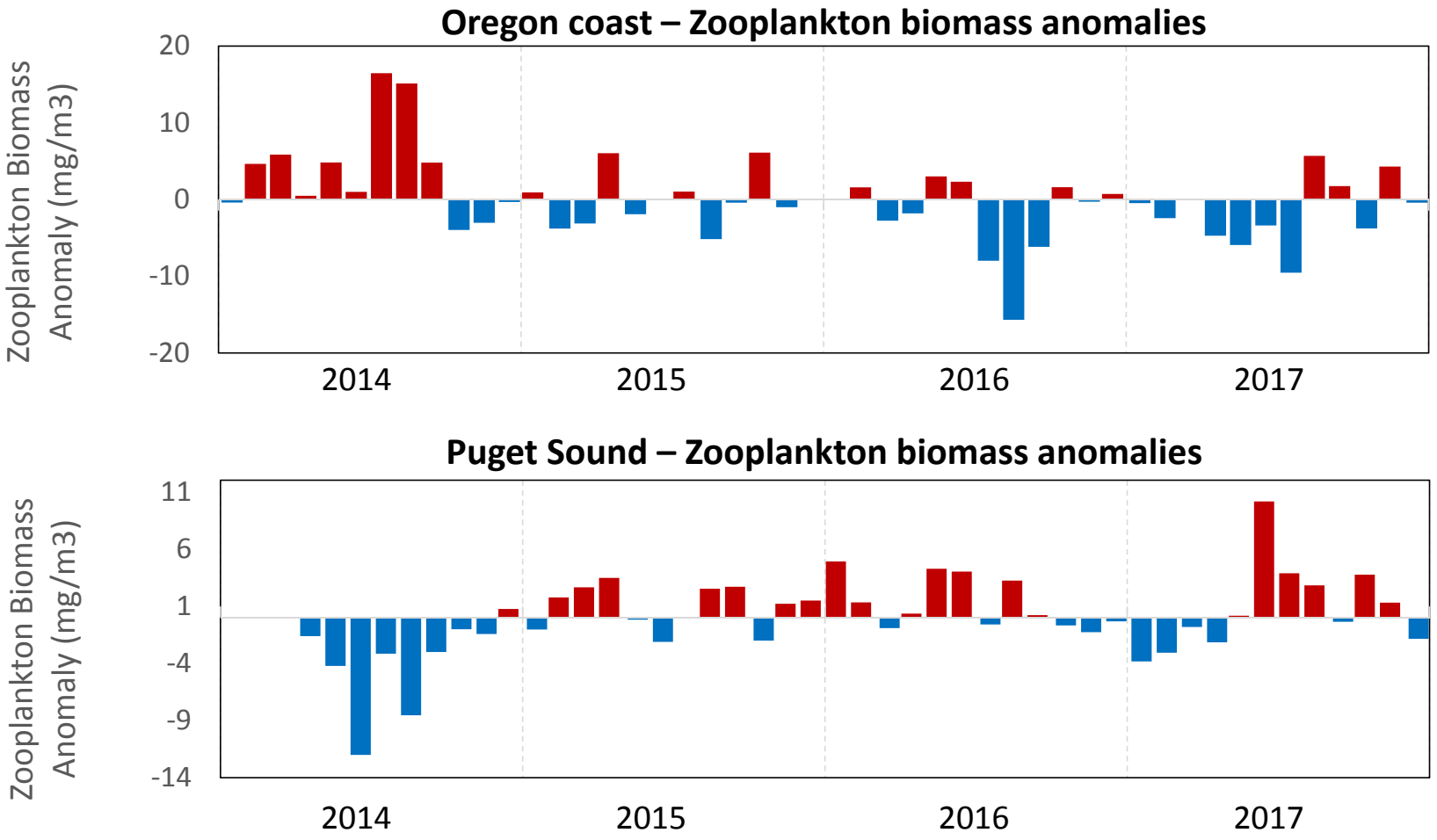
Relative to 1997-2011 mean

Nutrient anomalies

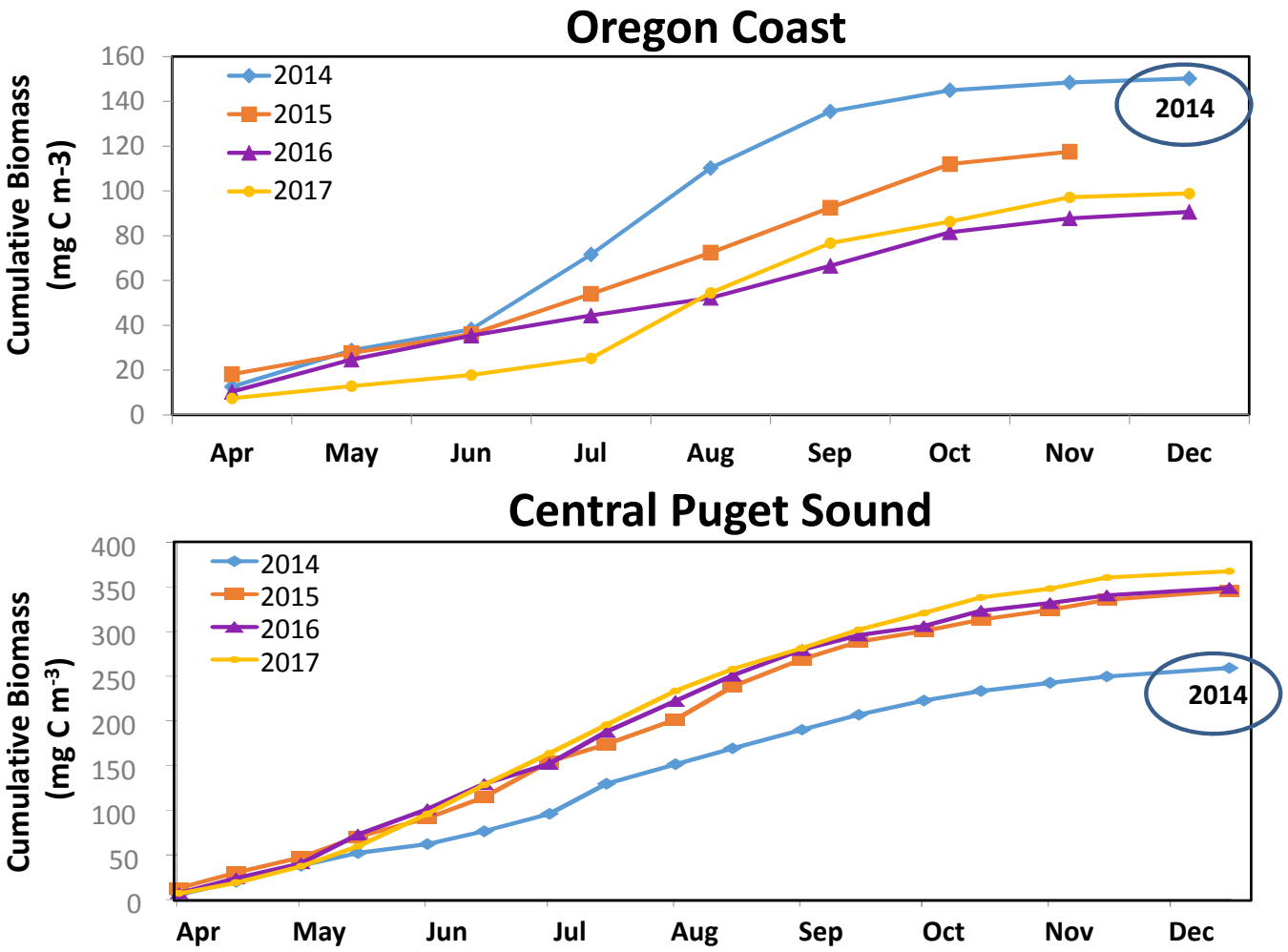
Chlorophyll anomalies



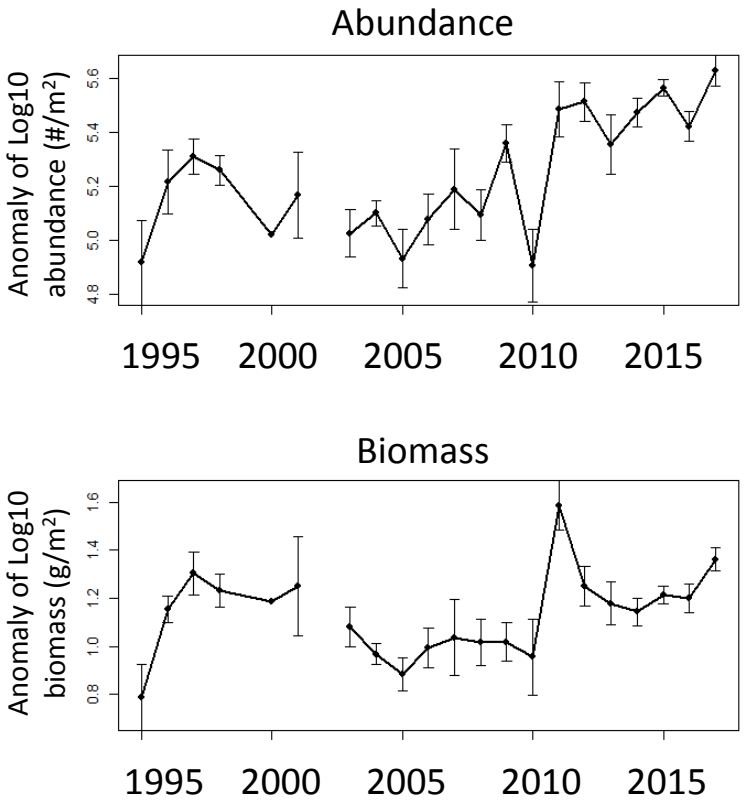
Zooplankton biomass anomalies: Relative to 2014-2017 mean

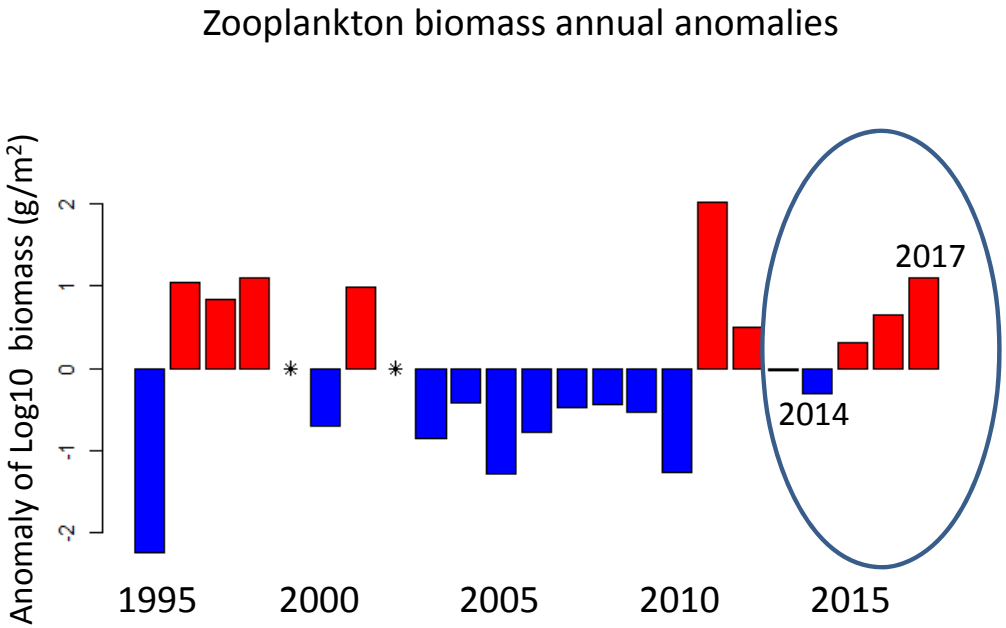


Annual cumulative zooplankton biomass:



Central Strait of Georgia – zooplankton biomass increase 2014-17





Young et al., Salish Sea Ecosystem Conference, 2018

Coastal salmon that out-migrated in 2014 and 2015 had some of lowest returns on record:

http://www.fpc.org

"Juvenile salmon growth was high in all years, 2014-2017."
(B. Beckman unpub. June IGF-1 data)

Coho survival and Chinook returns were lower in 2015.

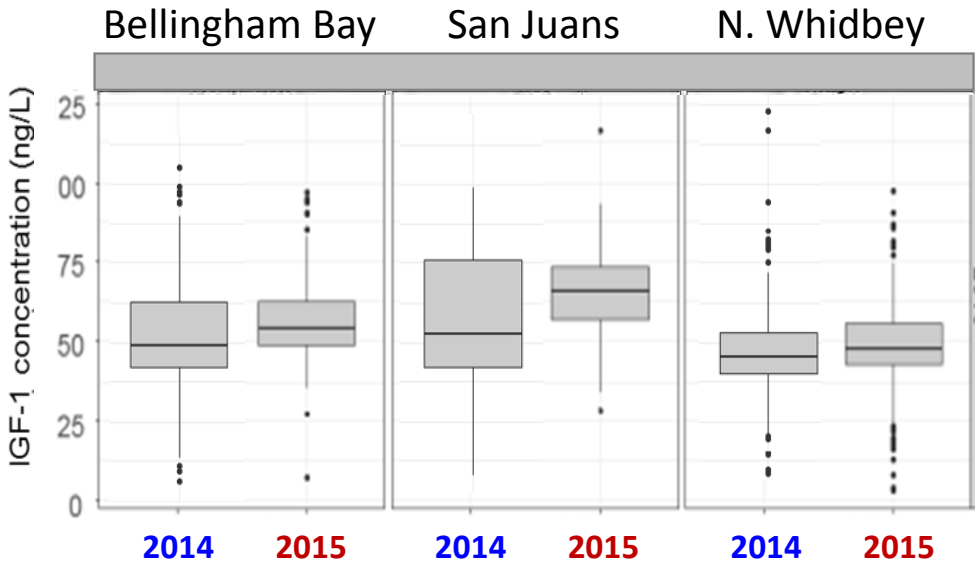
Year	Coho survival	Chinook returns
	Ranked from best (1) to worst (18)	
1998	17	7
1999	12	1
2000	3	2
2001	6	5
2002	4	8
2003	5	17
2004	14	14
2005	10	18
2006	9	12
2007	7	13
2008	2	3
2009	8	9
2010	11	10
2011	19	16
2012	15	6
2013	1	4
2014	16	11
2015	18	15
2016	13[2]	—

Puget Sound Juvenile Chinook salmon growth and size:

Tended to be higher and less variable in **2015** than **2014**

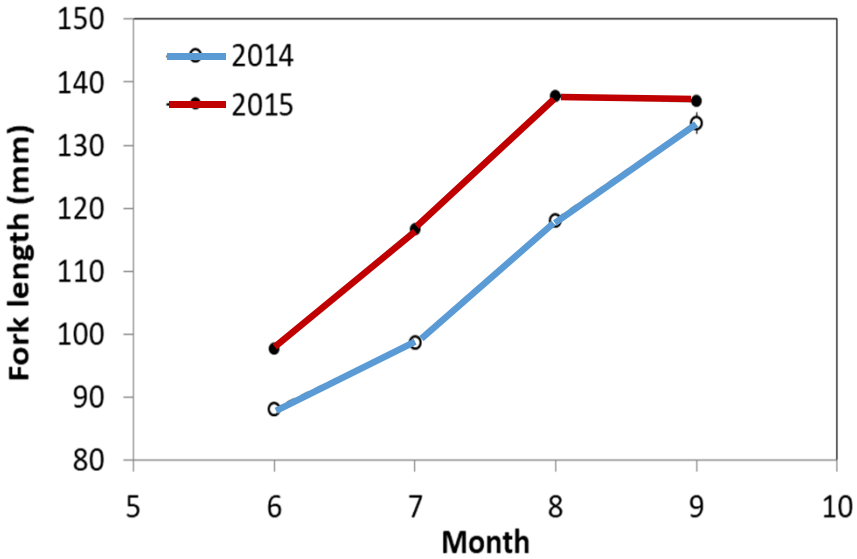
http://www.fpc.org

IGF-1 index of growth for 3 regions:



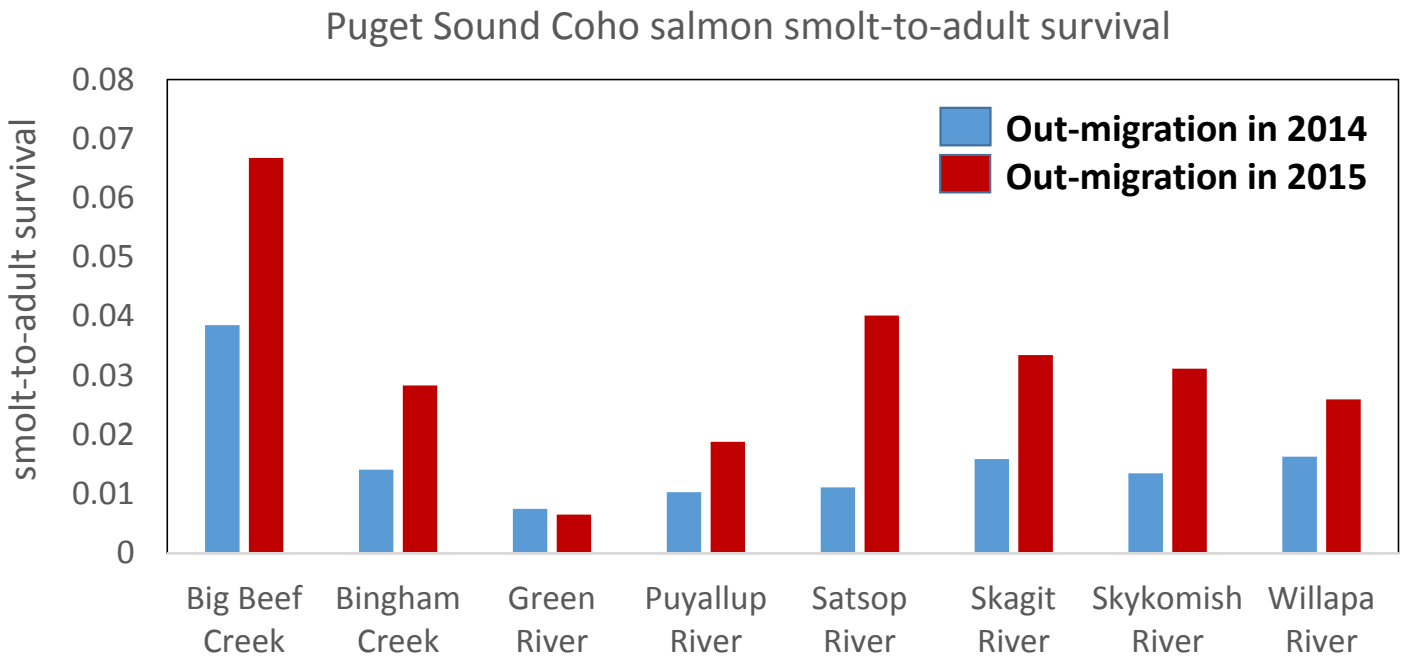
Chamberlain et al. 2017

N. Whidbey juvenile salmon size:

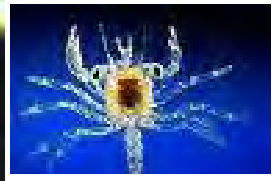


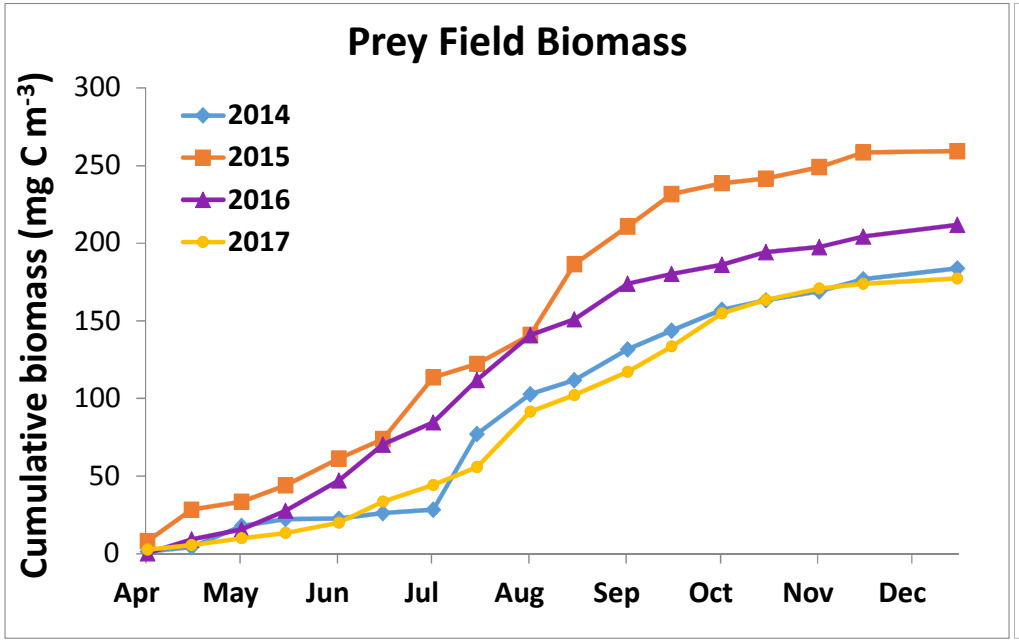
Courtesy of C. Greene et al., NOAA

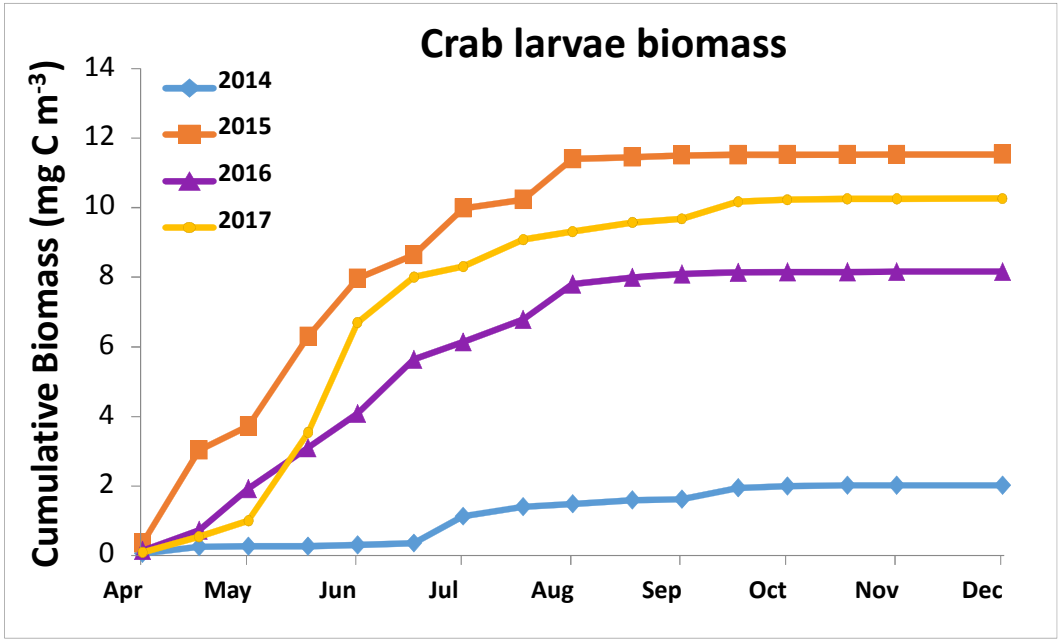
<u>Puget Sound</u> Coho salmon survival rate was higher for 2015 out-migrants than 2014:



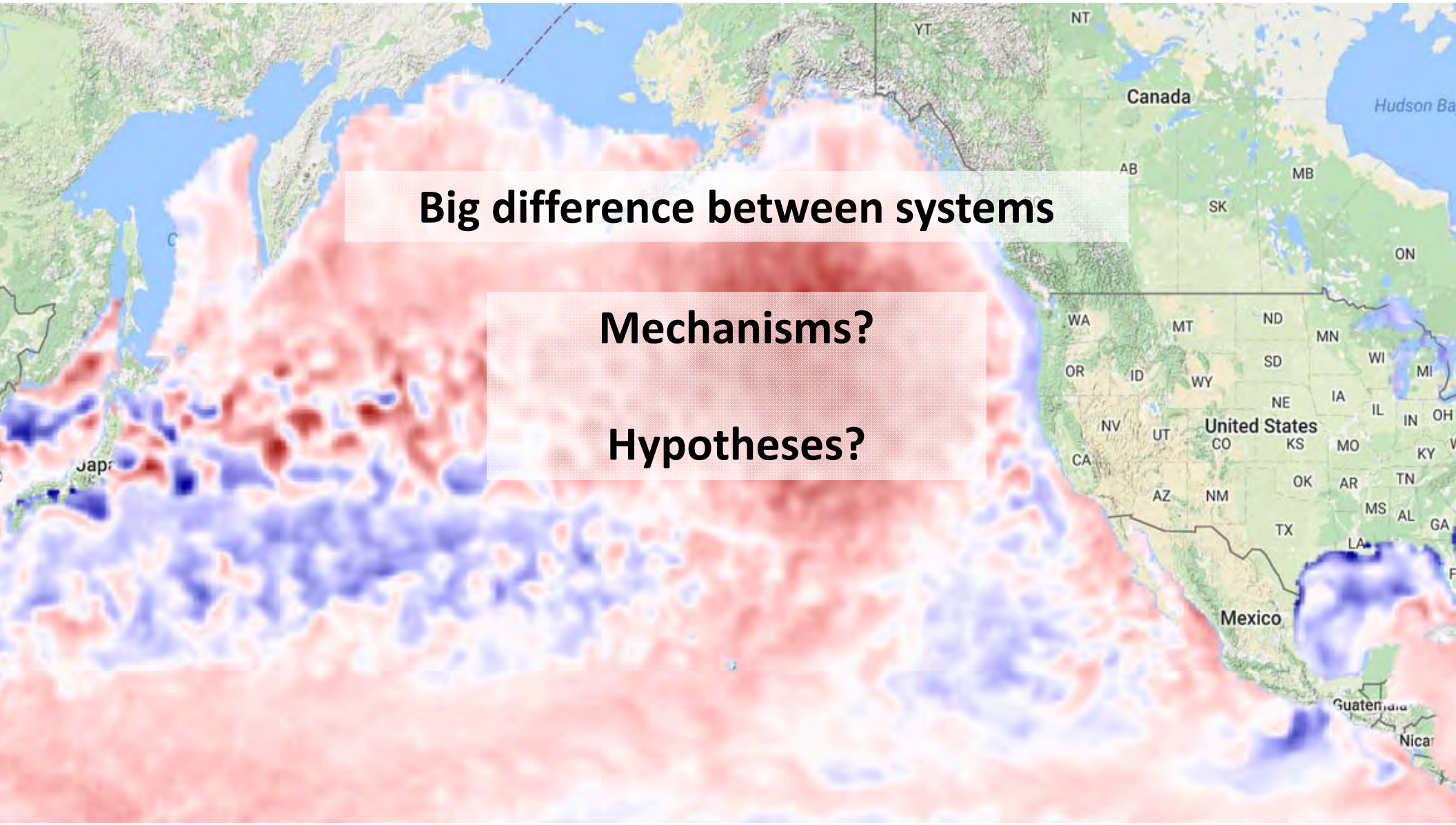
Puget Sound - salmon prey taxa much higher biomass in warm years:







Prey Field = Decapods + amphipods + ichthyoplankton + euphausiids


Big difference between systems
Mechanisms?
Hypotheses?
NT
YT
Canada
AB
MB
SK
ON
WA
MT
ND
MN
OR
ID
WY
SD
WI
MI
NE
IA
IL
IN
OH
NV
UT
United States
CO
KS
MO
KY
CA
OK
AR
TN
AZ
NM
MS
AL
GA
TX
LA
Mexico

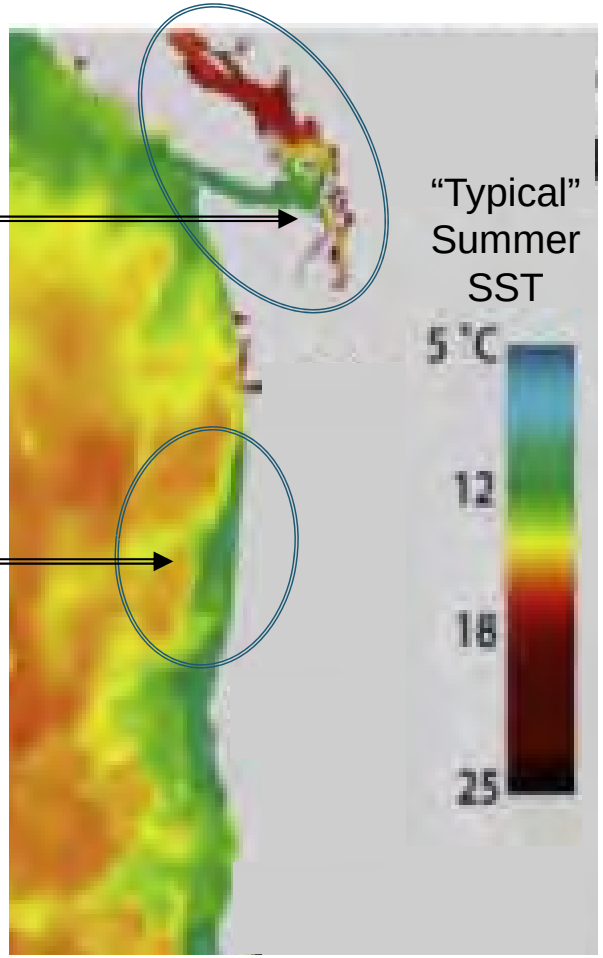
H1: Fundamental differences between systems

Deeper, warmer, more stratified system.
Circulation limited by sills.

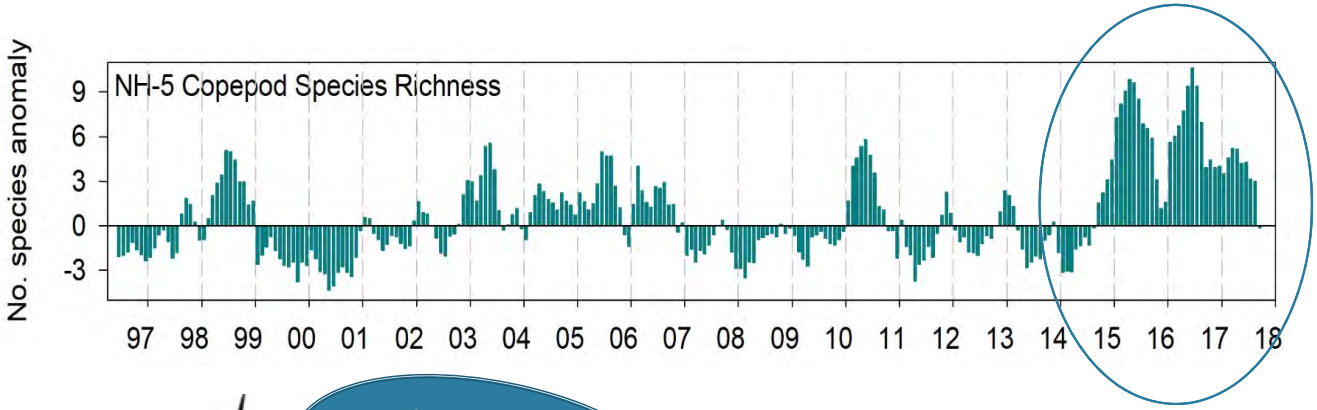
- 2015 drought decreased stratification
  →higher production

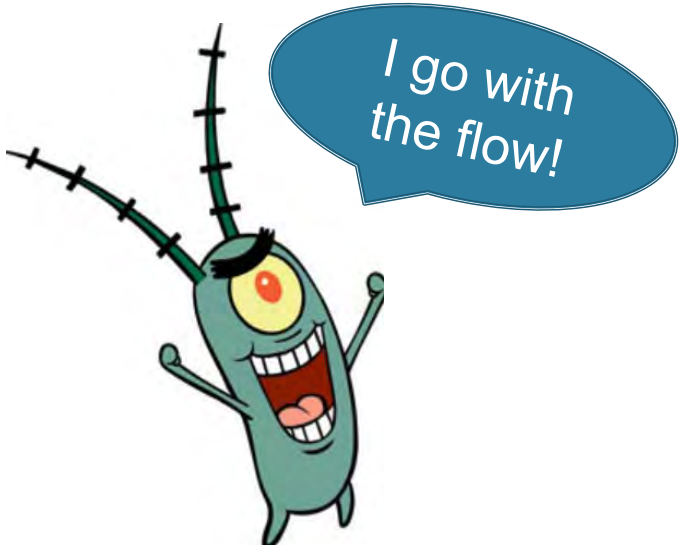
Shallower, colder upwelling site.
Strongly influenced by water mass advection.

- Upwelling of warmer, less saline deep water, low NO_3, increased stratification
  →lower production

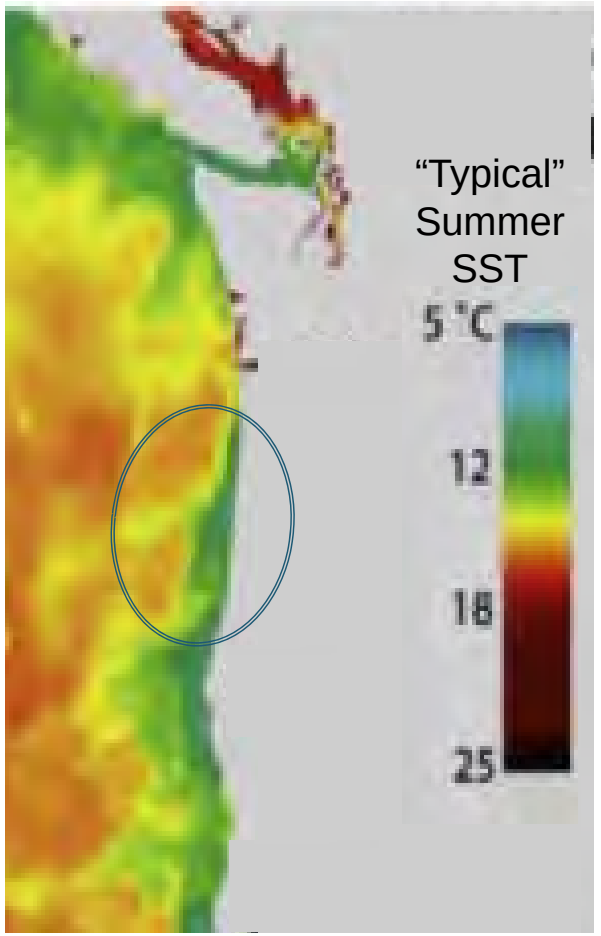


Strong evidence for advection-driven changes in California Current zooplankton





Very few unusual species observed in Puget Sound



H2: Different temperature optima of resident dominant species?

North Pacific warm-water species

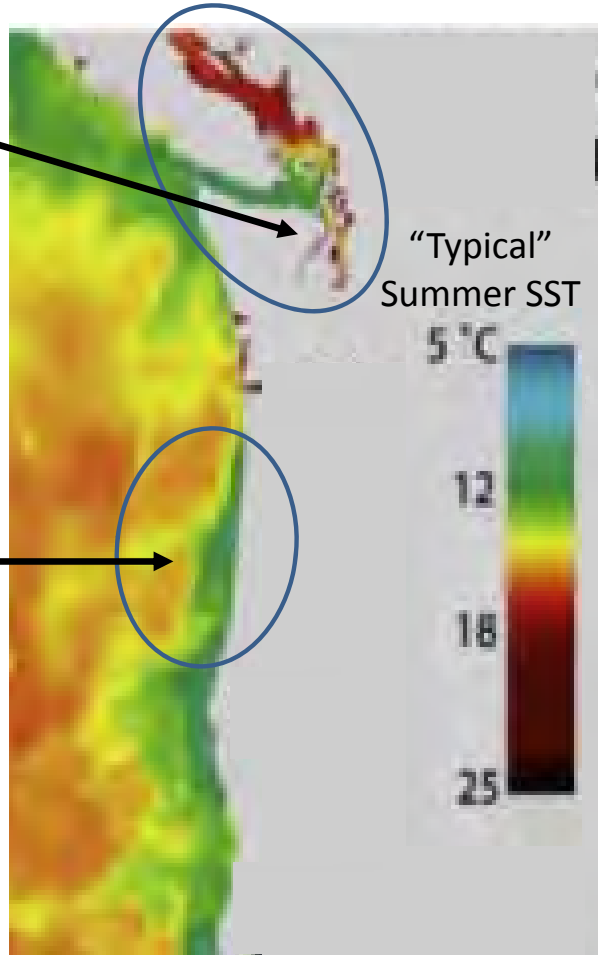
Puget Sound dominants:

Calanus pacificus
Corycaeus anglicus
Paracalanus
Pseudocalanus moultoni

Boreal cold-water species

Oregon Upwelling dominants:

Calanus marshallae
Pseudocalanus mimus
Acartia longiremis



Working Hypothesis:

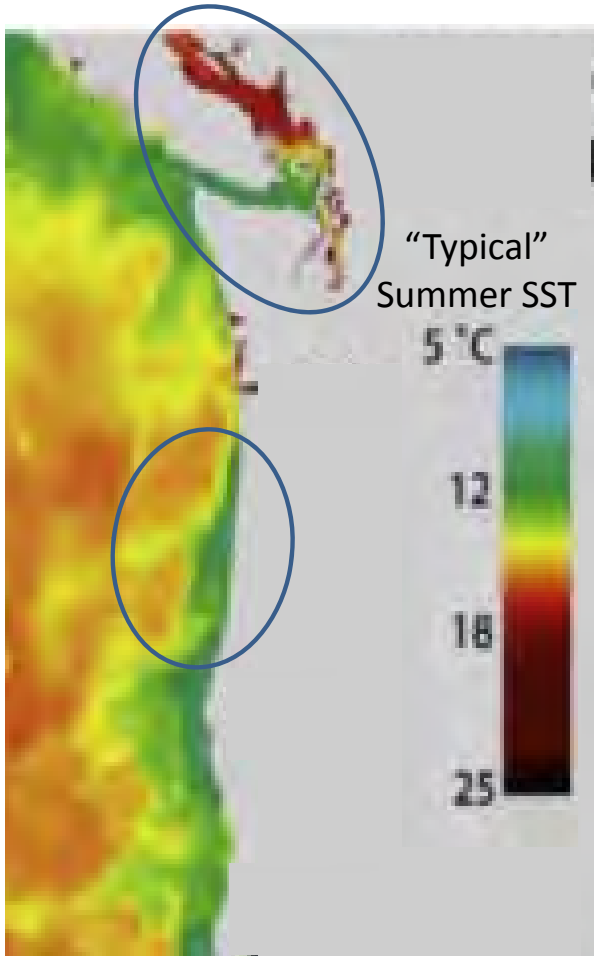
Puget Sound:

Higher temperature → higher growth of resident species, supported by sufficient primary production.

Oregon Coast:

Advection of high temperature, nutrient poor water & oceanic species assemblage.

→Insufficient primary production, only small species present



Conclusions

During Blob years:

Large regional contrasts in zooplankton observed:

- Lower zooplankton biomass on continental shelf
- Higher zooplankton biomass in Puget Sound

Mixed response in salmon:

- High juvenile growth in both regions during warm years
- Indication of better survival from Puget Sound rivers in 2015; worse on coast.
- But…2016-17 returns low in both regions (lag in PS?)

Mechanisms under investigation!

2017 conditions returning to ~normal (at least in Puget Sound).

Partnerships & Funding

SALISH SEA MARINE SURVIVAL PROJECT

Innumerous field crew!
All of the co-authors

Additional data from:
Kim Stark
Gabriela Hannach
Cheryl Morgan
Karen Suchy