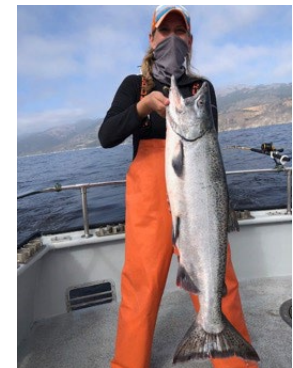
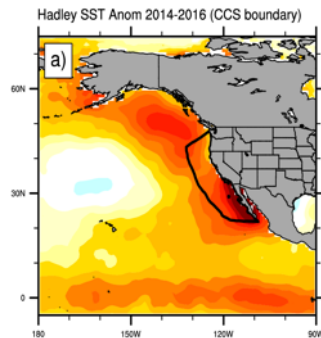
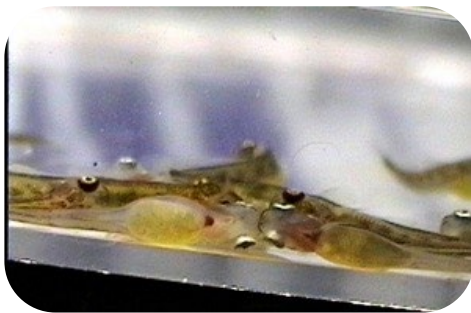


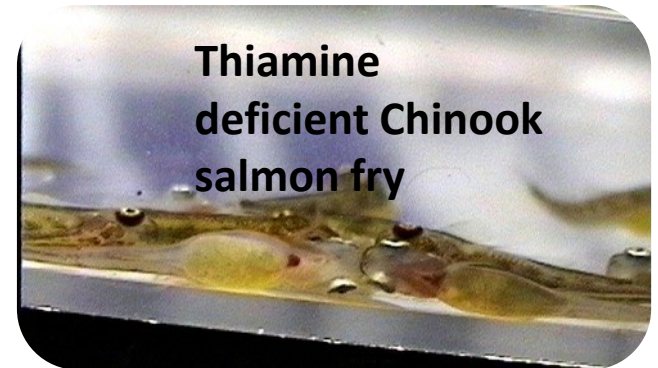
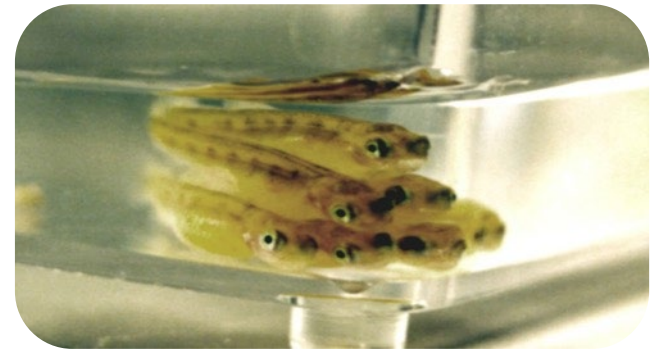
Emergence of thiamine deficiency in salmon in the California Current

Rachel Johnson, Nate Mantua, John Field, Tommy Williams, Anne Todgham, Nann Fangue, Carson Jeffres, Heather Bell, Dennis Cocherell, Dale Honeyfield, Jacques Rinchard, Donald Tillitt, Bruce Finney, Taylor Lipscomb, Scott Foott, Kevin Kwak, Mark Adkison, Brett Kormos, Steve Litvin, Illiana Ruiz-Cooley, and **Steve Lindley**



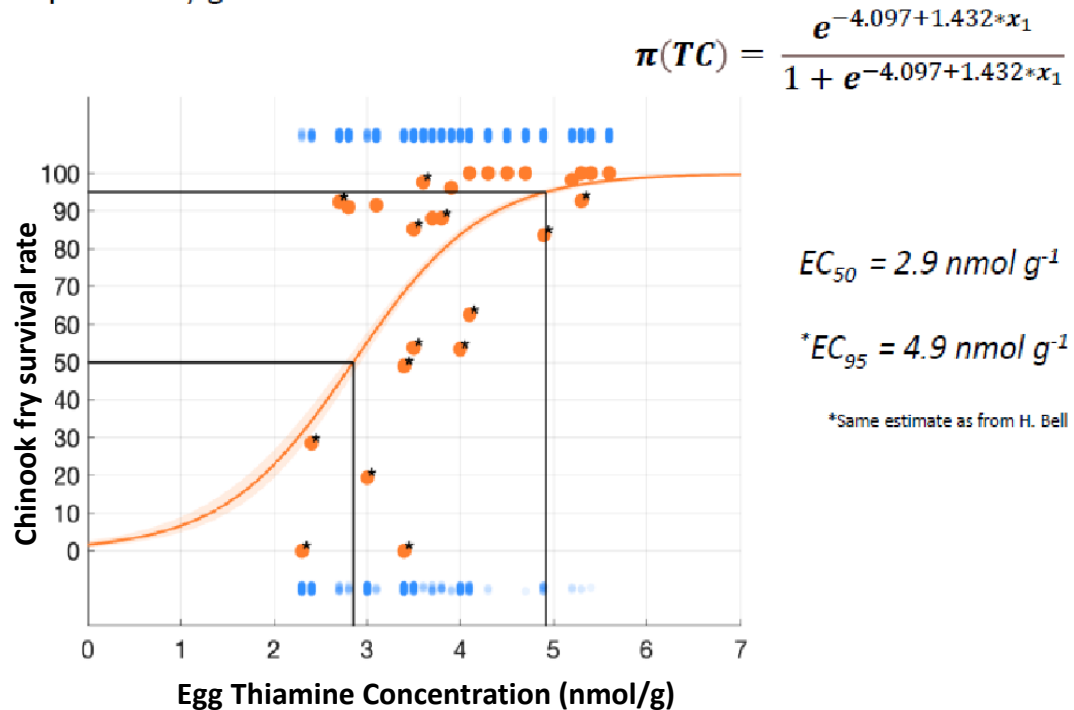
TDC detection in Sacramento River Chinook salmon

- Unusually high egg-to-fry mortality rates, fry with coagulated yolks, corkscrew swimming patterns, and anorexia 2-4 weeks after ponding observed in multiple CV Chinook salmon hatcheries early in 2020
- Scott Foott, USFWS CA-NV Fish Health Center Memo Jan 23, 2020
 - FHC and UC Davis assays found *“fry loss not associated with infectious agent”*
 - **Thiamine bath treatments:** treated fry swimming normally and feeding soon after
- Anecdotal reports of unusually high numbers of dead fry in some Central Valley screw traps downstream of natural spawning areas in early 2020



Assessing impacts: Thiamine-dependent mortality (TDM) estimates

- Analysis Method: A logistic regression model fit to the data to predict survival probability given thiamine concentration.



Estimated winter run Chinook salmon TDM

2020: 23%

2021: 44%

2022: 45%



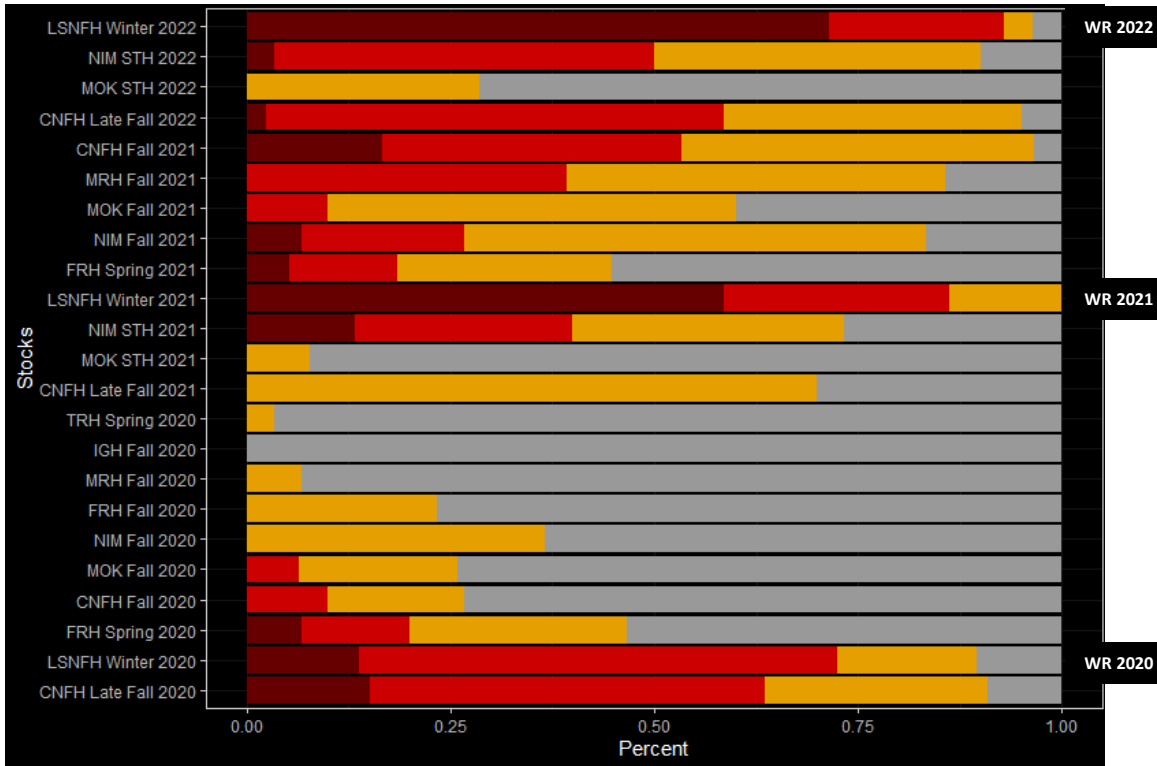
Broad scale egg surveillance 2020-2022

Proportion of Salmon and Steelhead Eggs with Different Levels of Thiamine

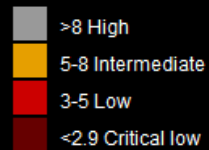
Recent



Earliest

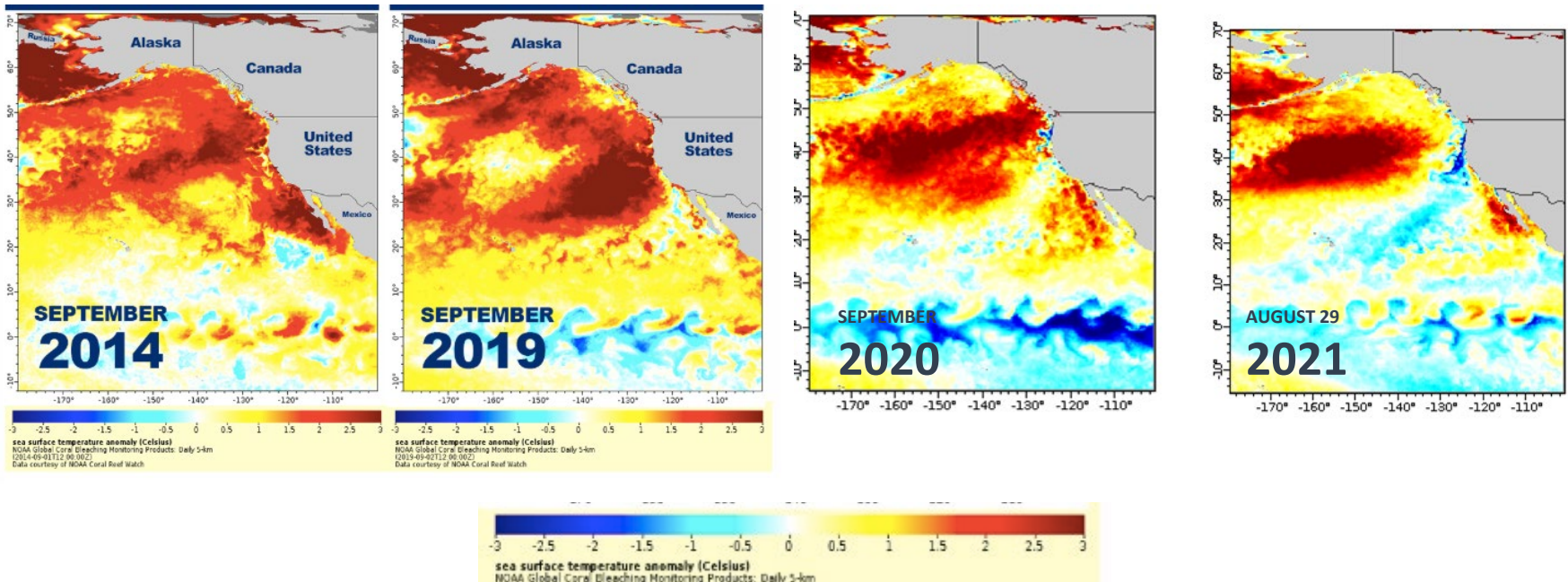


Thiamine Levels (nmol/g)



The Cause? Frequent Marine Heatwaves from 2014-2021?

Extreme and persistent warm periods have affected the northeast Pacific, bringing widespread impacts on marine life and fisheries.



The Cause?

“In California, 2019 northern anchovy abundance from both larval and midwater surveys was the highest in recorded history while many common forage fish (e.g., juvenile rockfishes, sanddabs) and krill were very low. This unique forage base had clear and predictable effects on predators.”

State of the California Current 2018-19

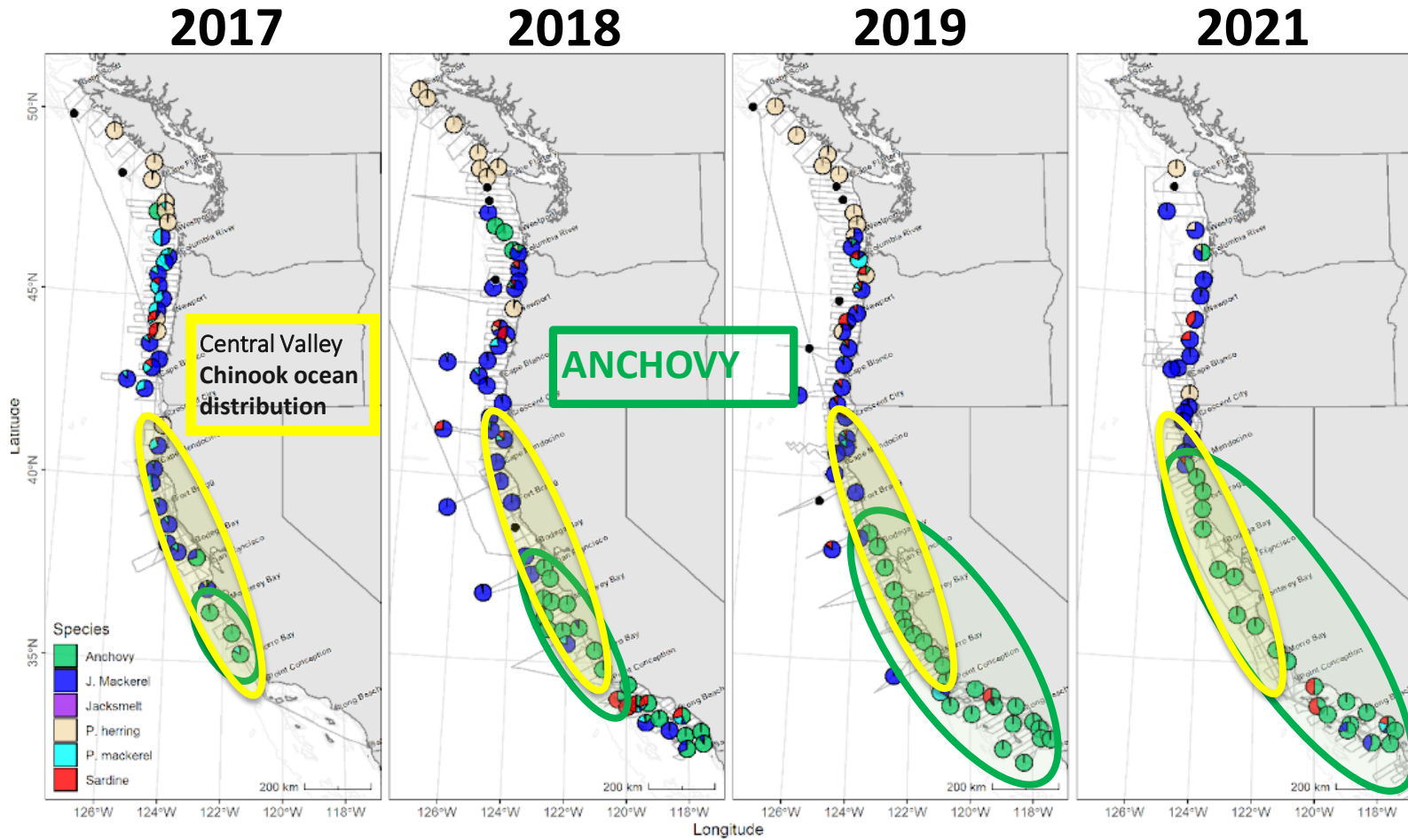
(Thompson et al. 2019, CalCOFI reports)



Coastal Pelagic Species from NMFS Summertime acoustic-trawl surveys

Central California anchovy stock biomass and north end of their distribution expanded greatly from 2017-2021 summer CPS trawl surveys.

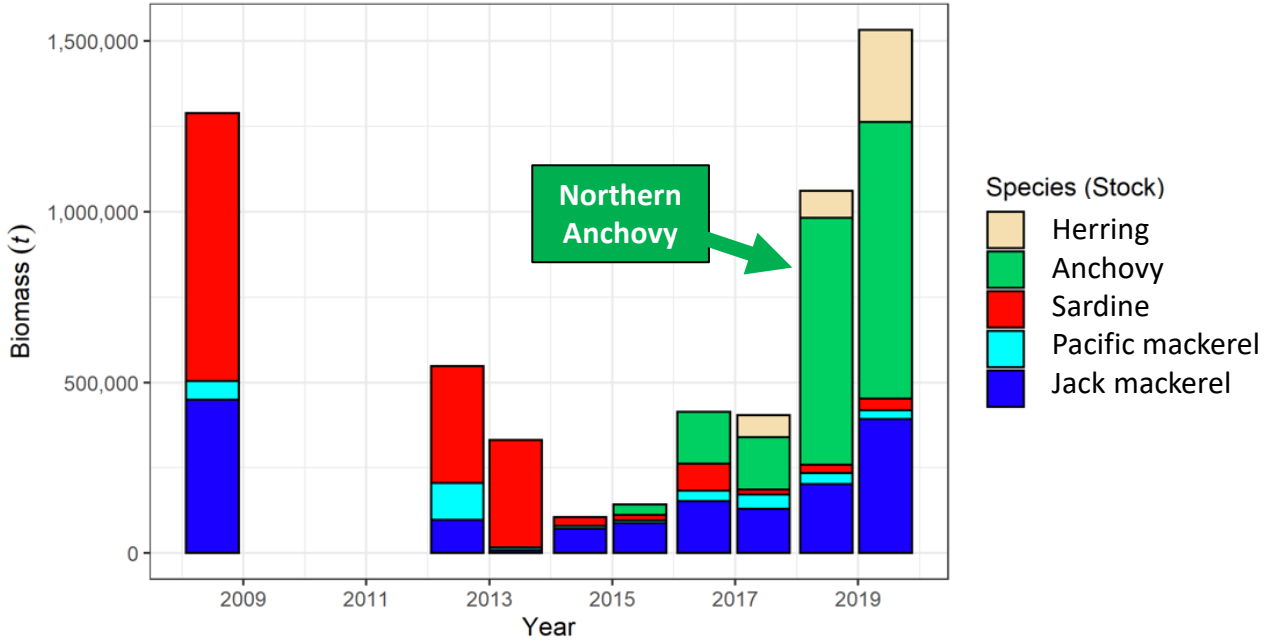
(NMFS Tech Memos; figure from K. Stierhoff, NMFS)



Forage Fish biomass in the California Current in summer

Dominated by Pacific sardine prior to 2014, central stock of Northern Anchovy after 2015

Fig. 29 from Stieroff et al. 2020, NMFS Tech Memo



2020

1980s

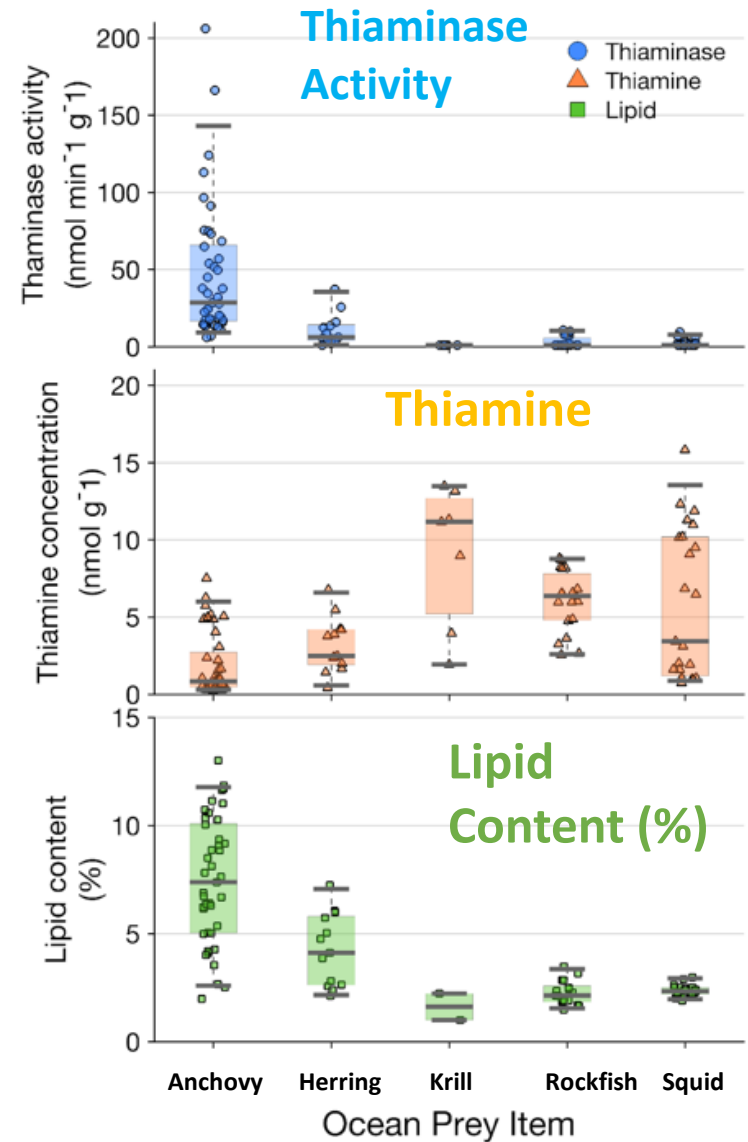


Photo: John Field, NMFS SWFSC

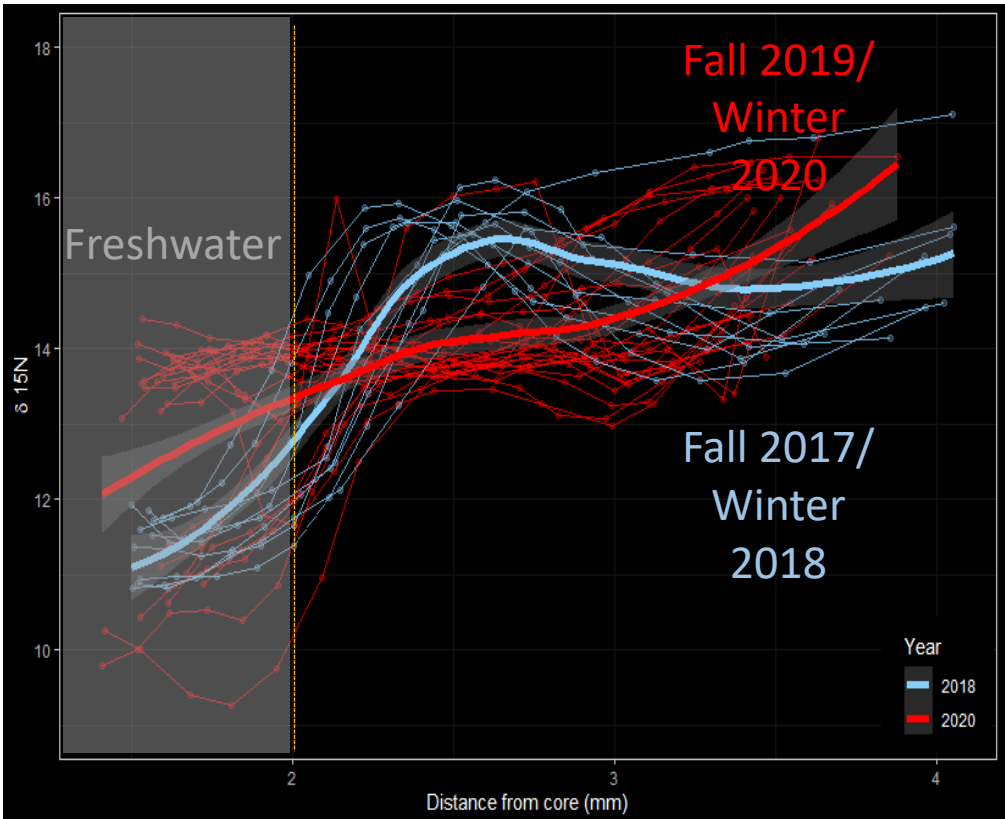
Prey Nutrition

Anchovies are especially high in thiaminase activity, low in thiamine, and high in lipid content

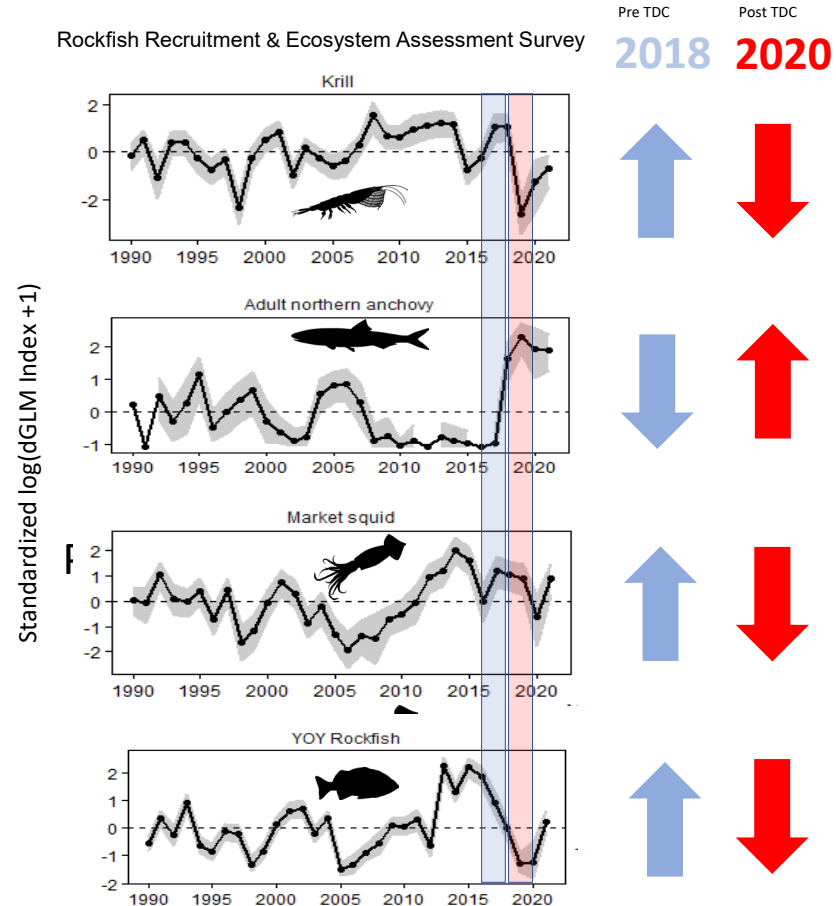
We are also looking at Fatty Acid profiles in salmon eggs and prey items and stable isotopes in salmon tissues and prey



Chinook salmon diet reconstruction from eye lenses



Rockfish Recruitment & Ecosystem Assessment Survey



Data courtesy of John Field

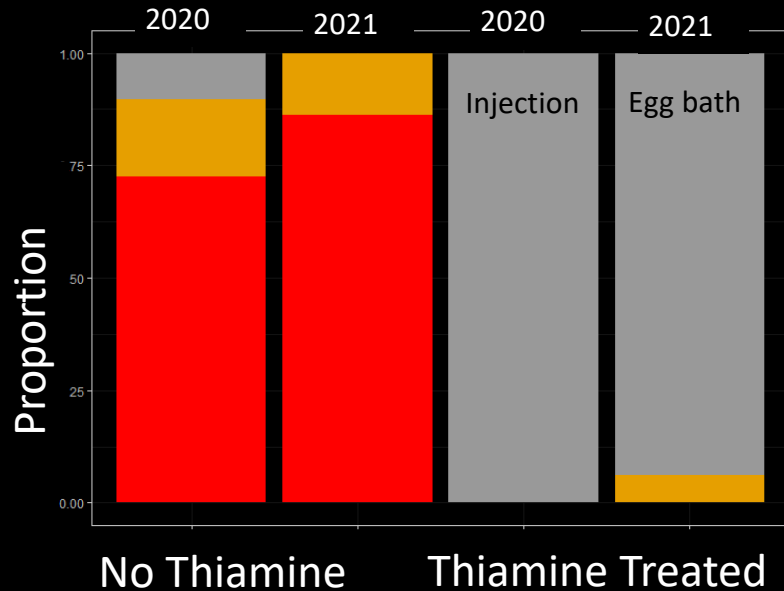


What can be done? Thiamine treatments

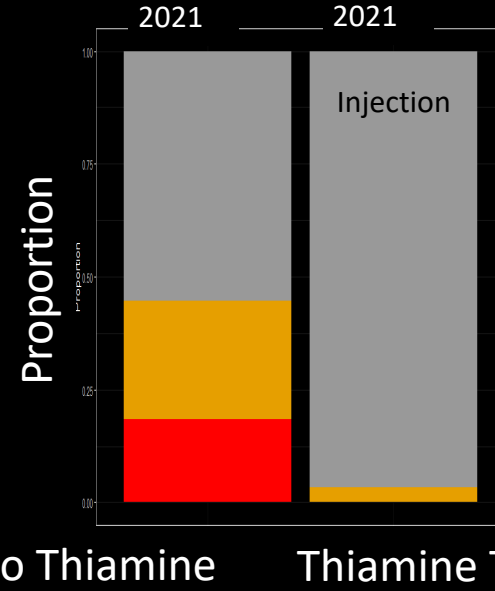


Released in river

Winter run Egg Thiamine



Spring run Egg Thiamine



Questions

- Will this go away soon?
- Is it happening elsewhere in the Pacific?
- Why is there so much variation in B1 content and in juvenile survival for a given level?
- Why are steelhead also affected?

Significance

Our research indicates that thiamine deficiency is a new stressor on California's already stressed salmon, linked with a recent and surprising dominance of northern anchovy in their ocean food-web.

Thiamine deficiency will likely persist and expand to impact other West Coast salmon populations if recent trends in the abundance and distribution of marine forage species continue.

Unlike many stressors on salmon, thiamine deficiency effects are at least partly observable and can be managed in fish hatcheries and possibly in early-migrating naturally-spawning populations.