Environmental fluctuation and shifting predation pressure contribute to variation in Puget Sound steelhead smolt survival

NOAA FISHERIES

Northwest Fisheries Science Center

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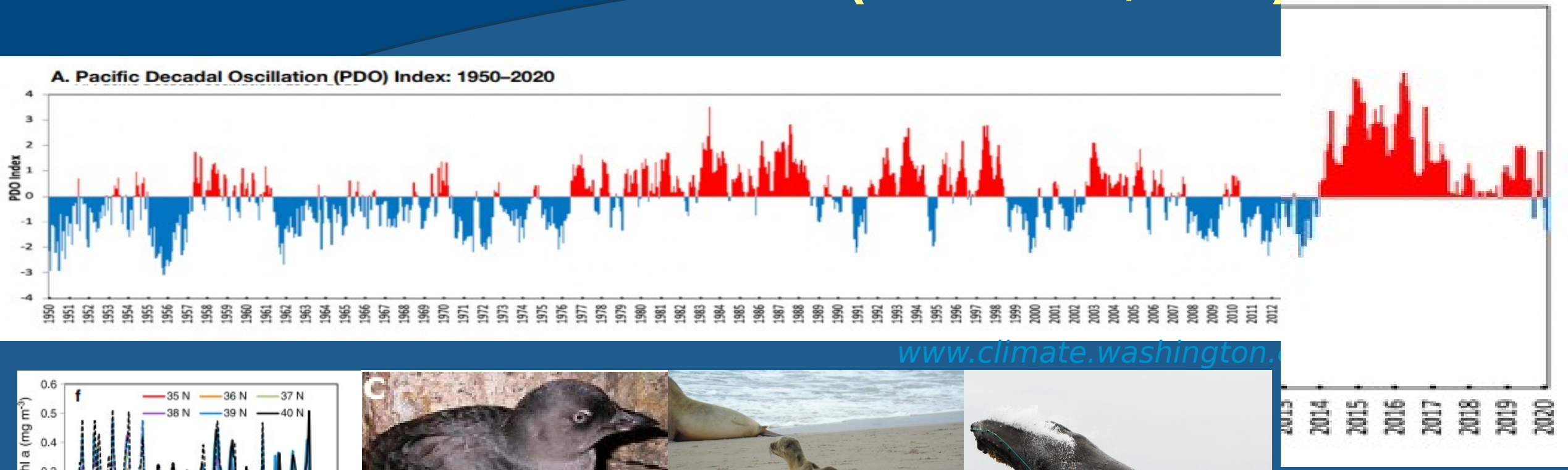
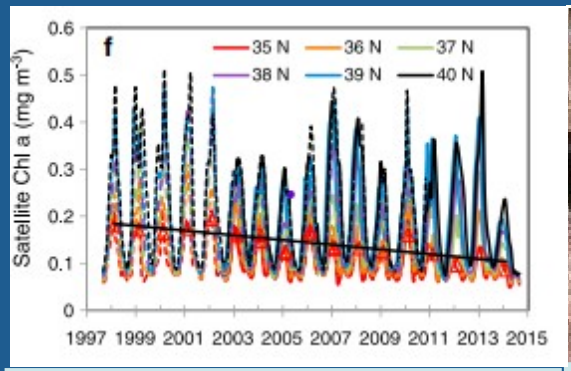
NE Pacific marine heat waves (2014-2016, 2019)



www.climate.washington.



Offshore phytopplankton production greatly reduced

Whitney (2015) Geophysical Res Lett

Planktivorous Casseins auklet die-off due to changes in prey abundance and quality

Jones et al 2018 Geophys Res Lett

Photo: NOAA Fisheries

Food limitation leads to starving and stranding of sea lions along CA coast

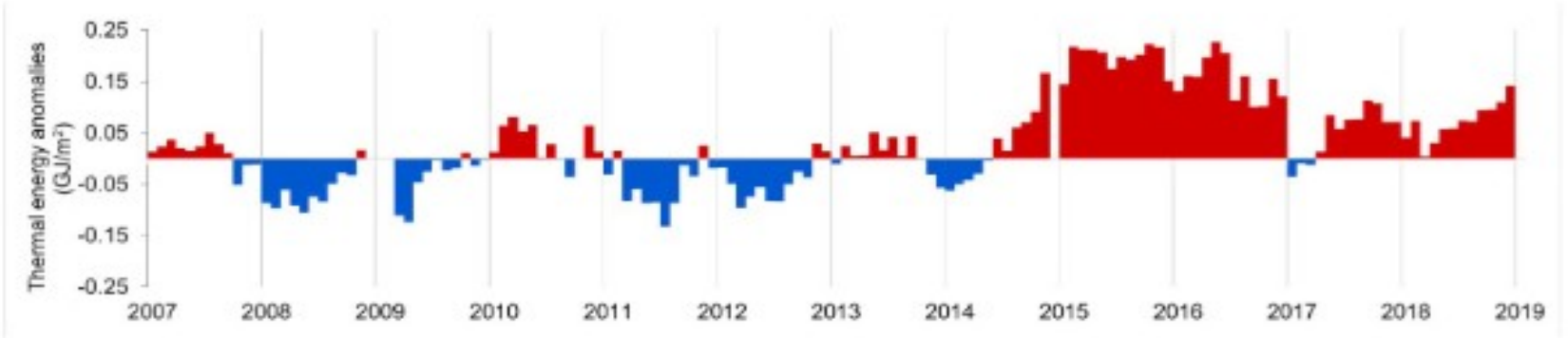
McClatchie et al (2016) R Soc

Photo: NOAA/NMFS WCR

Habitat compression increases fishery x whale interactions

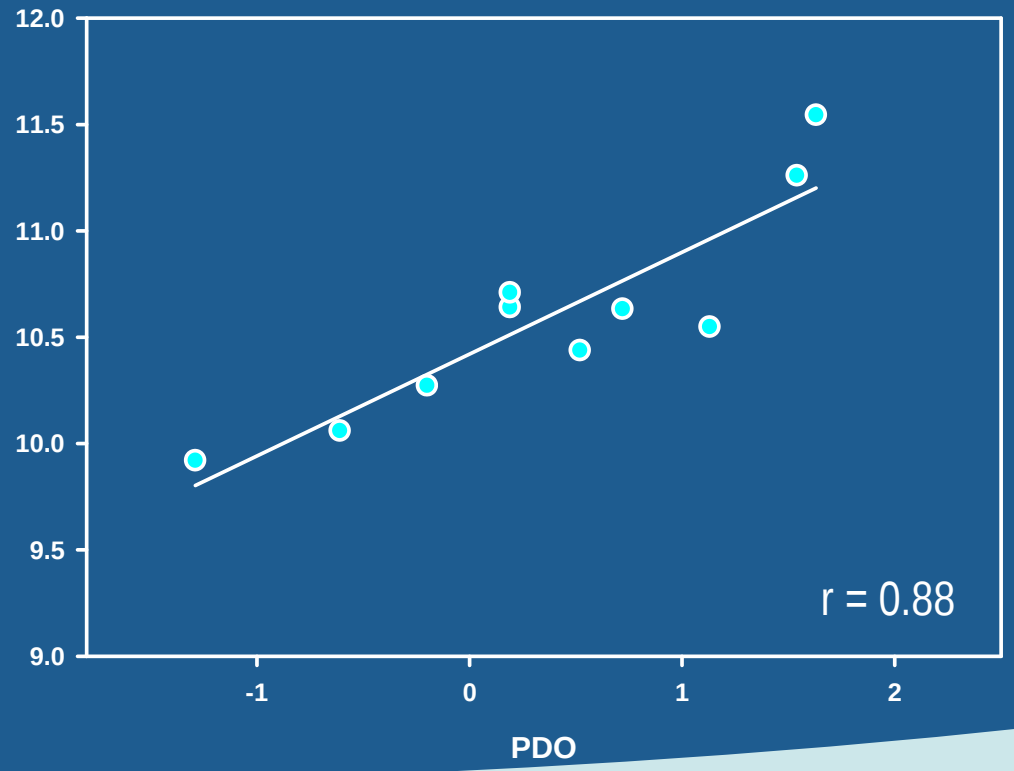
Santorra et al. (2020) Nature communications

Effects of the MHW in the Salish Sea



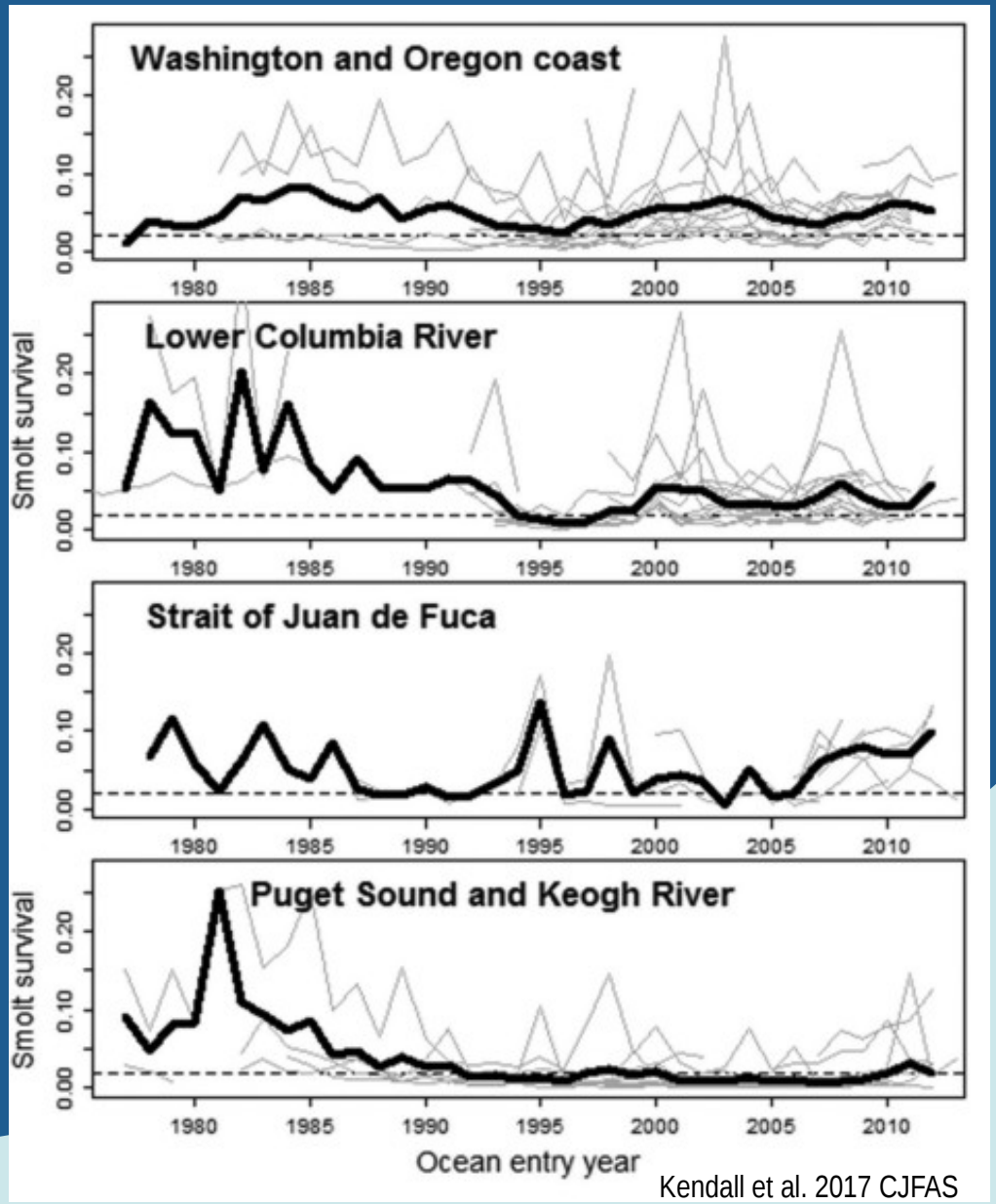
https://ecology.wa.gov/Research-Data/Monitoring-assessment/Puget-Sound-and-marine-monitoring

https://marinesurvivalproject.com/the-project/why/



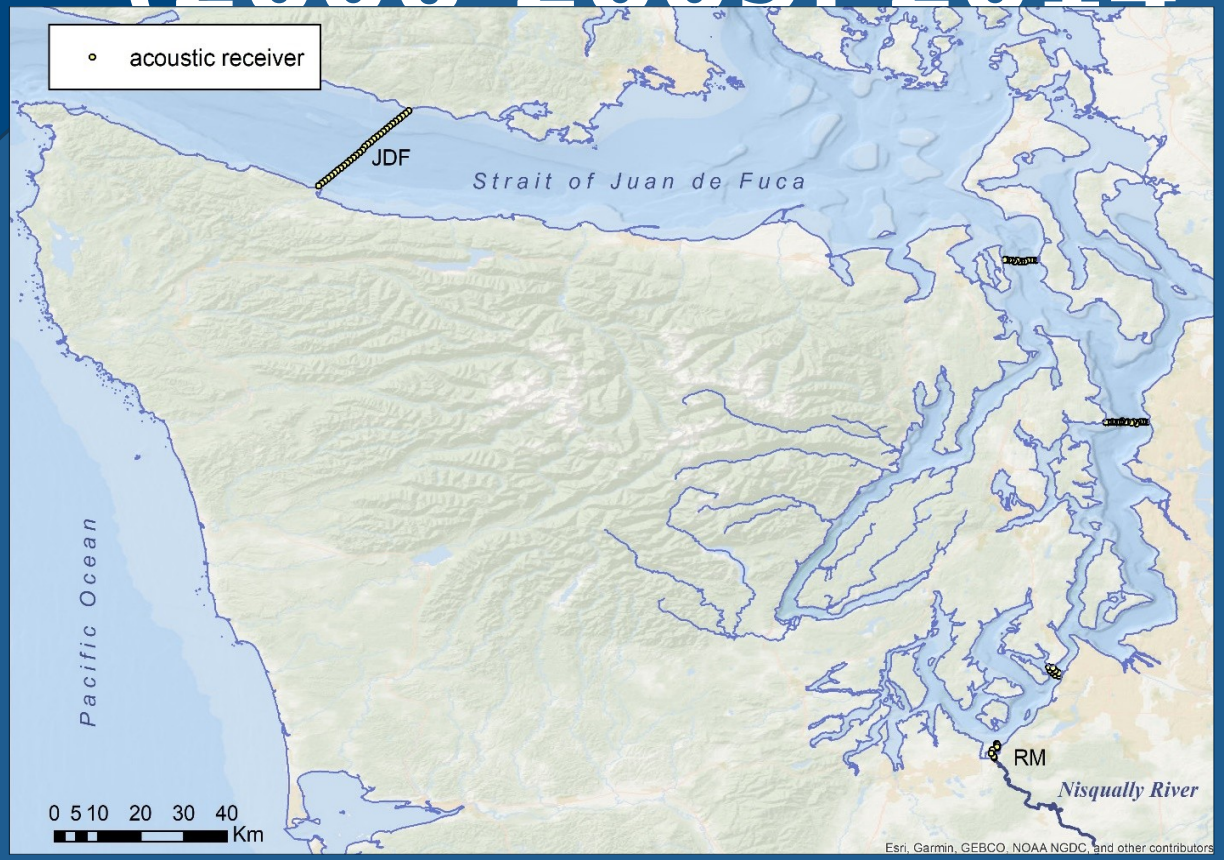
Effects of environmental variables on marine survival of salmon are well documented

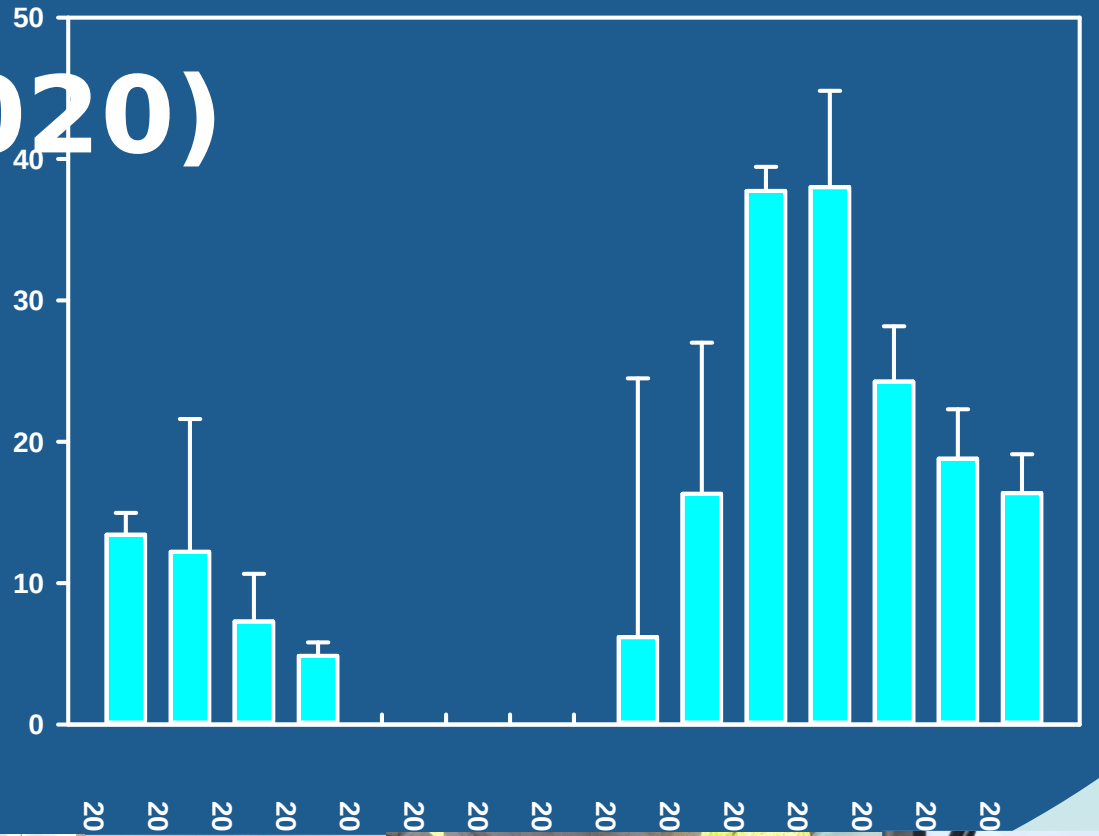
- Relationships vary over space
- Relationships vary over time
- Relationships vary by species or ecotype
- Steelhead total smolt to adult survival (SAR) is strongly influenced by local conditions
- Early marine migration is an important phase, influencing SAR



Kendall et al. 2017 CJFAS

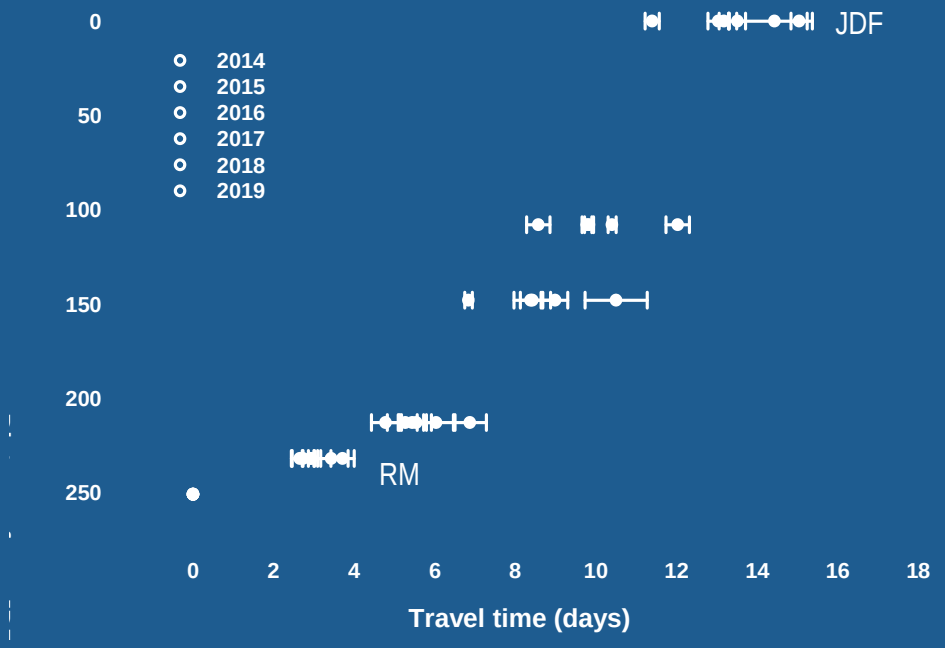
Puget Sound early marine survival estimates (2006-2009, 2014-2020)





Could steelhead survival increase be related to PS temperature increase?

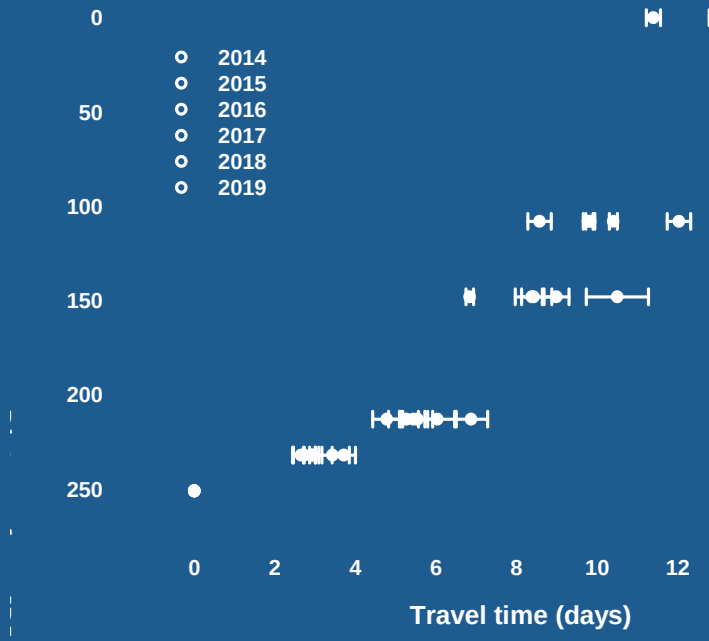
- What we know about Puget Sound steelhead
  - Quick migration

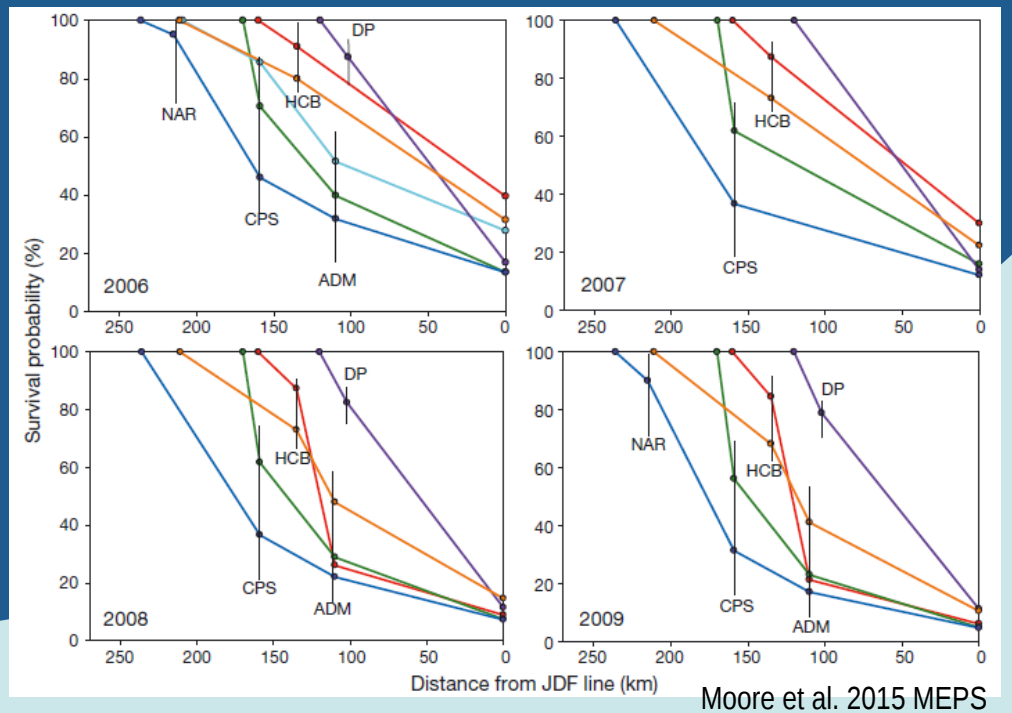


Moore et al. 2015 MEPS

Could steelhead survival increase be related to PS temperature increase?

- What we know about Puget Sound steelhead
  - Rapid migration
    (and similar among years)
  - High mortality

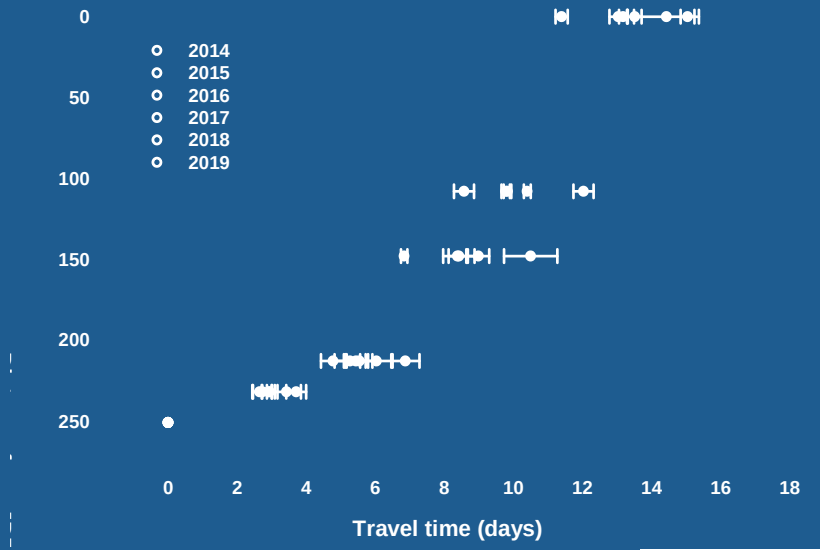


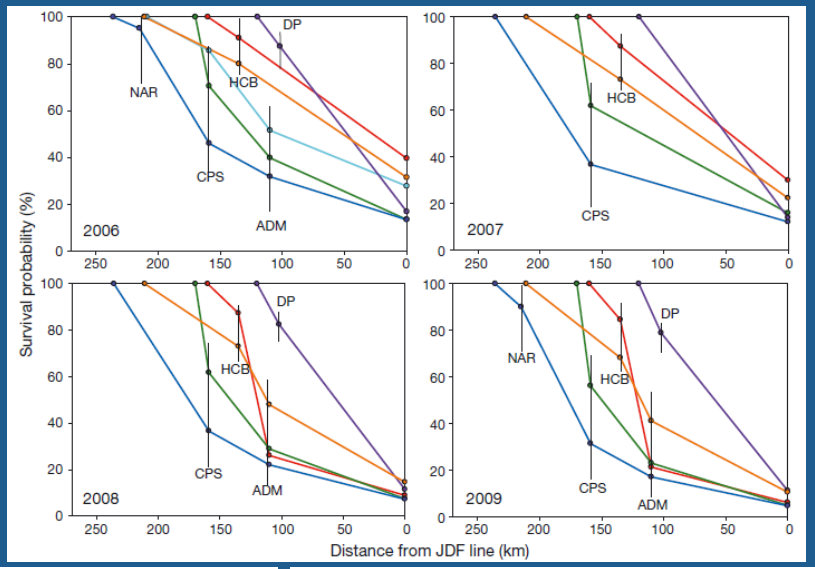


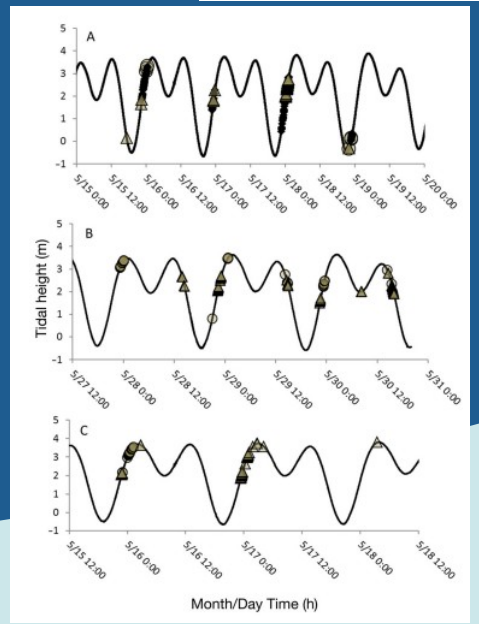
Moore et al. 2015 MEPS

Could steelhead survival increase be related to PS temperature increase?

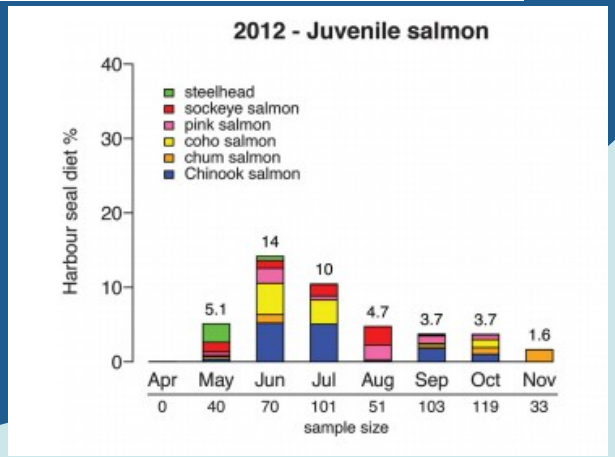
- What we know about Puget Sound steelhead
  - Quick migration (and similar among years)
  - High mortality
  - Predation (by harbor seals) likely an important source of mortality





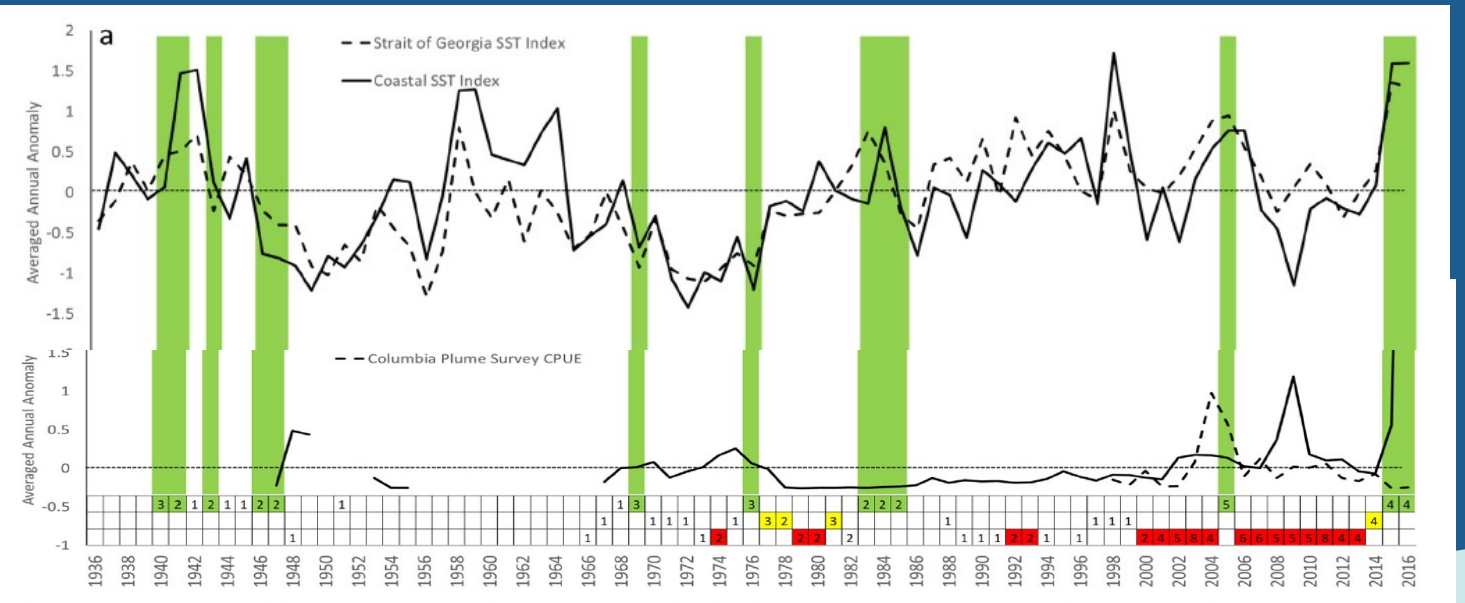


Berejikian et al. 2016 MEPS



Thomas et al. 2017 CJFAS

Northern anchovy increase in abundance in the Salish Sea



Strait of Georgia zooplankton survey

Strait of Georgia Age-0 herring survey

Fraser River plume study

S. Strait of Georgia tow net

Skagit Bay tow net

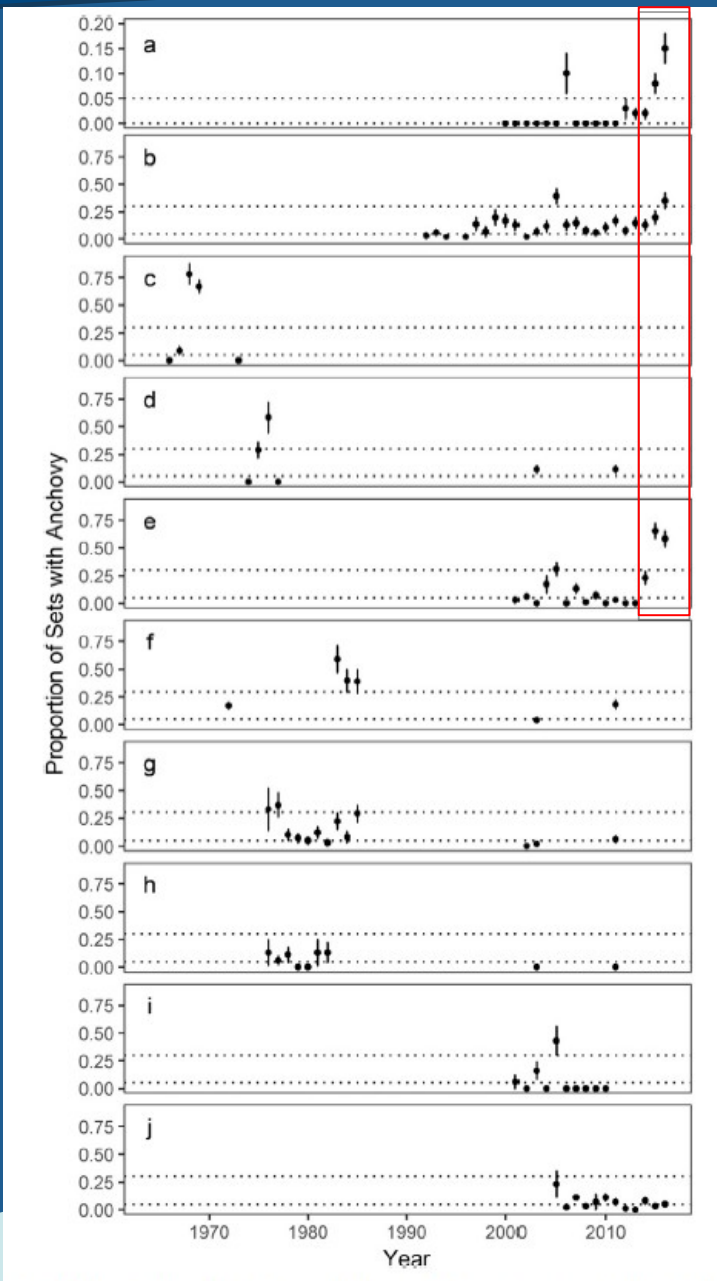
Whidbey Basin town net

Central Puget Sound tow net

South Puget Sound tow net

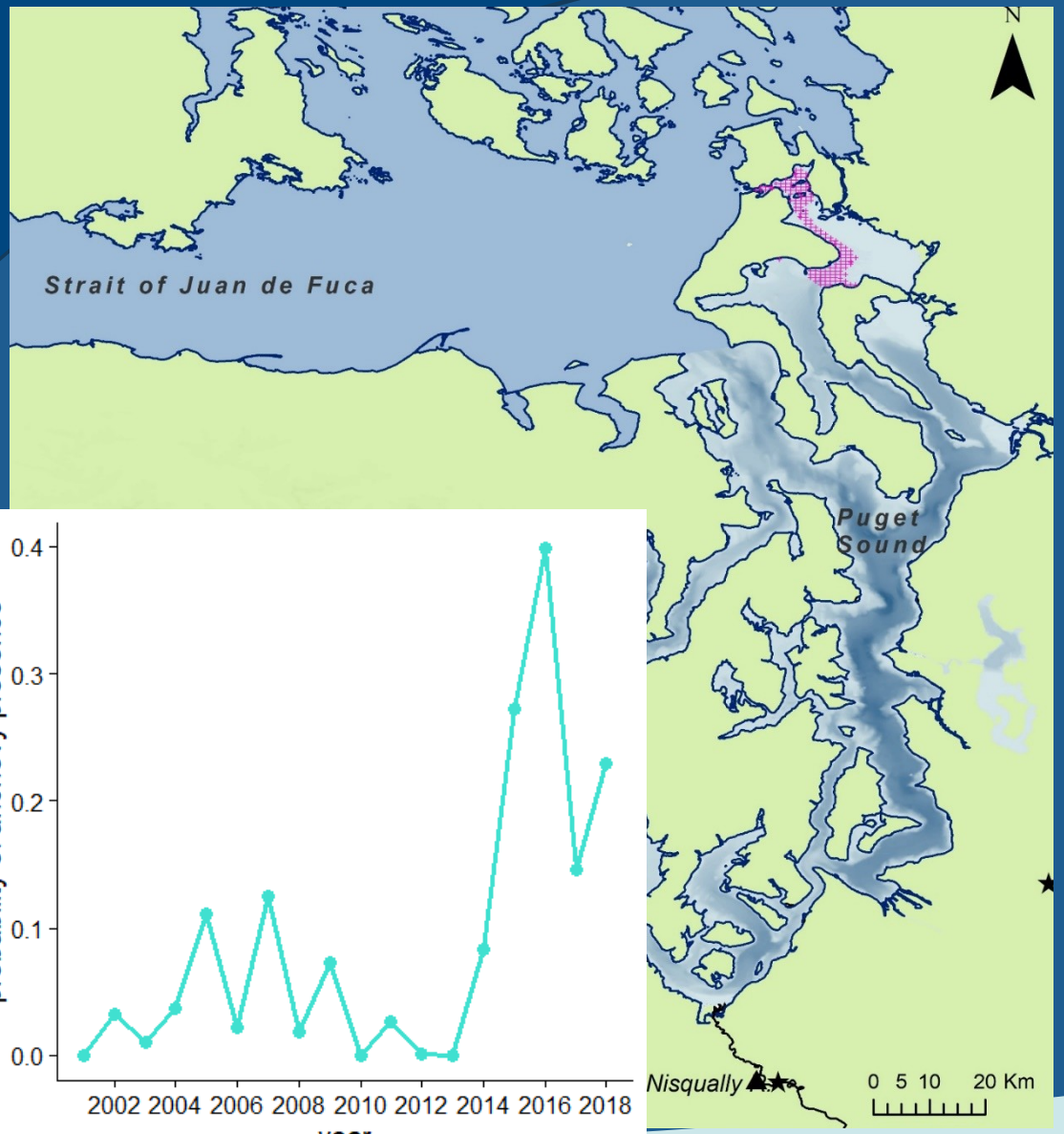
Snohomish beach seine

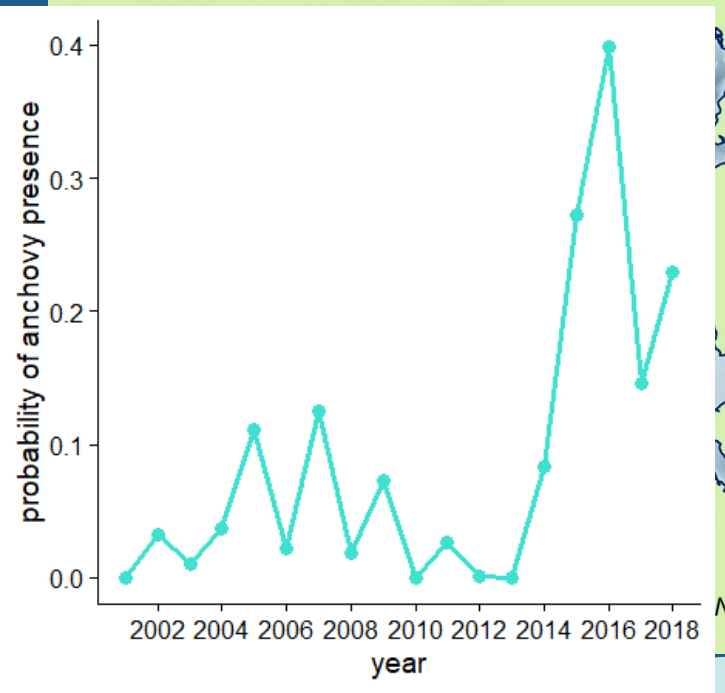
Elwha beach seine

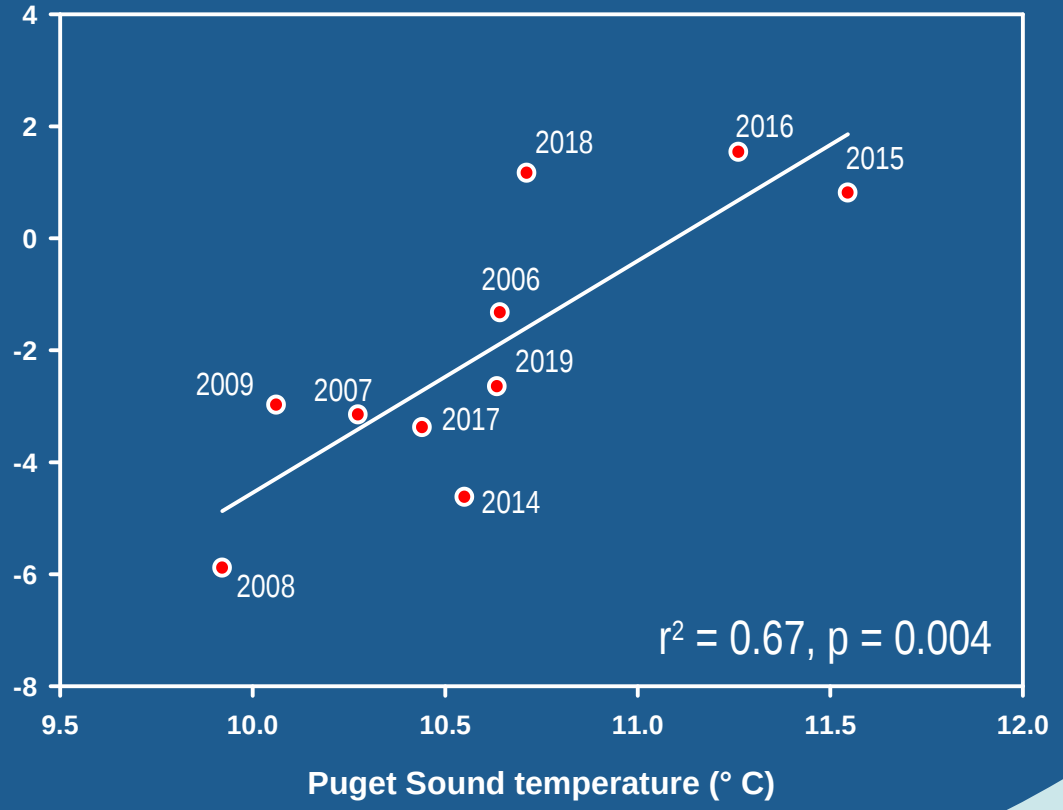


Duguid et al. (2018) Deep Sea Research Part II,

Larval (YOY) anchovy abundance in Skagit Bay







Recap

Increase in steelhead survival coincided with warm PS temperatures ☑

Anchovy abundance increase coincided with warm PS temperatures ☑

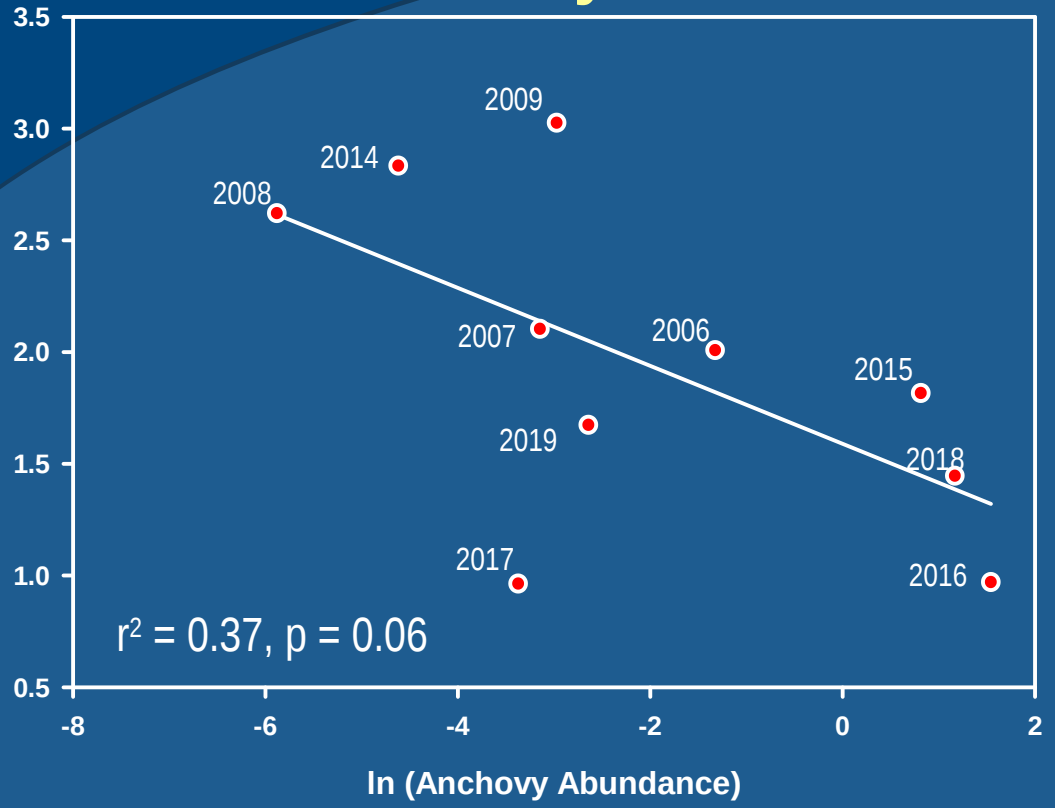
Predation important factor causing low steelhead survival ☑

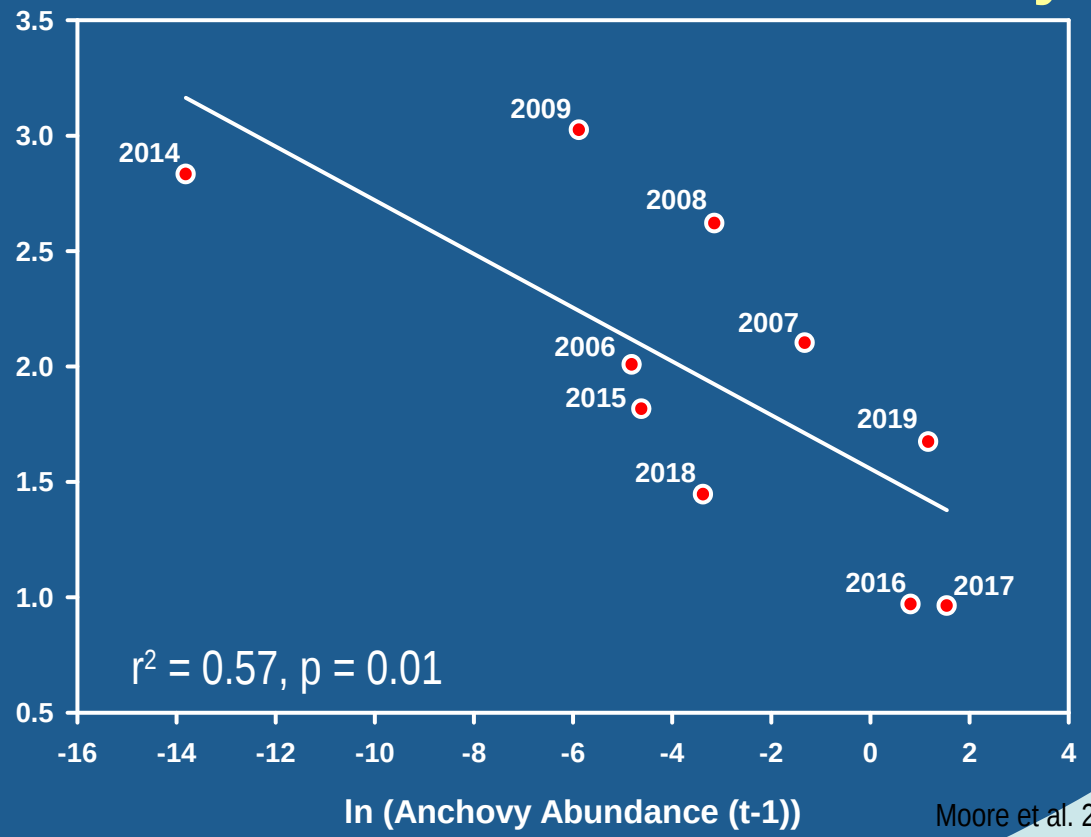
Migration behavior is similar among years ☑

Are steelhead predators eating anchovy instead of steelhead?

We have the data

Increased age 1+ anchovy abundance related to reduced steelhead mortality

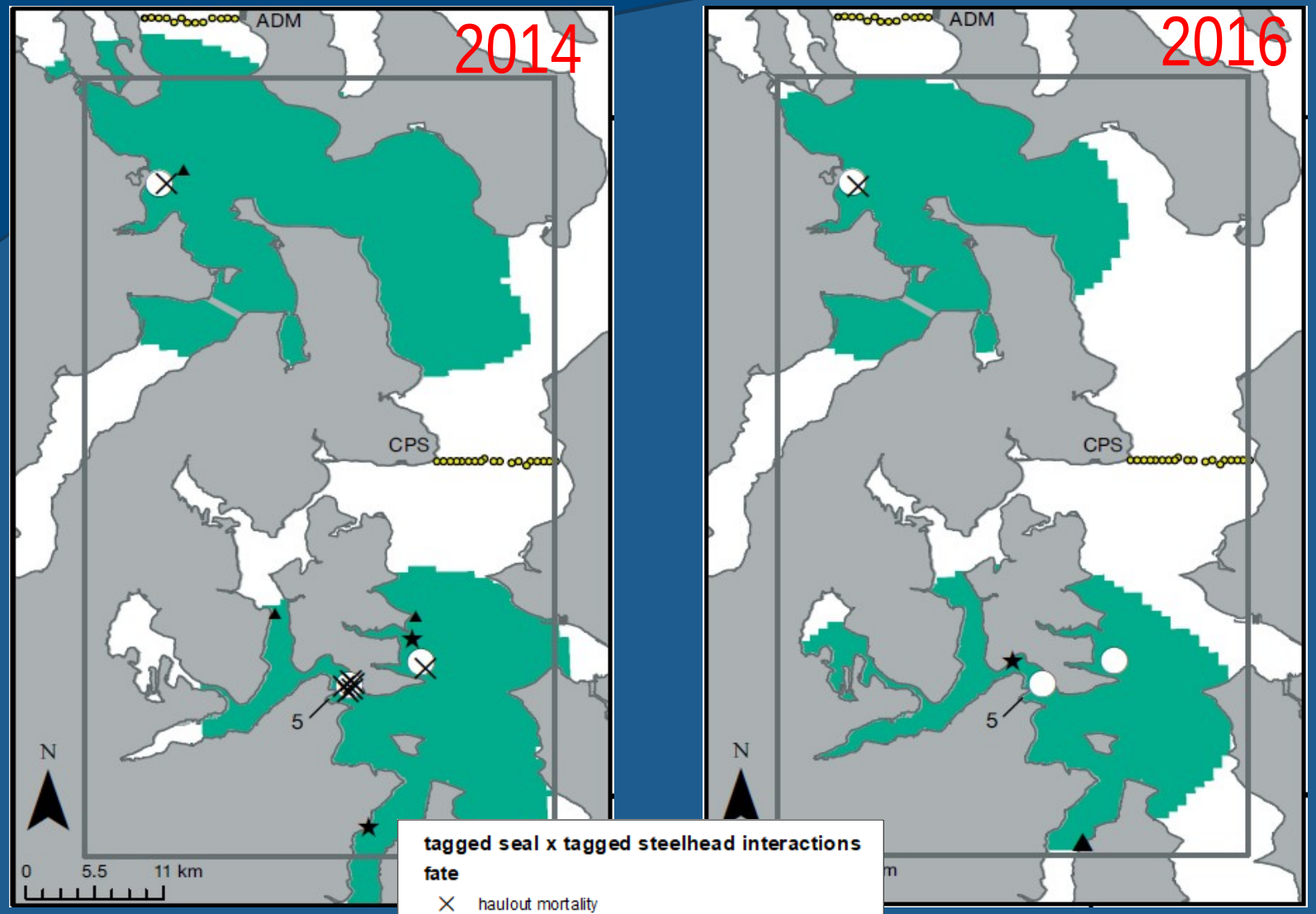




Moore et al. 2021 MEPS

Model	AICc	ΔAICc	Weight
$M_t = A_{t-1}$	23.2	0.00	0.710
$M_t = A_t$	26.2	3.00	0.158
$M_t = 1$	26.5	3.37	0.132

Prey switching hypothesis



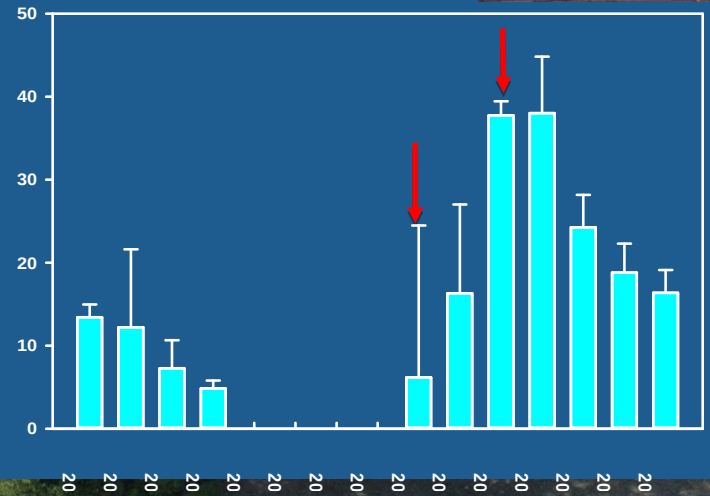
tagged seal x tagged steelhead interactions

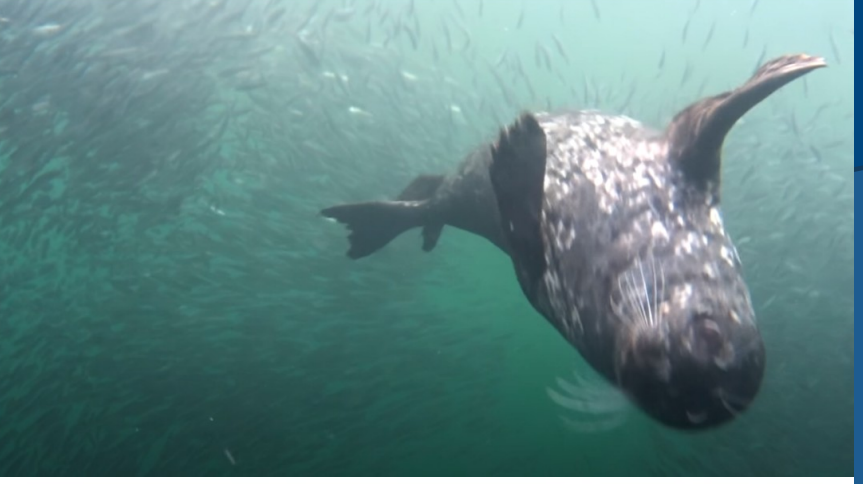
fate

- haulout mortality
- stationary
- survivor
- harbor seal haulout/tagging location

Central PS – 6 mortalities (17%)
North PS – 1 mortality (10%)

Central PS – 0 mortalities
North PS – 1 mortality (2%)





Conclusions/Implications

- Increase in steelhead survival related to increase in Northern anchovy abundance as an alternate prey source for steelhead predators
- Suggests potential variation in relationships between environmental variables and steelhead/salmon survival throughout the smolt – adult period
- Puget Sound temperature variation acted as an unplanned experimental variable, exposing the mechanisms and predator-prey dynamics affecting steelhead survival
- Puget Sound ecosystem –forage fish are an important component of the food web for salmon recovery

"Howe Sound Ballet: seals and sea lions feeding on anchovy"
https://www.youtube.com/watch?v=Ycx1hvrPAqc

Future reseach plans

- Continue annual tagging of Nisqually steelhead smolts
- Experimental approach to evaluate effects of a new Targeted Acoustic Startle Technology (TAST)
- Estimate consumption rate of harbor seals on steelhead in the Nisqually estuary
  - Harbor seal diet data from South Puget Sound
  - Estuary survival estimates
  - Smolt trap estimates

Acknowledgements

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Brian Murphy
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Rob Endicott
Michael Schmidt
Erik Neatherlin
Dan Lomax

Nisqually Indian Tribe
dxʷsqʷaliʔ abš
People of the river, people of the grass

Washington Department of Fish and Wildlife

National Oceanic and Atmospheric Administration
NOAA
U.S. Department of Commerce