

# Shifting phenology in a warming ocean: Spatio-temporal variability in hatching of Pacific Cod in the western Gulf of Alaska



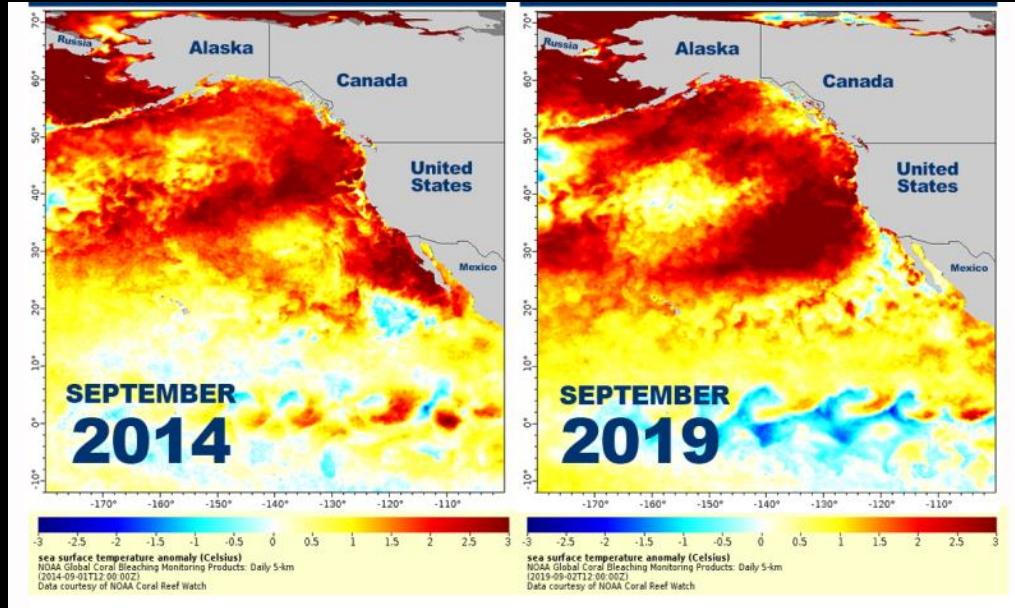
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Department of Fisheries, Wildlife, and Conservation Sciences,

<sup>2</sup>Alaska Coastal Observations and Research,

<sup>3</sup>NOAA, Alaska Fisheries Science Center

# Marine Heatwaves in the Gulf of Alaska



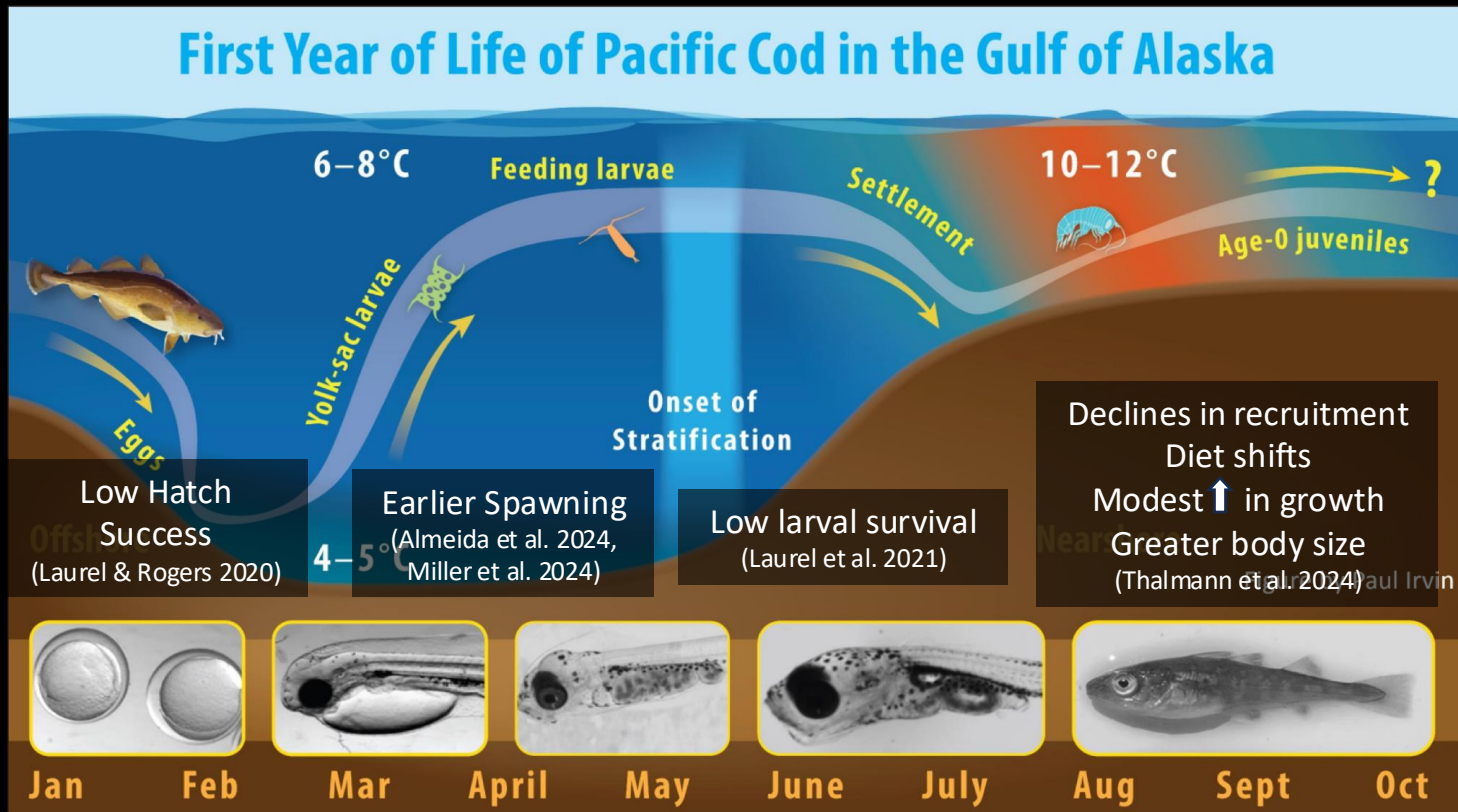
Pacific Cod (*Gadus macrocephalus*)  
\$103 million fishery

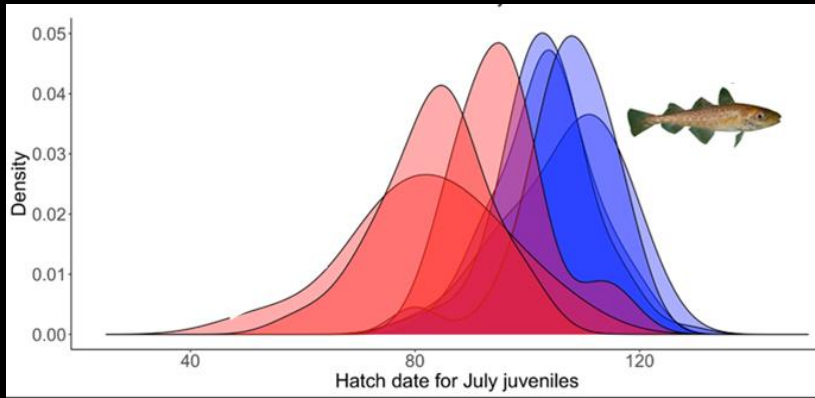
>70% decline in population biomass

**2020**

**Alaska Cod Fishery Closes**

# Impacts of marine heatwaves on early life





- (1) Has hatch phenology returned to pre-MHW values during recent, cooler years?
- (2) Does hatch phenology vary along the Alaskan Peninsula?

# Juvenile Collections



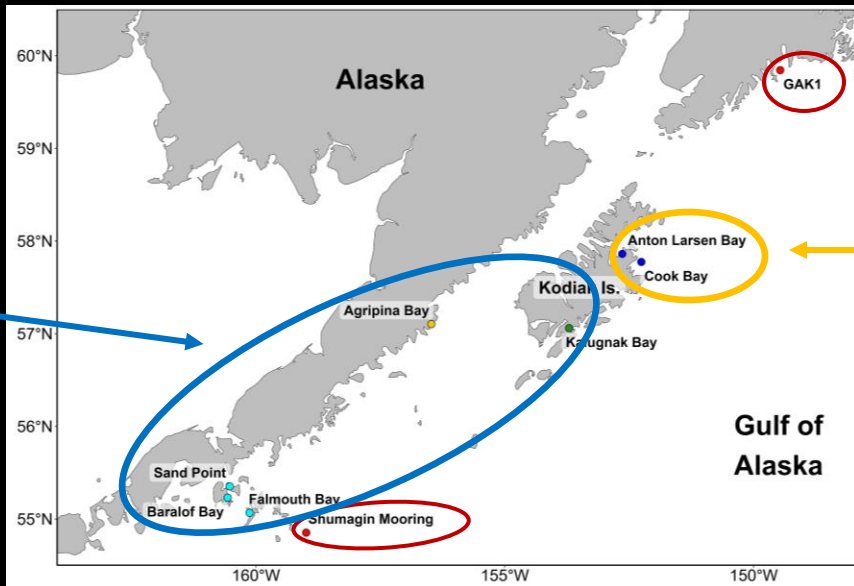
Juveniles  
July

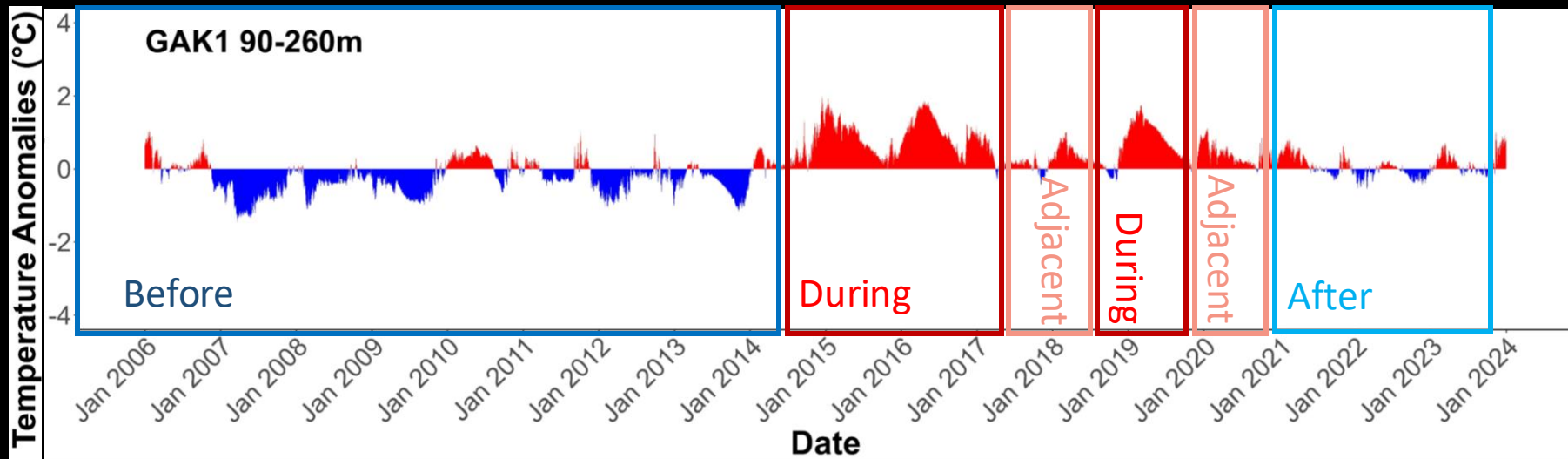
2007, 2009, 2010, 2012-2023

NOAA AFSC  
Eastern Kodiak Island  
Beach Seine Survey

Juveniles  
July & early August  
2018-2023

Alaska  
Coastal Observations  
and Research





Before MHWs -- 2007, 2009, 2010, 2012-2014

During -- 2015-2017, 2019

Adjacent -- 2018, 2020

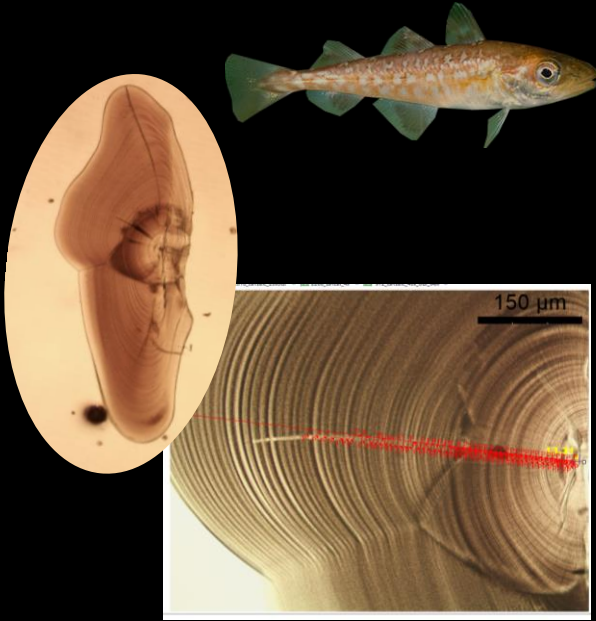
After -- 2021-2023



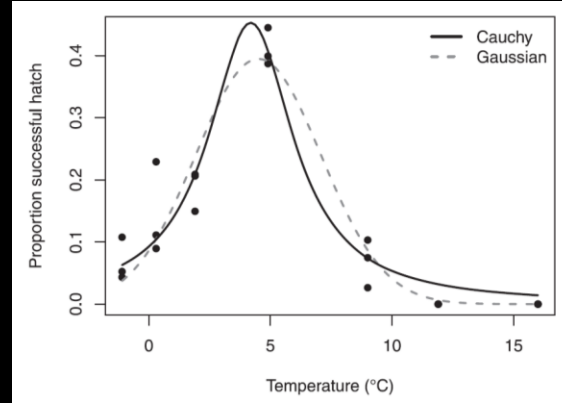
# Methods

Hatch Date

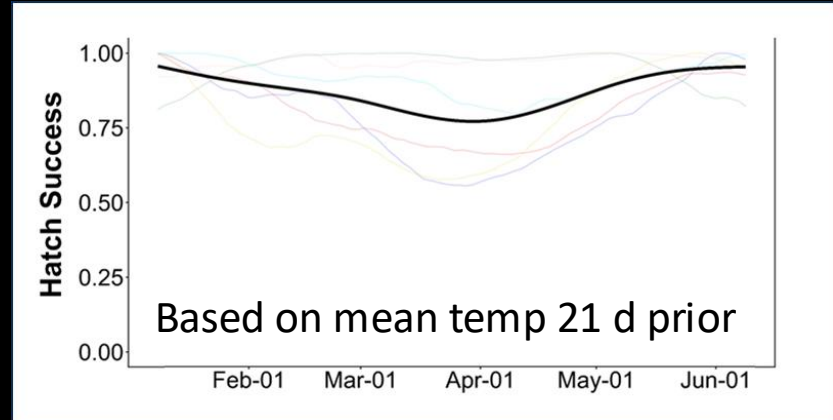
Daily otolith interpretation



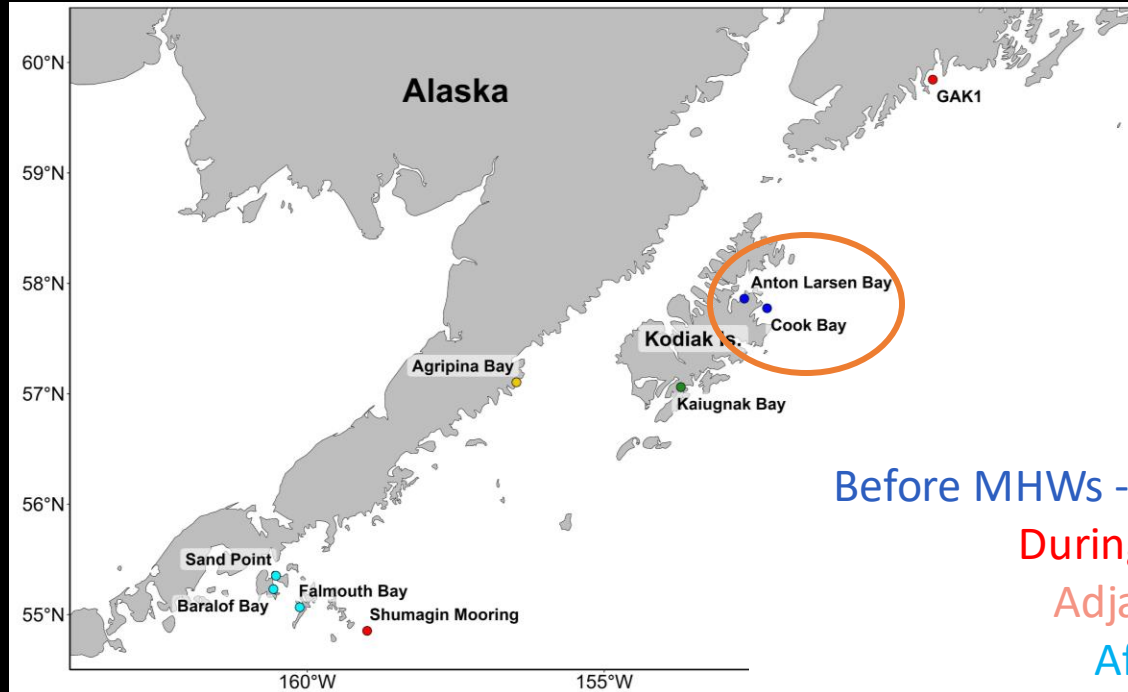
## Temperature-based probabilities of hatch success



Laurel & Rogers 2020



# Temporal Comparison



Eastern Kodiak Island:  
Anton Larsen Bay  
Cook Bay

Before MHWs -- 2007, 2009, 2010, 2012-2014

During -- 2015-2017, 2019

Adjacent -- 2018, 2020

After -- 2021-2023

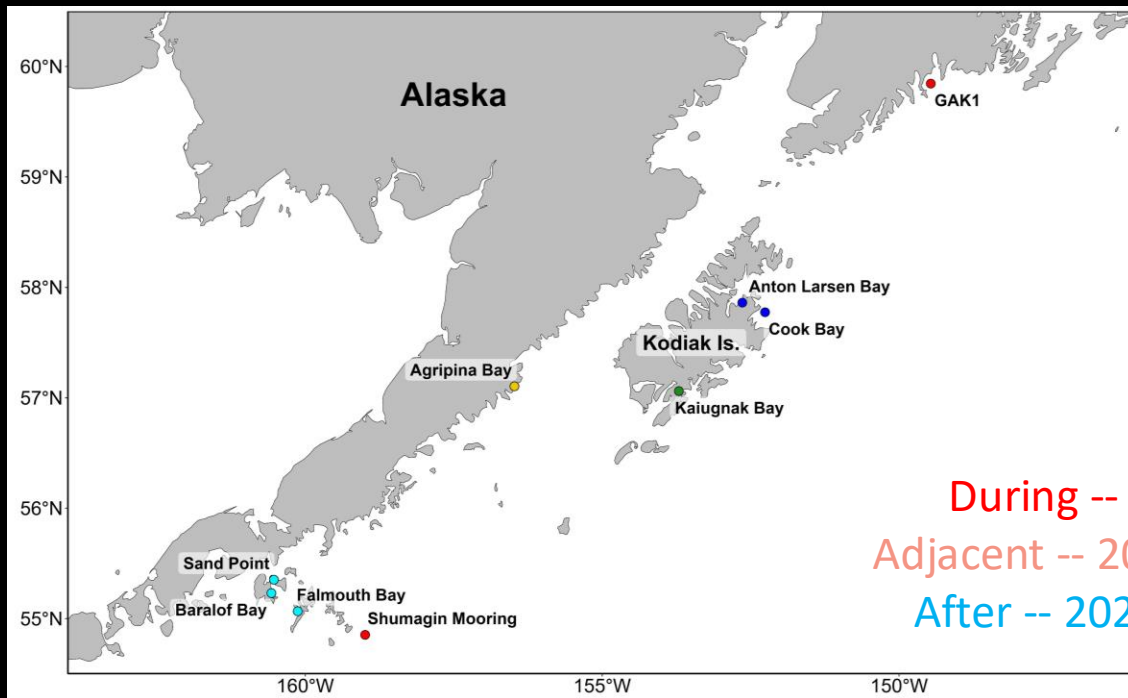


**Partial return to pre-MHW phenology:  
Hatch dates 1 to 2 weeks earlier during recent cooler years**

**&**

**Emergence of winter spawning cohort  
(Laurel et al., accepted, CJFAS)**

# Spatial Comparison



■ Eastern Kodiak ■ Kaiugnak Bay ■ Agripina Bay ■ Shumagin Islands

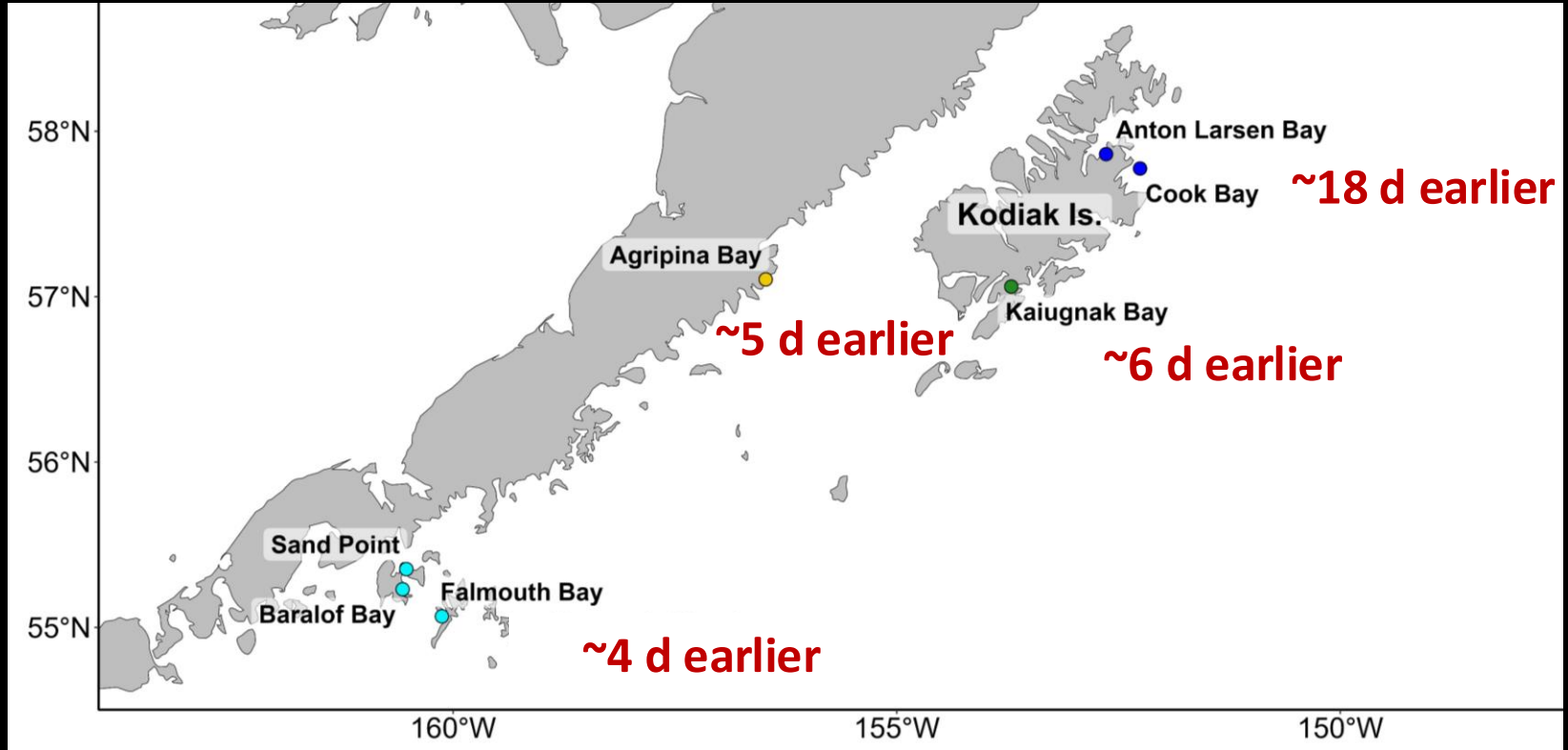
**Overall mean hatch date = 9 April**

**[same as long-term mean before MHWs along Eastern Kodiak Island]**

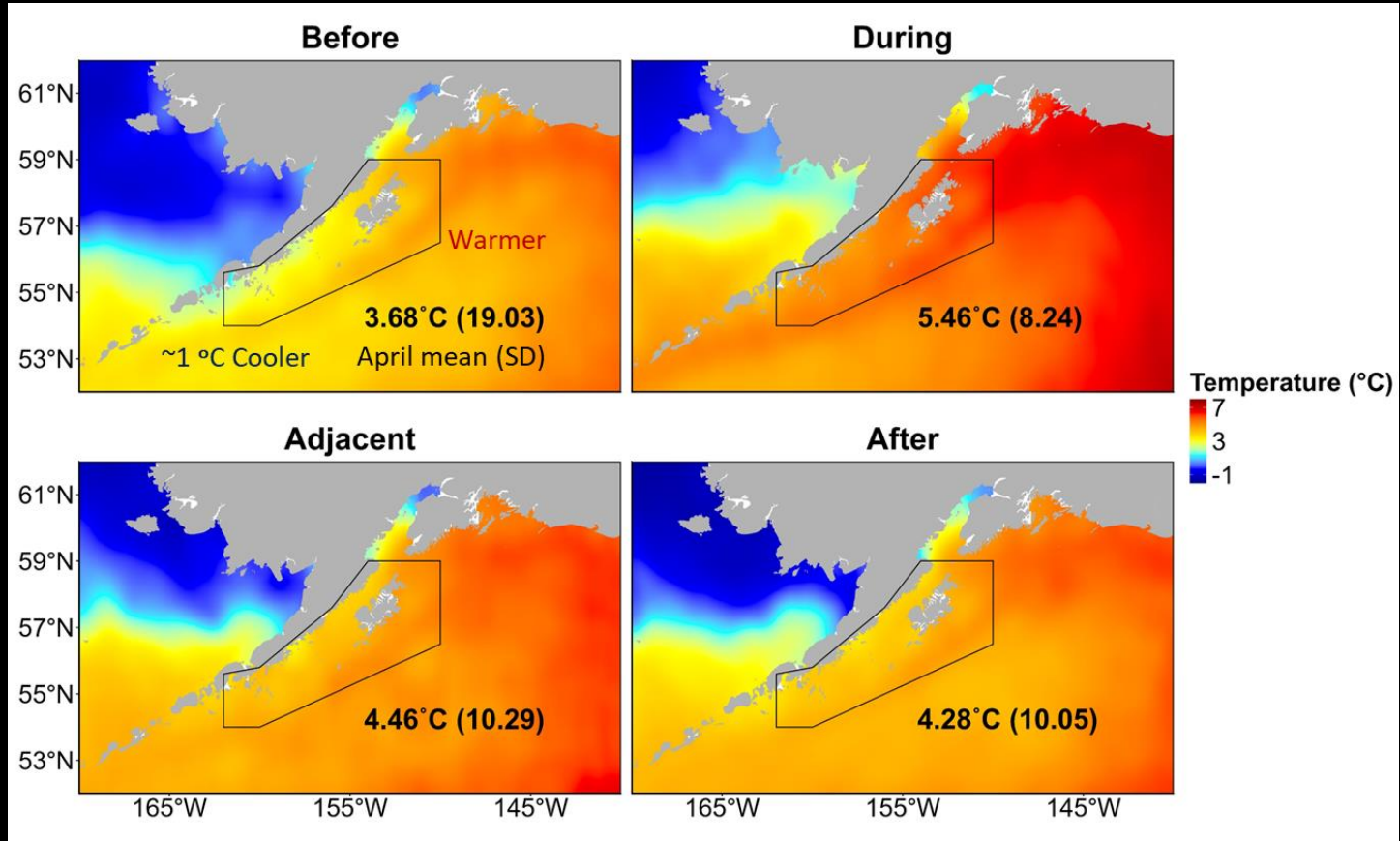
**Progressively later hatching moving south-westward**



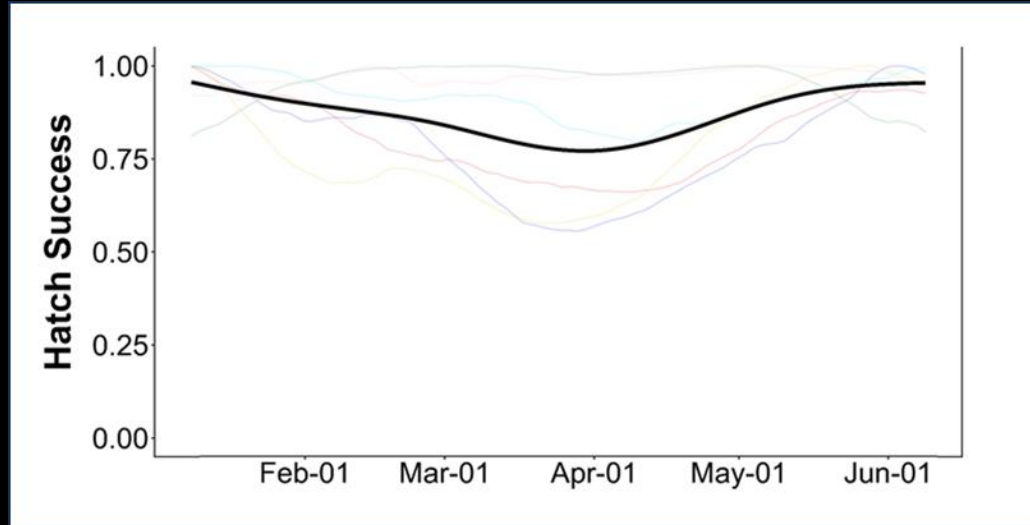
# Spatial gradient in the effect of MHW on hatch phenology: Muted response in the southwest



# Spatial gradient in temperature: Cooler in the southwest

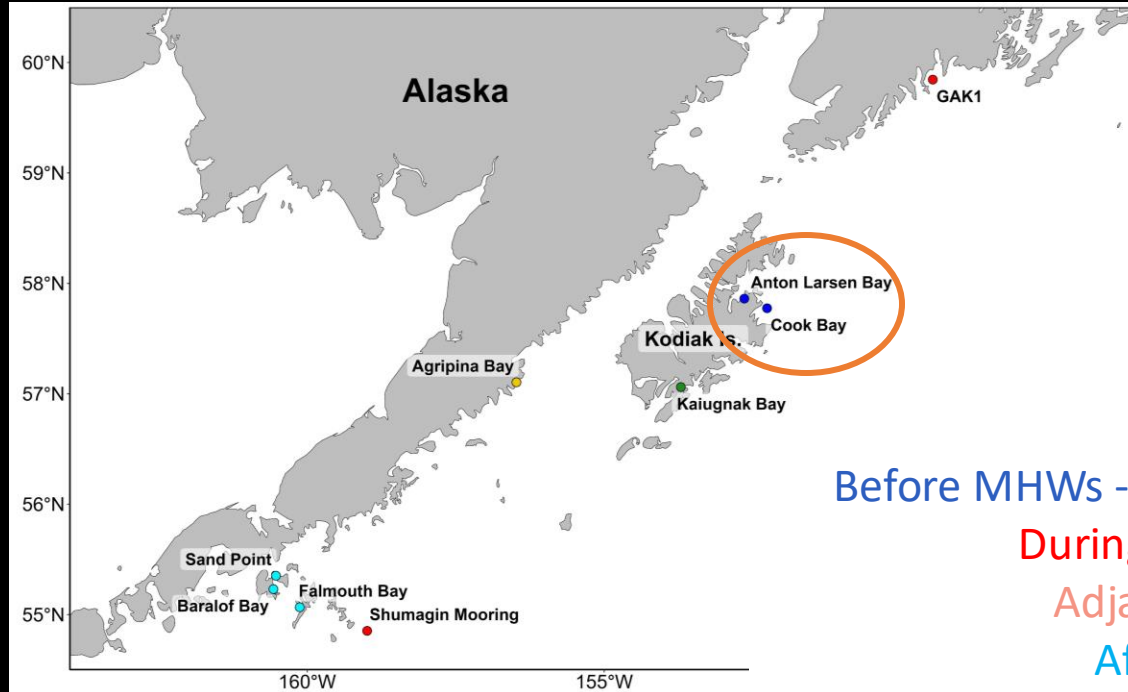


# Probability of successful hatching





# Temporal Comparison



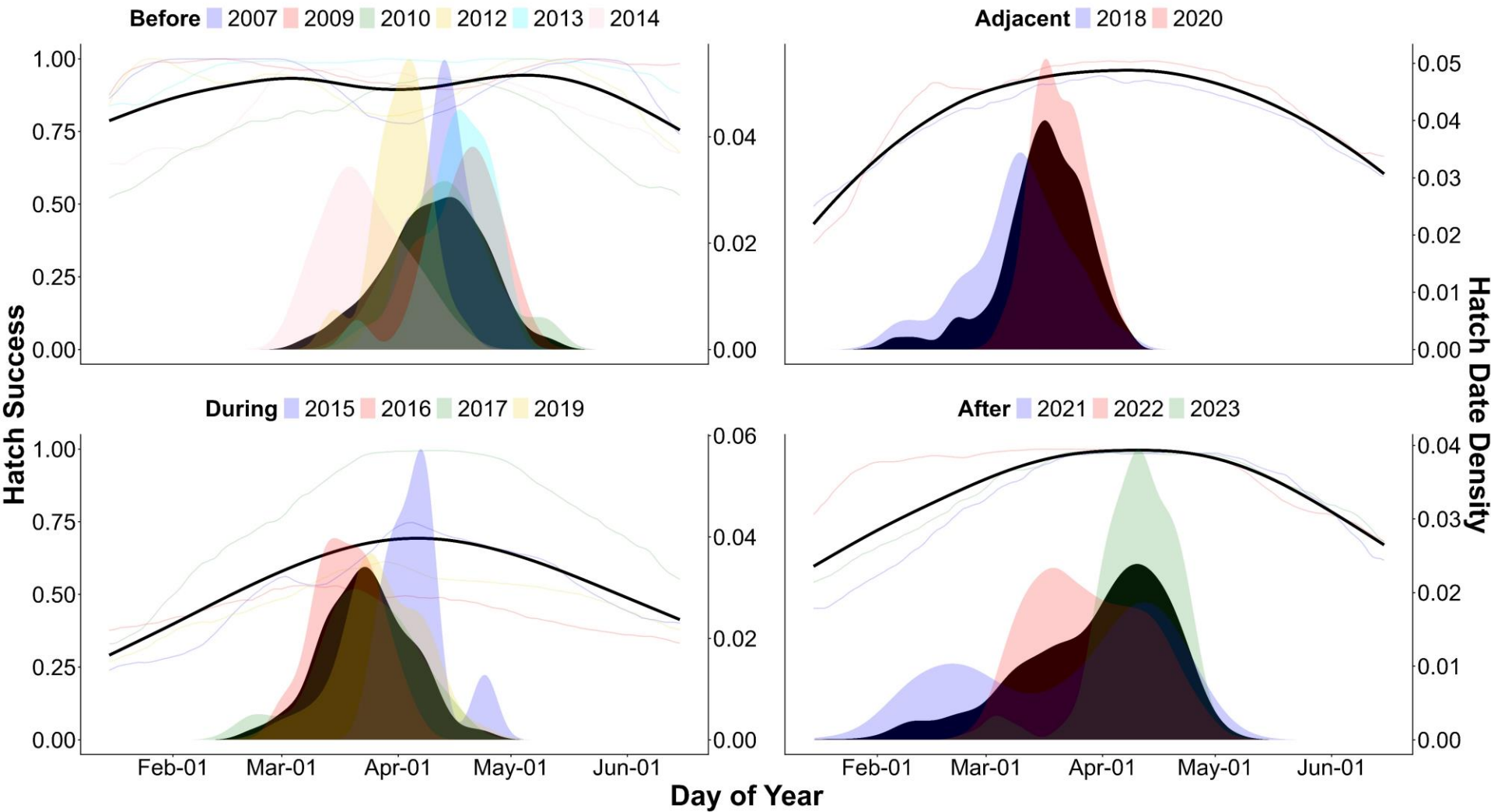
Eastern Kodiak Island:  
Anton Larsen Bay  
Cook Bay

Before MHWs -- 2007, 2009, 2010, 2012-2014

During -- 2015-2017, 2019

Adjacent -- 2018, 2020

After -- 2021-2023



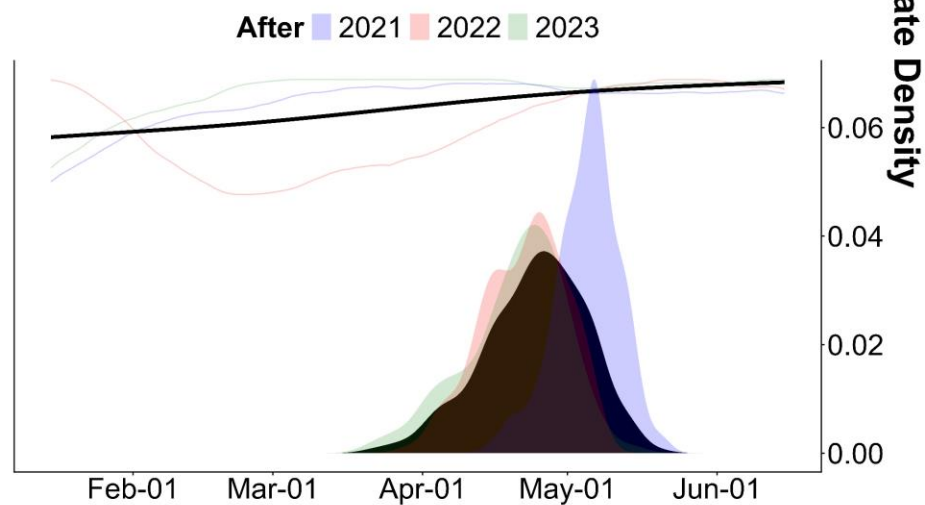
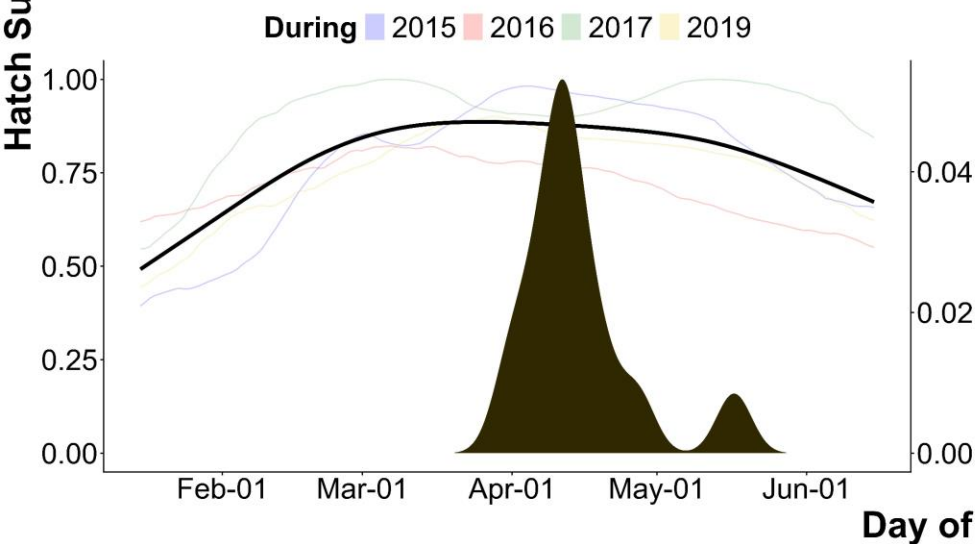
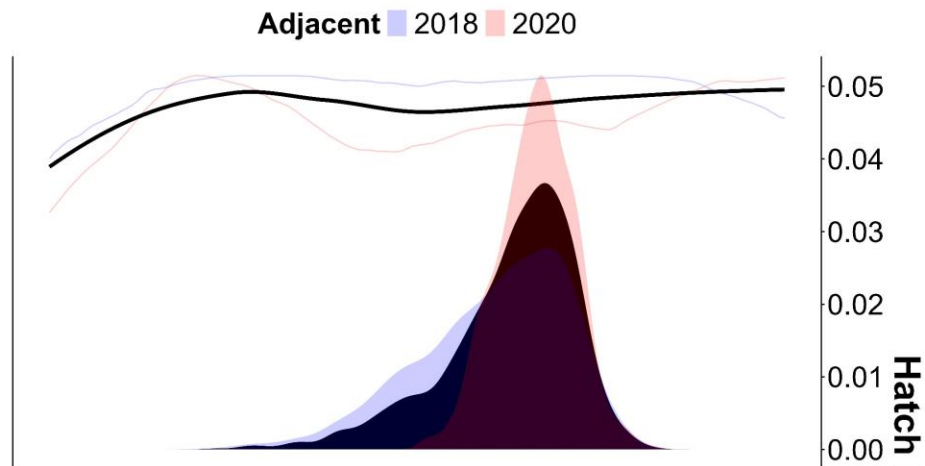
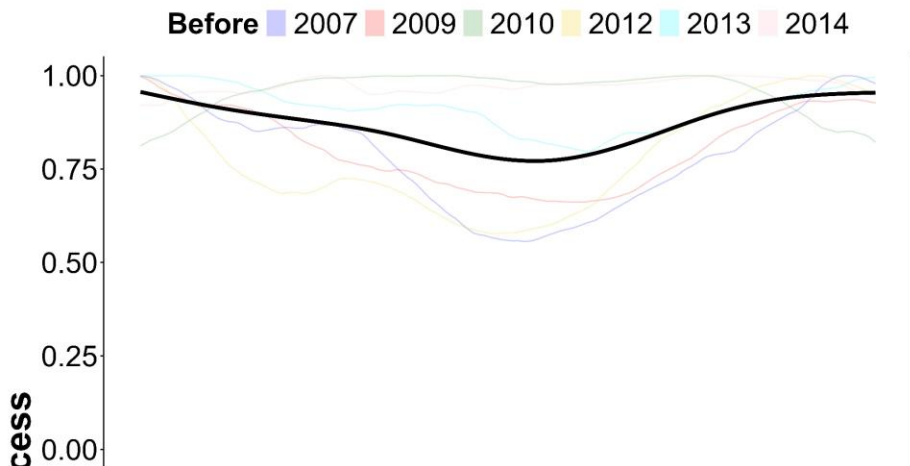
# Shumagin Islands



During -- 2019

Adjacent -- 2018, 2020

After -- 2021-2023

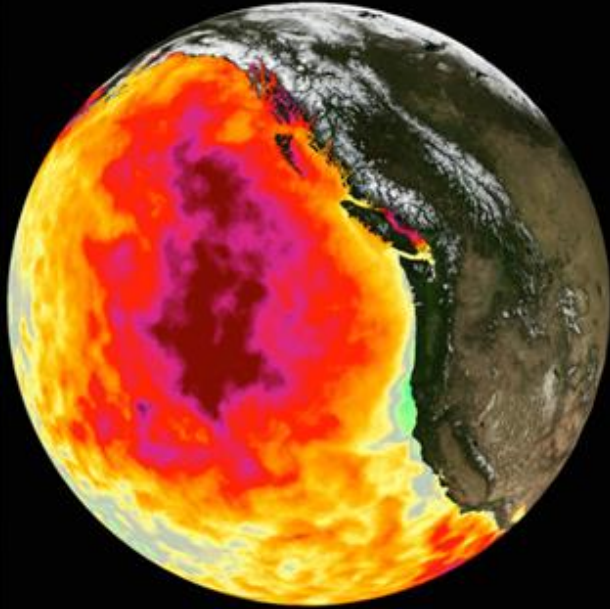


# Summary

- ✓ Partial return to pre-MHW hatch phenology in Eastern Kodiak:  
remains 1-2 weeks earlier & emergence of winter spawning cohort
- ✓ Notable spatial gradient in hatch phenology:  
~1 month later in the Shumagin Islands (to the southwest)  
compared with Eastern Kodiak (to the northeast)
- ✓ Hatch phenology aligns with predicted probability of hatch success based  
on available temperature data
- ✓ Thermal variation along Alaska Peninsula could provide some level of  
climate resilience (but recruitment uniformly low)

# Acknowledgements

Tom Hurst and many others at  
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Fisheries Commission**



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**Coastal Oregon Marine  
Experiment Station**