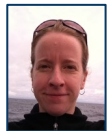


# ECOSYSTEM STATUS REPORTS

Scientific & Statistical  
Committee  
October 2, 2023



Elizabeth Siddon



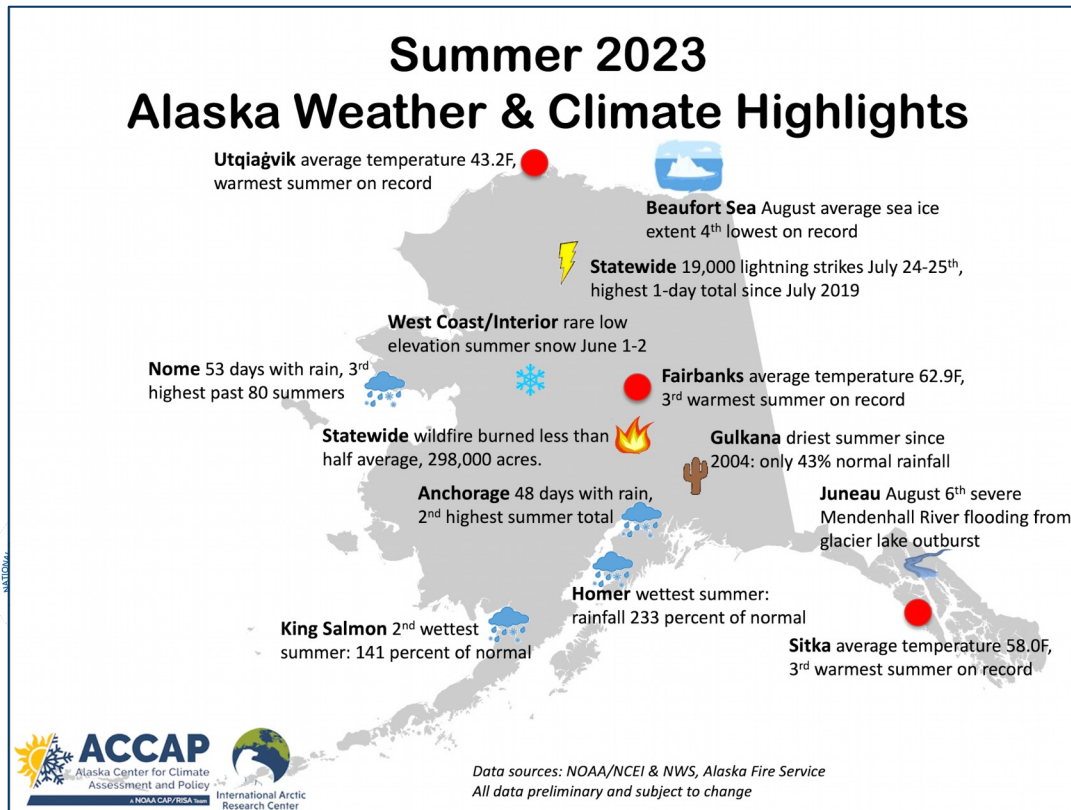
Bridget Ferriss



Ivonne Ortiz



Stephani Zador





- 2023 Previews and ‘red-flags’
  - Gulf of Alaska
  - Aleutian Islands
  - Eastern Bering Sea
- EBS crab-relevant ecosystem indicators

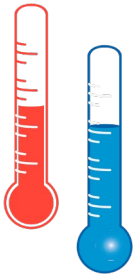
# 2023 GOA Preview

Bridget Ferriss



- No ecosystem concerns related to GOA groundfish in 2023 to highlight for the SSC to consider between now and December *\*given data so far\**

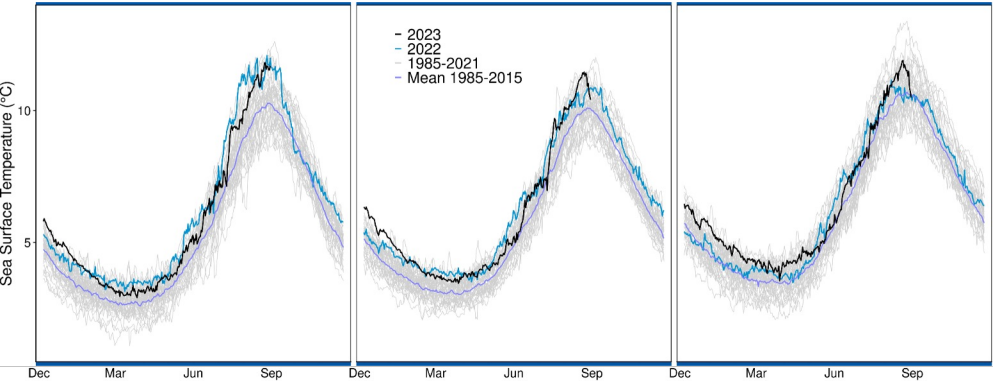
- Ocean temperatures remain average/cool
- Mixed pelagic feeding conditions for adult groundfish
- Some signs of lower productivity than 2022 at lower trophic levels (zooplankton, larval/juvenile fish)



- How will El Niño impact GOA (season, strength, depth, duration)?

# 2023 AI Preview

Ivonne Ortiz

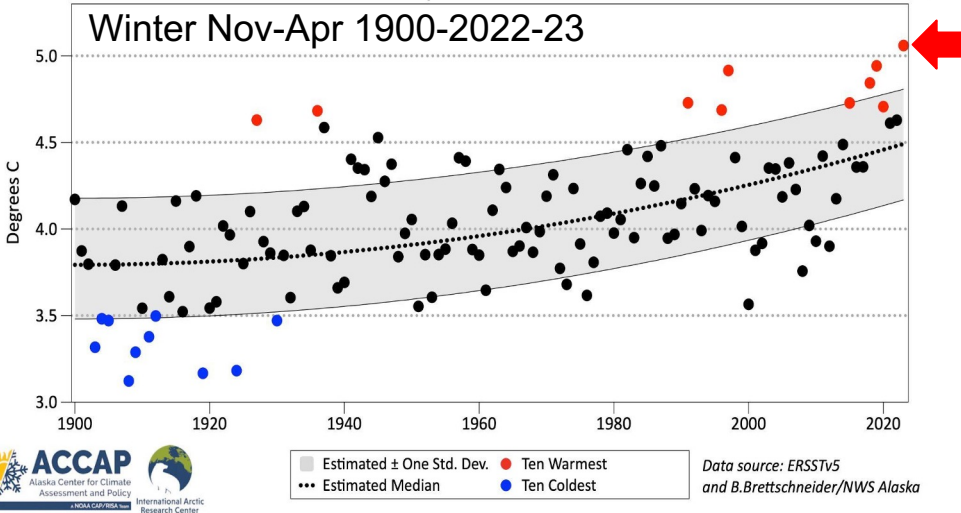


NOAA Coral Reef Watch data, courtesy National Environmental Satellite, Data, and Information Service (Updated: 09-02-2023)  
Data are modeled satellite products and periodic discrepancies or gaps may exist across sensors and products.  
Contact: matt.callahan@noaa.gov

**Sustained sea surface temperature above 1985-2014 mean starting 2013**

- Brief cooling (non MHW) late spring - early summer then returned to moderate MHW

**One of warmest winters on satellite and reconstructed SST records**



**Expected:**

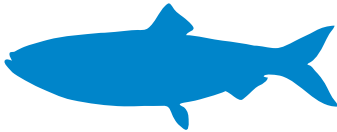
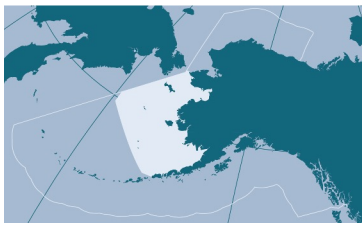
- Stronger MHW impacts in WAI and CAI
- Cumulative effects:
  - increased feeding and bioenergetic costs,
  - faster growth rates,
  - changes in prey timing and availability,
  - changes in phenology

*\*given data so far\**



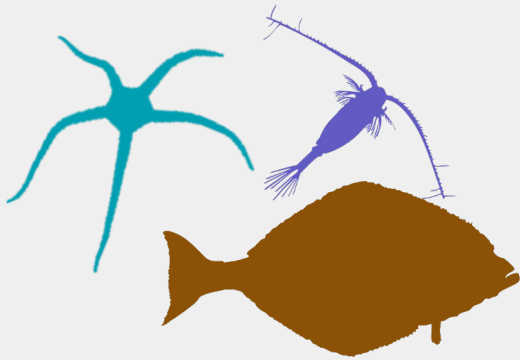
# 2023 EBS Preview

Elizabeth Siddon

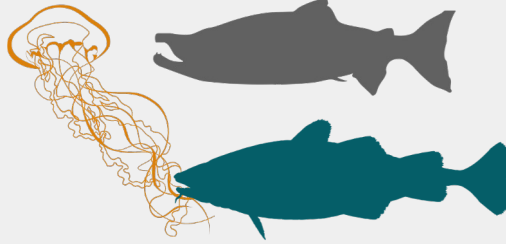


- Oceanographic conditions near long-term averages (more on this during the crab-focused slides)
- Western Alaska chum salmon returns in 2023
  - Examine potential ecosystem drivers
  - Integrative approach with community perspectives
- Herring Prohibited Species Catch (PSC)
  - A flatfish fishery exceeded PSC in 2023 (1<sup>st</sup> time in flatfish fishery since 1992)
  - Summer & Winter HSAs closed for a flatfish sector through March 1, 2024
  - Pollock fishery near PSC cap; noted herring were deeper and in more variable areas than in the past
  - Temperature influences migration timing and route

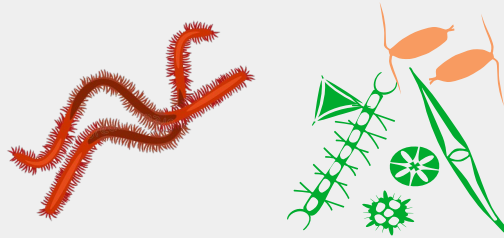
## COMPETITORS



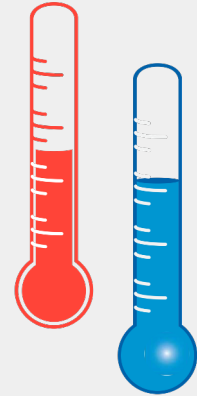
## PREDATORS



## PREY



## ENVIRONMENTAL PROCESSES



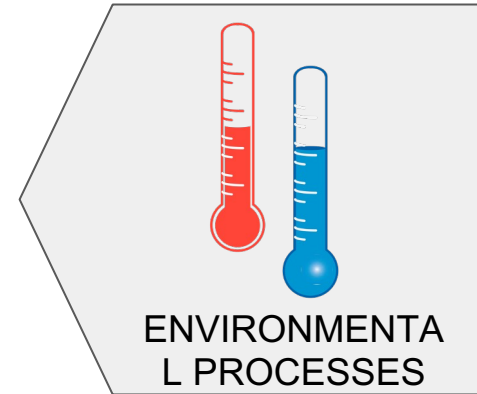
*Broad-scale climate patterns reflect a transition from La Niña to El Niño.  
Regional SST trends at or near the long-term average.  
Impact of El Niño on EBS remains to be seen...*

- **NPI** reflects the ALPS where positive values mean:
  - Weak ALPS, high SLP, calmer conditions
- **NPI** positive for most of 2022
- **AO** measures the polar vortex; transitioned from positive to negative in 2022

Bond (slides 20-22, 55)

- SSTs similar to the long-term mean in fall 2022 and spring/summer 2023
- SSTs slightly above the long-term mean in winter 2022/2023
- MHWs have been brief and infrequent since 2021

Lemagie & Callahan (slides 23-25)



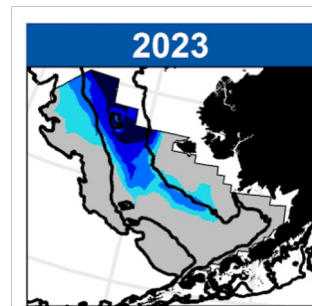
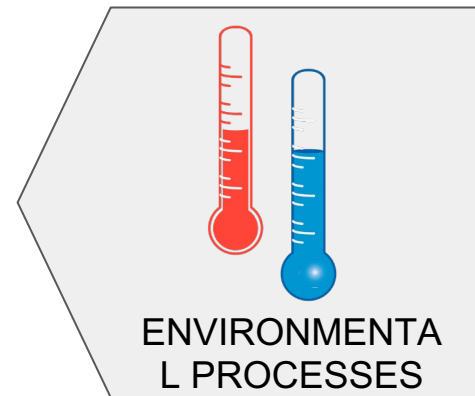
*Ice phenology shifted ~1 month later than last year.  
Sea ice thickness at or above time series median.  
2023 cold pool near historical average.*

- Ice phenology shifted ~1 month later than last year
  - Delayed sea ice growth due to slow freeze-up in Chukchi and impact of ex-typhoon Merbok
  - Ice melt-out slowed by cold April temperatures
- Early season ice extent similar to recent warm years
- Ice thickness at or above time series median

Thoman (slides 27-32)

- 2023 cold pool extent was near the historical average
  - Footprint similar to 2011, 2017, and 2022
  - Cold tongue along inner front shifted inshore
- Bottom & surface temperatures slightly colder
  - very cold bottom waters south of St. Matthew Island
  - Coldest bottom waters in southern inner domain since 2013

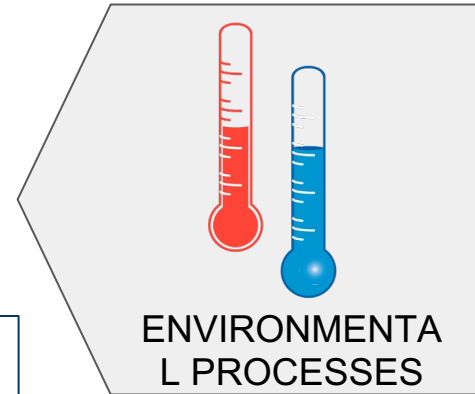
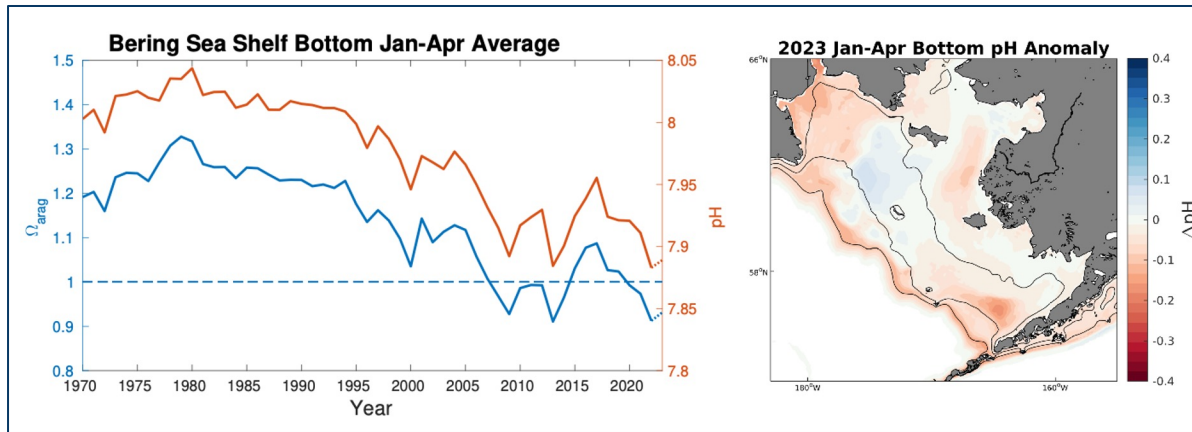
Rohan & Barnett (slides 33-36)



*Expansion of bottom water conditions (aragonite and pH)  
experimentally shown to negatively impact pteropods and red king crab.  
Snow crab appear resilient to OA; Bristol Bay nearshore regions appear buffered.*

- 2023:  $\Omega_{\text{arag}}$  and pH continuing near lowest values
- Multi-year outer shelf low pH anomaly diminished somewhat
- Long-term decrease means expansion of bottom water conditions experimentally shown to negatively impact growth and survival of pteropods and red king crab

Pilcher & Monacci (slide 37)





*Prey conditions for pelagic crab stages appear poor, though a moderate abundance of small copepods was available*

- 2023 Chl-a biomass among the lowest in every region

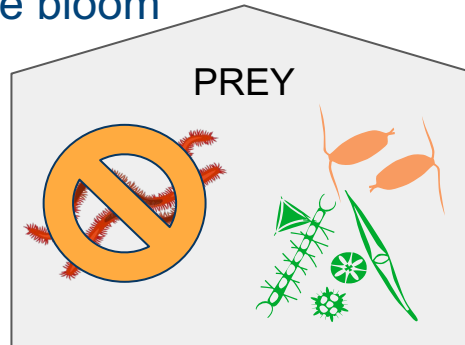
Nielsen (slide 41)

- Spring: small copepod abundances were moderate; large copepods and euphausiids were low. Lipid content of large copepods and euphausiids was low (new since CPT)
- Fall: small copepod abundances remained moderate; large copepods and euphausiids were low overall, within increasing abundance towards the north

Kimmel (slides 42-43)

- Fall: noticeable coccolithophore bloom

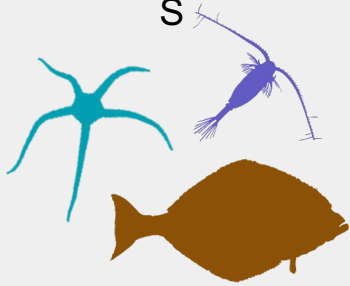
Eisner & Lange (slides 44-45)



Competitors for pelagic crab decreased in 2023.  
Competitors for benthic crab remained high or increased in 2022.

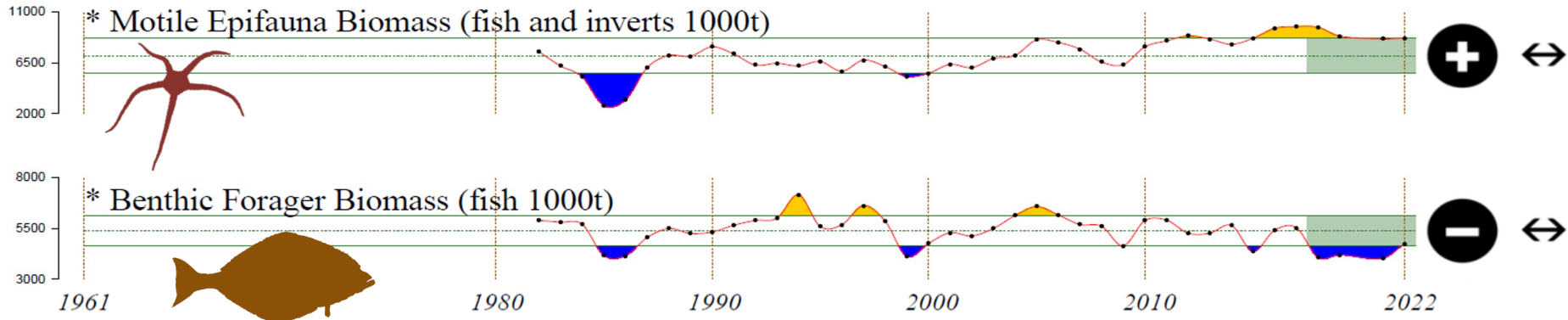


COMPETITOR  
S



- Motile epifauna biomass peaked in 2017 and remained above the long-term mean in 2022, driven by brittle/sea stars and other echinoderms
- Benthic forager biomass increased 18% in 2022, but remained below the time series mean

Whitehouse (slide 47)



*Predators of both pelagic and benthic crab increased in 2022.*



PREDATORS

- Pelagic foragers increased from 2021 to 2022 (+70%), driven by pollock and herring
- Apex predators increased from 2021 to 2022, driven by PCod and ATF

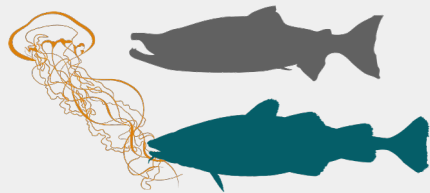
Whitehouse (slide 49)

- Groundfish community shifted north between 2010 and 2019, then south in 2021 as conditions cooled, and into slightly deeper waters in 2022

Mueter (slide 49)

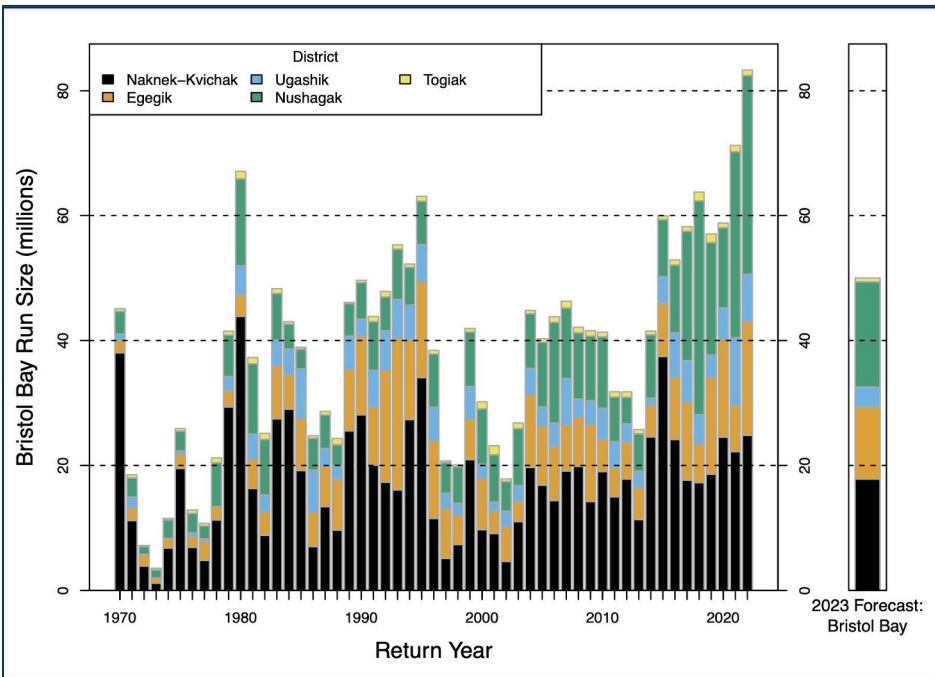
- Pacific cod condition improved from 2021 to 2022: cooler thermal experience, lowered metabolic demands, and/or improved prey quality/quantity

Rohan & Prohaska (slide 50)



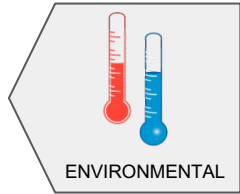
PREDATORS

*Predators of pelagic crab remained high in 2023.*



- 2023 (estimate: 54 million) was lower than the 2022 record run of 83 million sockeye
  - Juvenile sockeye feed on zooplankton and age-0 pollock in warm years; adults feed on zooplankton and krill
- Cunningham (slide 51)

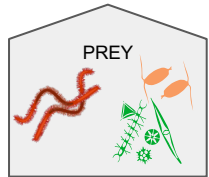
# Summary



- Return to average conditions
- Impact of developing El Niño TBD
- OA trends concerning, though not considered to be driving crab declines



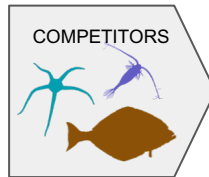
- Return to average conditions
- Impact of developing El Niño TBD
- OA trends concerning, though not considered to be driving crab declines



- Low chl-a biomass
- Low/moderate zooplankton abundance and low lipid content
- Coccolithophore bloom



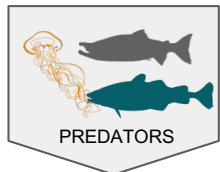
- *Indirect* measurement of infaunal prey based on the 2022 benthic forager guild indicates adequate availability



- Low/moderate abundance of zooplankton



- Motile epifauna guild remained high in 2022
- Benthic forager guild increased from 2021 to 2022



- Predators of pelagic crab increased in 2022
- Bristol Bay sockeye salmon remained high in 2023



- Predators of pelagic crab increased in abundance and condition in 2022

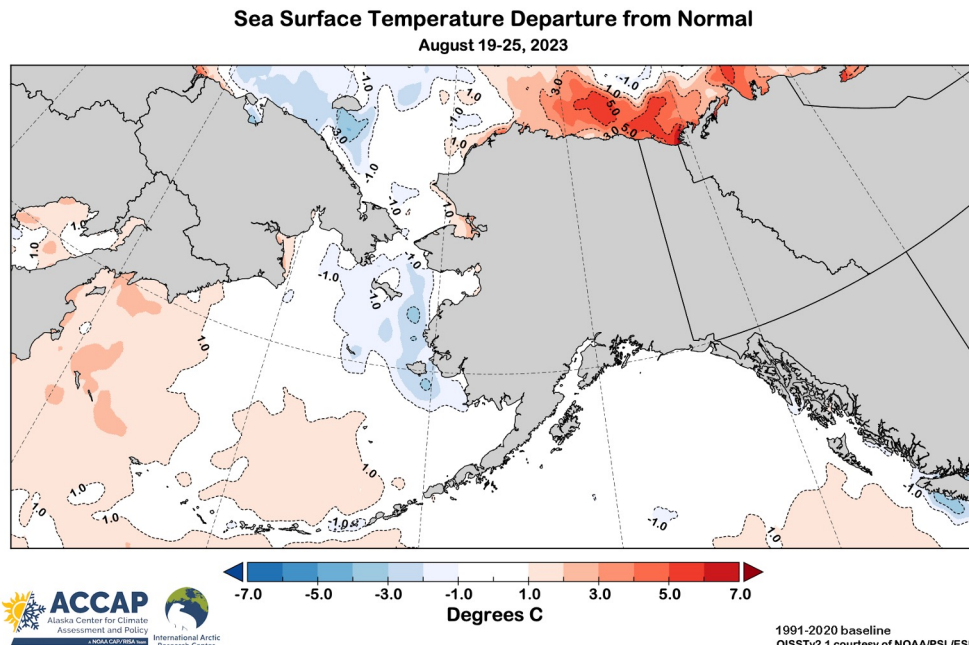




# ECOSYSTEM STATUS REPORT

NPFMC Crab Plan Team  
September 12, 2023

Elizabeth Siddon



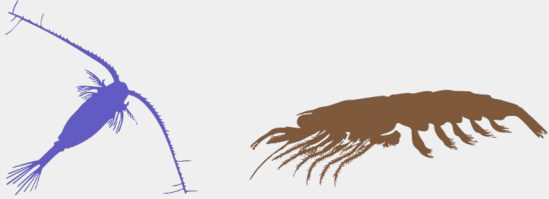


## Crab-relevant ecosystem information

- Pelagic and benthic stages
- Environmental processes, prey, competitors, predators
- 2023 (where available) in context

# Pelagic larval indicators

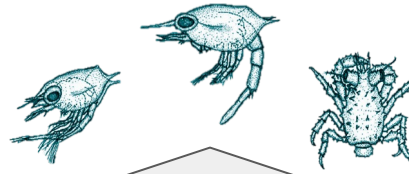
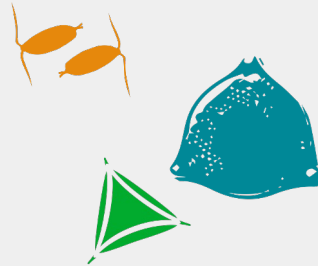
## COMPETITORS



## PREDATORS



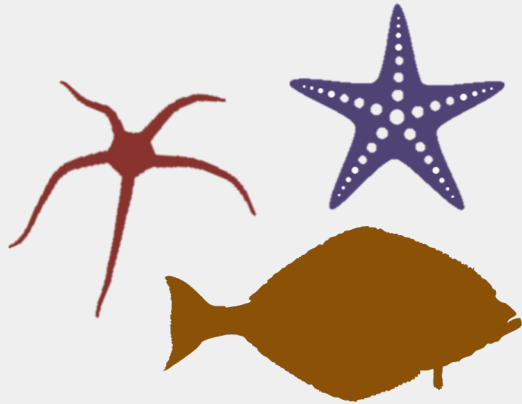
## PREY



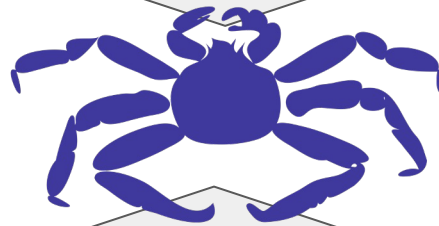
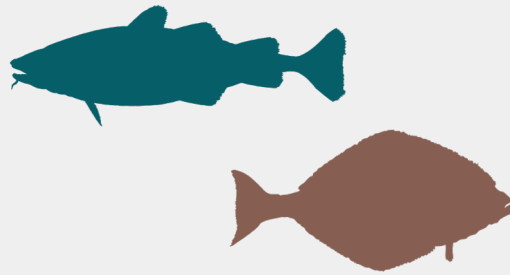
ENVIRONMENTAL  
PROCESSES

# Benthic juvenile/adult indicators

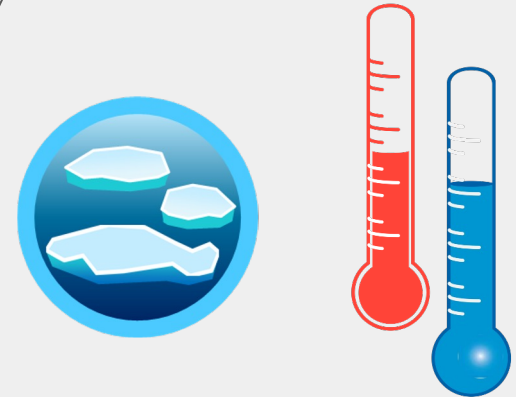
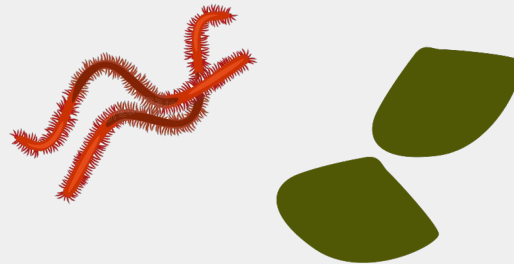
COMPETITORS



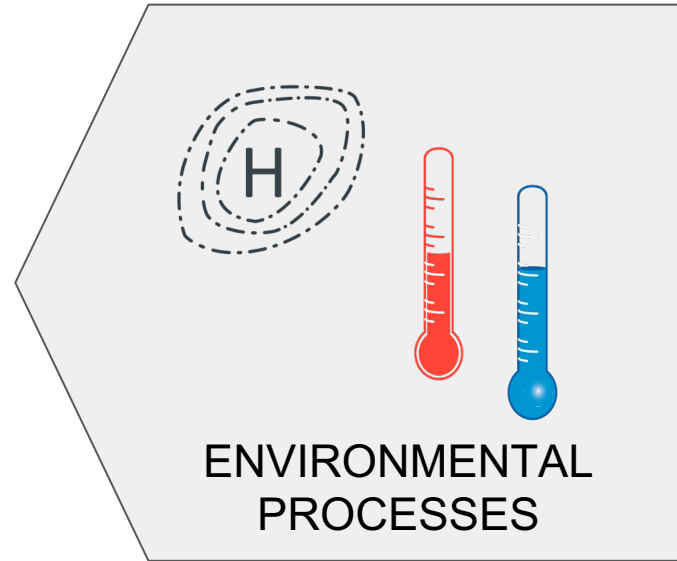
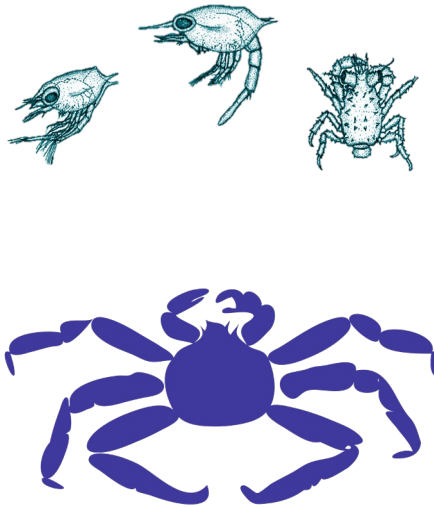
PREDATORS



PREY



ENVIRONMENTAL  
PROCESSES

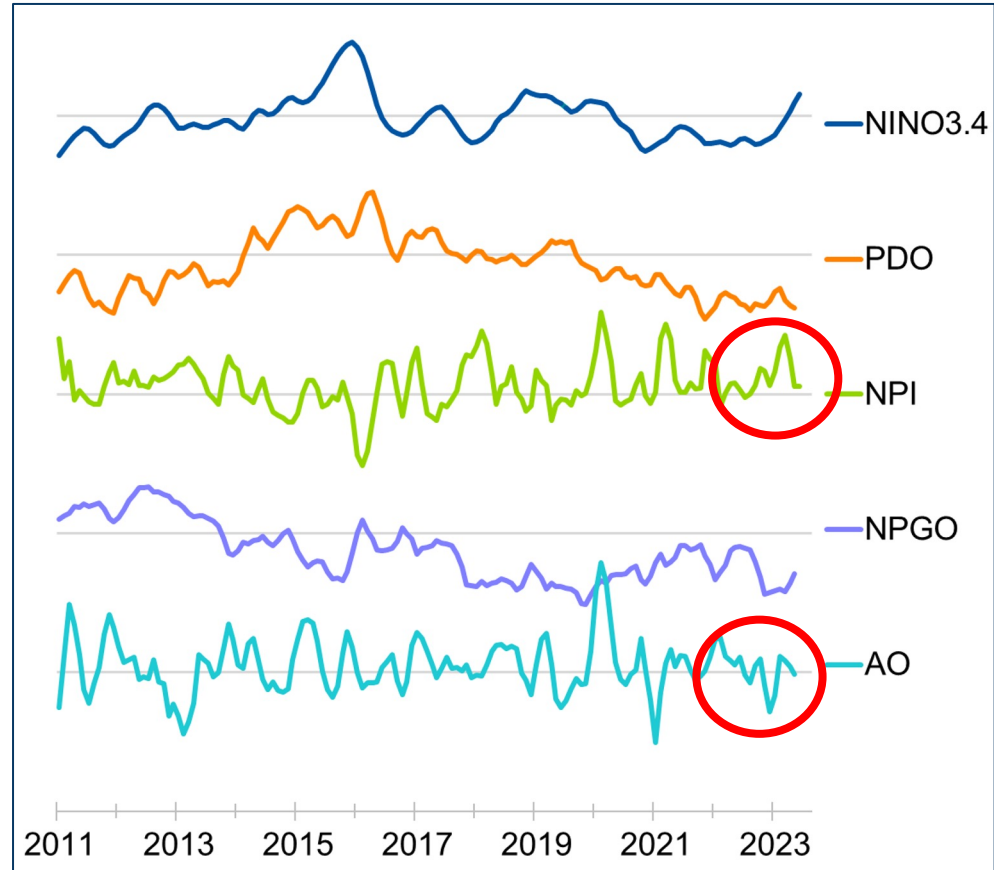




# North Pacific Climate Indices

Bond

- **NPI** reflects the ALPS where positive values mean:
  - Weak ALPS, High SLP, Calmer conditions
- **NPI** positive for most of 2022
  - Linked with extended La Niña and decline in PDO
- **AO** measures the polar vortex; transitioned from positive to negative in 2022
- Negative **AO** usually leads to Arctic air, but late 2022 had warm weather north of AK



# Fall & Winter 2022/2023 SLP & SST

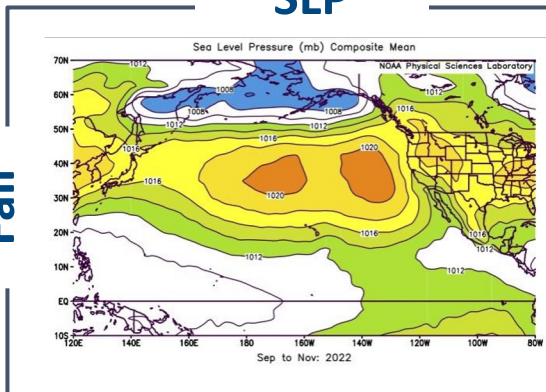
Bond

High SLP across North Pacific; lower SLP from Siberia to Chukchi Sea.

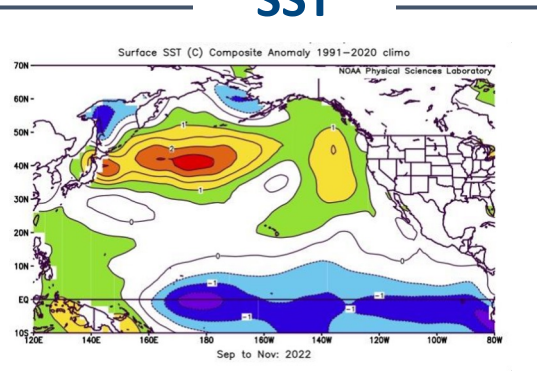
**Winds from the west** across the Bering Sea.

Fall

SLP



SST



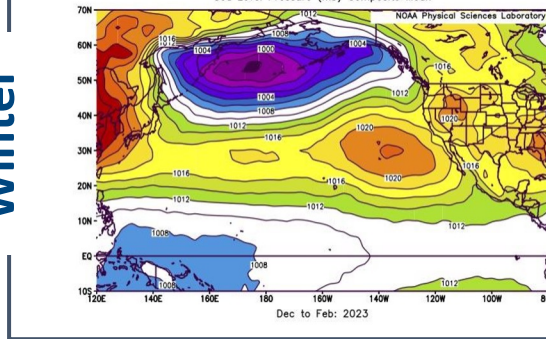
Cool tropical Pacific associated with La Niña.

Cool SST conditions on EBS shelf.

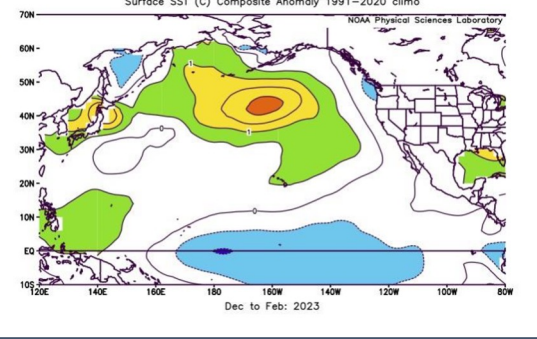
ALPS shifted west. **Winds from the west** from Sea of Okhotsk to eastern Aleutian Islands.

Winter

Sea Level Pressure (mb) Composite Mean

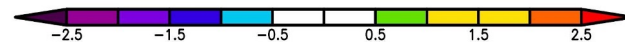
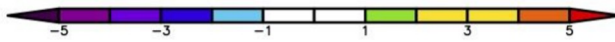


Surface SST (C) Composite Anomaly 1991-2020 climo



La Niña weakened.

Average SSTs on EBS shelf.



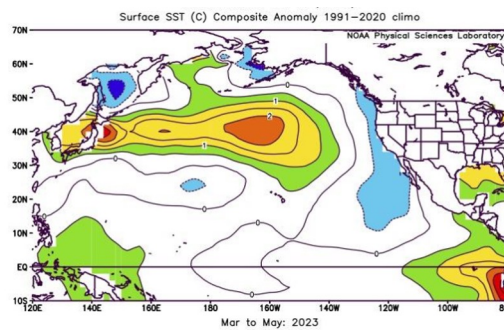
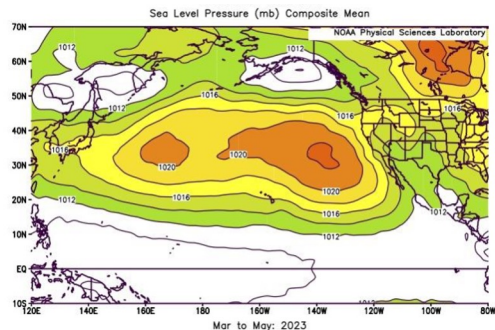
# Spring & Summer 2023 SLP & SST

Bond

SLP

SST

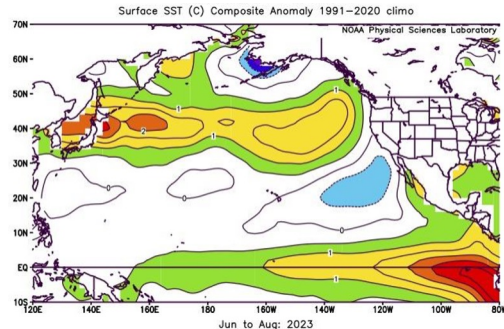
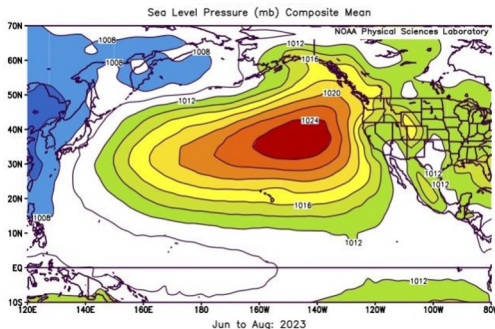
Spring



Average SSTs in tropical Pacific.

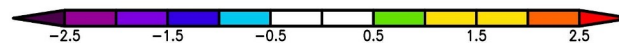
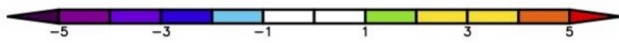
Return of cool SST conditions on EBS shelf.

Summer



Strong warming in tropical Pacific defined El Niño in June 2023.

Continuation of cool conditions on EBS shelf.

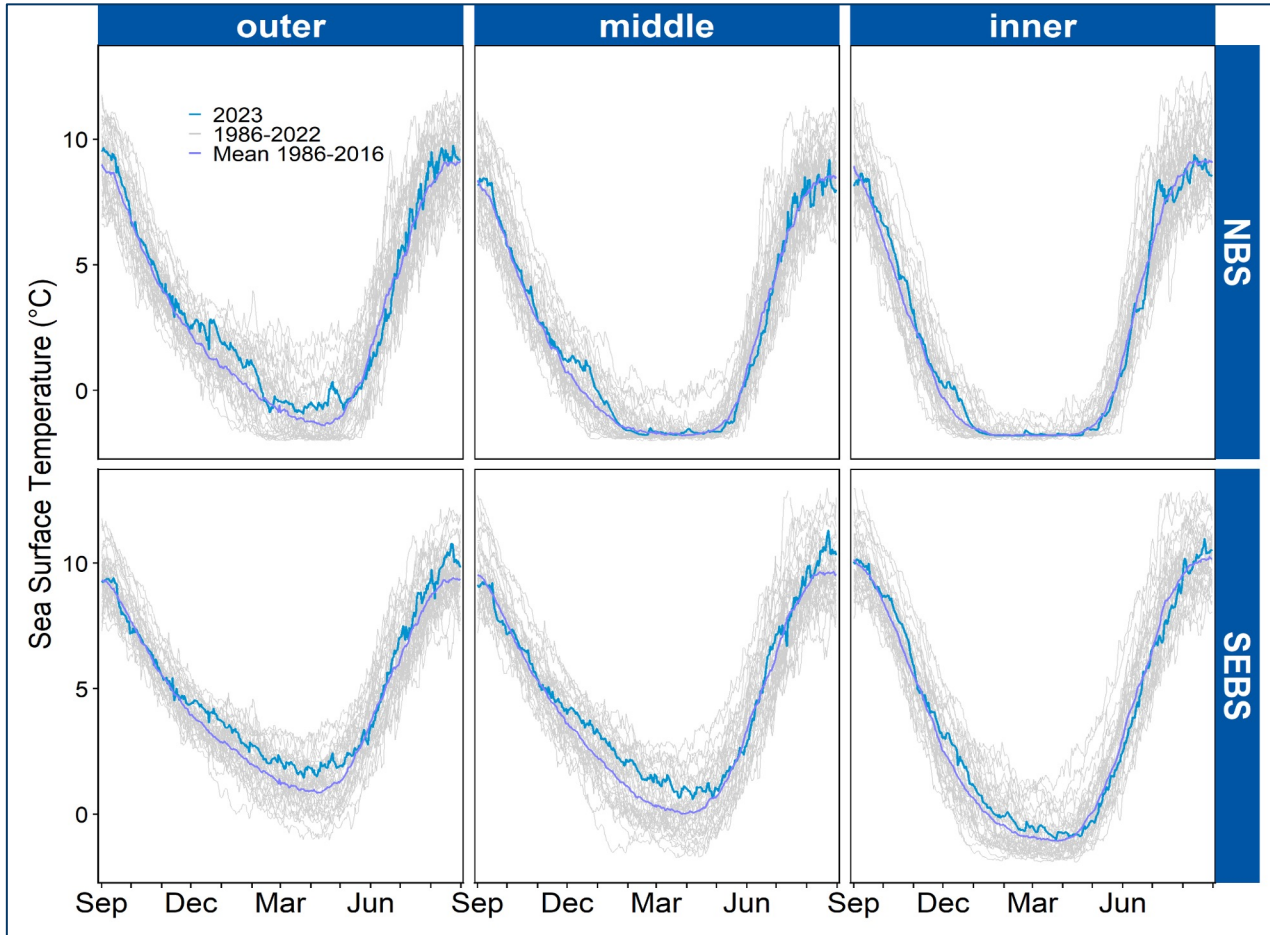


High SLP in North Pacific. **Winds from the west** across most of the Bering Sea.

Dipole in western North Pacific: lower SLP from Sea of Okhotsk to Alaska and higher south of 40°N. **Southwesterly winds** between dipole.

# Sea Surface Temperature

Lemagie & Callahan

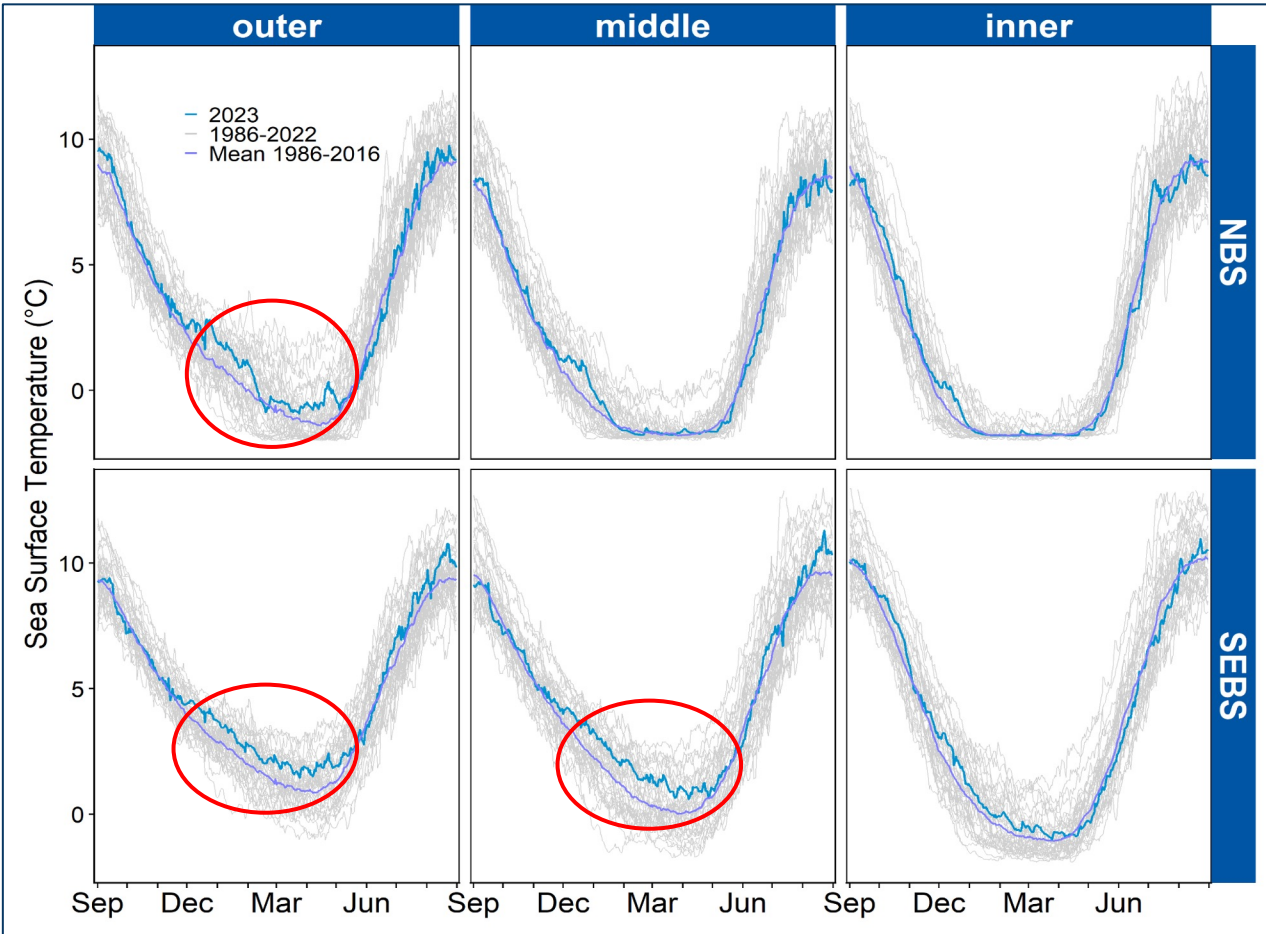


- SSTs were similar to the long-term mean in fall 2022 and spring/summer 2023
- SSTs were slightly above the long-term mean in winter 2022/2023, especially in the outer domain and southern middle domain



# Sea Surface Temperature

Lemagie & Callahan

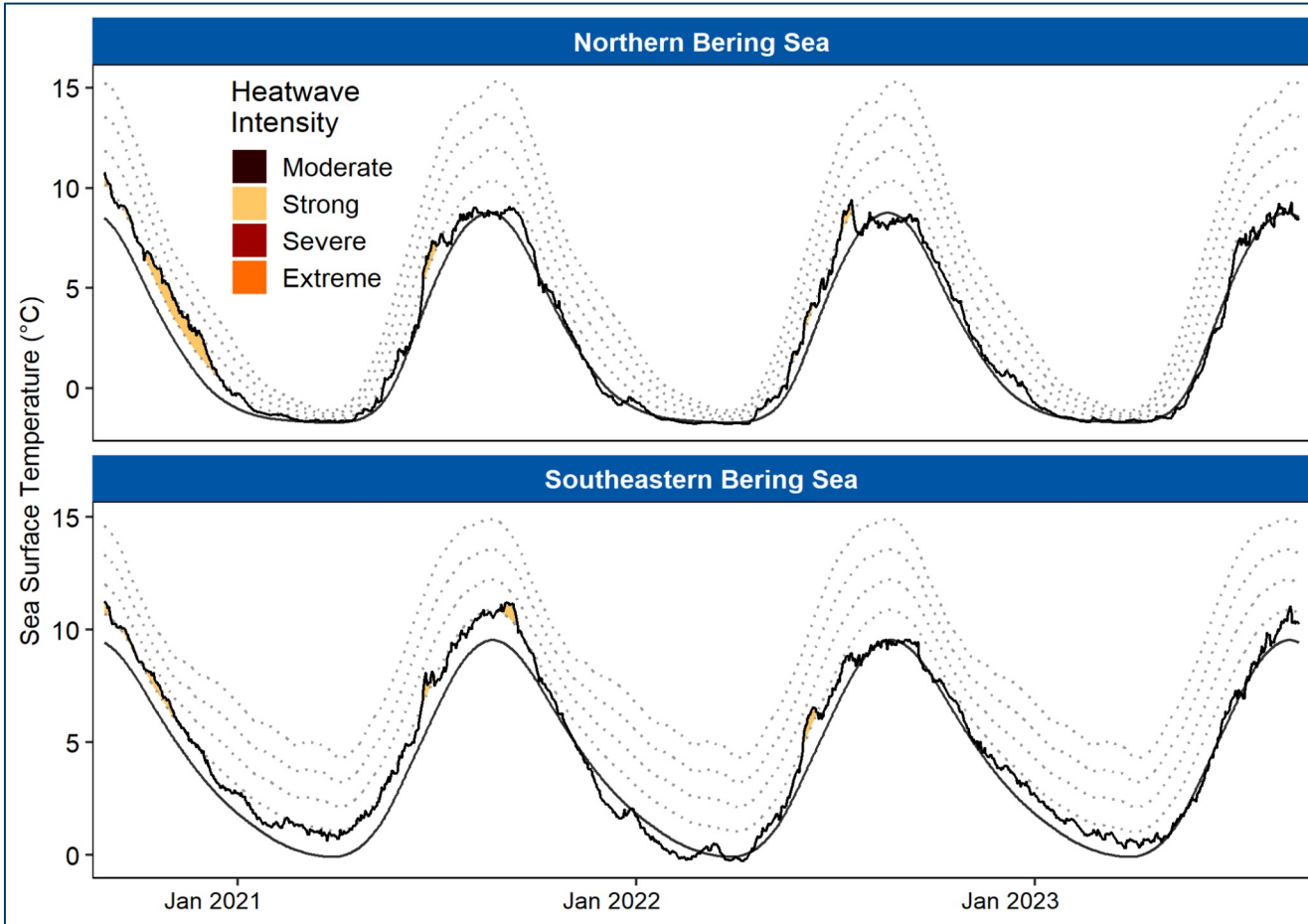


- SSTs were similar to the long-term mean in fall 2022 and spring/summer 2023
- SSTs were slightly above the long-term mean in winter 2022/2023, especially in the outer domain and southern middle domain



# Marine Heatwave Index

Lemagie & Callahan

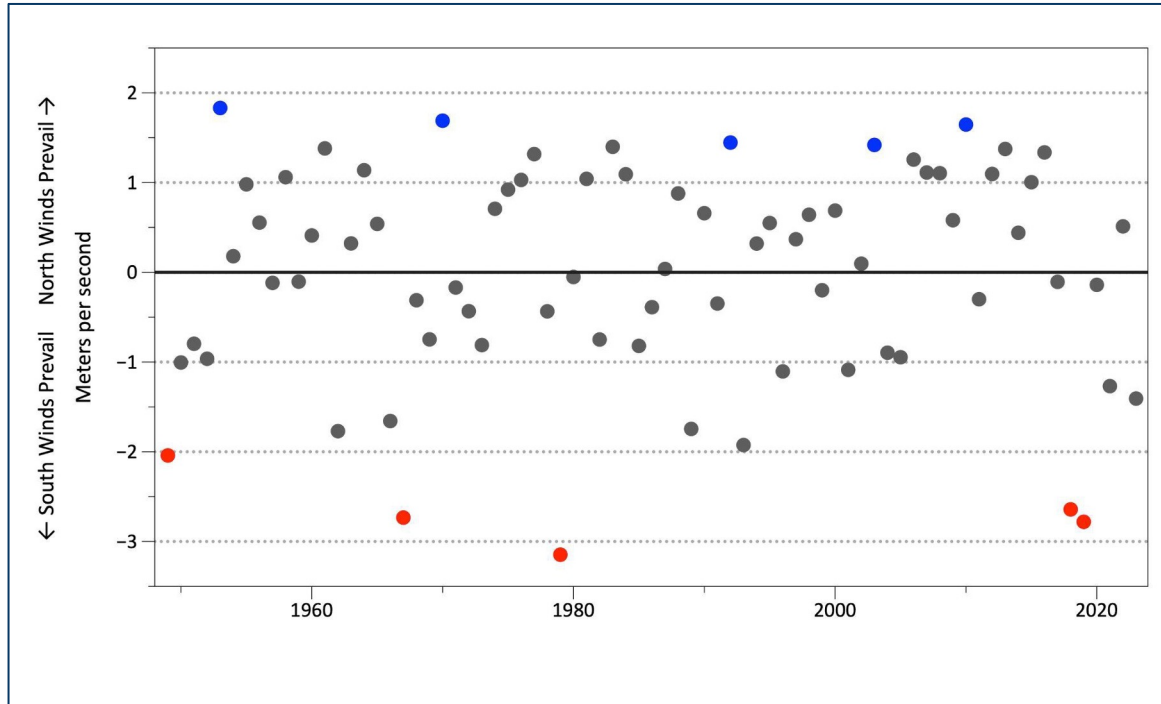


- MHWs have been brief and infrequent since 2021



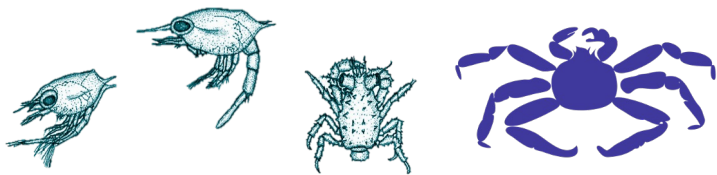
# Winter Winds (Nov. - Mar.)

Thoman



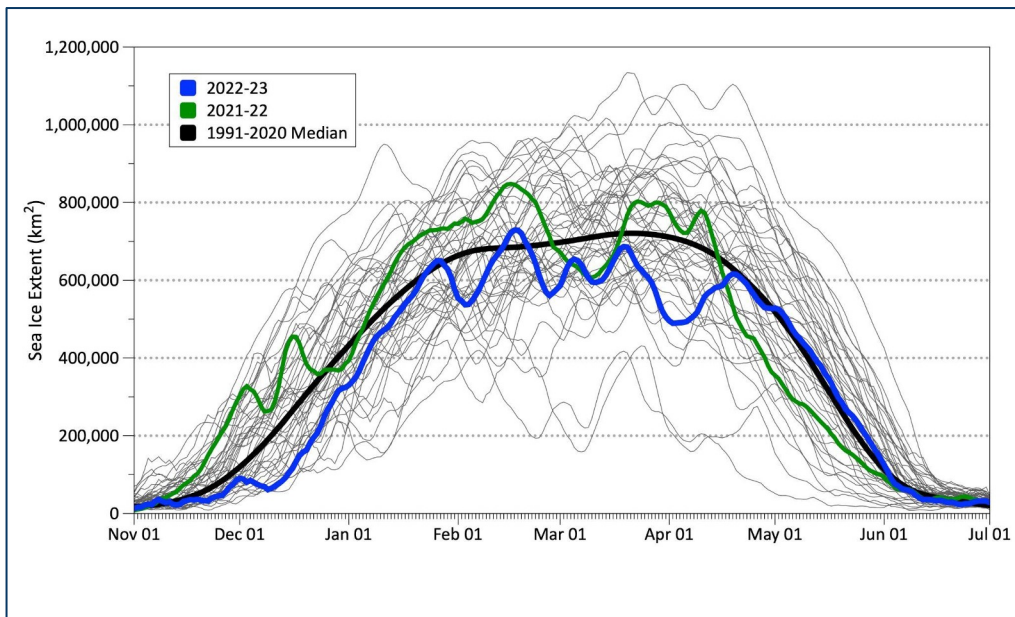
- Winds were more southerly (from the south) in winter 2022/2023
- Southerly winds bring warmer air over the EBS
- 6 of the past 7 winters had southerly winds

● Winters ending in 2018 and 2019 were among 5 years with the strongest south winds, which contributed to low sea ice extent in those years.

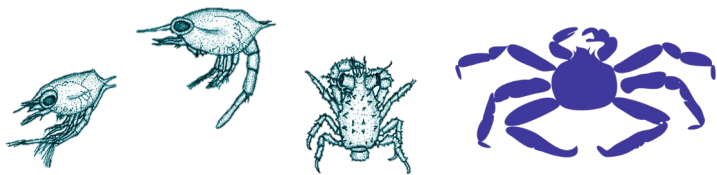


# 2023 Sea Ice

Thoman



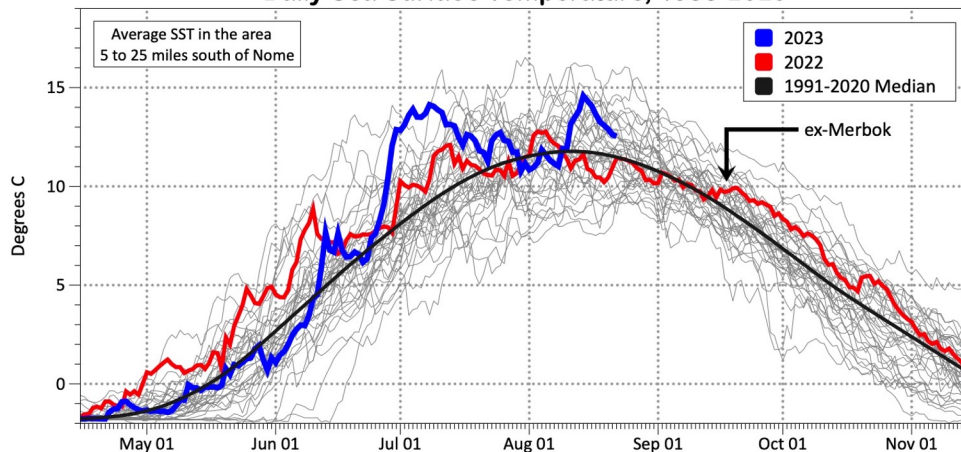
- Ice phenology shifted ~1 month later than 2021/2022
- Delayed sea ice growth in Nov & Dec:
  - Stormy weather
  - Slow freeze-up in the Chukchi
  - Impact of Merbok (next slide)
- Ice melt-out in spring was slowed by cold April temperatures
- Maximum ice extent occurred February 17; sea ice did not reach St. Paul Island (9<sup>th</sup> year in past decade)



# 2023 Sea Ice

Thoman

Offshore Nome, Alaska  
Daily Sea Surface Temperature, 1985-2023



- Ice phenology shifted ~1 month later than 2021/2022
- Delayed sea ice growth in Nov & Dec:
  - Stormy weather
  - Slow freeze-up in the Chukchi
  - Impact of Merbok (next slide)
- Ice melt-out in spring was slowed by cold April temperatures
- Maximum ice extent occurred February 17; sea ice did not reach St. Paul Island (9<sup>th</sup> year in past decade)

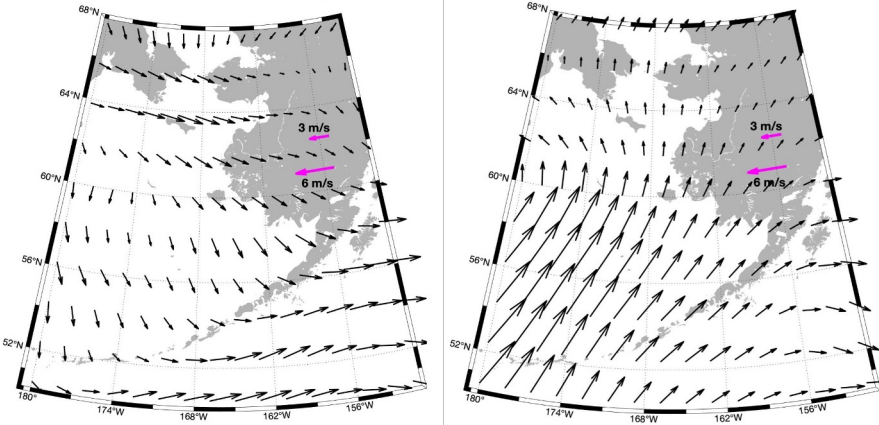
## Wind Anomalies

# Winds & Sea Ice

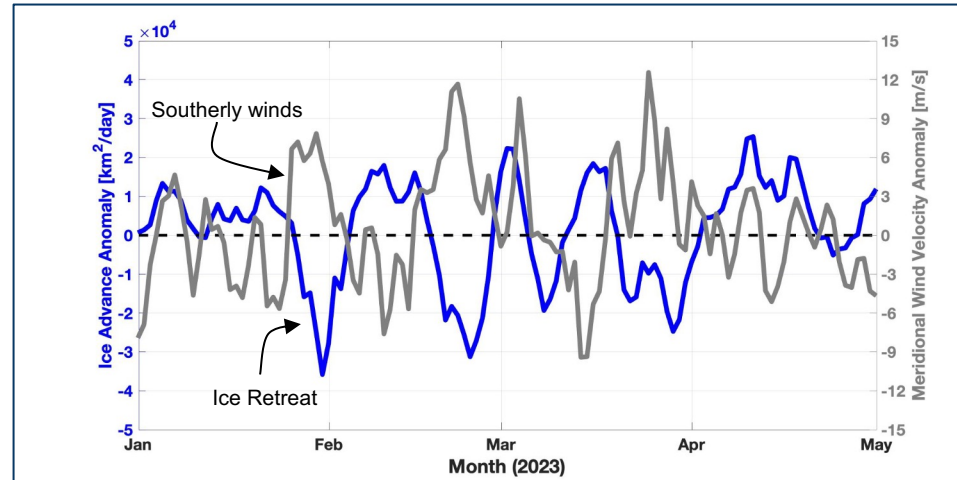
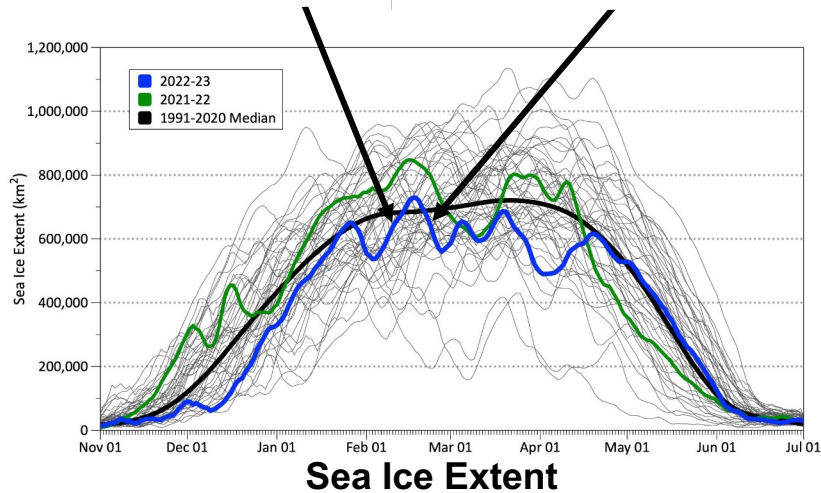
Hennon, Thoman

Feb-01 to Feb-14 (2023)

Feb-15 to Feb-28 (2023)

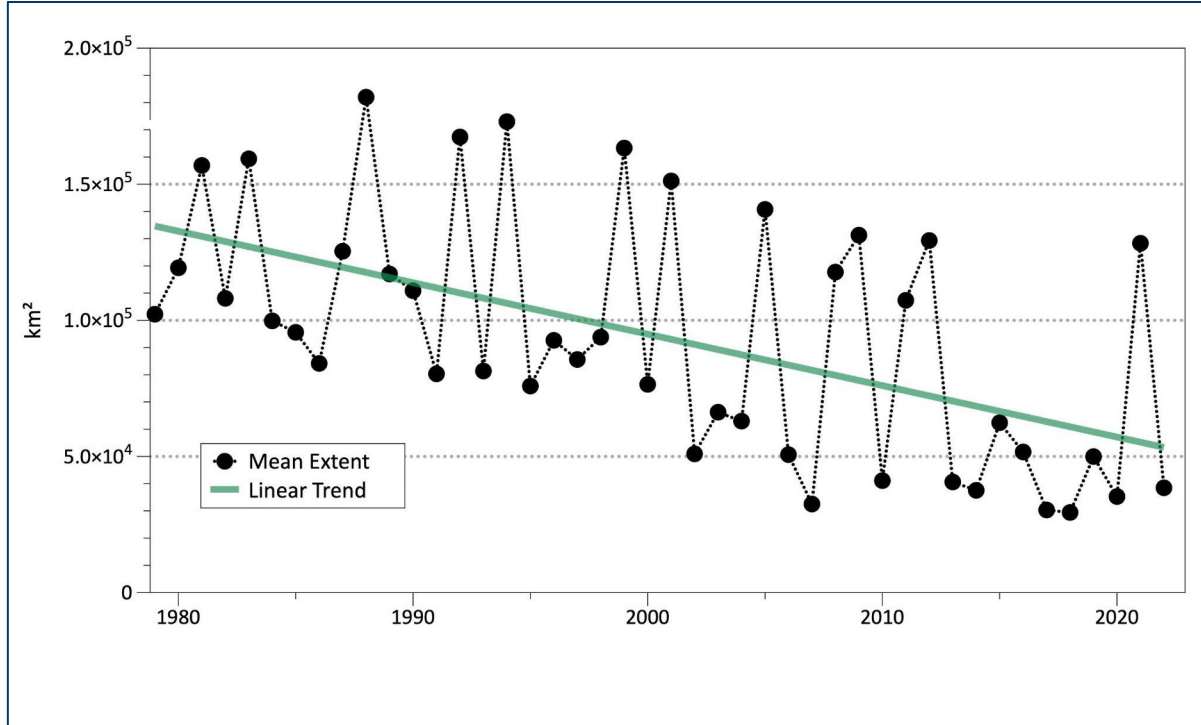


- Short term variability in sea ice extent is correlated to anomalous wind events
- Ice generally **advances** with **northerly** (from the north) winds and **retreats** with **southerly** winds



# Early Season Ice Extent (Oct.-Dec.)

Thoman



- 2022 was similar to most years since 2013 (except 2021)
- 2022 was lower than any year prior to 2007
- Early season ice extent has decreased 55% over 45-year time series



# Bering Sea Ice Thickness

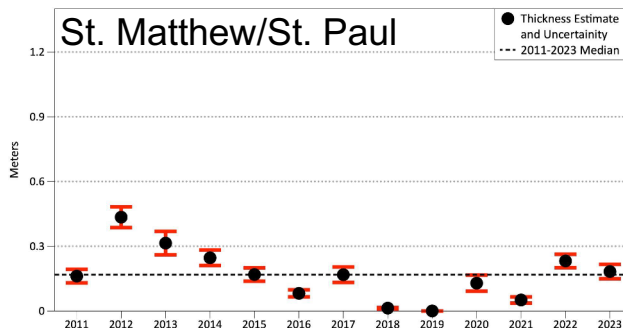
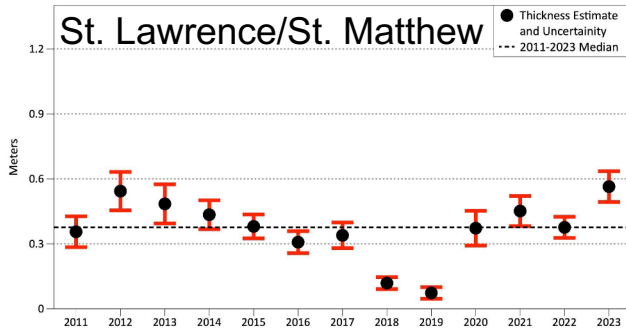
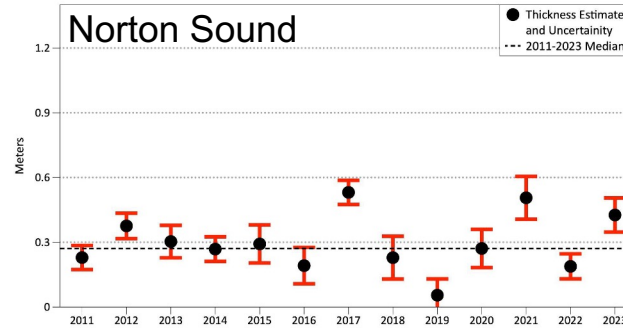
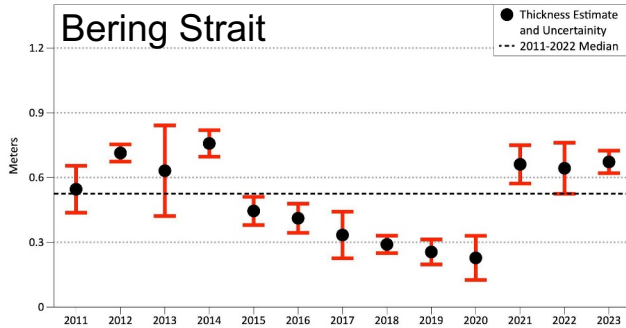
Thoman



- 3<sup>rd</sup> week of March
- Ice thickness is related to duration or residency of ice over the shelf
- Abundance of ice-associated algae correlated to ice duration?

# Bering Sea Ice Thickness

Thoman



- Ice thickness was higher in Norton Sound and St. Lawrence to St. Matthew than 2022
- St. Lawrence to St. Matthew ice thickness was the highest since 2013
- Other regions close to the 13-year median

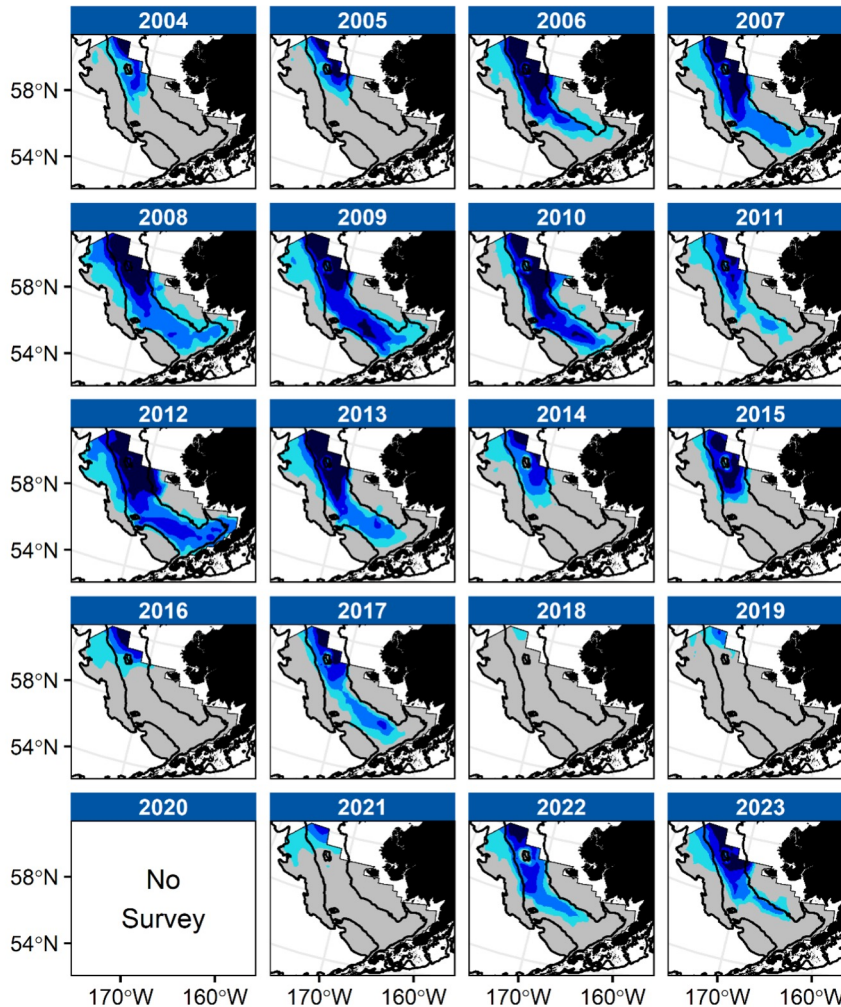




# Cold Pool

Rohan & Barnett

Bottom  
Temperature (°C)



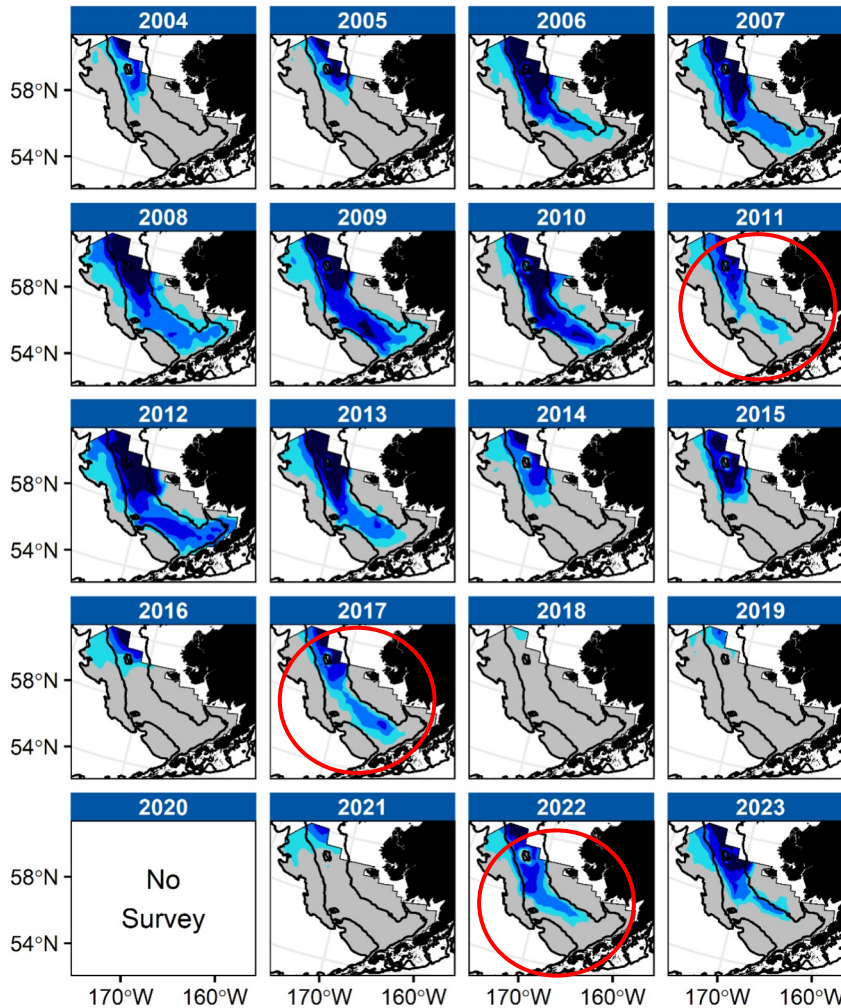
- Average cold pool extent
  - *Slightly larger than 2022*
- Footprint of the cold pool was similar to 2011, 2017, and 2022
- Cold tongue along the inner front was shifted inshore



# Cold Pool

Rohan & Barnett

Bottom  
Temperature (°C)

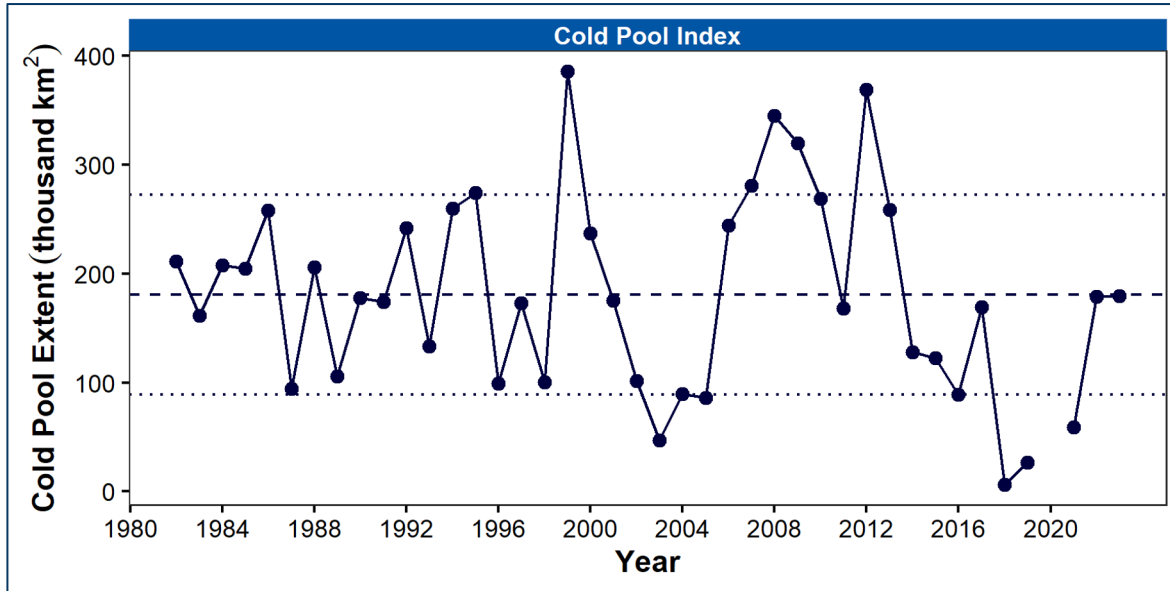


- Average cold pool extent
  - *Slightly larger than 2022*
- Footprint of the cold pool was similar to 2011, 2017, and 2022
- Cold tongue along the inner front was shifted inshore

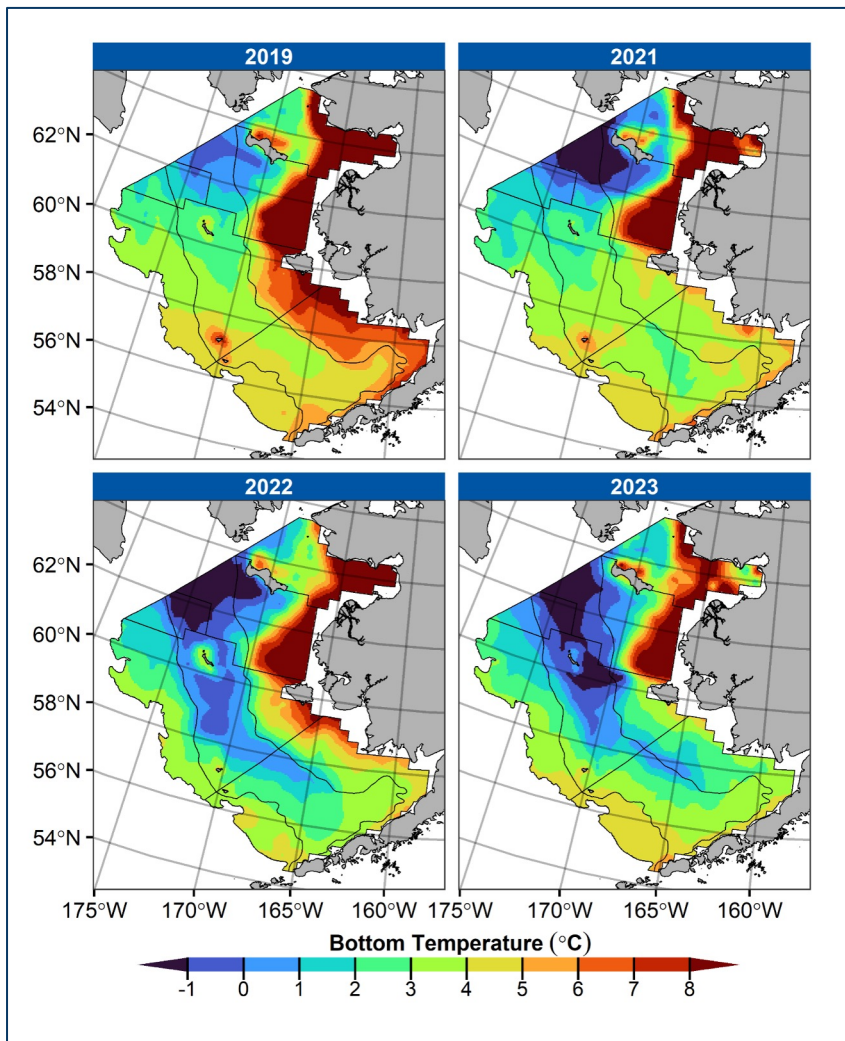


# Cold Pool

Rohan & Barnett



- Average cold pool extent
  - *Slightly larger than 2022*
- Footprint of the cold pool was similar to 2011, 2017, and 2022
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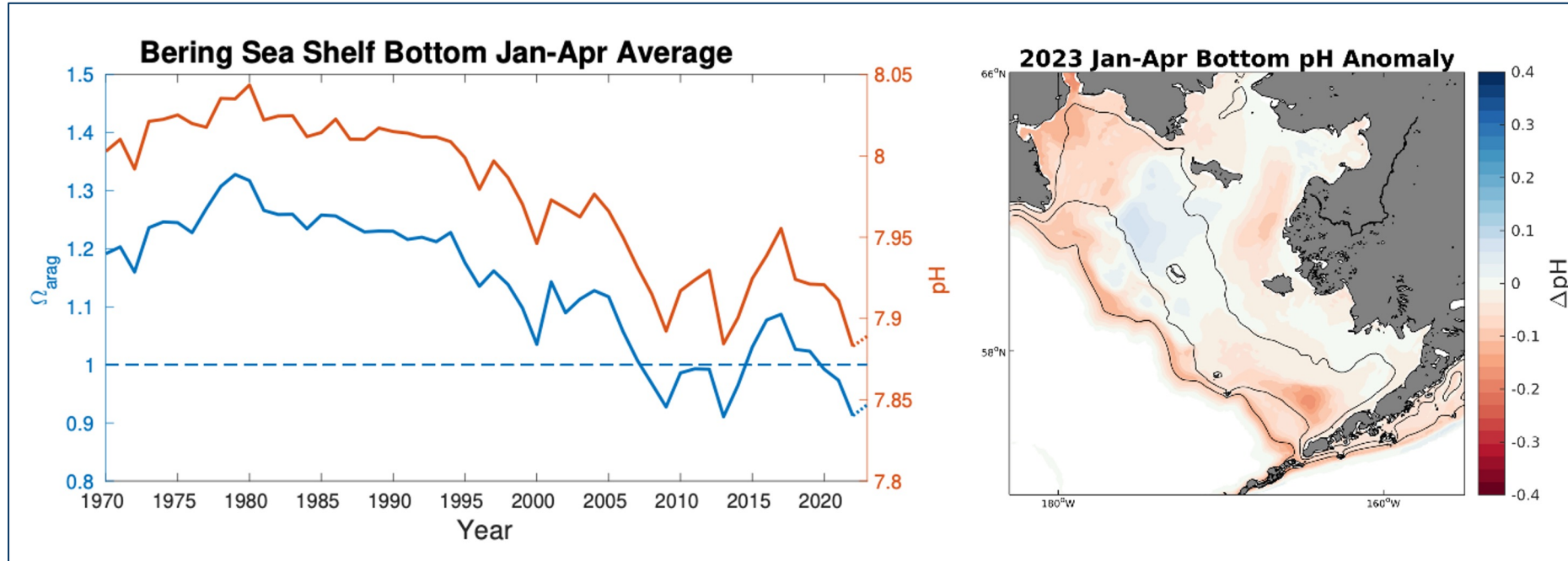
# Cold Pool

Rohan & Barnett

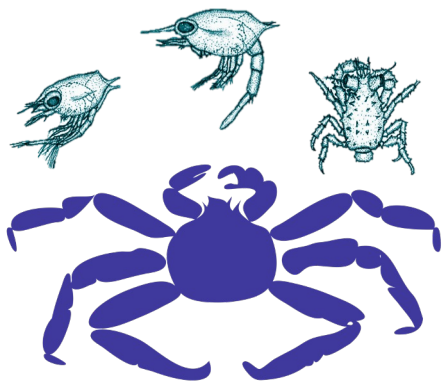
- Bottom and surface temperatures were slightly colder than time series average
- Very cold bottom temperatures south of St. Matthew Island for the first time since 2015
- Coldest bottom temperatures in the southern inner domain since 2013

# EBS Ocean Acidification

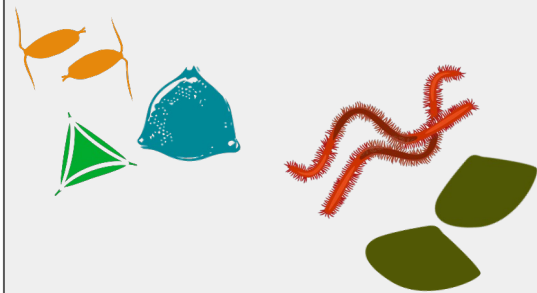
Pilcher & Monacci



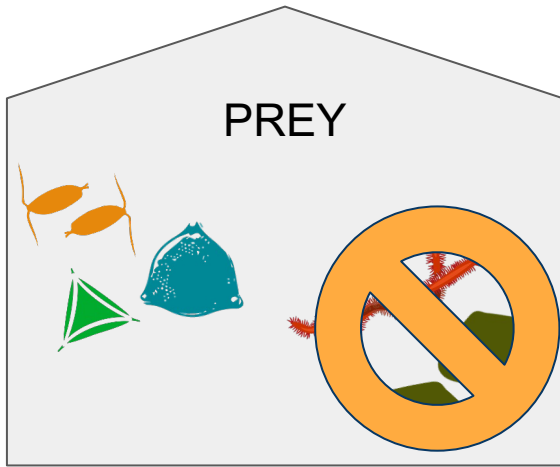
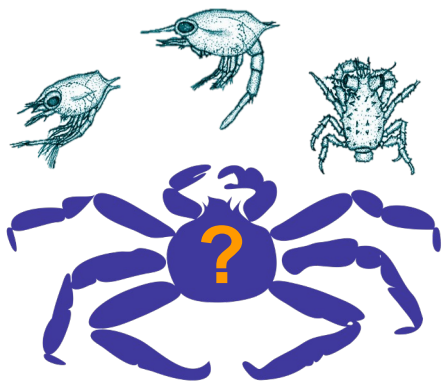
- Through Jan-Apr of 2023,  $\Omega_{\text{arag}}$  and pH continuing near lowest values
- Multi-year outer shelf low pH anomaly diminished somewhat, though still present in southeastern shelf

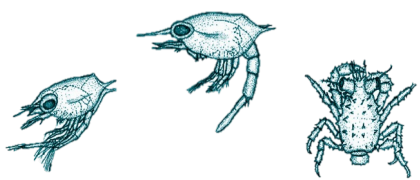


PREY



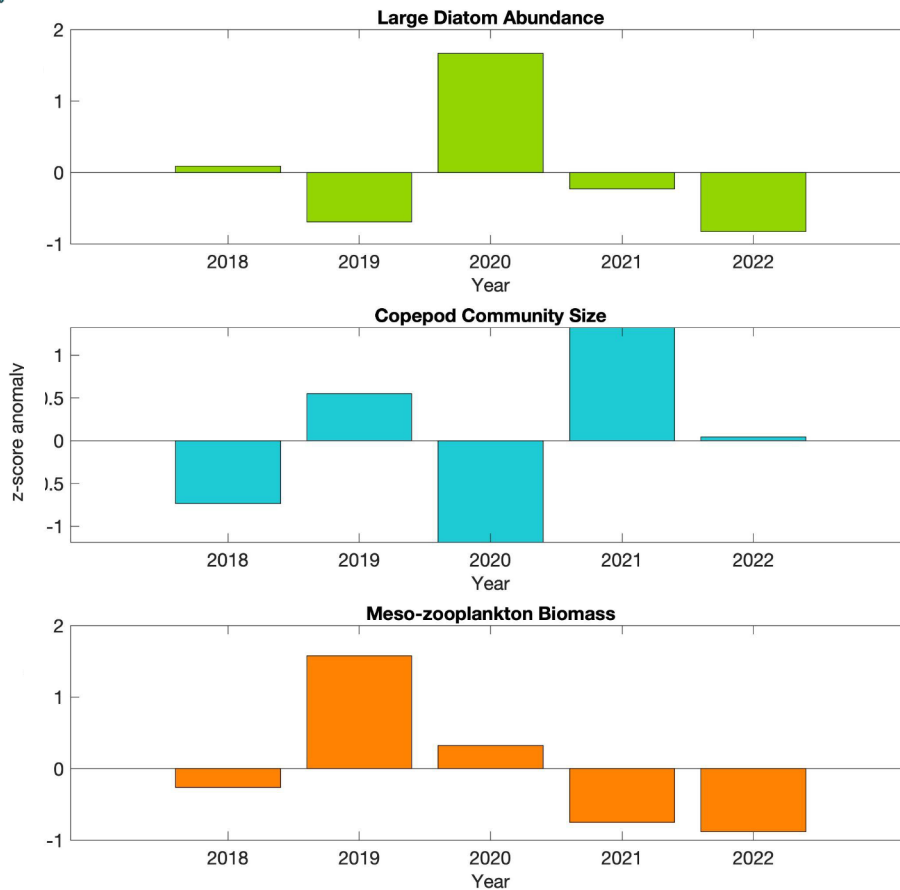
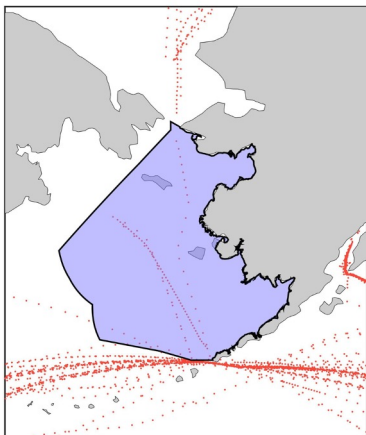






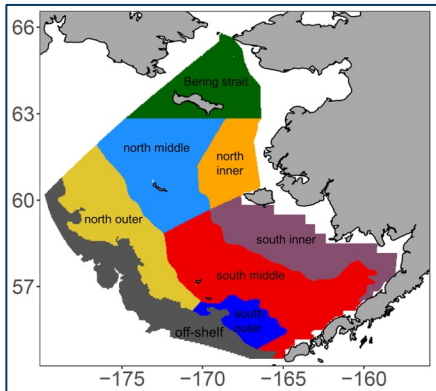
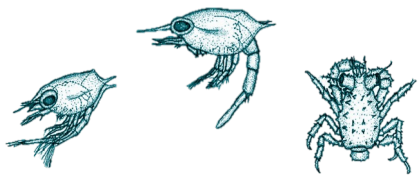
# 2022 Continuous Plankton Recorder

## Ostle & Batten



- The mean diatom abundance was negative in 2022
- Copepod community size was positive in 2021, where it had been negative in 2020
- Meso-zooplankton biomass was negative in 2022

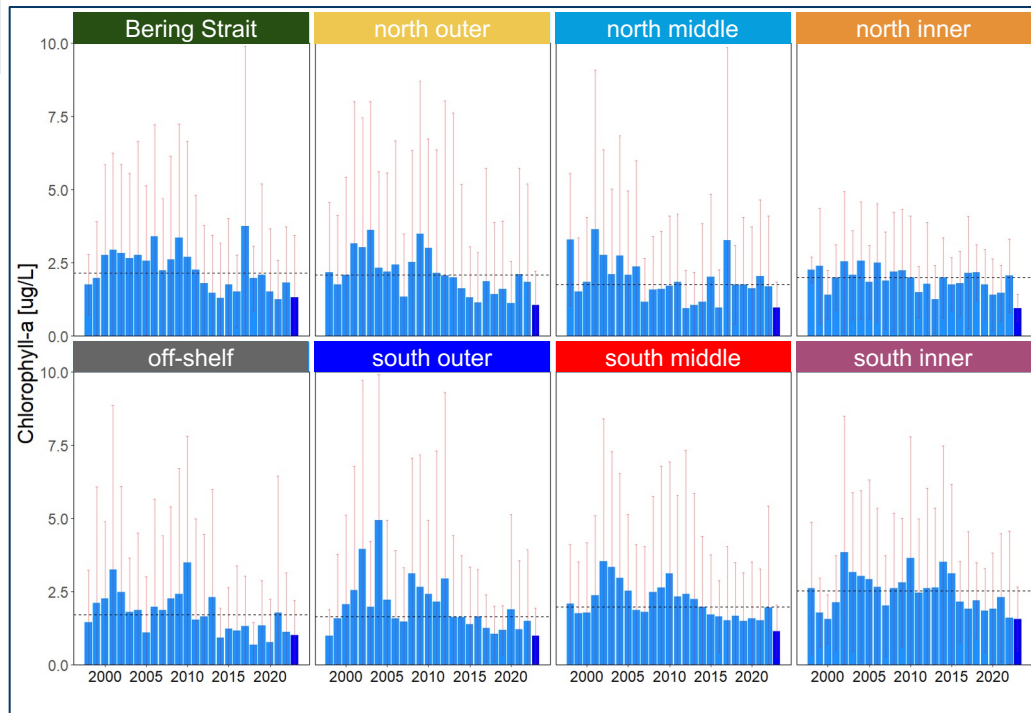


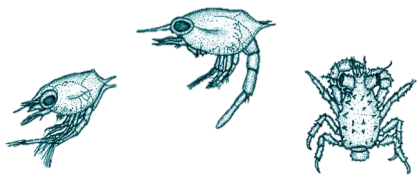


# 2023 Spring Bloom

## Nielsen, Callahan

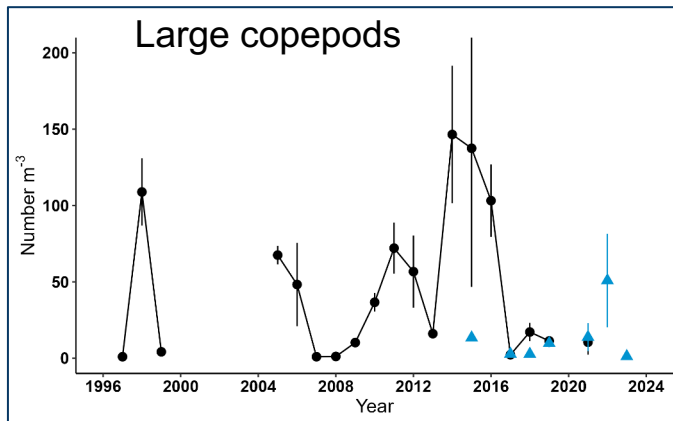
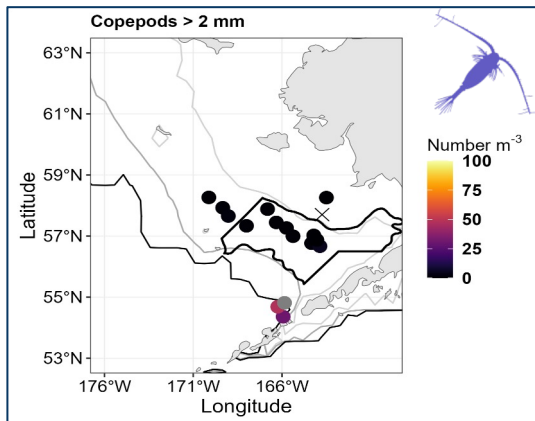
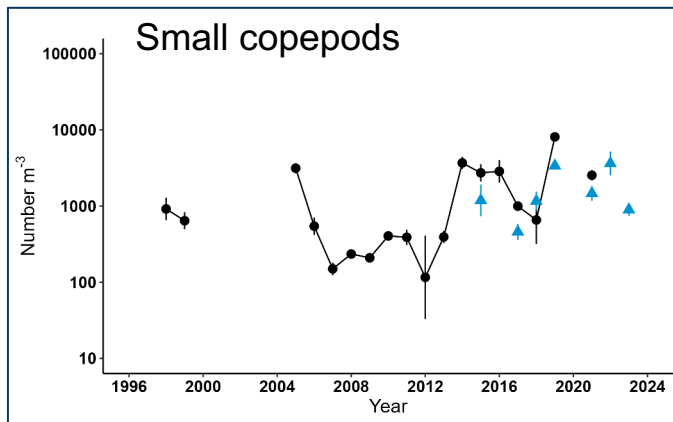
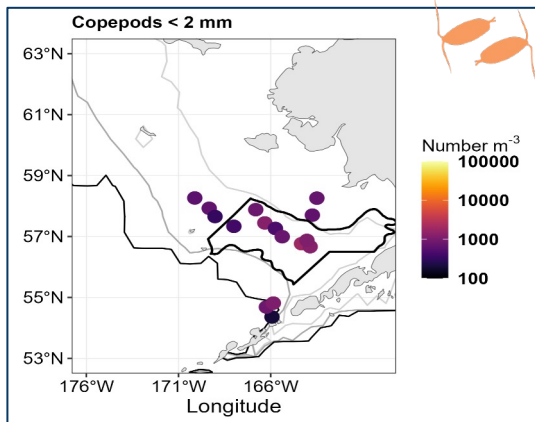
- Preliminary interpretation:
- Now using Globcolour because MODIS is not consistently updated
- Chl-a biomass for 2023 is among the lowest in every region
- Still investigating the reason; bloom timing analysis underway



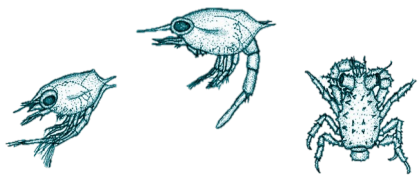


# Spring 2023 Rapid Zooplankton Assessment

Kimmel



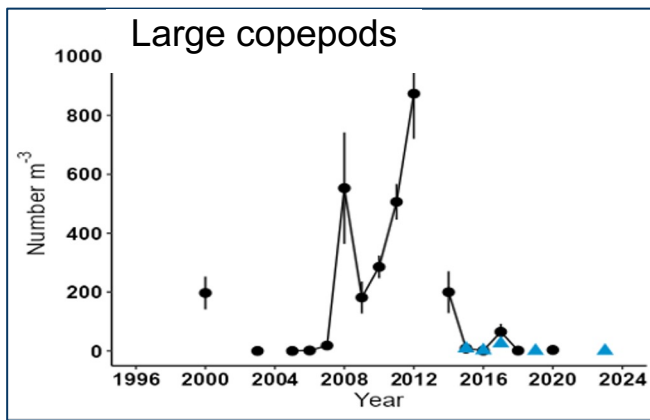
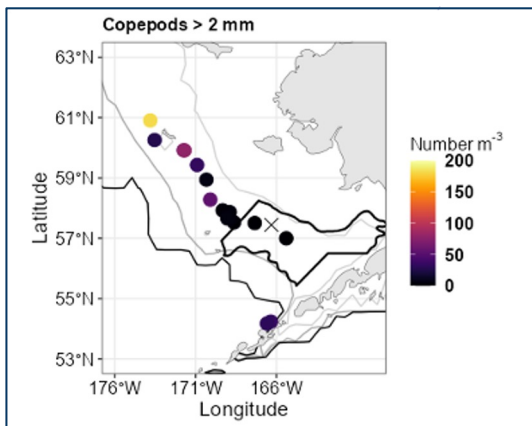
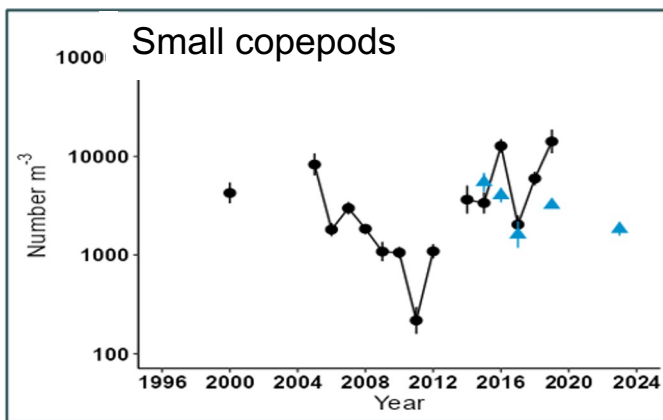
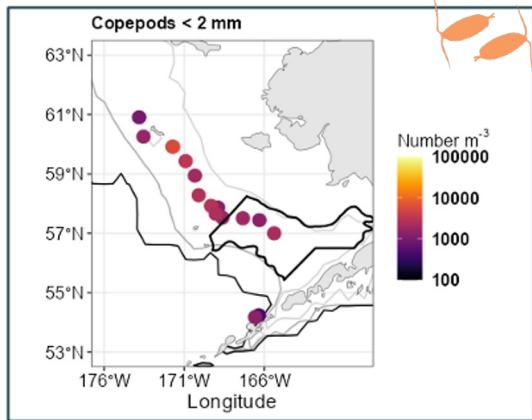
- Spring RZA abundances very low
- Small copepods low, similar to cold years. Cold temps limit population growth by reducing development time & turnover rates
- Large copepods low, similar to cold years after warm periods
- Euphausiid numbers very low, typical of early spring



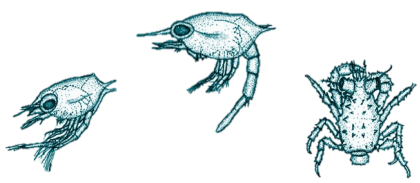
Fall 2023

# Rapid Zooplankton Assessment

Kimmel



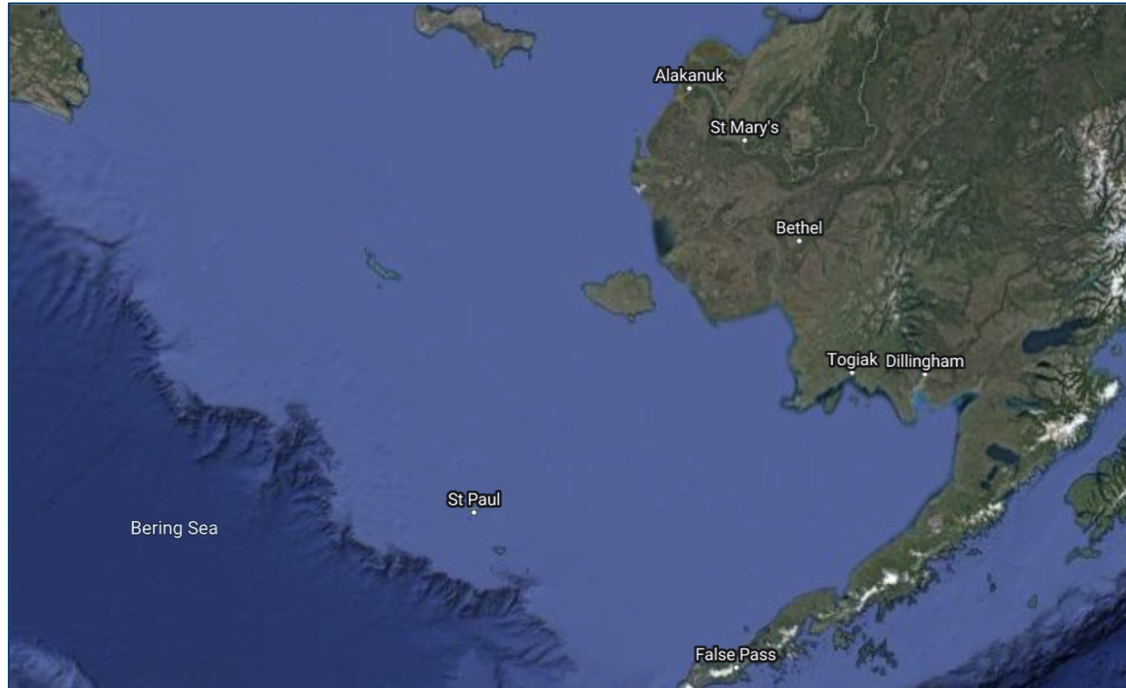
- Small copepods moderate; no N/S spatial gradient; similar abundance to colder years and lower than recent warm years
- Large copepods (and euphausiids) were low in the south and increased to the north
- Lipid-rich copepods in NBS, but not SEBS (cold pool did not extend south)

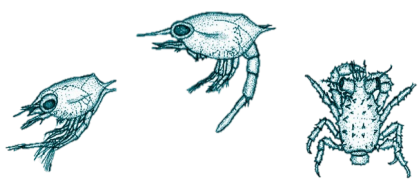


# 2023 Coccolithophores

## Eisner & Lange

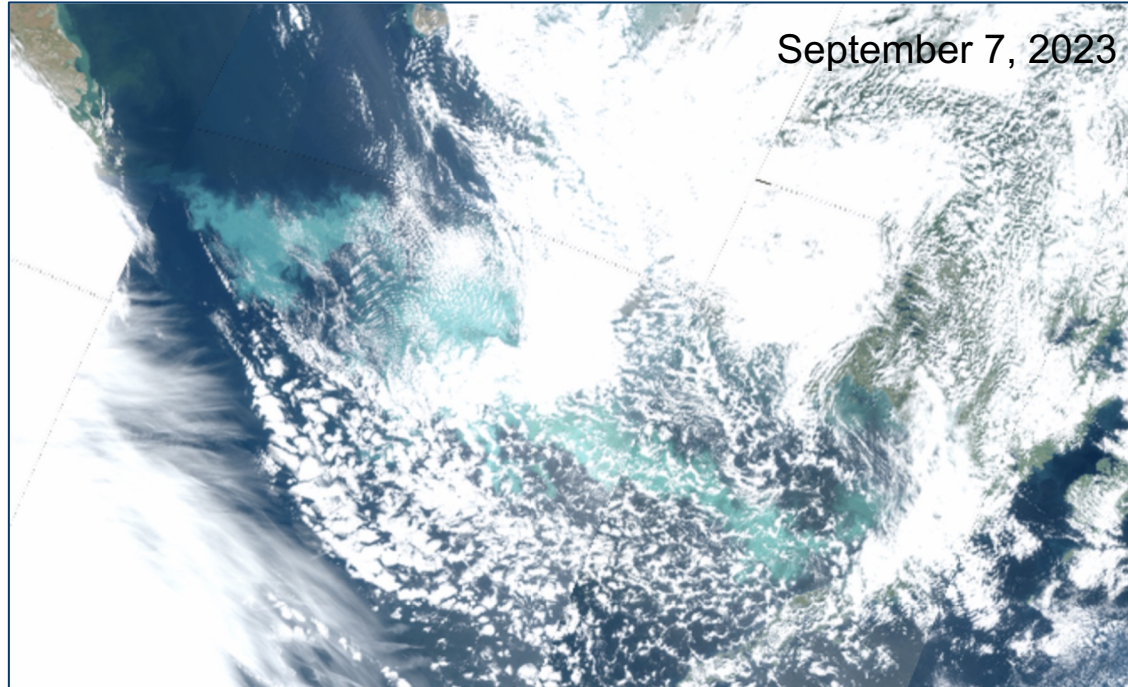
- Coccolithophore bloom index increasing since 2018 in inner and middle domains
- 2023: a noticeable coccolithophore bloom (full index available in October)
- *Implications:* coccolithophores result in longer trophic chains, may be a less desirable food source, and can reduce foraging success for visual predators





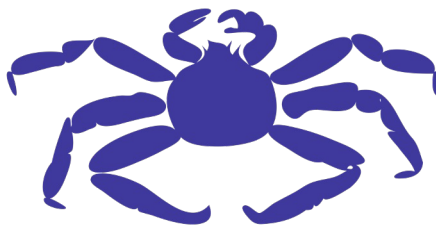
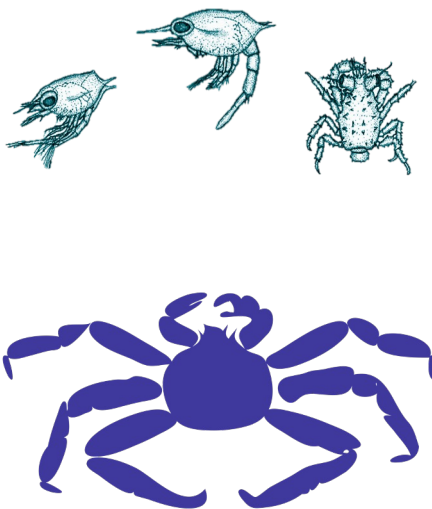
# 2023 Coccolithophores

Eisner & Lange



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- *Implications:* coccolithophores result in longer trophic chains, may be a less desirable food source, and can reduce foraging success for visual predators.

# COMPETITORS





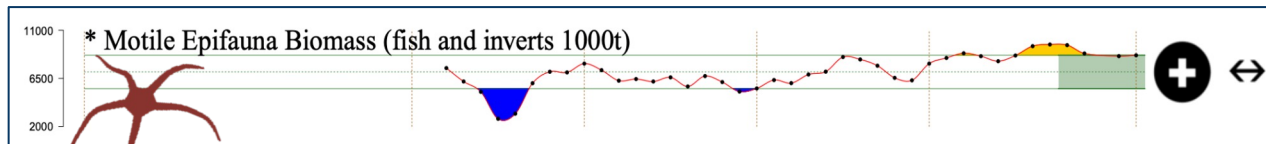


# 2022 Motile Epifauna and Benthic Foragers

Whitehouse

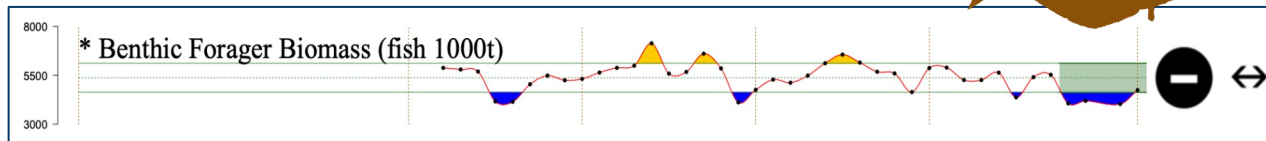
Motile epifauna and benthic foragers are competitors with benthic crab for prey and space.

*Indicates benthic productivity*

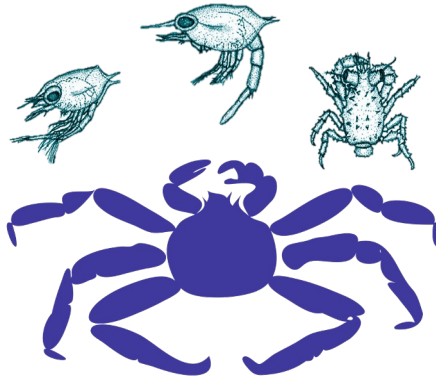
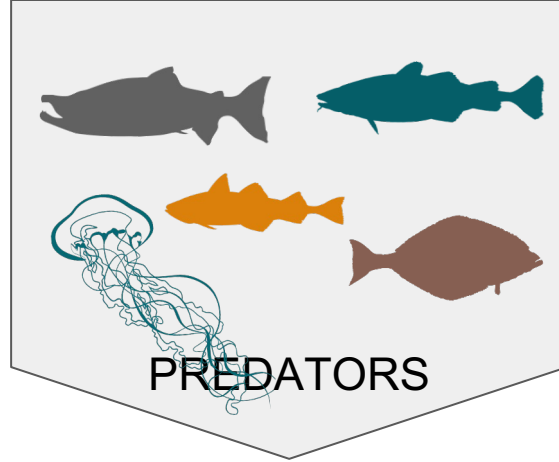


- Motile epifauna biomass peaked in 2017 and remained above the long-term mean in 2022

*Indirect indicator of infauna*



- Benthic foragers biomass increased 18% in 2022 from time series low in 2021; remained below time series mean

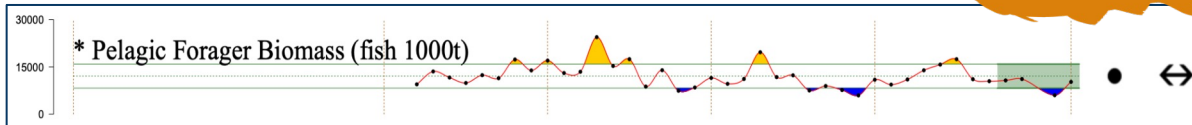




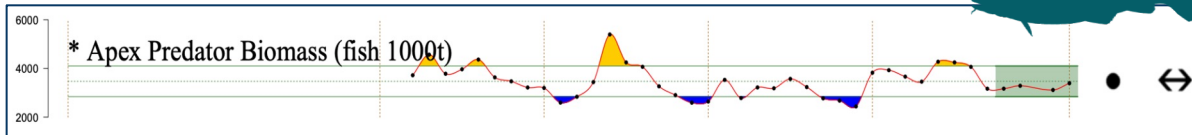
# 2022 Pelagic Foragers and Apex Predators

Whitehouse

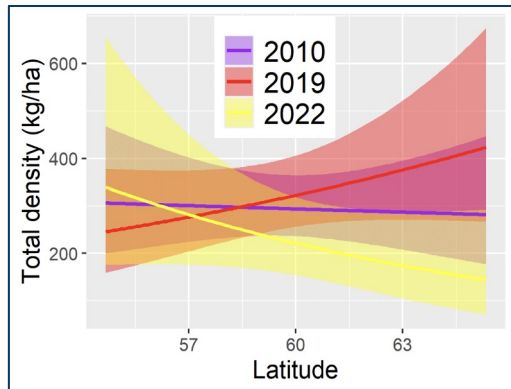
Pelagic foragers are predators of larvae while apex predators consume small benthic crab stages.



- Pelagic foragers (pollock and herring) increased sharply from 2021 to 2022.



- Apex predators (P. cod and ATF) increased from 2021 to 2022 to long term mean.



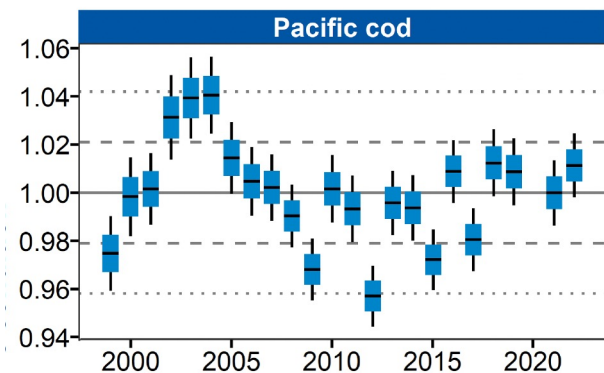
- The groundfish community shifted north between 2010 and 2019, then south in 2021 as conditions cooled, and into slightly deeper waters in 2022



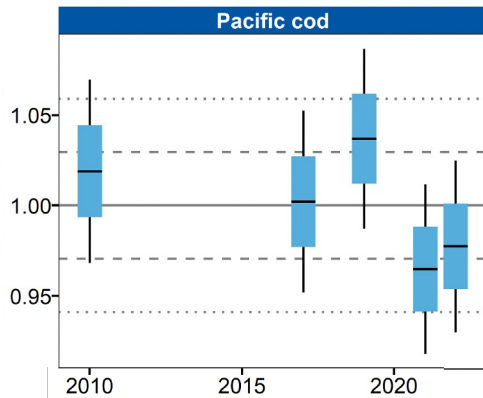
# 2022 Adult Pacific Cod Condition

Rohan & Prohaska

EBS



NBS



- EBS: PCod condition positive and slightly higher than 2021
- NBS: PCod condition continued to be negative, though slightly higher than 2021

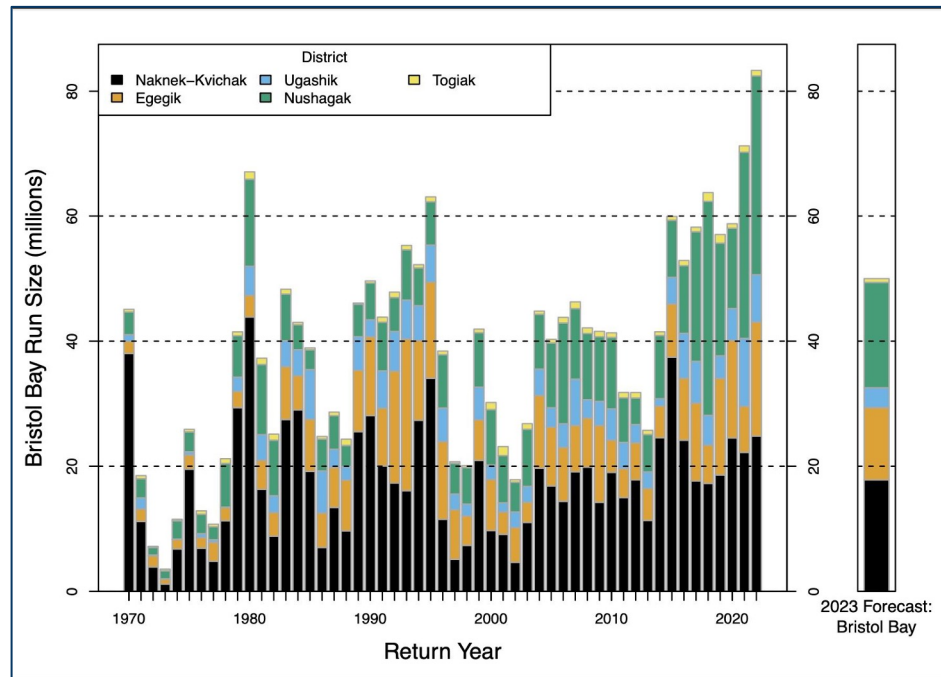


# 2023 Bristol Bay Sockeye Salmon

## Cunningham

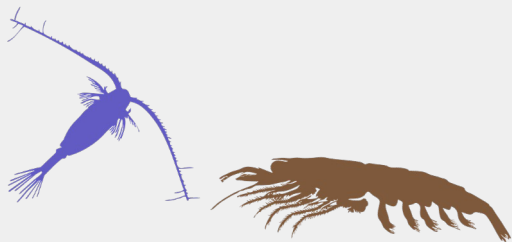


- 2023 (estimate: 54 million) was lower than the 2022 record run of 83 million sockeye
- Smaller size-at-age (density-dependent growth)
- Large average size of sockeye compared to recent years (>80% 3-ocean: 1.3+2.3)
- Juvenile sockeye feed on zooplankton and age-0 pollock in warm years; adults feed on zooplankton and krill



# 2023 Summary & Larval Implications

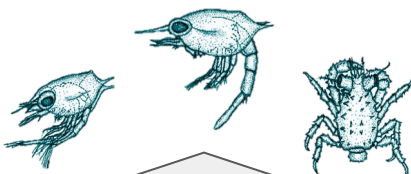
COMPETITORS



PREDATORS



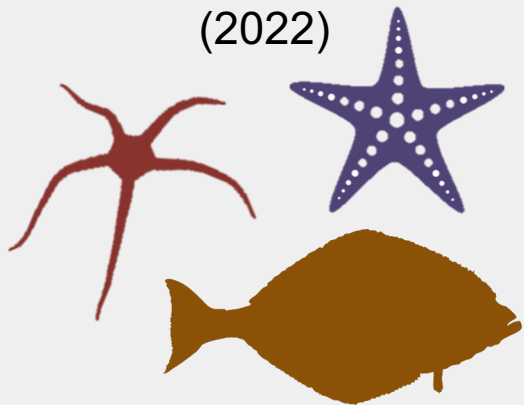
PREY



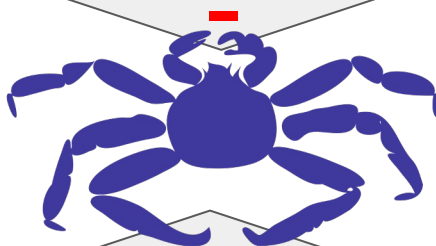
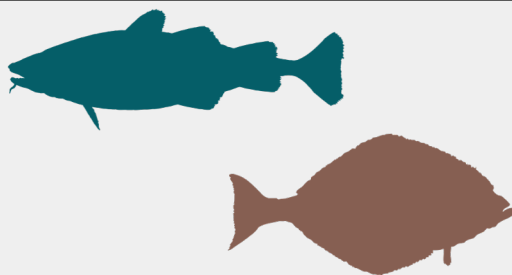
ENVIRONMENTAL  
PROCESSES

# 2023 Summary & Adult Implications

COMPETITORS  
(2022)



PREDATORS  
(2022)



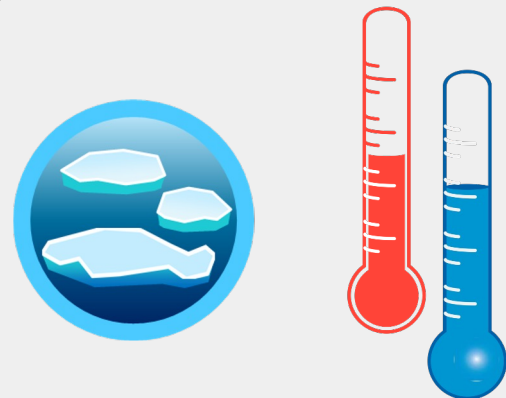
+

(indirect)

PREY

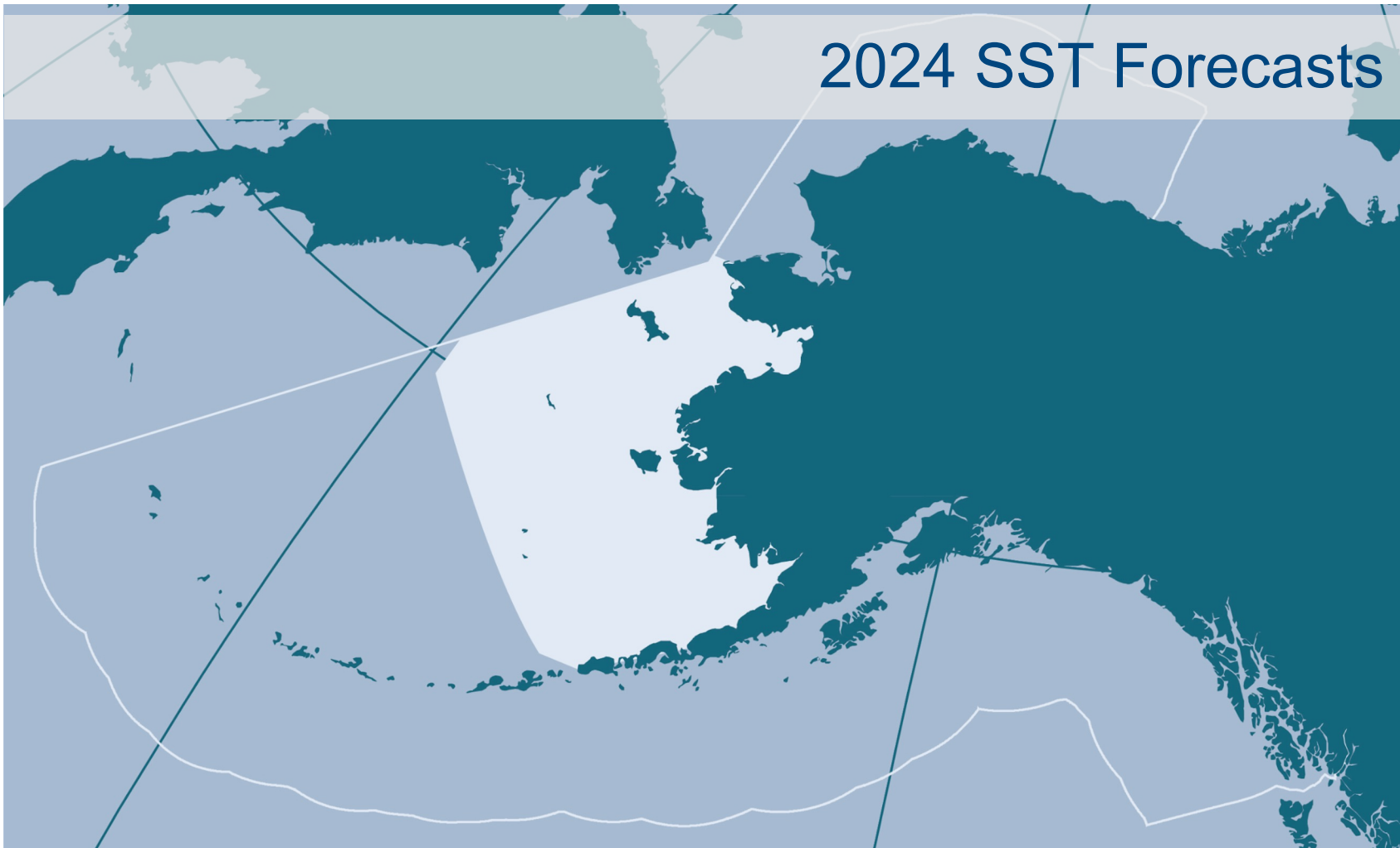


+



ENVIRONMENTAL  
PROCESSES

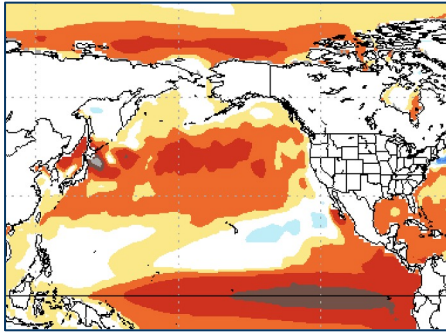
# 2024 SST Forecasts



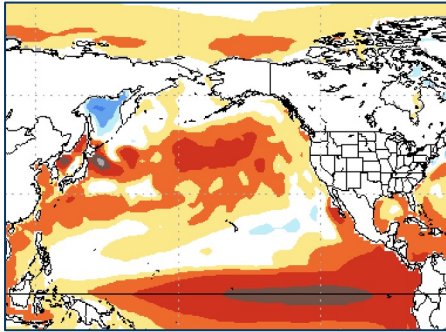
# SST Projections from the National Multi-Model Ensemble

Bond

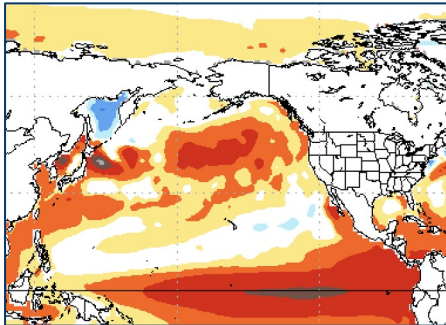
Oct - Dec  
2023



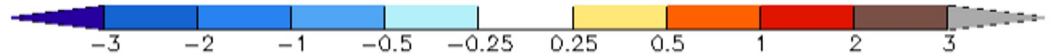
Dec 23 -  
Feb 24



Feb -  
April  
2024



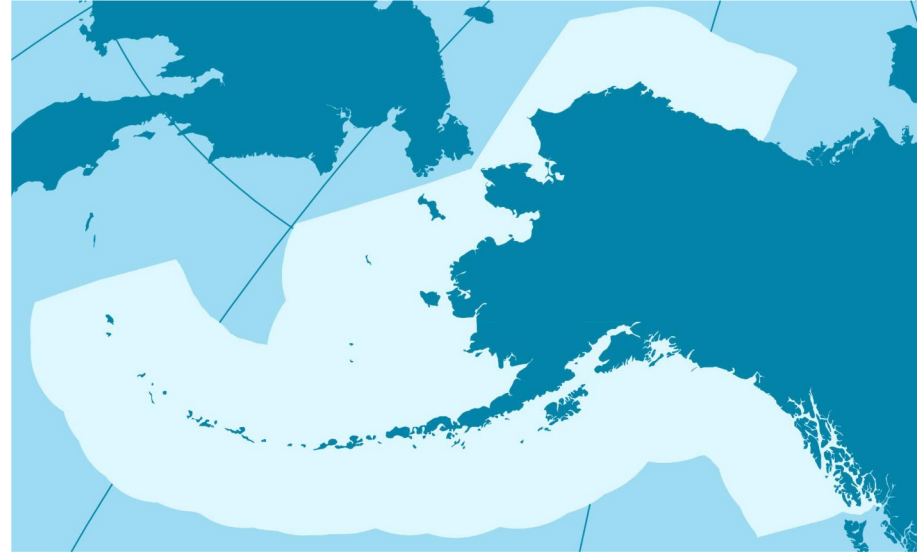
- **TOP:** El Niño in tropical Pacific. Modest warming for western Aleutian Islands, southeast Bering Sea shelf, and Gulf of Alaska.
- **MIDDLE:** Similar to earlier period (Oct-Dec 2023). Tropical Pacific has SST anomalies  $>2^{\circ}\text{C}$ , representing a strong El Niño.
- **BOTTOM:** Moderation of tropical Pacific SSTs; warming along PNW coast and SEAK (typical response to El Niño). Sea ice could extend south of  $60^{\circ}\text{N}$  and as far south as Bristol Bay.





### ***Please note...***

- AFSC Ecosystem Status Reports underwent a CIE (Center for Independent Experts) review in Spring 2023
- The panel provided several recommendations in response to the review's Terms of Reference
- A summary of proposed actions in response to those recommendations was presented by Dr. Ivonne Ortiz during the Groundfish Plan Team
  - [ESR CIE Review PRESENTATION](#) (new since CPT)
- Some recommendations (e.g., Risk Tables) may be of interest to CPT members or crab stock assessment authors



Full **ESR Climate Overview** presentation to the September 2023 Groundfish Plan Teams is available at:

[ESR Climate Overview](#)

- North Pacific: slides 4-8
- EBS: slides 9-25
- AI: slides 26-32
- GOA: slide 33-41