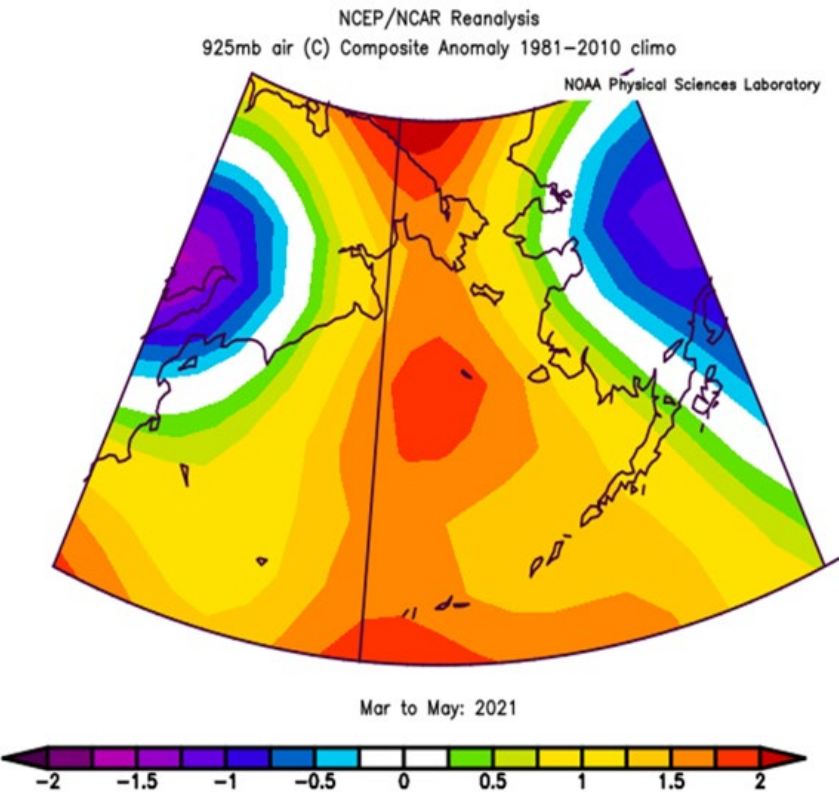


ECOSYSTEM STATUS REPORT



Elizabeth Siddon
Bridget Ferriss
Ivonne Ortiz
Stephani Zador
Kerim Aydin

NPFMC Crab Plan Team
September 13, 2021





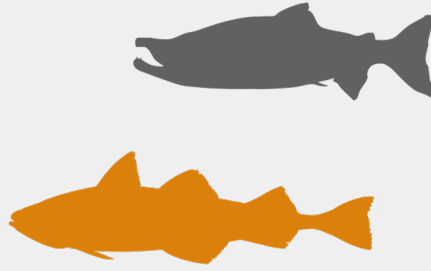
1. 2020 crab-relevant information (review)
2. 2021 climate and oceanography
3. 2022 sea surface temperature forecasts

2020 pelagic larval indicators

COMPETITORS



PREDATORS



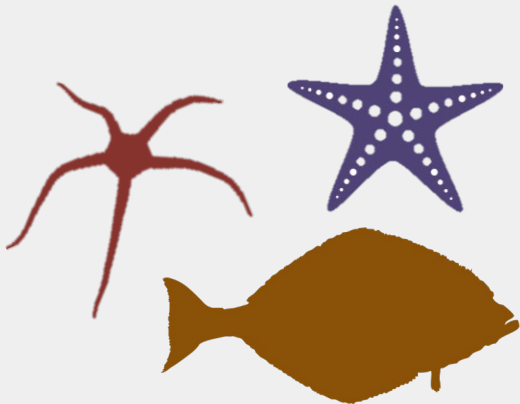
PREY



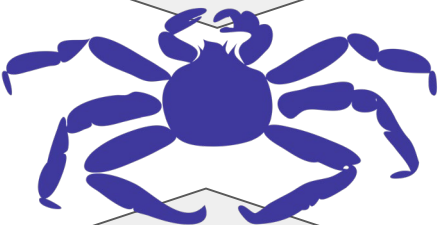
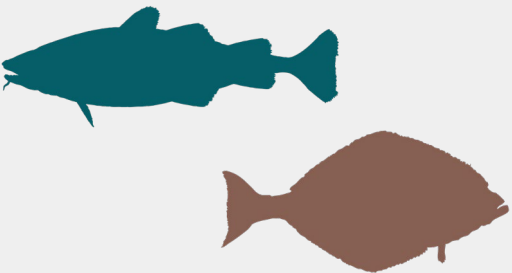
ENVIRONMENTAL PROCESSES

2020 benthic adult indicators

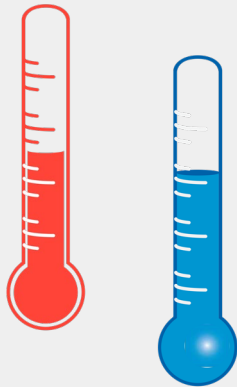
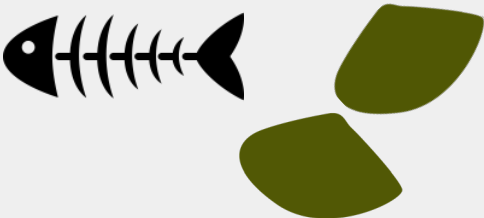
COMPETITORS



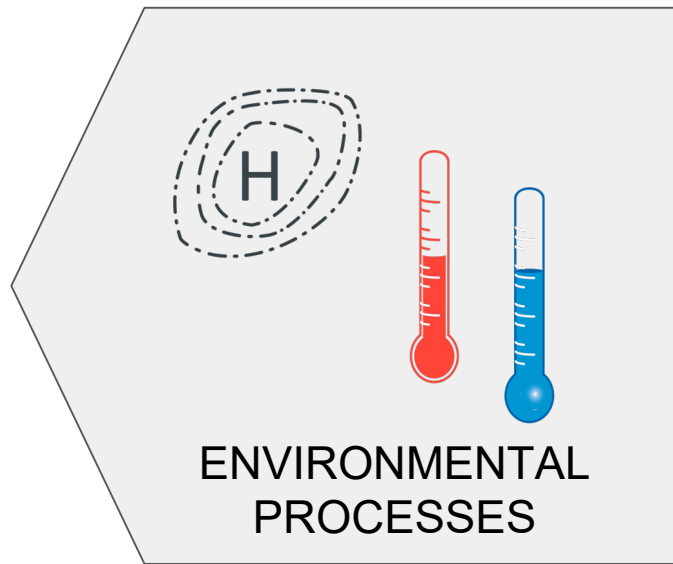
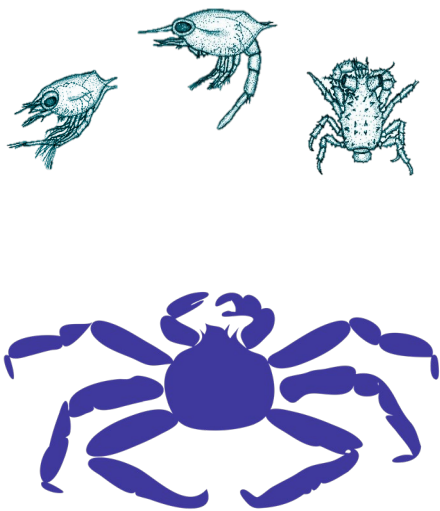
PREDATORS

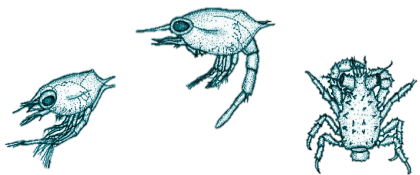


PREY



ENVIRONMENTAL PROCESSES

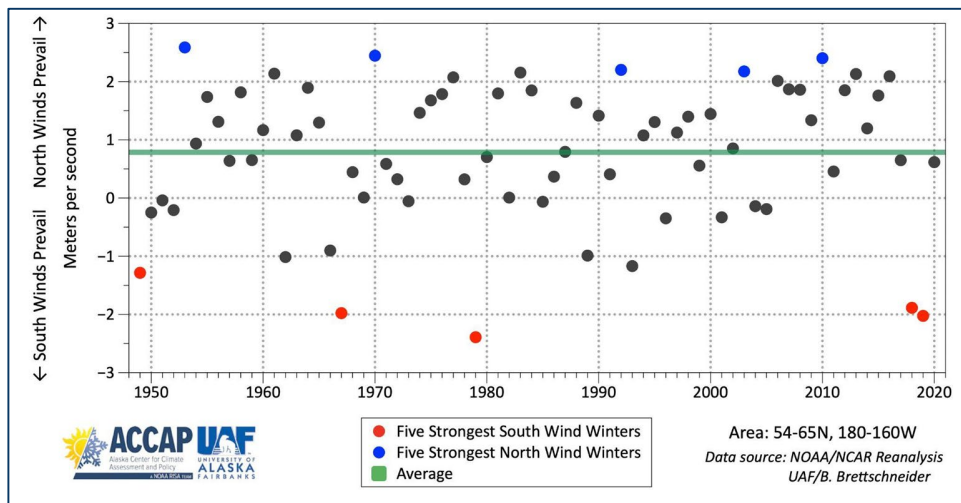


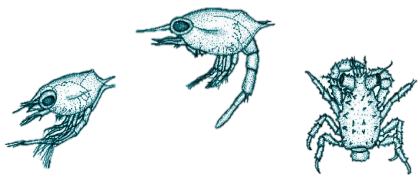


2020 Winds

Thoman

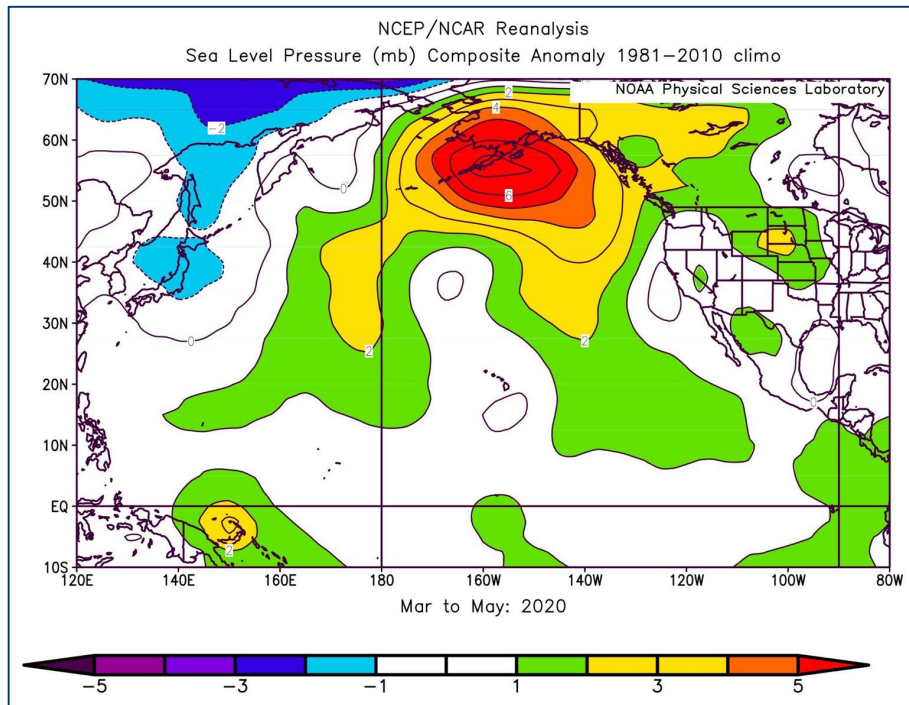
- Winter 2019/2020 had wind speed direction near the long-term average.





2020 Winds

Bond

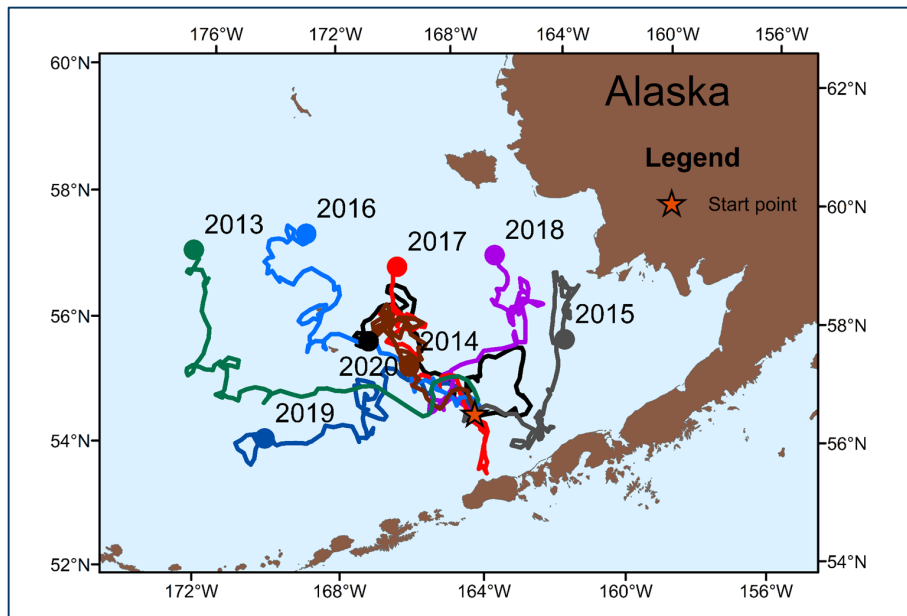


- Winter 2019/2020 had wind speed direction near the long-term average.
- March-May 2020 had winds from the south over the shelf.

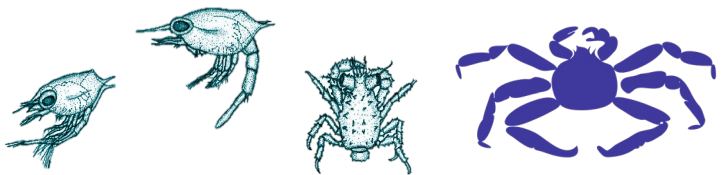


2020 Winds

Cooper & Wilderbuer

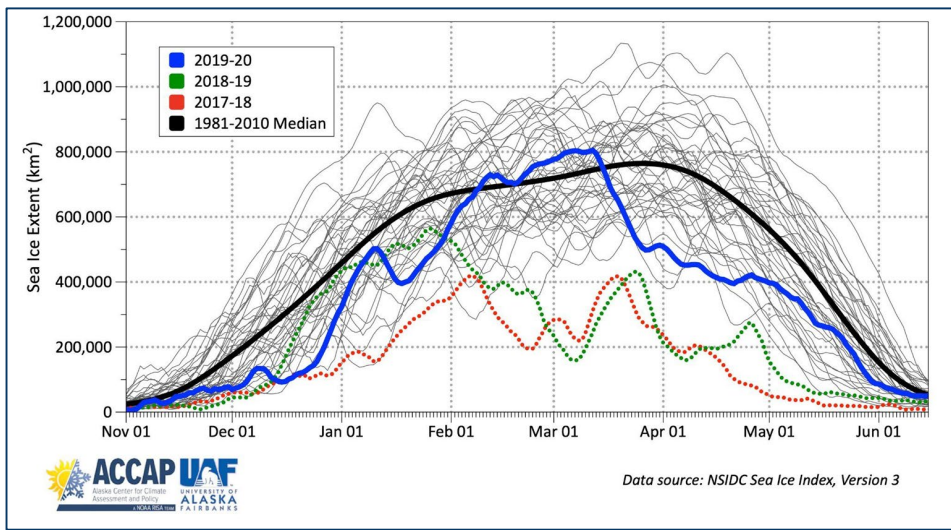


- Winter 2019/2020 had wind speed direction near the long-term average.
- March-May 2020 had winds from the south over the shelf.
- April - June 2020 drift trajectory (black line) show drift over the middle shelf.
- Only 2015 and 2018 had drift trajectories consistent with above-average recruitment of northern rock sole.



2020 Sea Ice

Thoman

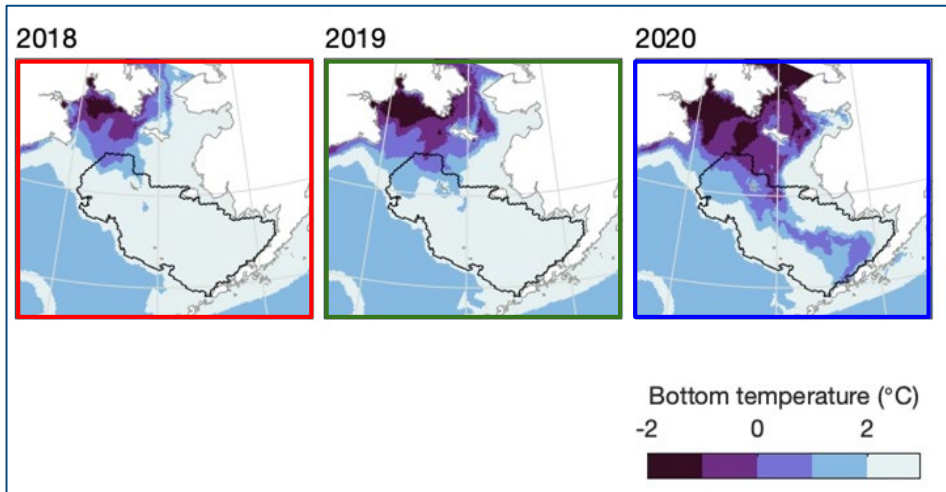


- In winter 2019/2020, residual warmth delayed sea ice formation until late December 2019.
- Considerable cooling then allowed rapid ice build-up, even exceeding median ice extent in parts of February and March 2020.
- However, ice thickness was low and ice retreated quickly in spring 2020.

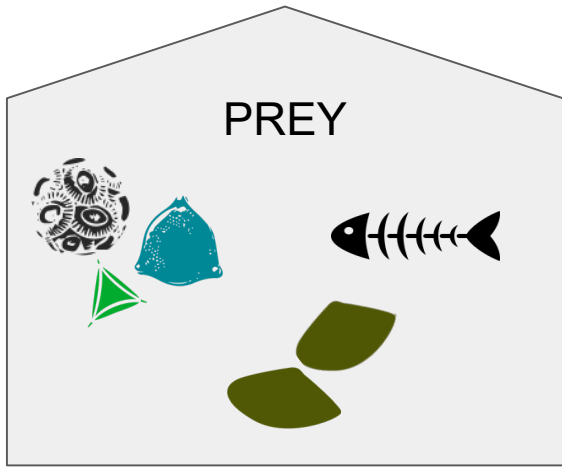
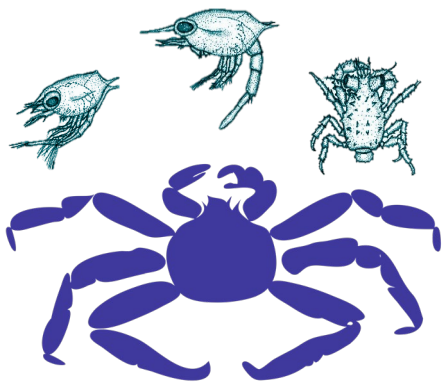


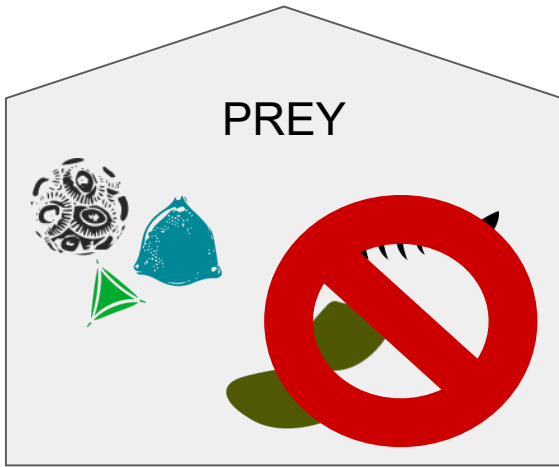
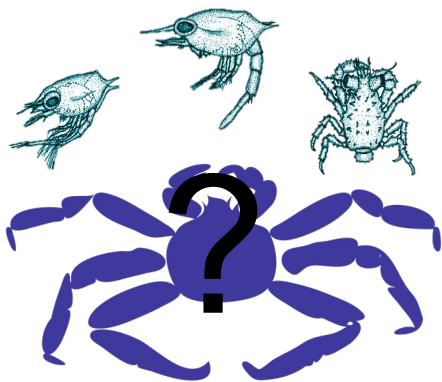
2020 Cold Pool

Kearney



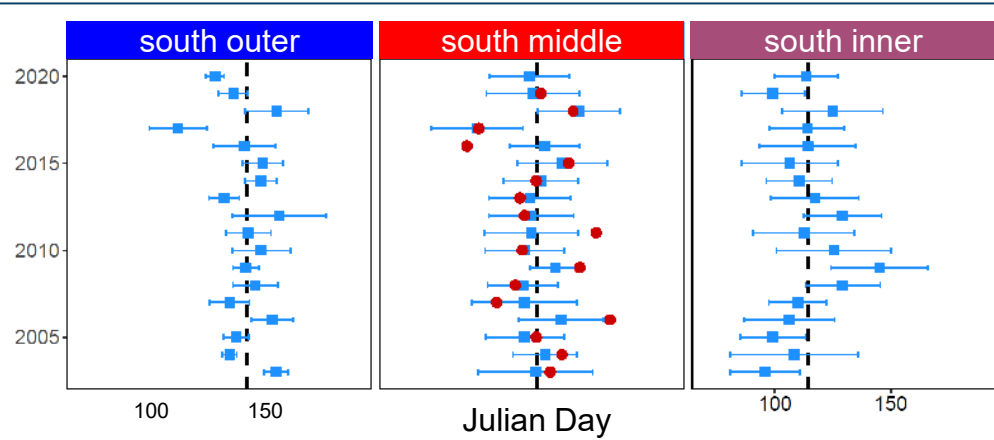
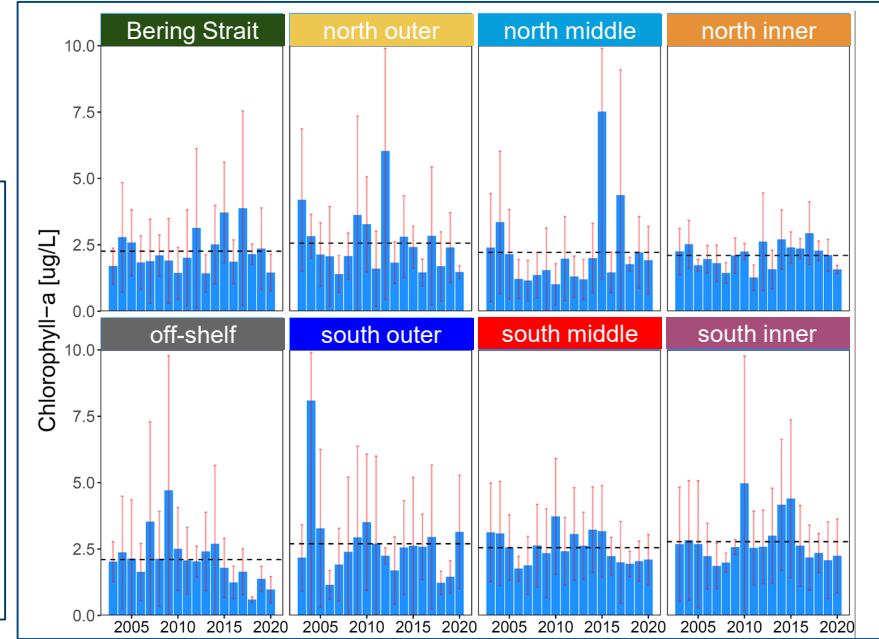
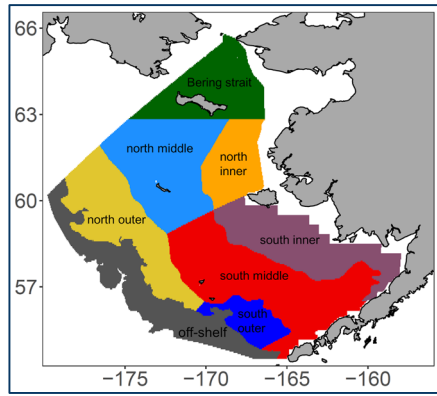
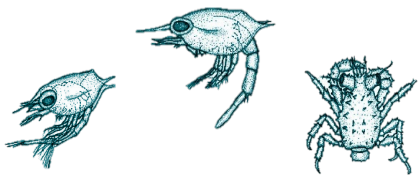
- Bering 10K ROMS hindcast of bottom water temperature, extracted for July 1 of each year.
- 2020 was an average year based on the amount of $<2^{\circ}\text{C}$ and $<0^{\circ}\text{C}$ waters over the shelf.
- Reduced ice thickness and duration may impact ice algae and primary productivity.



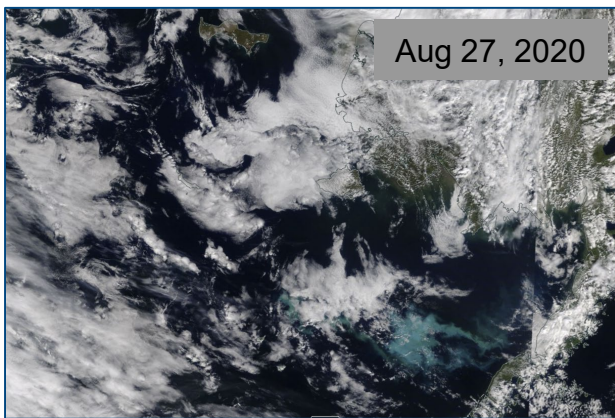
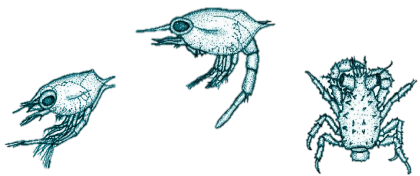


2020 Spring Bloom

Nielsen

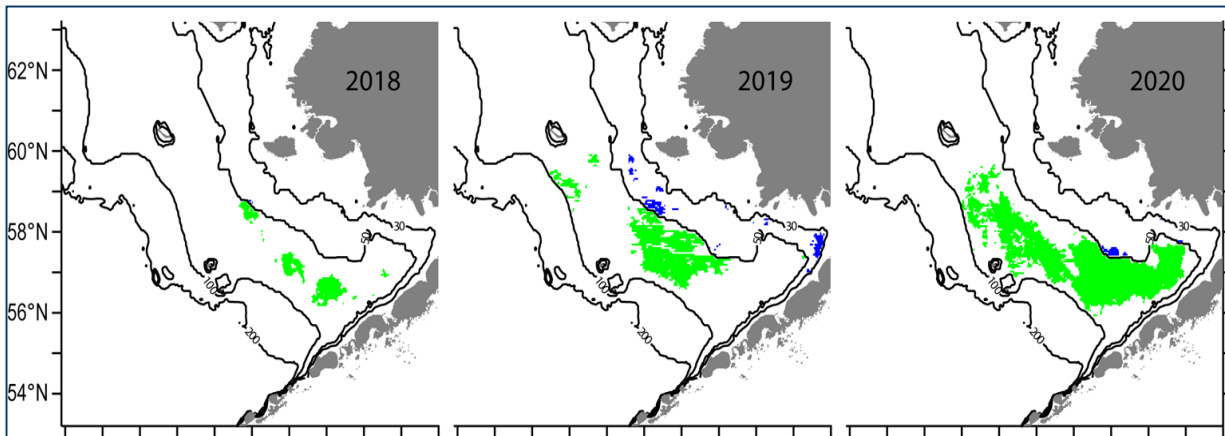


- Satellite-derived chlorophyll-a data shows temporal (left) and spatial (right) variability over the Bering Sea.
- Stock-specific indicators can be developed that are subsetted for a management area and larval period.



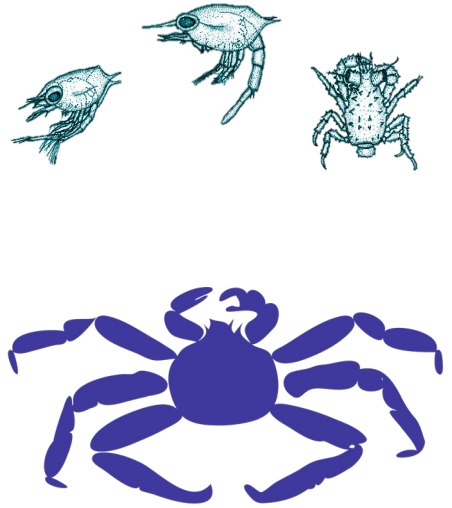
2020 Coccolithophores

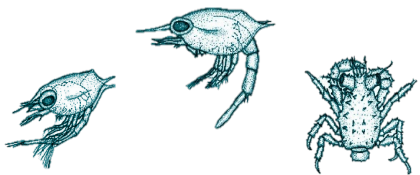
Ladd & Eisner



- Bloom index below average in 2018 and 2019.
- Increased in 2020, particularly on the middle shelf.
- Results in longer trophic chains and may be a less desirable food source.

COMPETITORS





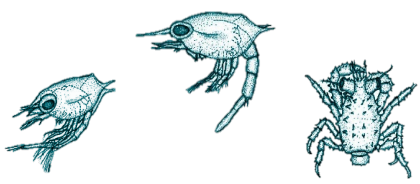
2020 (indirect) Zooplankton Integrated Seabird Information

Summary Statement

During 2020, the U.S. Fish and Wildlife Service was unable to conduct field research in the eastern and northern Bering Sea due to COVID-19 travel restrictions. Coastal community members, tribal governments, and state/university partners provided information on seabird dynamics; the U.S. Fish and Wildlife Service biologists helped to synthesize this information.

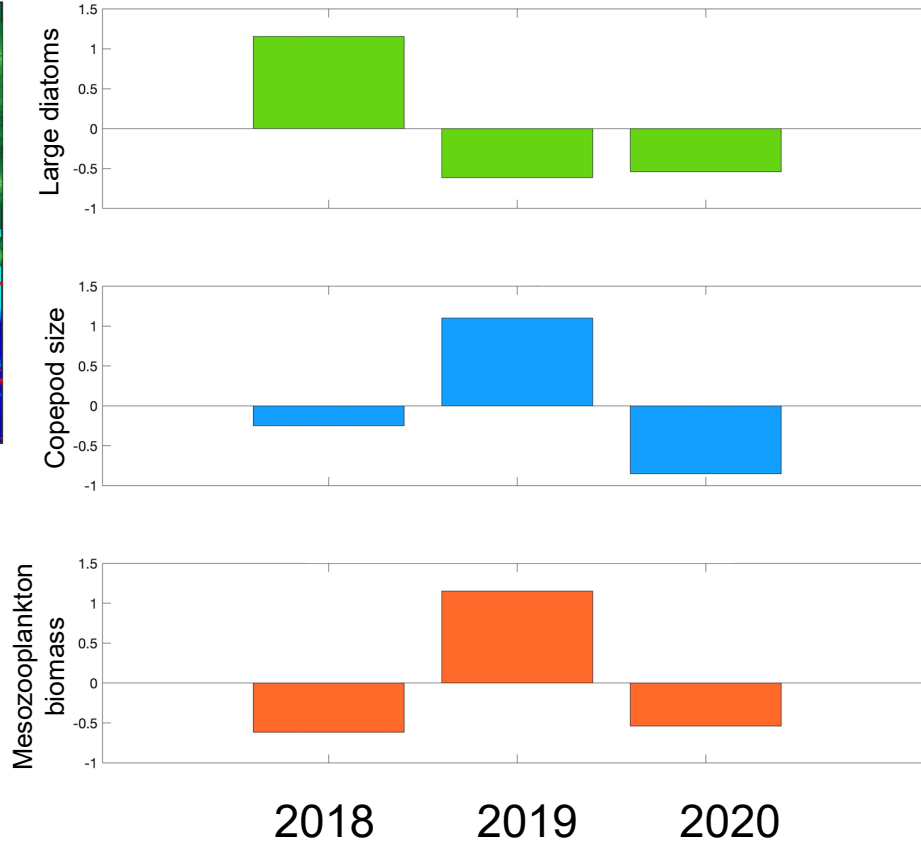
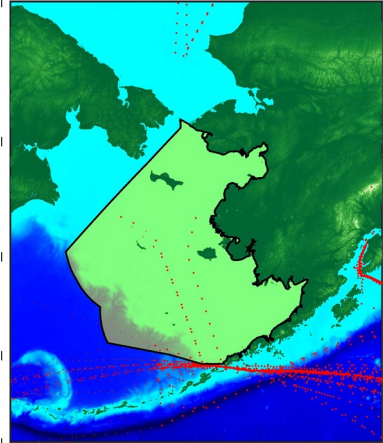


- At the Pribilof Islands, it was an average, to slightly below average, year for most fish-eating seabird species (e.g., black-legged kittiwakes, common murre).
- Plankton-eating species (e.g., least auklets) continued to decline. Complete lack of parakeet auklets from St. Paul Island.
- Fish-eating seabirds were able to find moderate/sufficient food; plankton-eating seabirds were not.



Continuous Plankton Recorder

Ostle & Batten



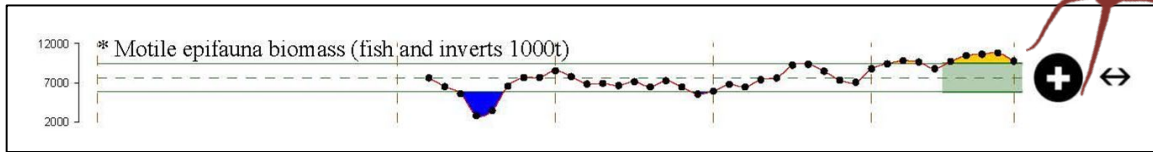
- The mean diatom abundance remained negative in 2020.
- Copepod community size was negative in 2020, where it had been positive in 2019.
- Mesozooplankton biomass was also negative in 2020, where it had been positive in 2019.



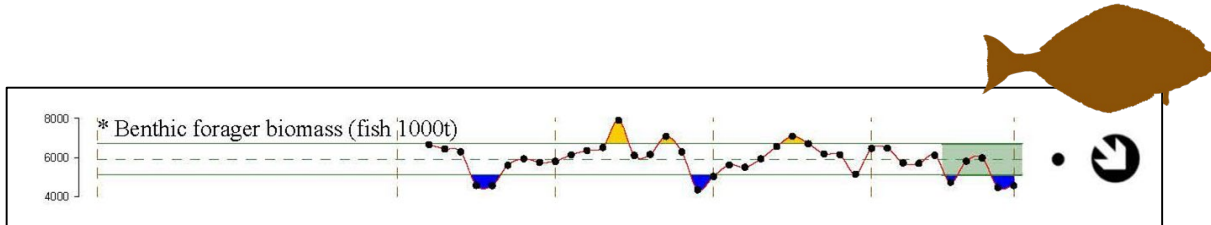
2019 Motile Epifauna and Benthic Foragers

Whitehouse

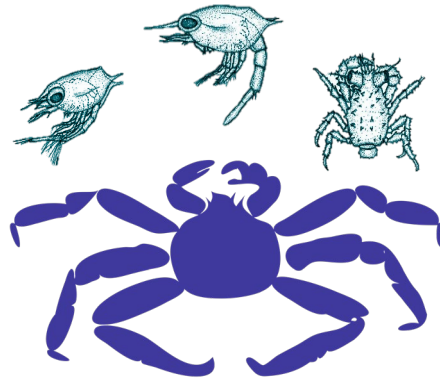
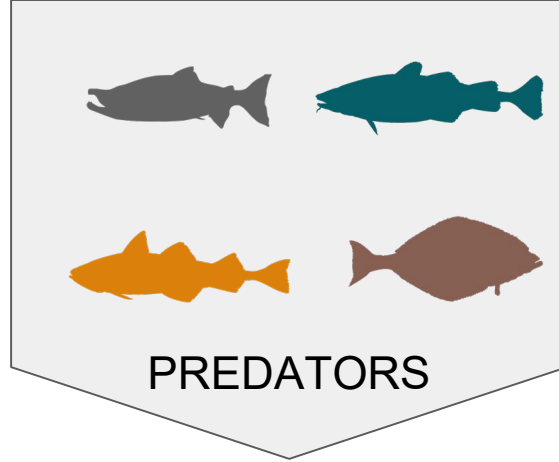
Motile epifauna and benthic foragers are competitors with benthic crab for prey and space.



- Motile epifauna biomass was above the long-term mean, but **decreased** from 2018 to 2019.



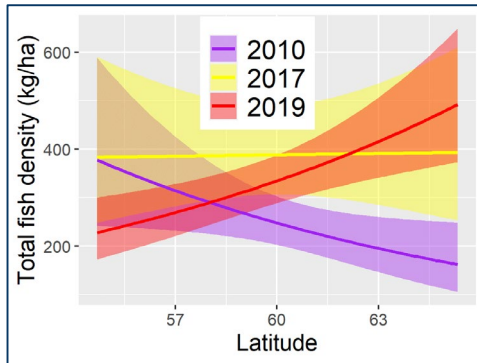
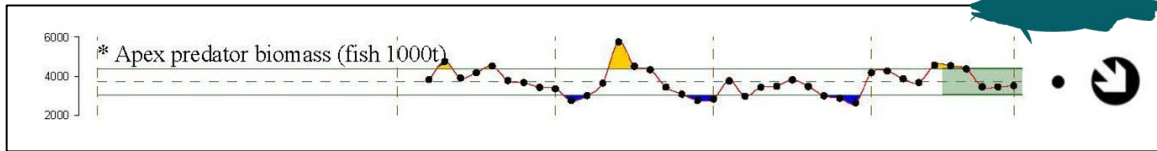
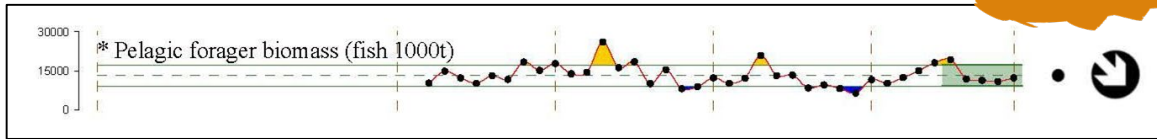
- Benthic foragers **remained low** in 2019.



2019 Pelagic Foragers and Apex Predators

Whitehouse

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



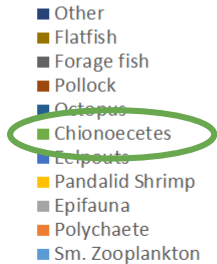
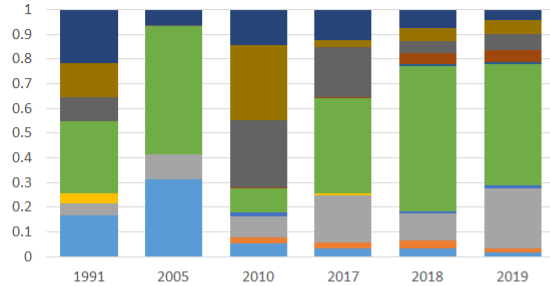
- Pelagic foragers (pollock and jellyfish) were at the long-term mean.
- Apex predators (Pacific cod and ATF) were at the long-term mean.
- Strong directional trend of the fish community to the north in 2019.



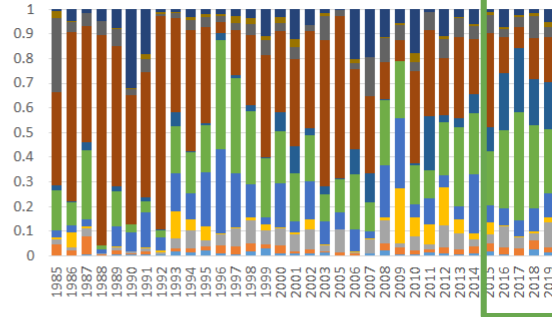
Adult Pacific Cod Food Habits

Aydin

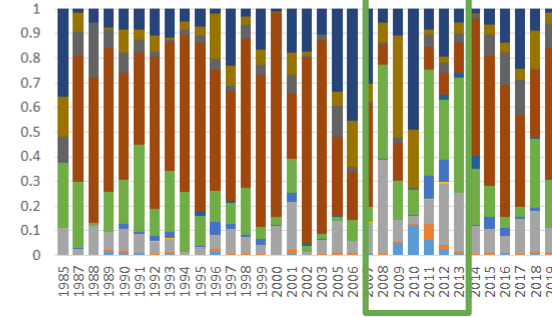
Northern Bering Sea



Northwest outer domain



Southeast middle domain

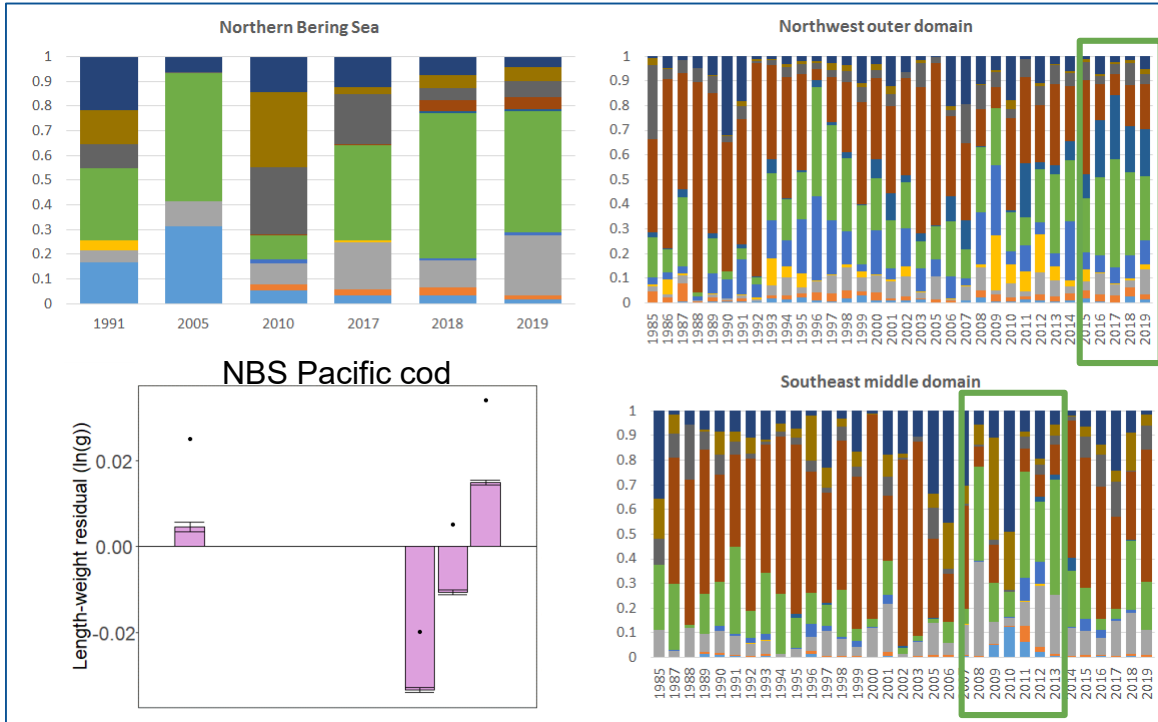


- Southeast middle: pollock are dominant, except in 2008-2012 when replaced by *Chionoecetes*.
- Northwest outer: pollock are dominant, but in 2016-2019 *Chionoecetes* and octopus increased.
- NBS: For most years, *Chionoecetes* (primarily ID'd as snow crab) are dominant.



Adult Pacific Cod Food Habits

Aydin



- Southeast middle: pollock are dominant, except in 2008-2012 when replaced by *Chionoecetes*.
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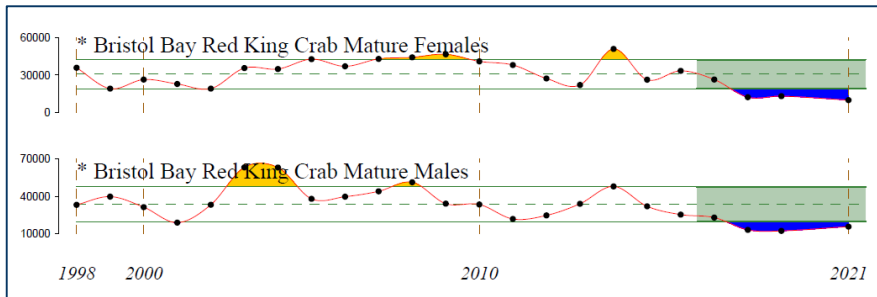
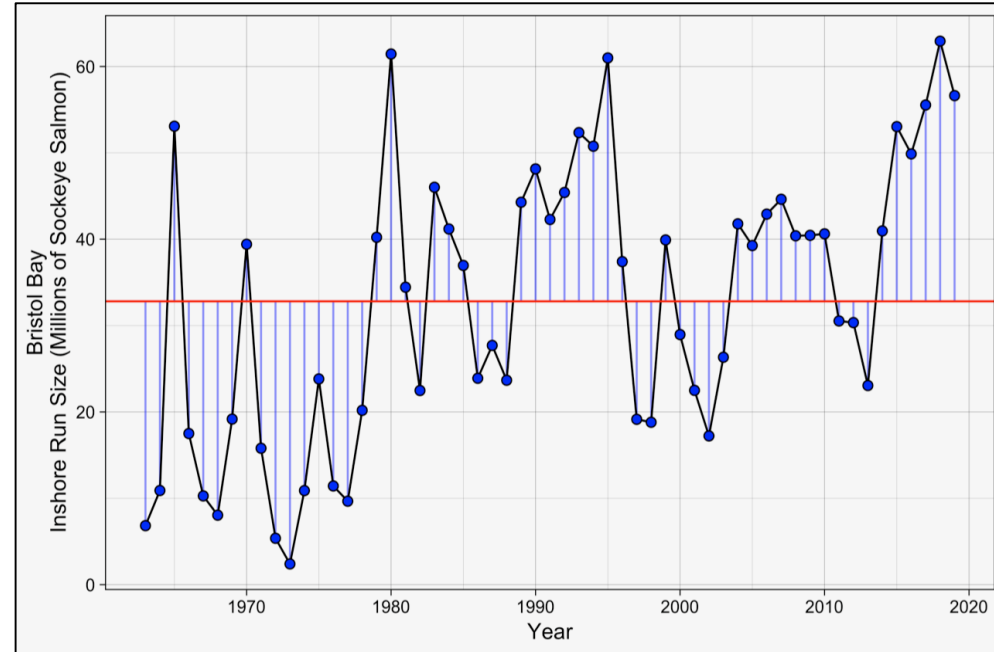


2020 Bristol Bay Sockeye Salmon

Cunningham et al.



- 2020 was the 5th largest run on record.
- Juvenile sockeye feed on zooplankton and age-0 pollock in warm years; adults feed on zooplankton and krill.
- Are there system-wide impacts?



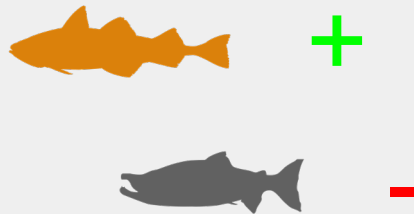
2020 Summary

& Larval Implications

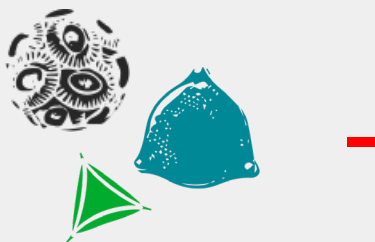
COMPETITORS



PREDATORS



PREY



ENVIRONMENTAL
PROCESSES

2020 Summary & Adult Implications

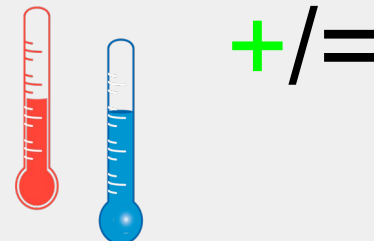
COMPETITORS
(2019)



PREDATORS

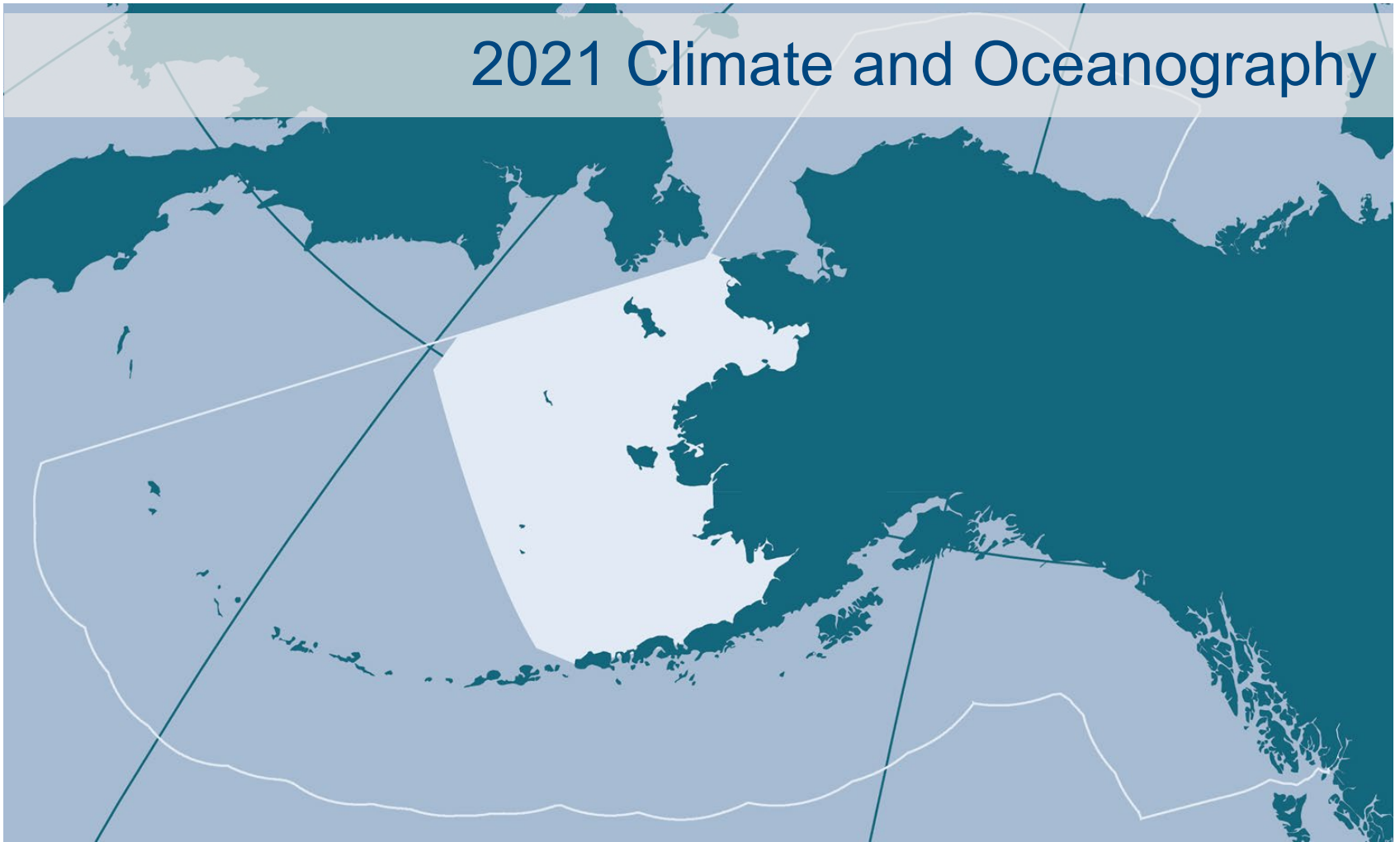


PREY



ENVIRONMENTAL
PROCESSES

2021 Climate and Oceanography



Climate Indices

Bond

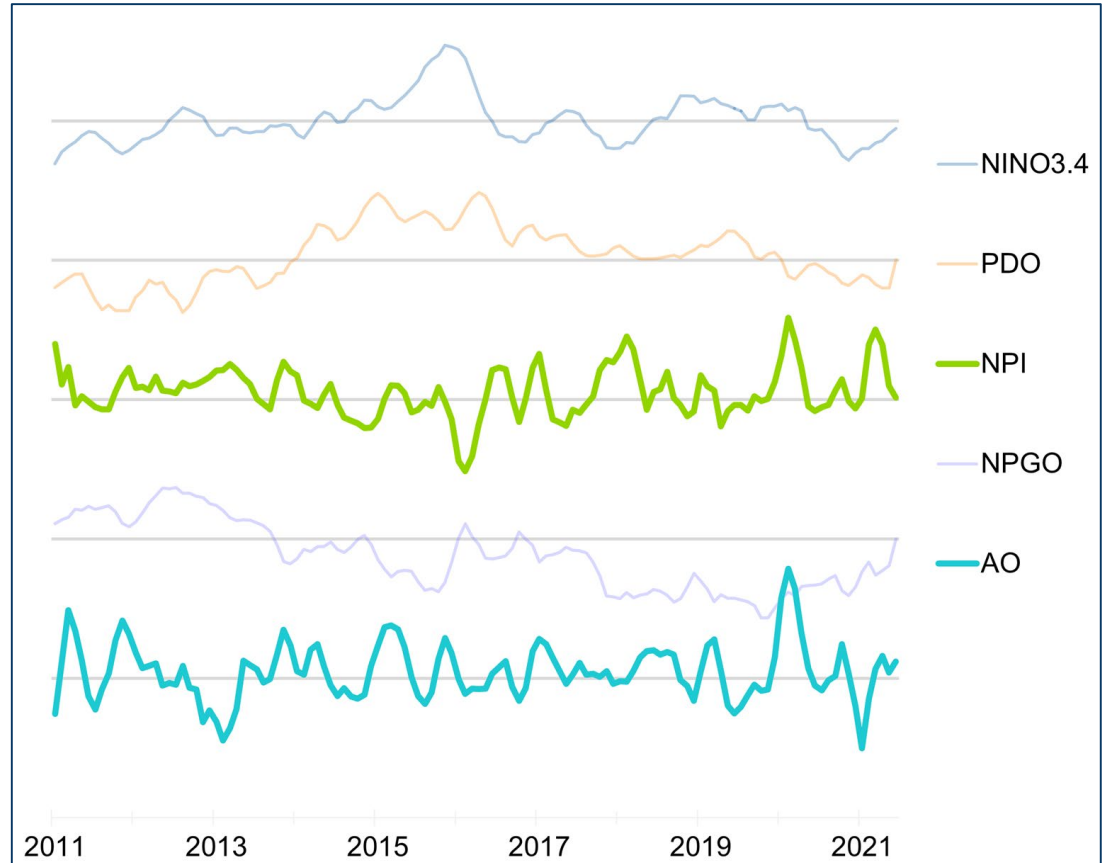
NINO3.4 was negative (La Niña) last fall/winter, but returned to near-neutral in spring/summer 2021. Weak-moderate La Niña conditions expected by late fall 2021.

PDO remained moderately negative driven by SSTs in subtropics and mid-latitudes.

NPI reflects ALPS; strongly positive winter 2020/2021 (high SLP); returned to near-neutral in summer 2021.

NPGO negative since 2014, but reduced intensity from 2020.

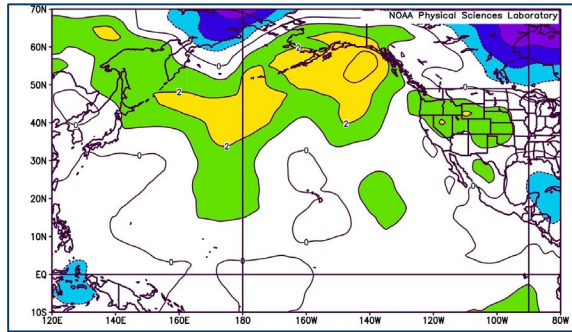
AO measures the polar vortex; strongly positive in early 2020, negative in winter 2020/2021, then positive in spring/summer 2021.



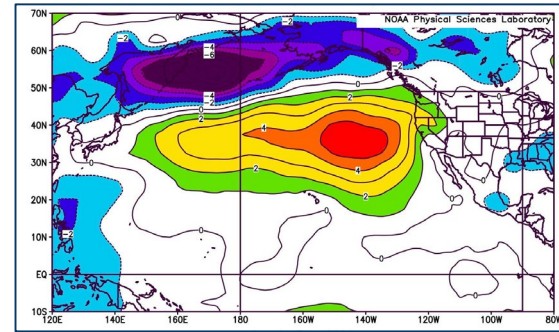
Sea Level Pressure Anomalies

Bond

Positive SLP south of AI and in GOA; EBS had winds from the SW and suppressed storminess over the SEBS shelf and GOA.



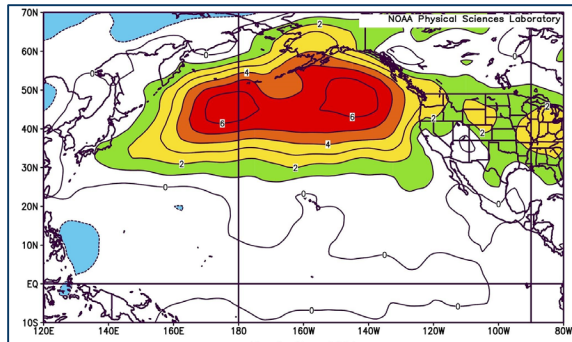
Autumn 2020



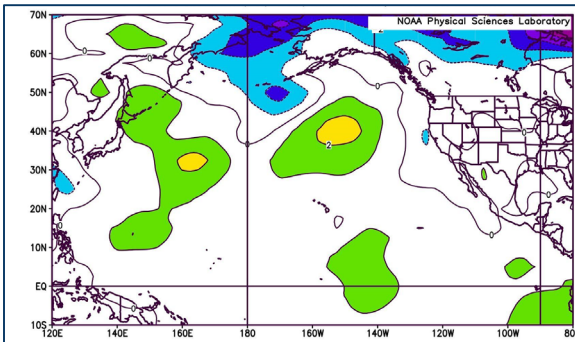
Winter 2020/2021

Strongly negative SLP in the SW Bering Sea; positive SLP in central NPac and westerlies from the AI to GOA.

Positive SLP in NPac expanded and brought westerly winds for EBS and GOA.

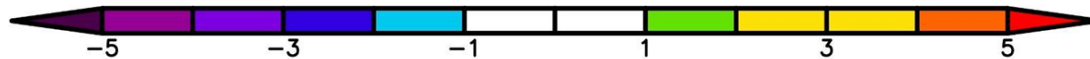


Spring 2021



Summer 2021

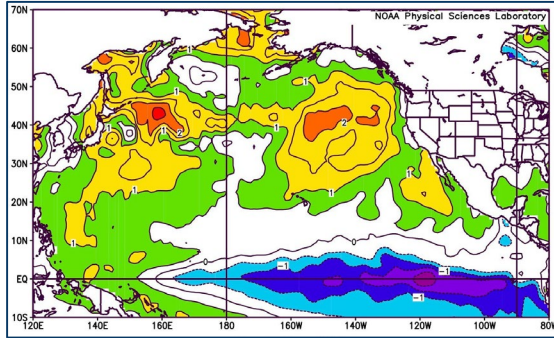
SLP more moderate; anticyclonic winds for NPGA & EGOA; negative SLP over NBS & Chukchi implies enhanced storminess.



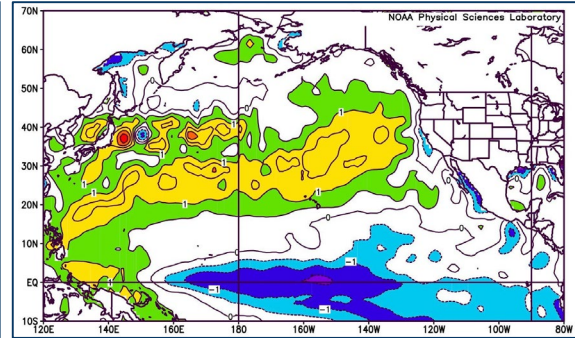
Sea Surface Temperature Anomalies

Bond

Warm SSTs across NPac, especially near the Gulf of Anadyr and eastern basin. Development of moderate La Niña.



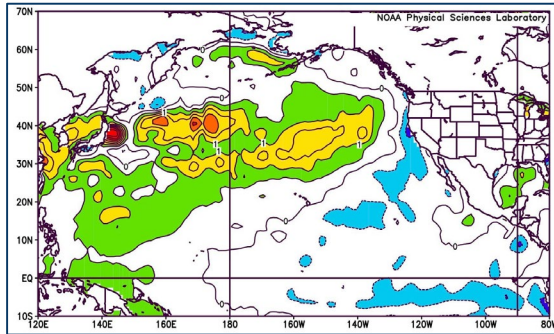
Autumn 2020



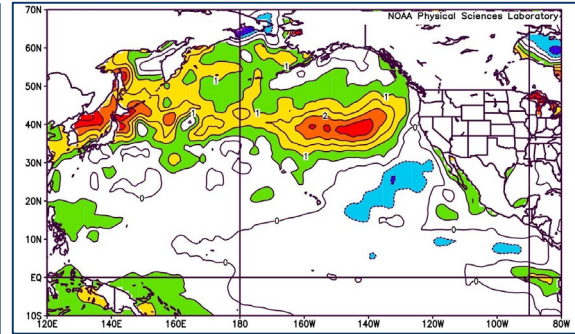
Winter 2020/2021

Moderate SST anomalies between 15° - 45°N; minimal anomalies on EBS shelf and in GOA. La Niña remained present.

Pattern cont'd with slight warming in SEBS. Minor cold anomaly in Shelikof Strait. Near-neutral ENSO conditions.

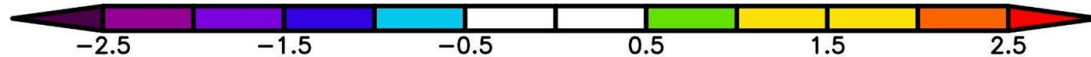


Spring 2021



Summer 2021

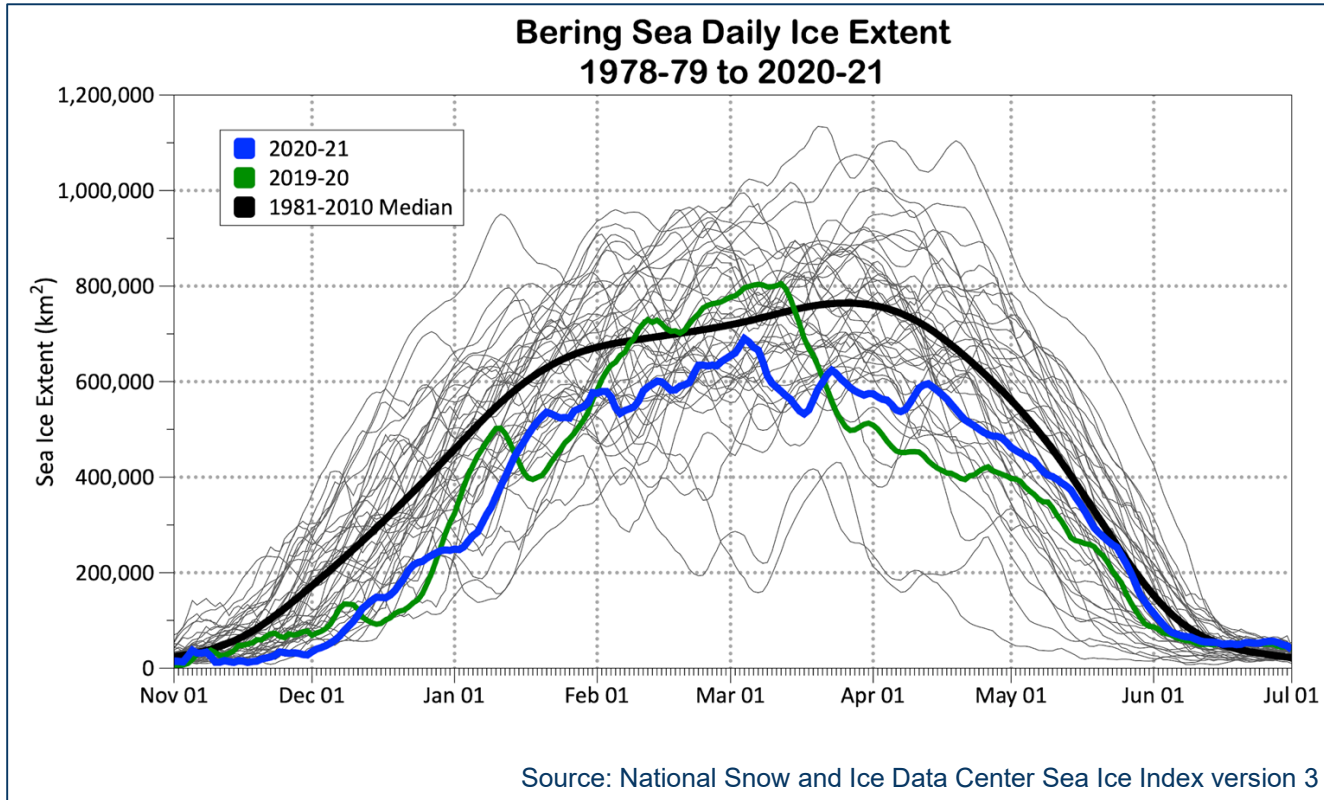
SST anomalies in mid-latitudes increased and in WAI; minor warm SST anomalies on SEBS shelf; NGOA was near-normal.



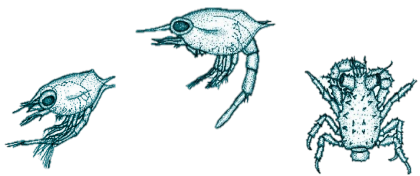
From NOAA's Optimum Interpolation SST analysis

Bering Sea Ice Extent

Thoman



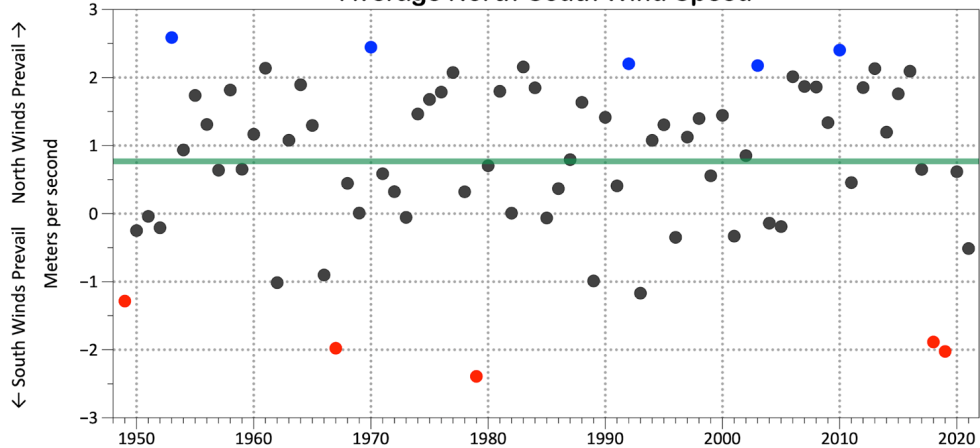
- Residual warmth delayed freeze-up into winter.
- Cooling in late winter resulted in a rapid build-up of sea ice.
- Ice advance stalled at end of January.
- Ice was steady from February through early April.



2021 Winds

Thoman

November through March, 1948-49 through 2020-21
Eastern Bering Sea
Average North-South Wind Speed



- Winter 2020/2021 had wind speed directions that prevailed from the south.

Bering Sea Ice Thickness

Thoman

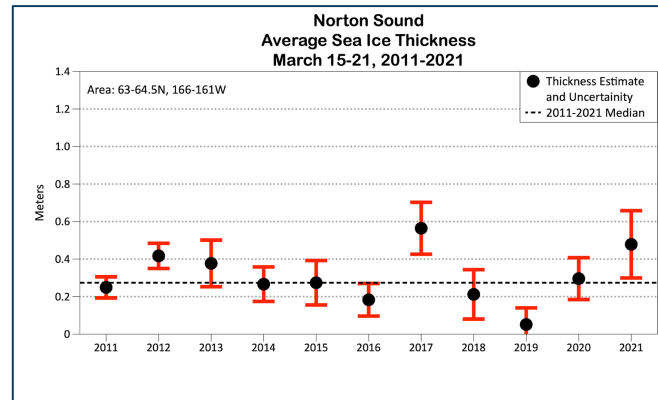
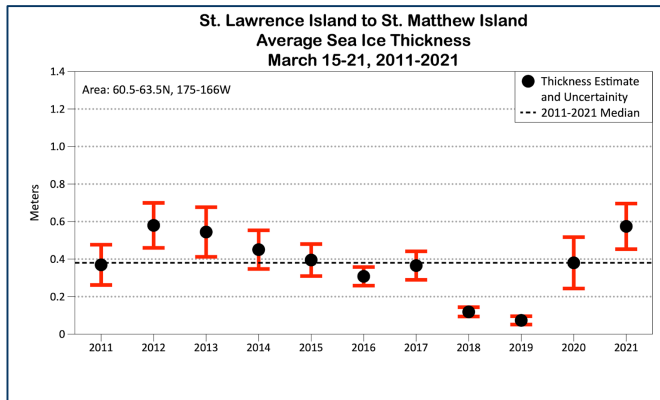
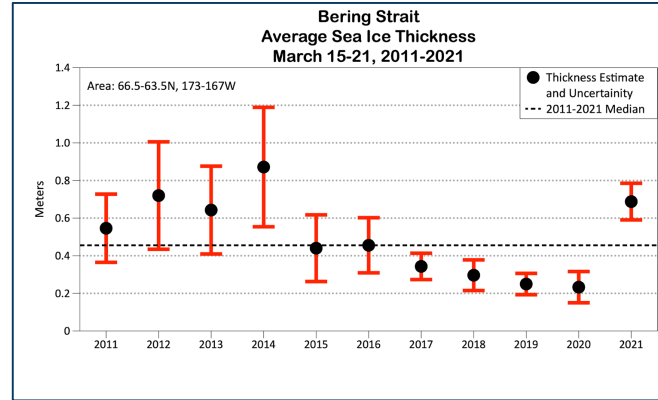
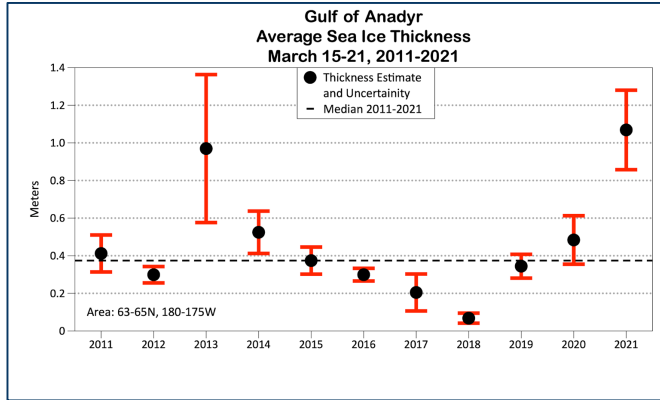


- 3rd week of March.
- Ice thickness is related to duration or residency of ice over the shelf.
- Abundance of ice-associated algae correlated to ice duration?

Bering Sea Ice Thickness

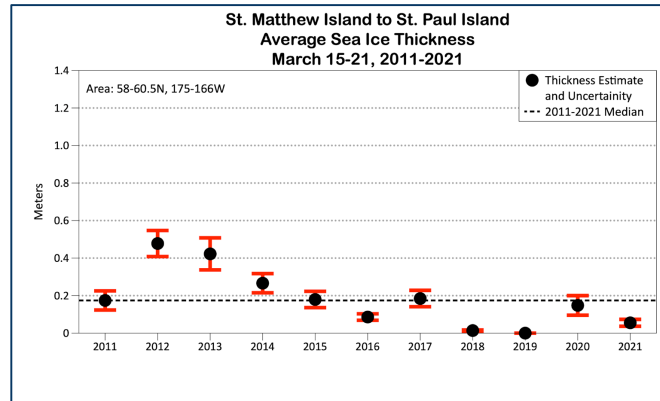
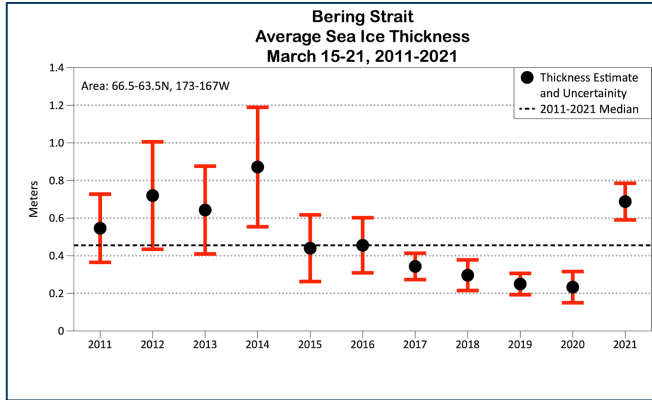
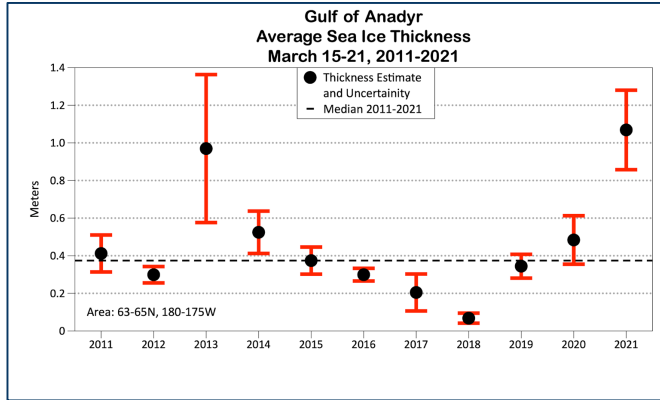
Thoman

- Northern and western areas: ice thickness increased in 2021.



Bering Sea Ice Thickness

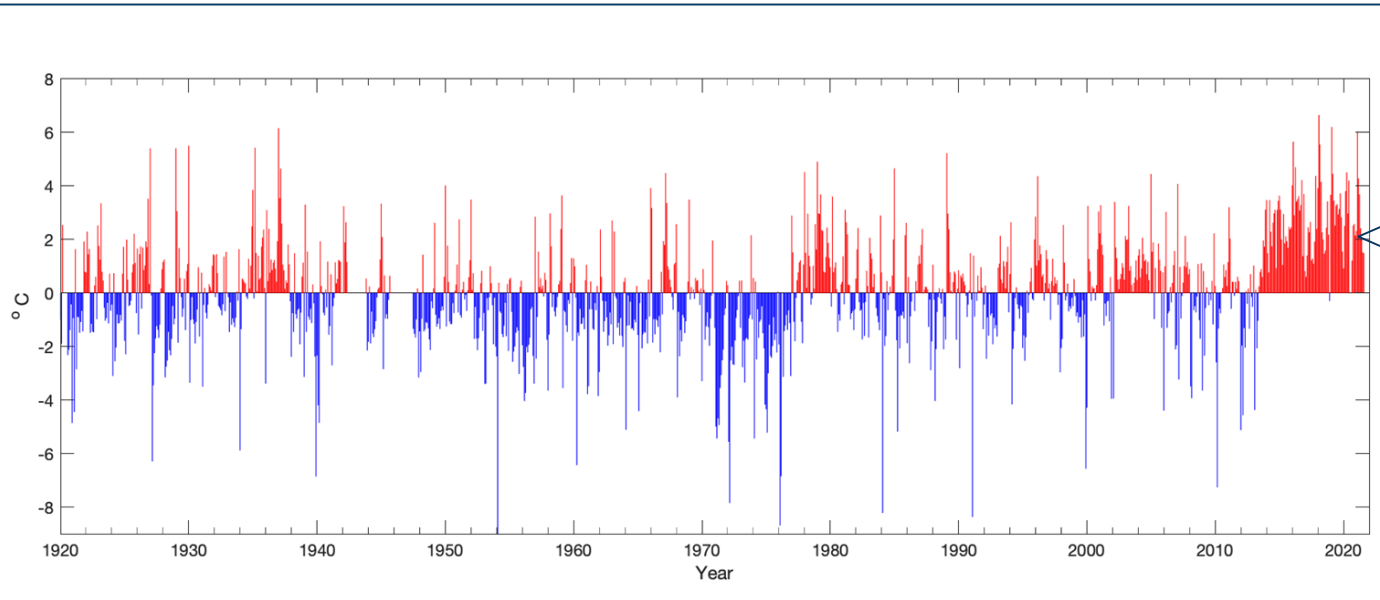
Thoman



- Northern and western areas: ice thickness increased in 2021.
- South of St. Matthew: ice thickness remained very low in 2021.
- Unusual weather pattern in Jan-Mar allowed ice in NBS to thicken, but prevented ice from moving south.

St. Paul Air Temperature Anomalies

Wang



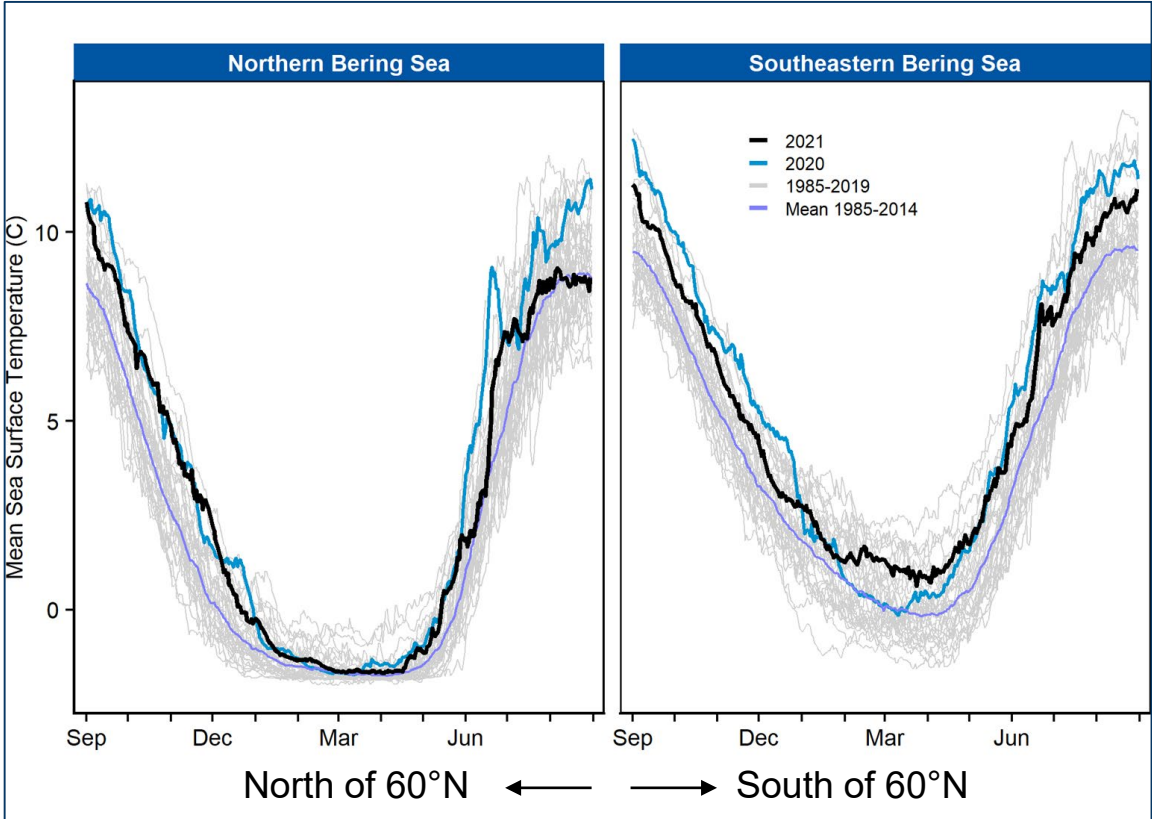
Increased duration and magnitude of current warm period.

Is the Bering Sea more vulnerable to continued change with thinner and less sea ice?

EBS Sea Surface Temperature

Watson

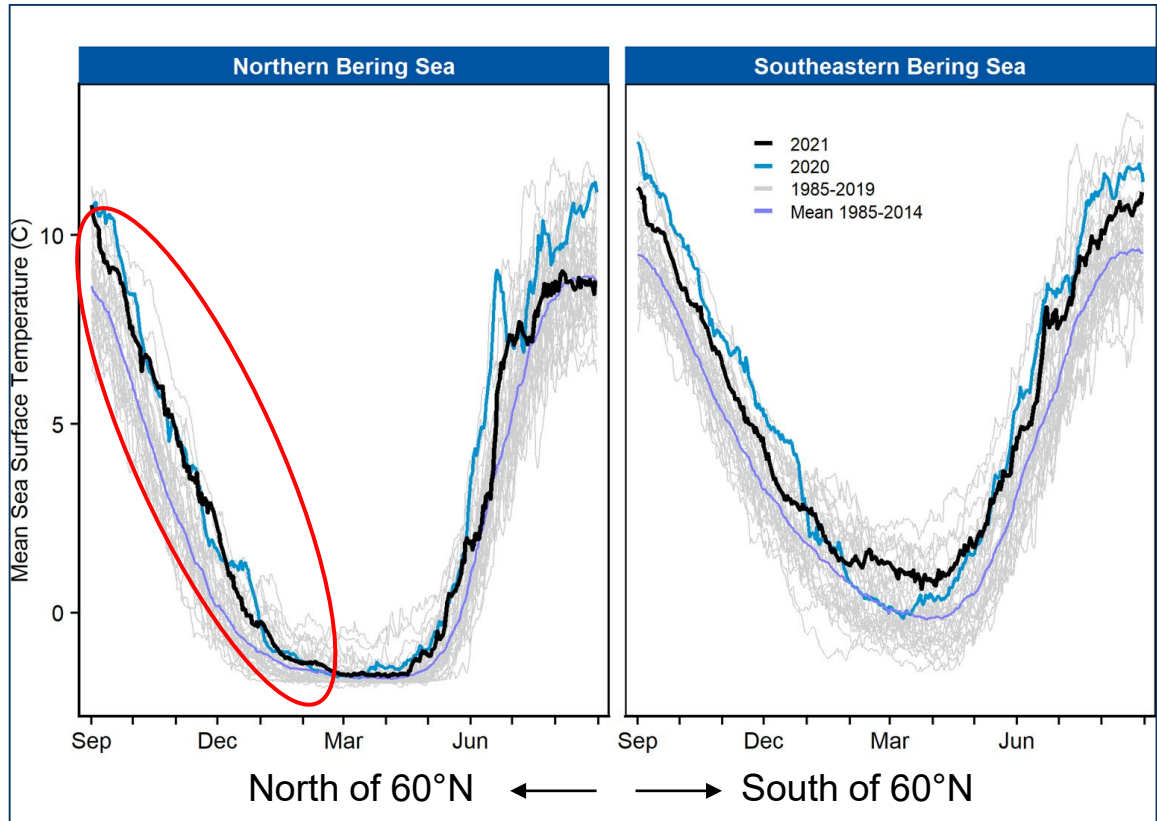
- Both regions continued to experience SSTs warmer than baseline (1985-2014).



EBS Sea Surface Temperature

Watson

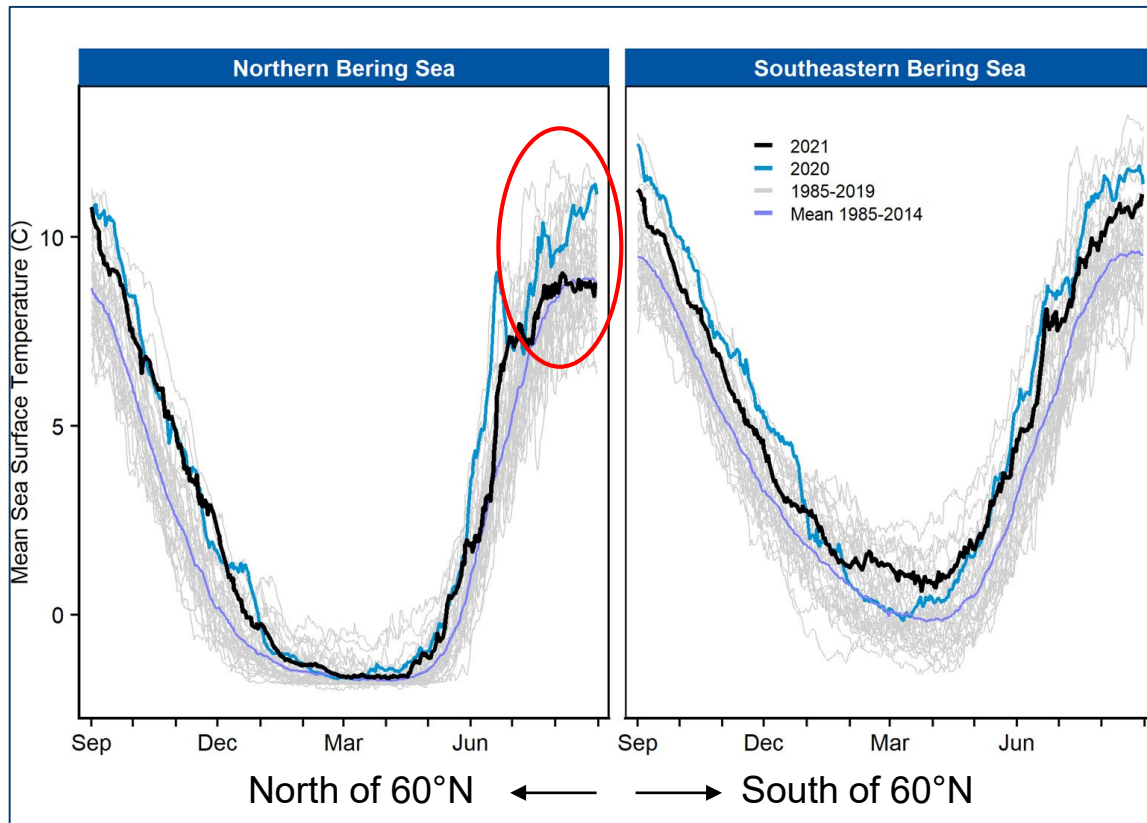
- Both regions continued to experience SSTs warmer than baseline (1985-2014).
- NBS: fall and winter similar to previous year; summer 2021 has been cooler.



EBS Sea Surface Temperature

Watson

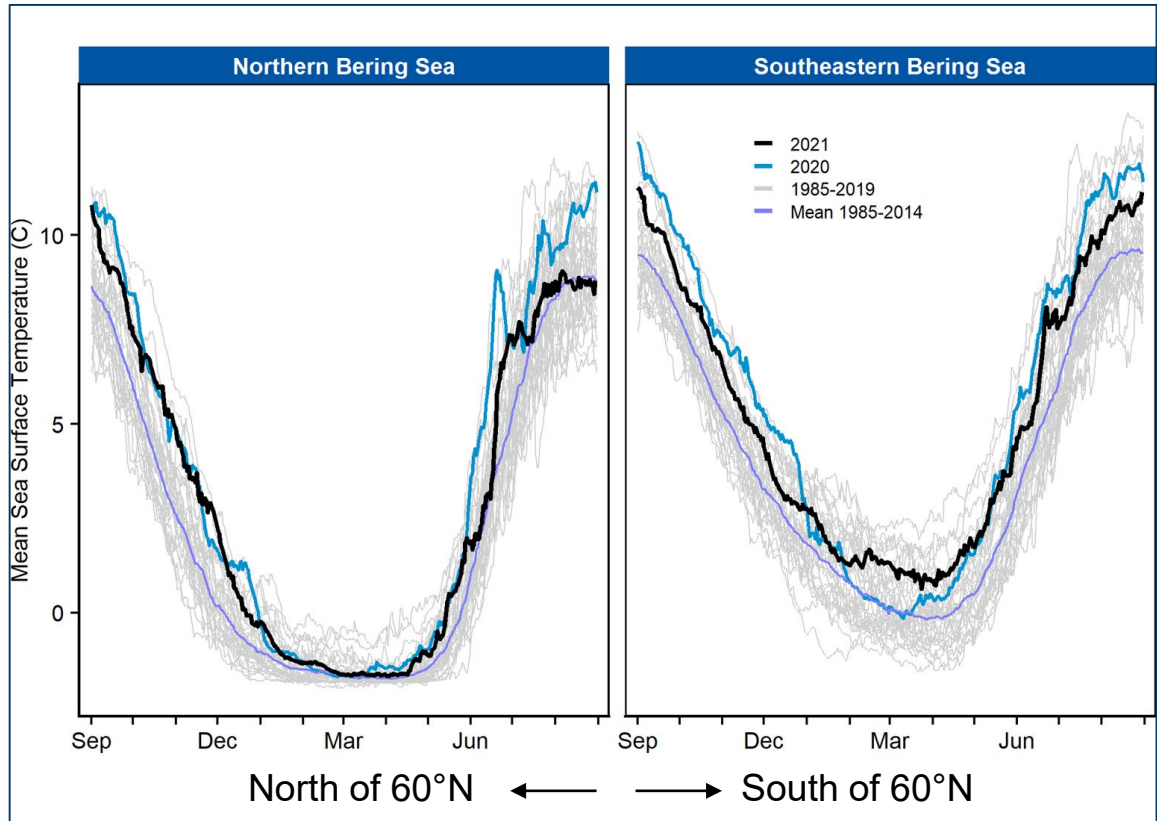
- Both regions continued to experience SSTs warmer than baseline (1985-2014).
- NBS: fall and winter similar to previous year; summer 2021 has been cooler.



EBS Sea Surface Temperature

Watson

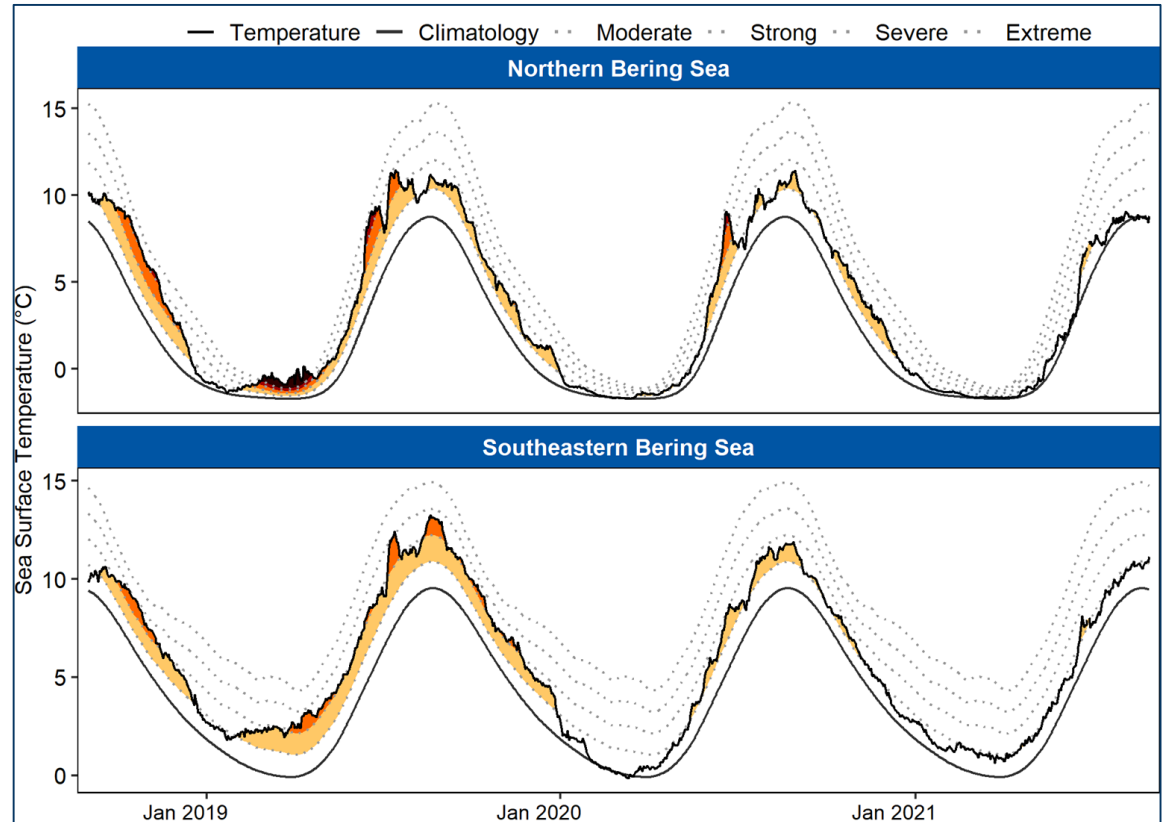
- Both regions continued to experience SSTs warmer than baseline (1985-2014).
- NBS: fall and winter similar to previous year; summer 2021 has been cooler.
- SEBS: generally cooler than previous year.



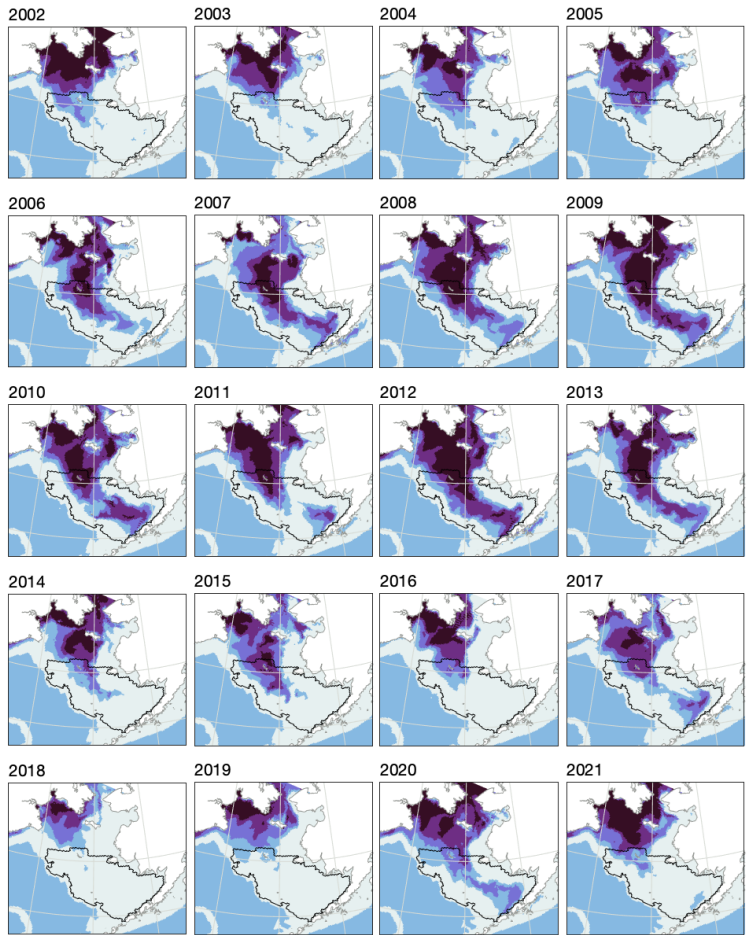
EBS Marine Heatwave Index

Watson

- MHWs have been minor compared to recent years; not triggered as often or as severely during 2021.
- However, temperatures hovered just below the threshold, yielding cumulatively warm SST conditions.

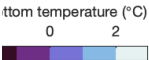


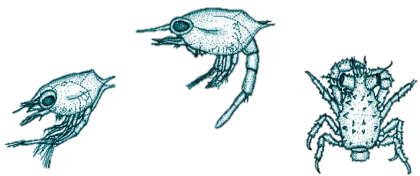
EBS Bottom Temperatures and Cold Pool Extent Kearney



- 2021 was a warm year, but not excessively warm.
- 2021 cold pool extent is similar to previous warm years of 2002-2005.

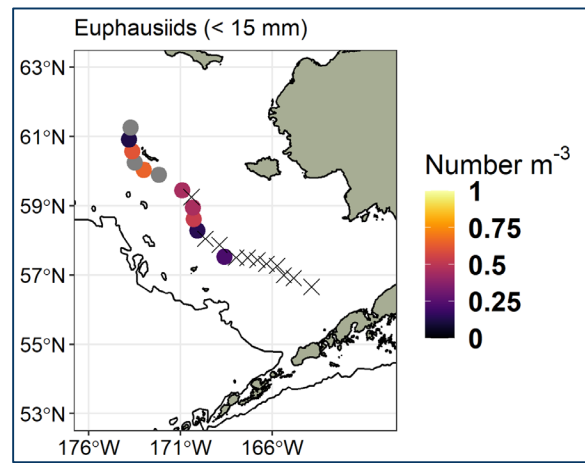
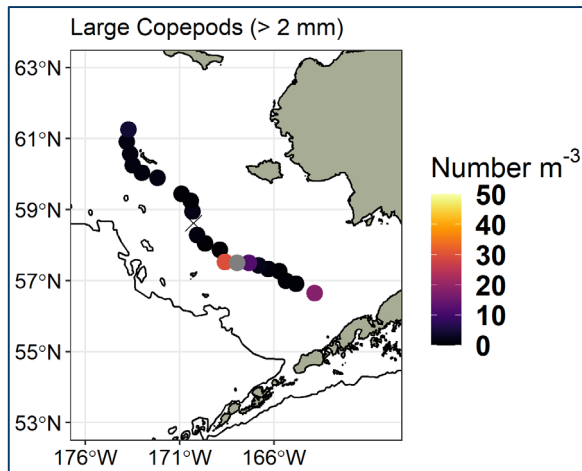
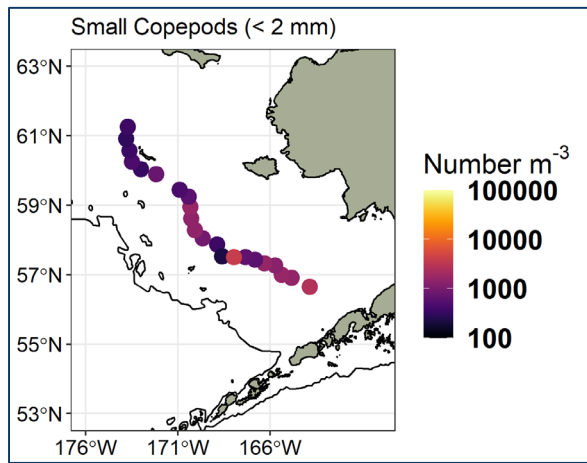
Bering 10K ROMS hindcast





2021 Spring Zooplankton

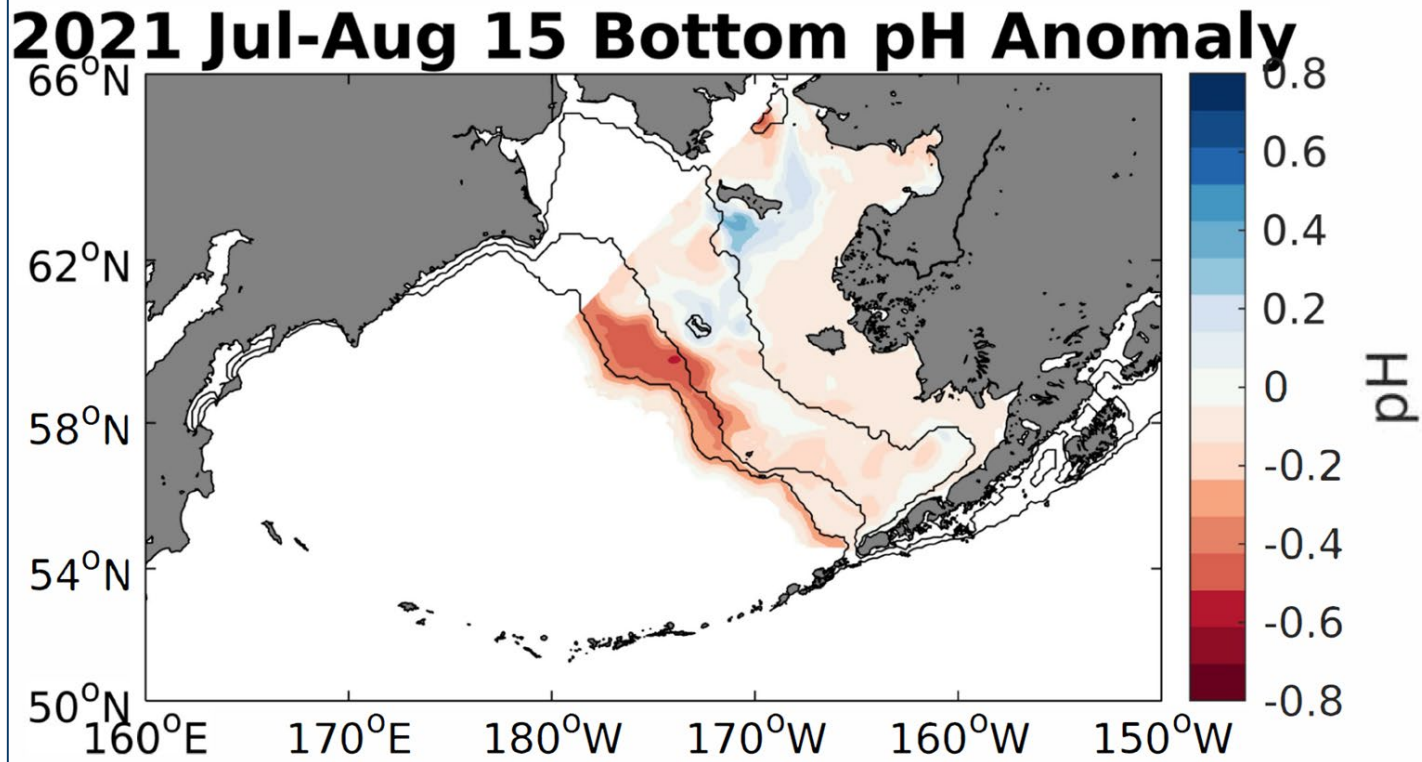
Kimmel



- Small copepod abundances were consistent along the shelf and comparable to recent years. Small copepods show little interannual variability in the Bering Sea.
- Large copepod abundances were low, and were low compared to historical values.
- Euphausiids were very low in abundance, particularly in the southern Bering Sea.

Ocean Acidification

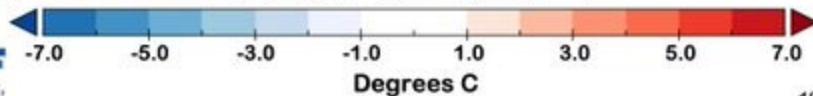
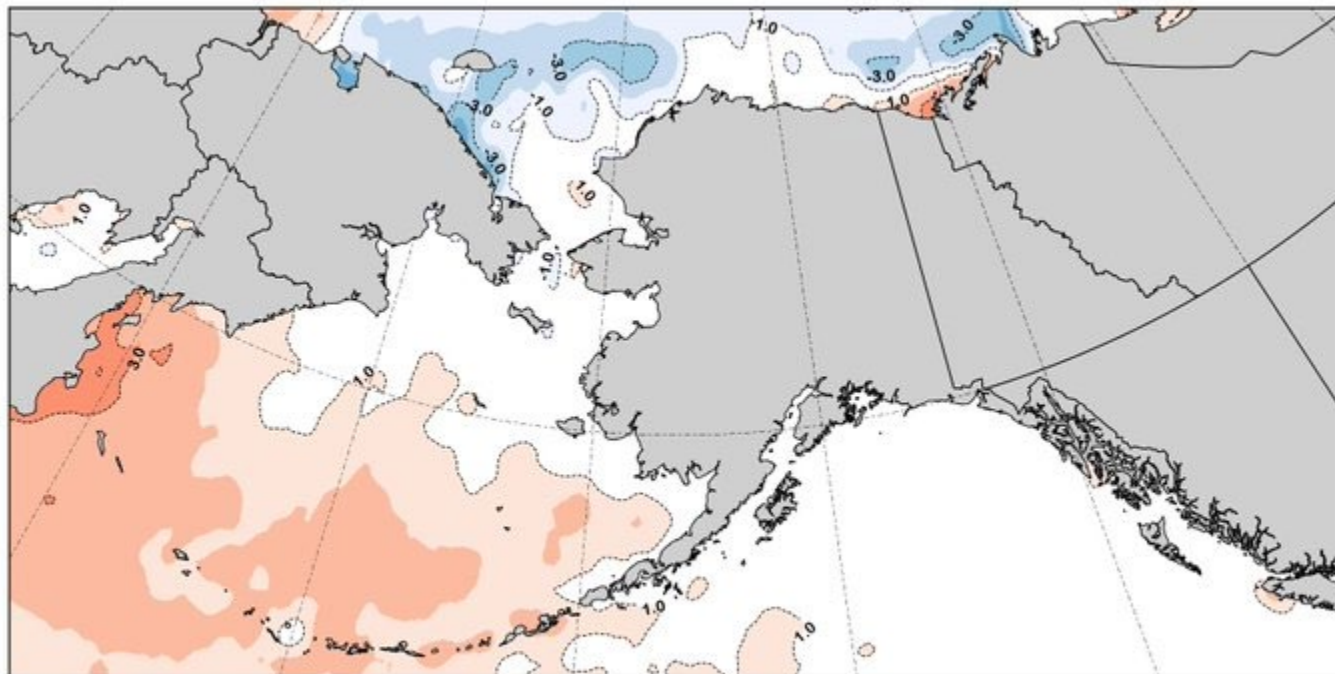
Pilcher, Cross



- Anomaly plot shows 2021 compared to the 2003-2020 mean.
- Low pH conditions on the outer shelf persist, although less so over the southern outer shelf than 2020.

Sea Surface Temperature Departure from Normal

September 3-9, 2021



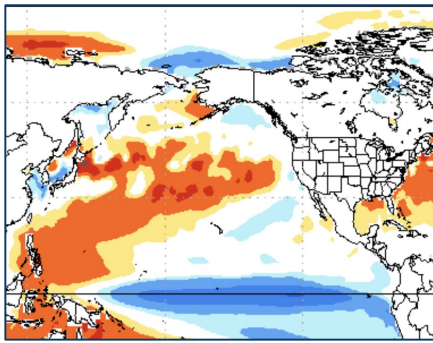
1991-2020 baseline
OISSTv2.1 courtesy of NOAA/PSL/ESRL

2022 Sea Surface Temperature Forecasts

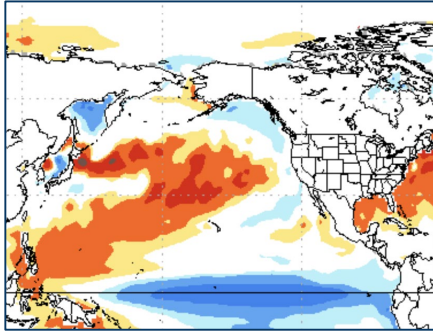
SST Projections from the National Multi-Model Ensemble

Bond

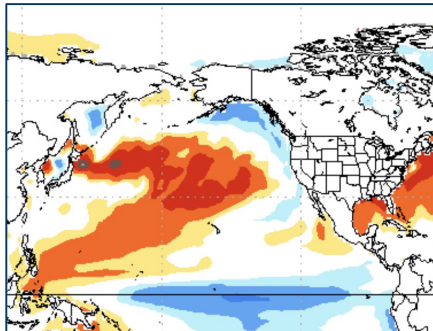
Oct - Dec
2021



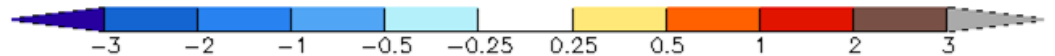
Dec 21 -
Feb 22



Feb -
April
2022



- **TOP:** warm waters in central+western NPac continue; SEBS predicted to be warm; north of Bering Strait predicted to be cold due to fewer storms and incursions of mild, maritime air masses.
- **MIDDLE:** high SLP over western Bering Sea resulting in decreased warmth over SEBS; consistent with La Niña winters.
- **BOTTOM:** near-normal temperatures to the Bering Sea and AI with neutral La Niña conditions.





Questions?

Feedback?