



NOAA
FISHERIES

Alaska
Fisheries
Science
Center

NMFS Climate Science Strategy

Southeastern Bering Sea

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**NOAA
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NOAA Fisheries Climate Science Strategy Highlights



Climate Science Strategy Objectives

Climate-Informed
Reference Points

Robust Management Strategies

Adaptive Management Processes

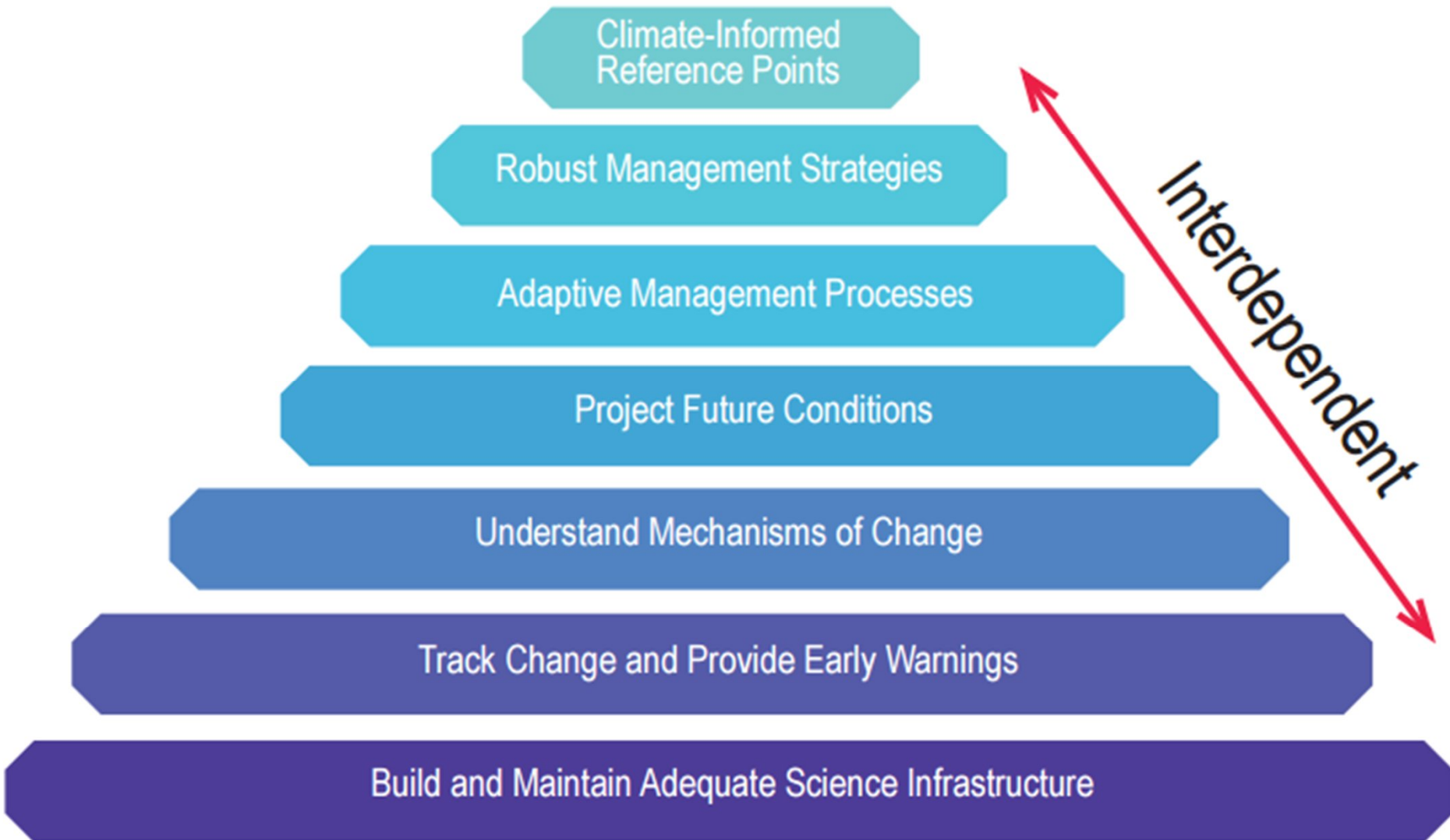
Project Future Conditions

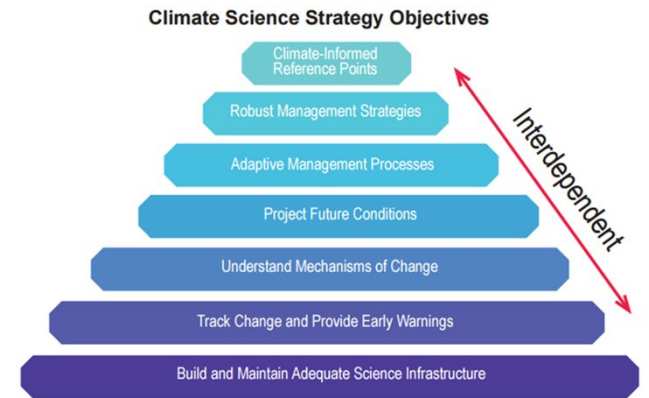
Understand Mechanisms of Change

Track Change and Provide Early Warnings

Build and Maintain Adequate Science Infrastructure

Interdependent





Climate informed management

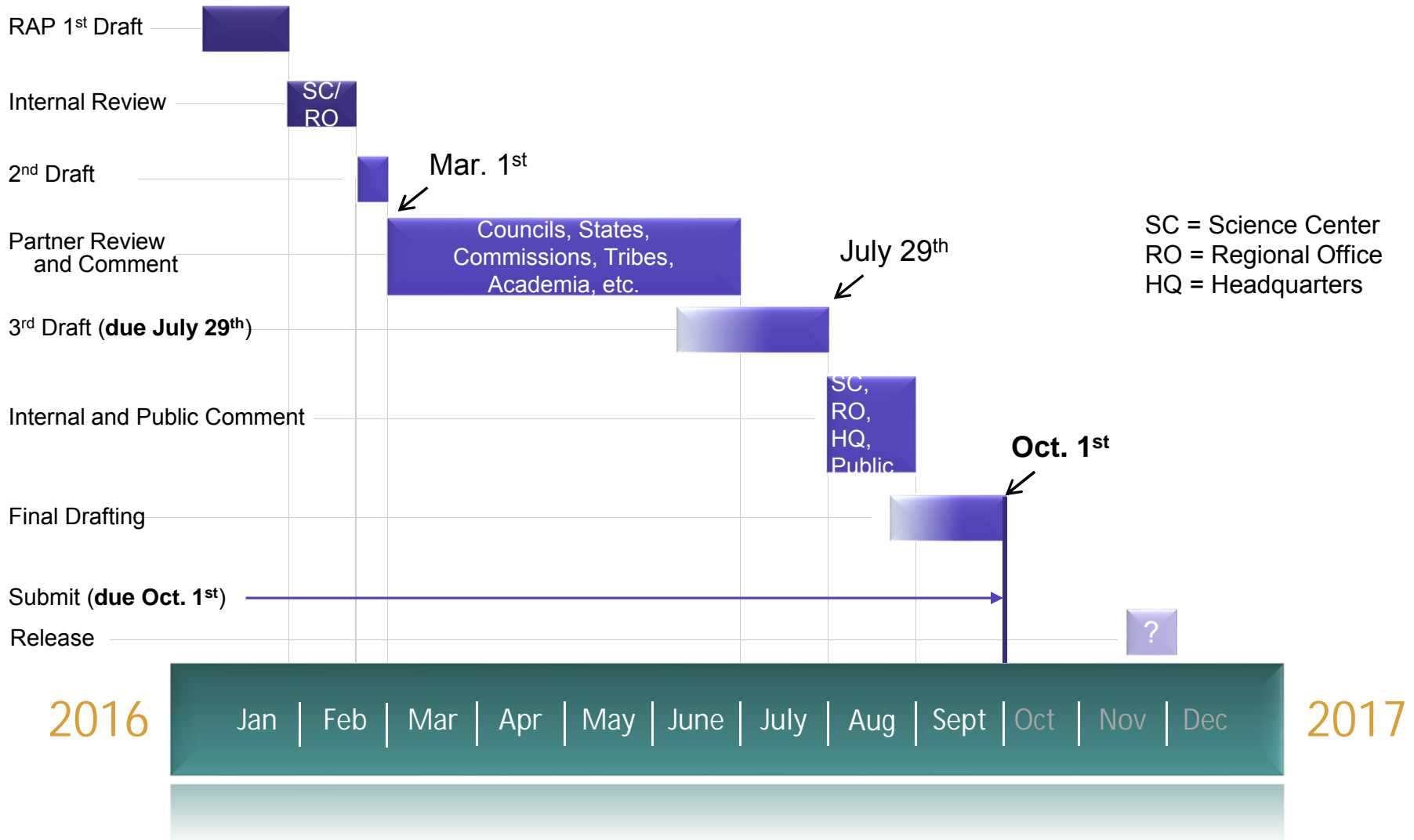
Models (projections and MSE)

Process studies

Ecosystem monitoring

Science infrastructure

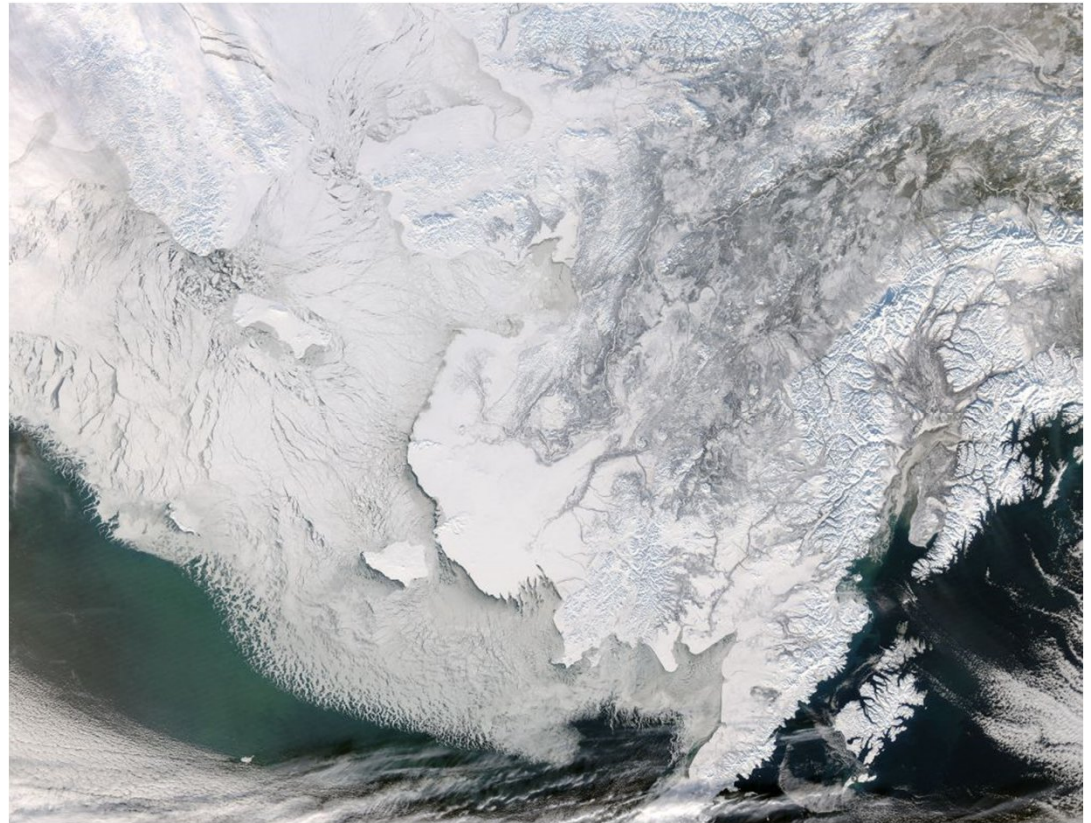
Timeline: RAP Development



Southeastern Bering Sea Regional Climate Science Strategy

Assessment

Action Plan



Climate-informed management (Obj. 1-3)

Objective 1: Identify appropriate, climate informed reference points for managing living marine resources (LMRs).

Objective 2: Identify robust strategies for managing LMRs under changing climate conditions.

Objective 3: Design adaptive decision processes that can incorporate and respond to changing climate conditions.

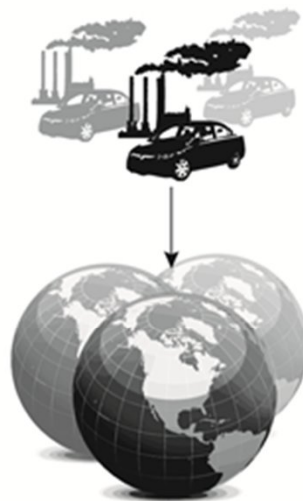
Alaska CLIMATE Project

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FATE: Fisheries & the Environment

SAAM: Stock Assessment Analytical Methods

S&T: Climate Regimes & Ecosystem Productivity



IPCC Scenarios (x3)

AR4 A1B
AR5 RCP 4.5
AR5 RCP 8.5

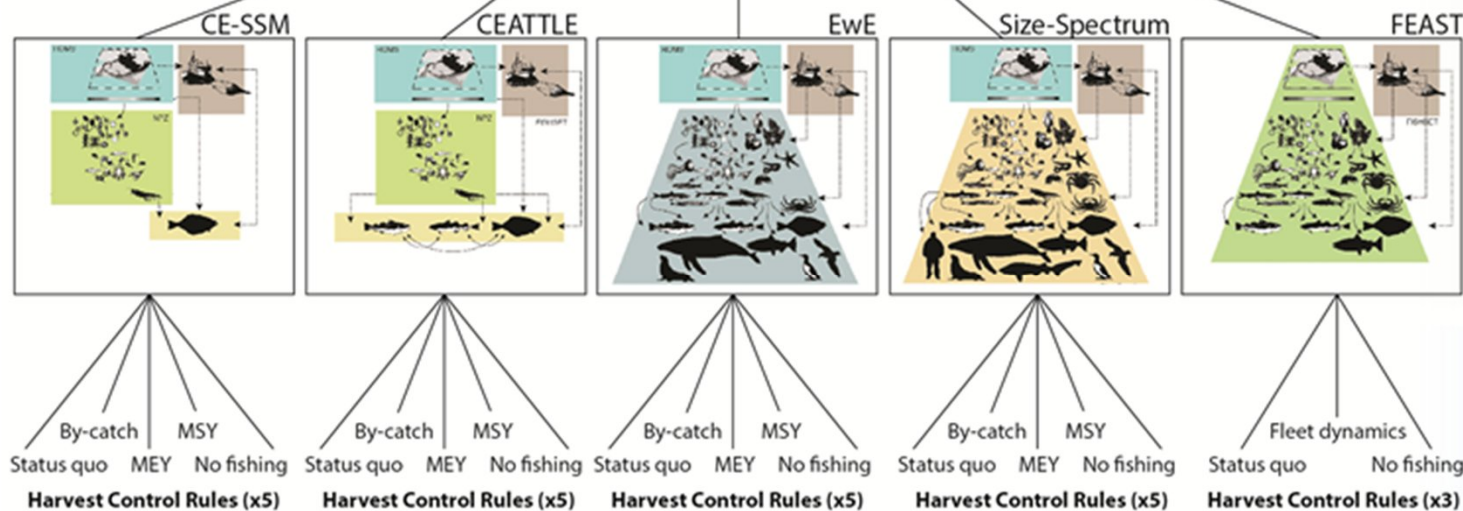
Global Climate Models (x 11)

ECHO-G (AR4 A1B)
MIROC3.2 med res. (AR4 A1B)
CGCM3-t47 (AR4 A1B)
CCSM4-NCAR- PO (AR5 RCP 4.5 & 8.5)
MIROCESM-C- PO (AR5 RCP 4.5 & 8.5)
GFDL-ESM2M*- PO (AR5 RCP 4.5 & 8.5)
GFDL-ESM2M*- PON (AR5 RCP 4.5 & 8.5)

Future Climate Scenarios



Bering Sea Models



Climate-enhanced Biological Models



Fishing Scenarios



NPFMC Fisheries Ecosystem Plan. Approved by the Council in December 2015, the FEP includes a climate module that would:

- 1) synthesize current climate change project outcomes;
- 2) prioritize species for MSE evaluation; and
- 3) run MSEs on specific species and scenarios identified by the Council.

Identify future states (Obj. 4)

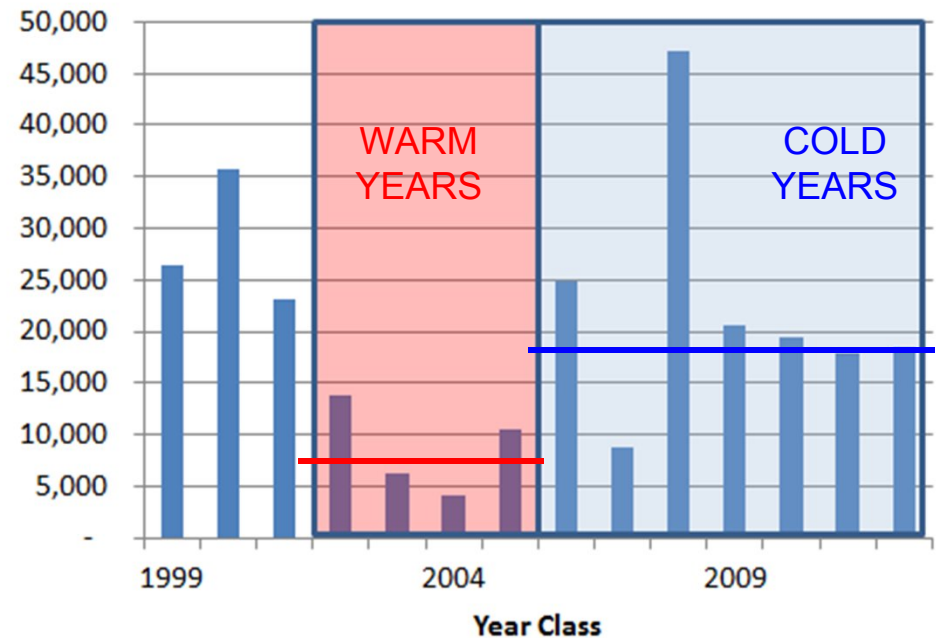
Objective 4: Identify future states of marine and coastal ecosystems, LMRs, and LMR dependent human communities in a changing climate.

Climate and Fisheries

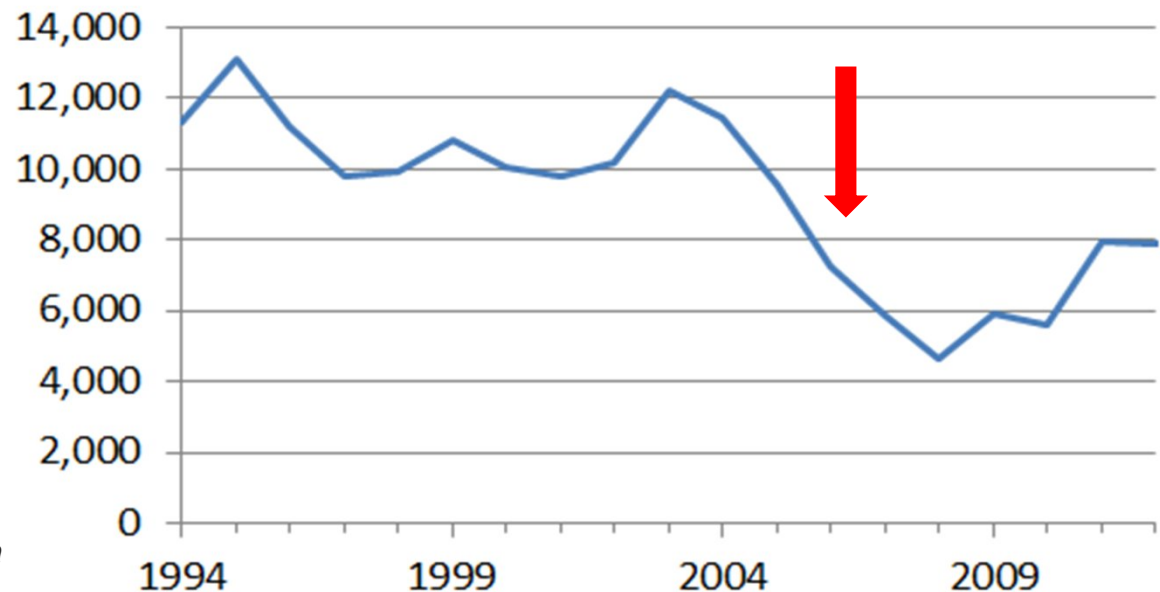
EXPLAIN THIS:

Walleye pollock abundance dramatically fell in the early 2000's, leading to a 40% drop in the quota for the largest single fishery in the US, and then rebounded.

Age-1 number (millions)



Age-3+
Biomass
(thousands t)



Ianelli, J.N., Barbeaux, S., Honkalehto, T., Kotwicki, S., Aydin, K. and Williamson, N., 2012. Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. Anchorage, AK: North Pacific Fishery Management Council; 2009. *Assessment of the walleye pollock stock in the eastern Bering Sea* for, pp.49-148.

EXPLANATION:

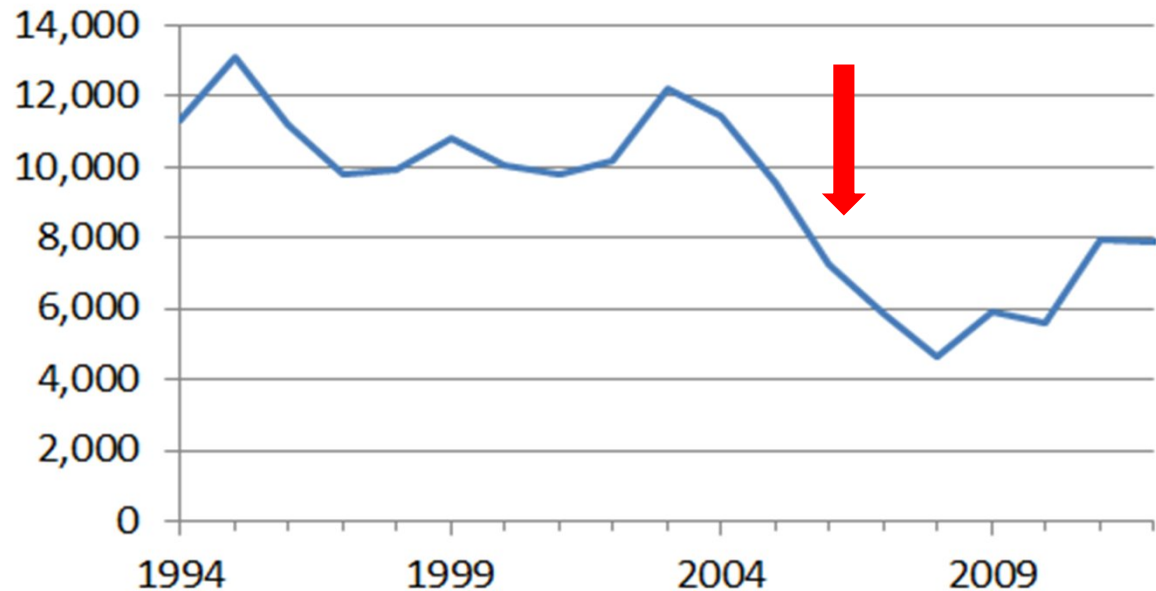
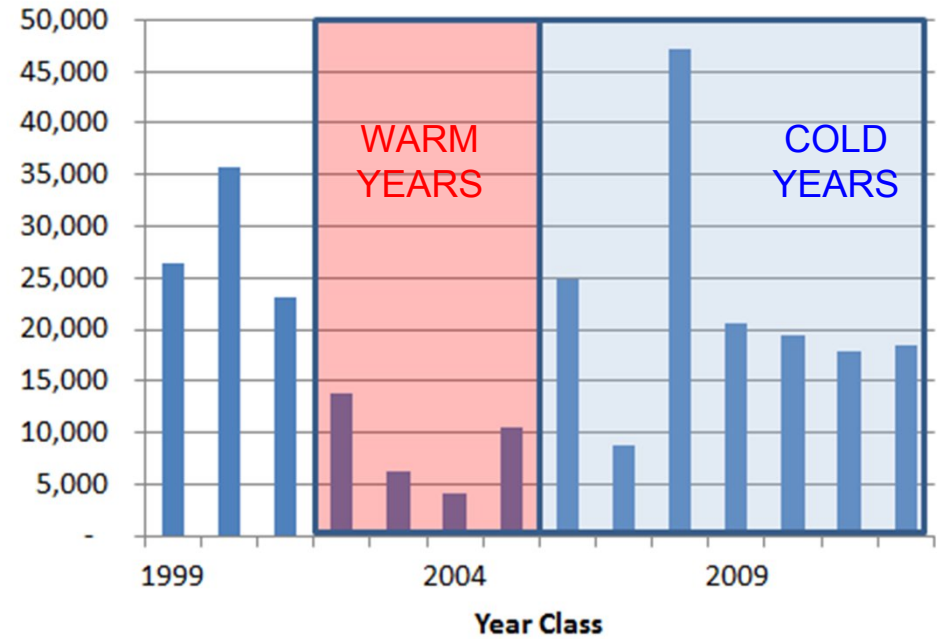
Due to bloom timing, large crustacean zooplankton benefit from icy winters, providing prey for age-0 pollock to enter their first winter fat (and happy?)



Age-3+ Biomass (thousands t)

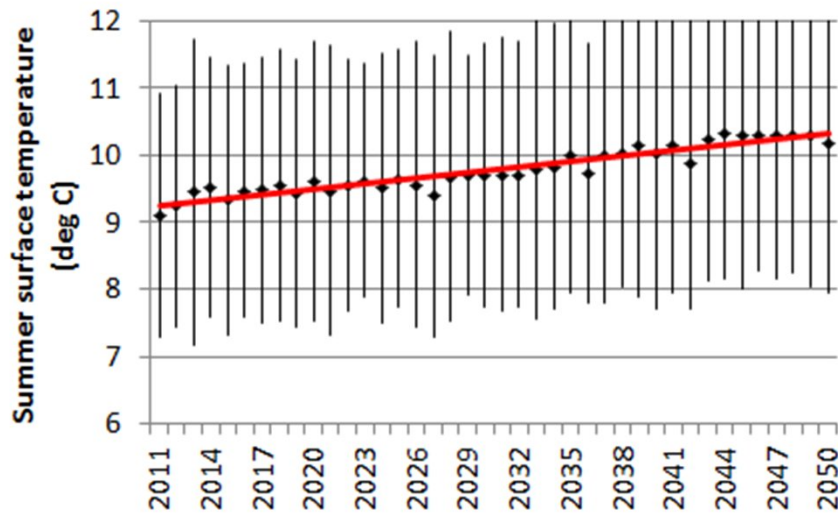
Heintz, R.A., Siddon, E.C., Farley, E.V. and Napp, J.M., 2013. Correlation between recruitment and fall condition of age-0 pollock (*Theragra chalcogramma*) from the eastern Bering Sea under varying climate conditions. *Deep Sea Research Part II: Topical Studies in Oceanography*, 94, pp.150-156.

Age-1 number (millions)

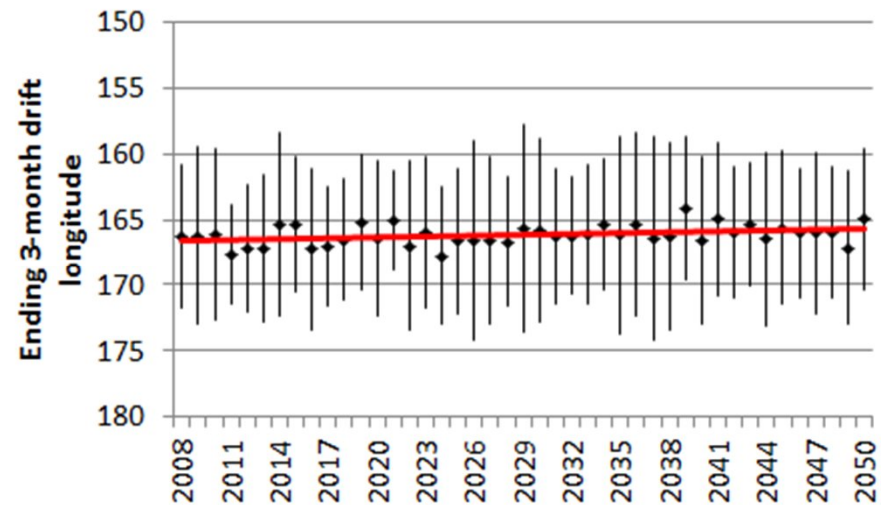


Ocean model projections

Temperature



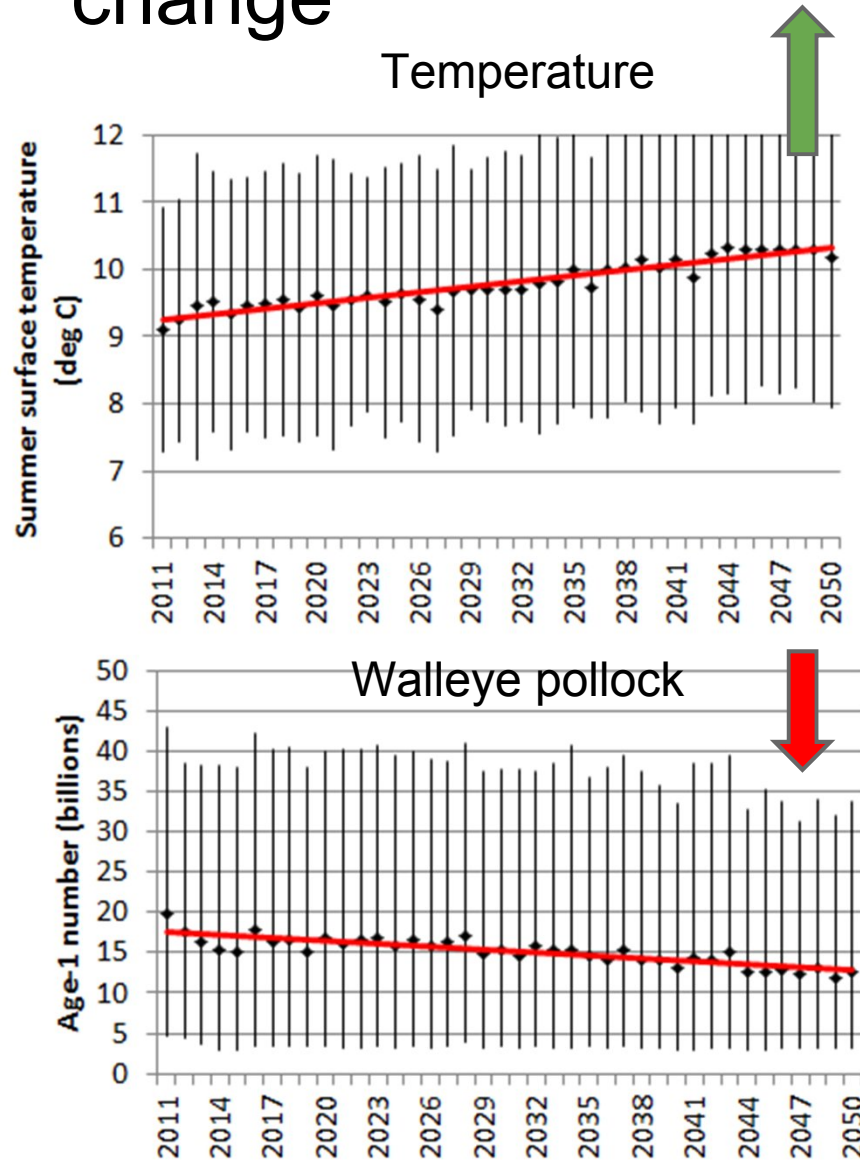
Inshore transport



Mueter, F.J., Bond, N.A., Ianelli, J.N. and Hollowed, A.B., 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. *ICES Journal of Marine Science: Journal du Conseil*, p.fsr022.

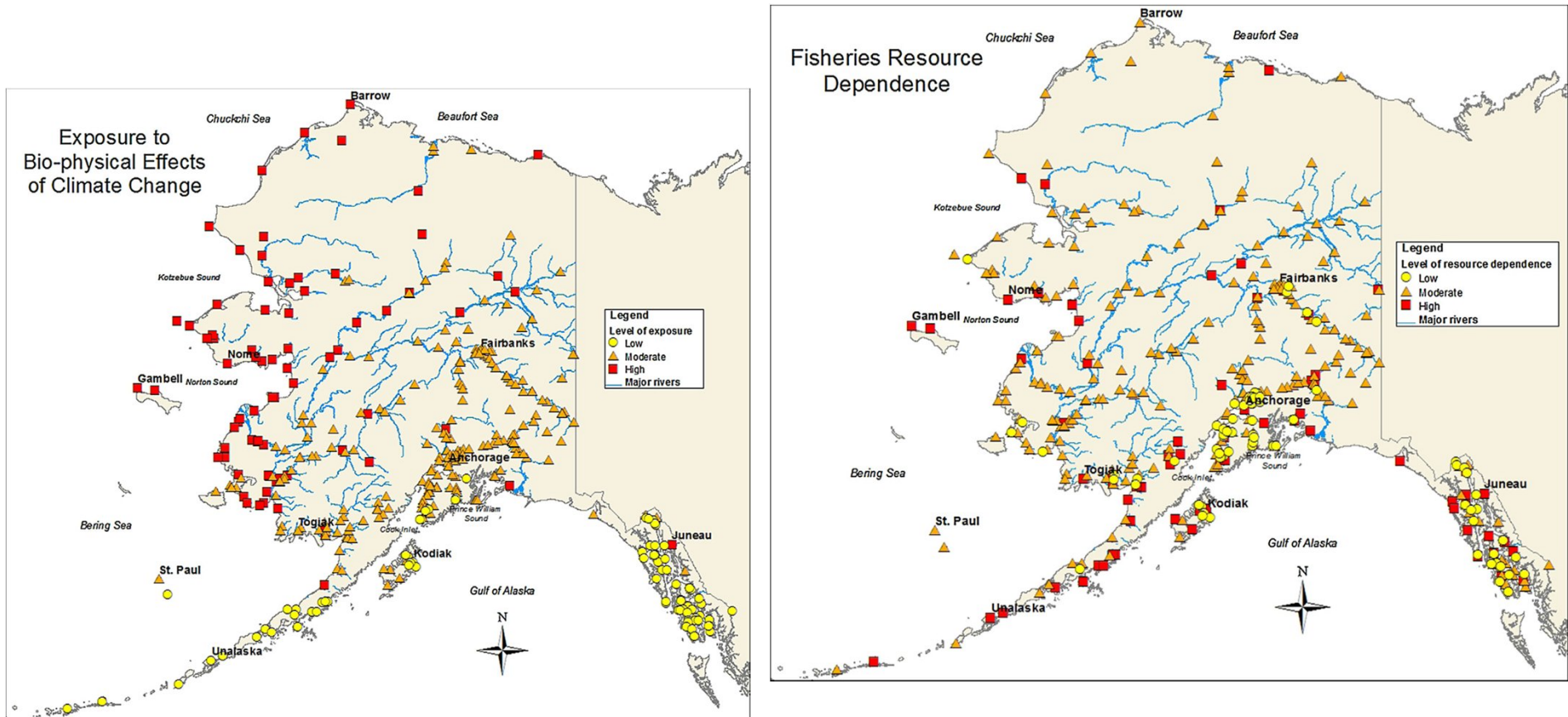
Wilderbuer, T., Stockhausen, W. and Bond, N., 2013. Updated analysis of flatfish recruitment response to climate variability and ocean conditions in the Eastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 94, pp.157-164.

Project pollock abundance under future climate change



Mueter, F.J., Bond, N.A., Ianelli, J.N. and Hollowed, A.B., 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. *ICES Journal of Marine Science: Journal du Conseil*, p.fsr022.

Identify human community dependence on LMRs and effects of climate change.



Himes-Cornell, A. and Kasperski, S., 2015. Assessing climate change vulnerability in Alaska's fishing communities. *Fisheries Research*, 162, pp.1-11.

Identify mechanisms (Obj. 5)

Objective 5: Identify the mechanisms of climate impacts on LMRs, ecosystems, and LMR dependent human communities.

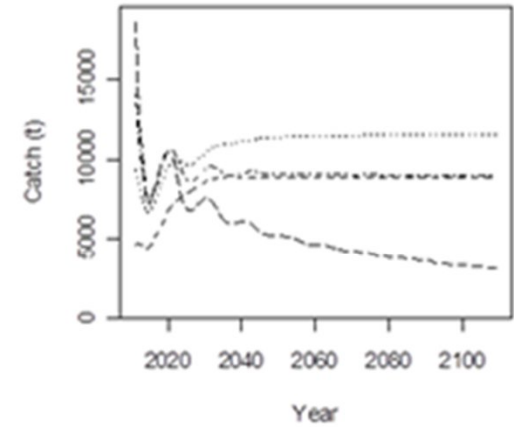
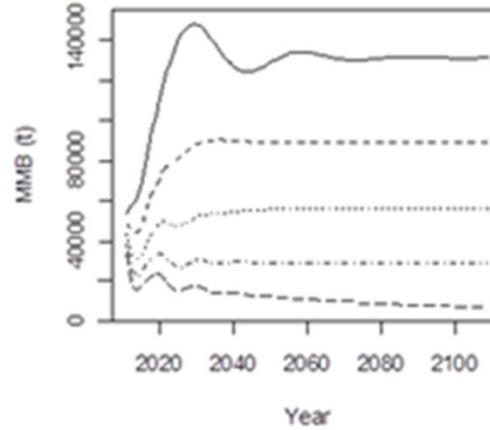
Ocean acidification research

Long, W.C., Swiney, K.M. and Foy, R.J., 2013. Effects of ocean acidification on the embryos and larvae of red king crab, *Paralithodes*

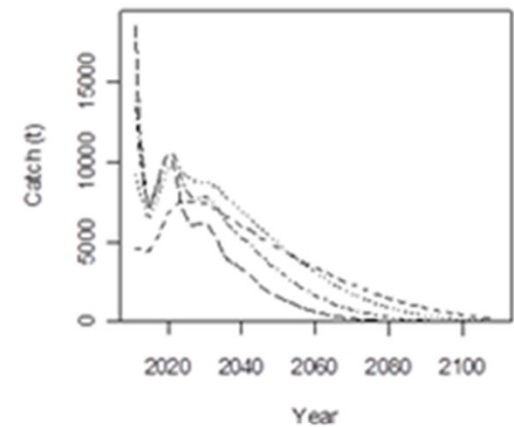
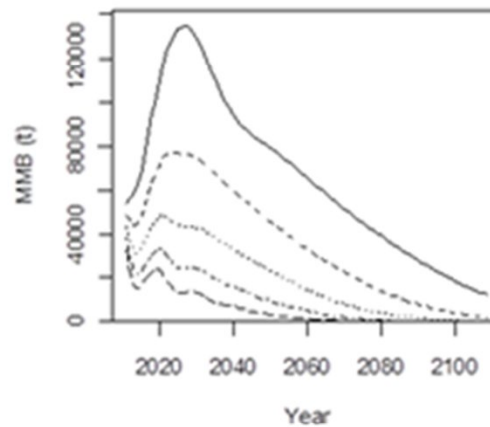
camtschaticus. *Marine pollution bulletin*, 69(1), pp.38-47.

Punt, Poljak, Dalton, Foy. 2014. Evaluating the impact of ocean acidification on fishery yields and profits: The example of red king crab in Bristol Bay. *Ecol. Modeling*. 285: 39-53.

stock dynamics without OA

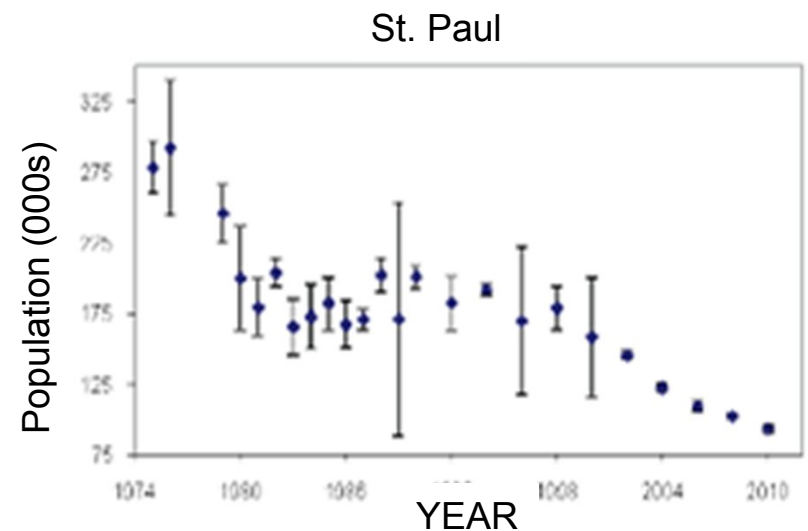


stock dynamics with OA



Fur seal research

- Pup production on the Pribilof Islands decreased by approximately 45% since 1998. Cause unknown, but may include direct and indirect effects of fishery competition as well as climate.
- Satellite telemetry in 2015 and 2016 is being used to understand effects during the winter migration and summer foraging.
- This project will link fine-scale changes in fur seal foraging behavior with measures of pollock distribution and abundance in real time.

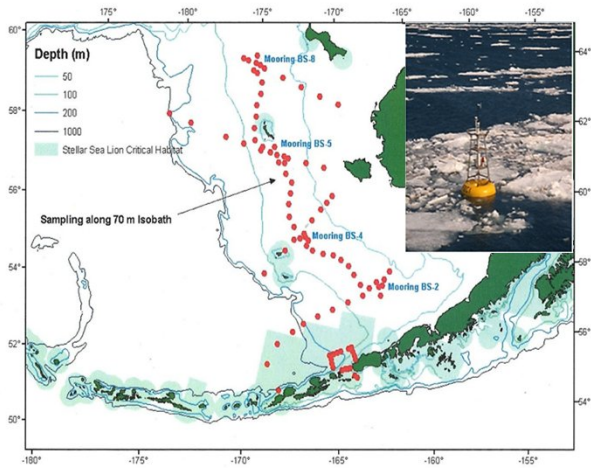


Allen, B.M., Angliss, R.P. and Wade, P.R., 2011. *Alaska marine mammal stock assessments, 2010*.

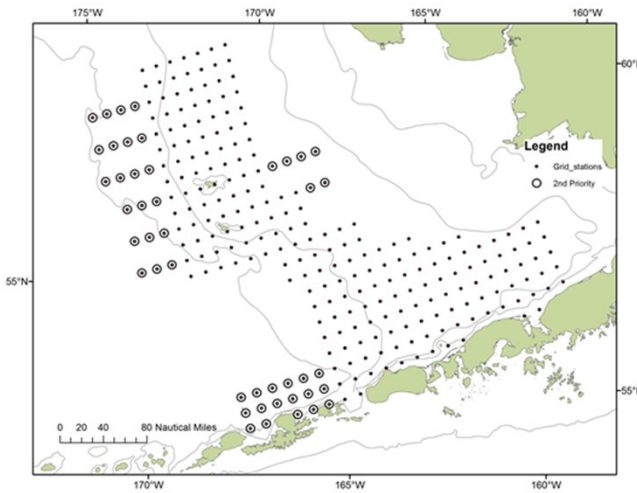
Track trends in ecosystems (Obj. 6)

Objective 6: Track trends in ecosystems, LMRs and LMR dependent human communities and provide early warning of change.

April-May & Sept-
Oct physics



May, larval

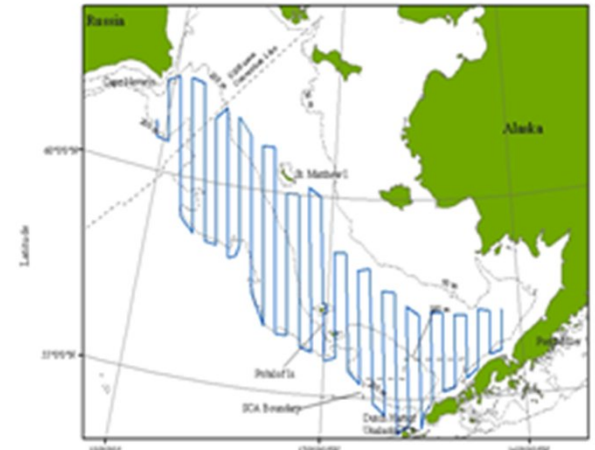


Seasonal surveys

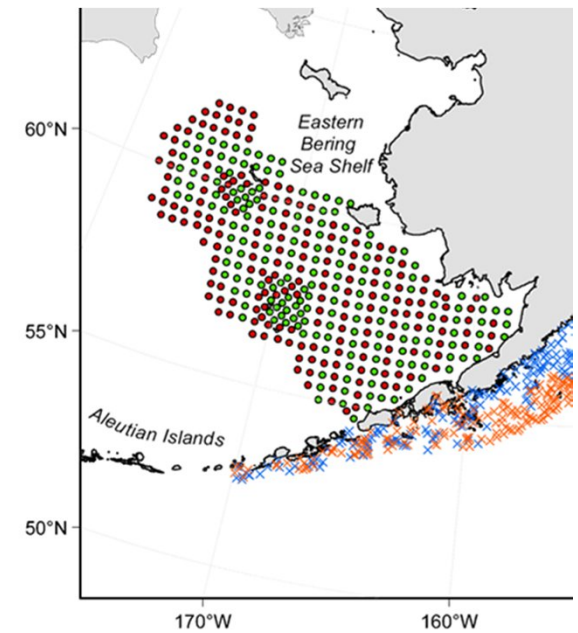
August-September,
age-0



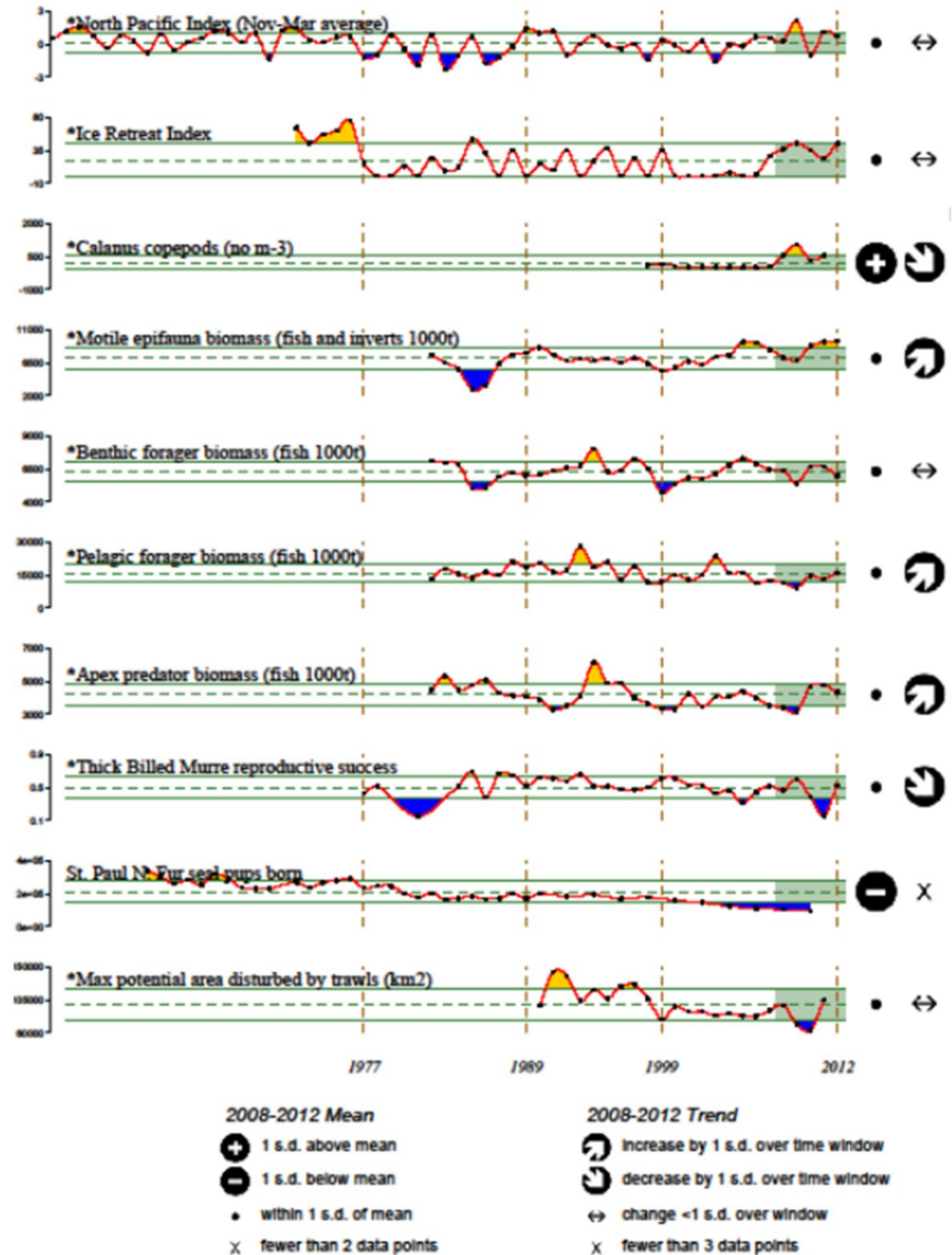
June-July, age-1



June-July, age-3+






Alaska Marine Ecosystem Considerations



Challenge 1

Our ability to project future impacts is limited by our understanding of ecological processes. Understanding is sufficient for **only 3 of 21** comprehensively assessed stocks in the southeastern Bering Sea.

- Walleye pollock (through loss of sea ice) 
- Red king crab (through increased CO2) 
- Northern rock sole 

Mueter, F.J., Bond, N.A., Ianelli, J.N. and Hollowed, A.B., 2011. Expected declines in recruitment of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea under future climate change. *ICES Journal of Marine Science: Journal du Conseil*, p.fsr022.

Long, W.C., Swiney, K.M. and Foy, R.J., 2013. Effects of ocean acidification on the embryos and larvae of red king crab, *Paralithodes camtschaticus*. *Marine pollution bulletin*, 69(1), pp.38-47.

Wilderbuer, T., Stockhausen, W. and Bond, N., 2013. Updated analysis of flatfish recruitment response to climate variability and ocean conditions in the Eastern Bering Sea. *Deep Sea Research Part II: Topical Studies in Oceanography*, 94, pp.157-164.

Punt, Poljak, Dalton, Foy. 2014. Evaluating the impact of ocean acidification on fishery yields and profits: The example of red king crab in Bristol Bay. *Ecol. Modeling*. 285: 39-53.

Climate vulnerability assessment

A climate vulnerability assessment for the southeastern Bering Sea, which will **qualitatively assess** species vulnerabilities to climate change and provide guidance on research prioritization, currently is underway. The vulnerability assessment uses expert elicitation methods to quantify a species' exposure and sensitivity to expected climate change.

Vulnerability Rank

	Low	Moderate	High	Very High
Very High	Moderate	High	Very High	Very High
High	Low	Moderate	High	Very High
Moderate	Low	Moderate	Moderate	High
Low	Low	Low	Low	Moderate

Recruitment Processes Alliance

Research is conducted to understand processes affecting recruitment strength, including effects of climate. This is a partnership between OAR and AFSC that joins six AFSC programs with researchers from the PMEL:

[Recruitment Processes](#),

[Ecosystem Monitoring and Assessment](#),

[Recruitment Energetics and Coastal Assessment](#),

[Resource Ecology and Ecosystem Modeling](#),

[Status of Stocks and Multispecies Assessment](#),

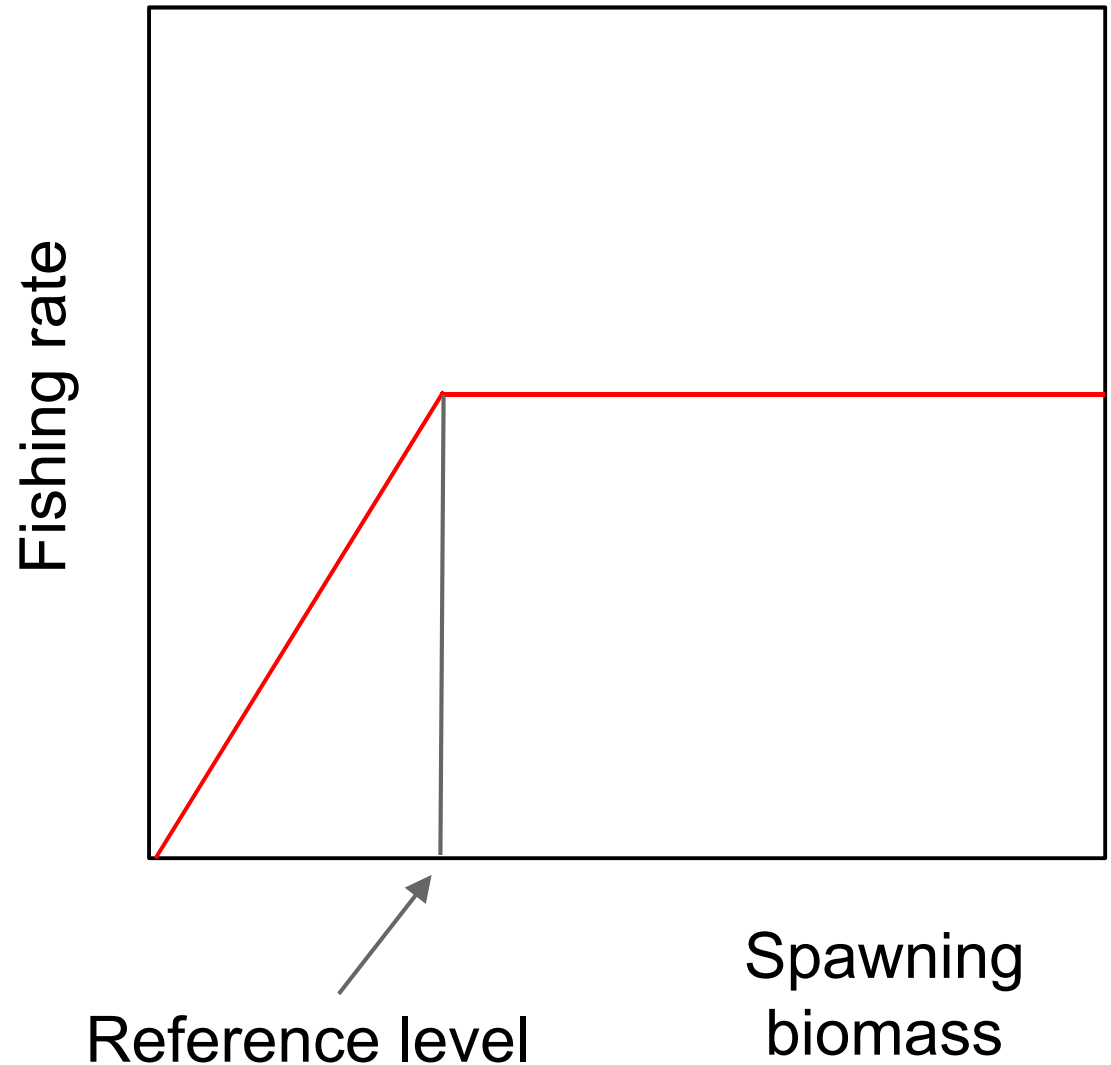
[Marine Ecology and Stock Assessments](#)

[Pacific Marine Environmental Laboratory](#)

A significant fraction of AFSC resources are invested in this effort (e.g., ~15% of labor).

Challenge 2 (Obj. 3)

- Setting sustainability goals under changing climate.
- Spatial management under shifts in species distribution.
- Allocation under shifting species composition
- How and when the North Pacific Fishery Management Council should react to climate-induced reference point changes.



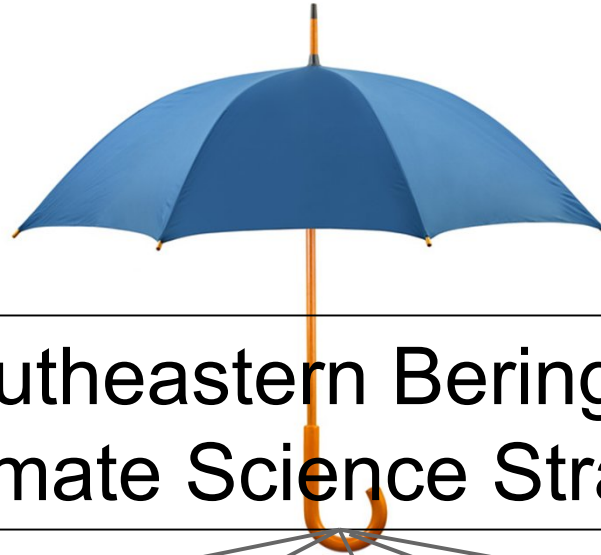
NMFS Climate Science Strategy



Pacific Islands



California Current



**Southeastern Bering Sea
Climate Science Strategy**



Gulf of Mexico



Georges Bank



Aleutian Islands



Gulf of Alaska

**Southeastern
Bering Sea
Vulnerability
Analysis**

**Recruitment
Processes
Alliance**

ACLIM

Shifts in
Distribution and
abundance,
Juvenile &
Adult
Distribution
Phenology
Growth
Maturity

**Community
Profiles, and
Vulnerability
Analysis**

Improve efforts to identify and adapt to climate change impacts on fisheries:

- Identify winners and losers and adjust management programs (i.e., catch share programs) as necessary
- Identify and monitor thresholds in ecosystem parameters that signal the need to adjust management strategies

Action Plan (with level funding)

- NPFMC Bering Sea Fisheries Ecosystem Plan.
- Alaska CLIMate Project (ACLIM) – Proposed Transition to Operationalize
- Climate vulnerability assessment for the southeastern Bering Sea.
- Belmont Forum project.
- Recruitment Processes Alliance.
- [Loss of Sea Ice research.](#)
- [Ocean Acidification research.](#)
- Fur seal research.
- Assess economic and human community impacts.
- Alaska Integrated Ecosystem Assessments and [Alaska Marine Ecosystems Considerations.](#)
- Standard ecosystem monitoring.
- Advanced technology.

Action Plan

- With some additional funds:
 - Fully support NOAA oceanographic moorings to monitor the ecosystem.
 - Invest in modeling infrastructure.
 - Comprehensive climate assessment completed every five years.
 - Invest in regional and international coordination.
 - Improve communication of the risks of climate change to fishing dependent communities
 - Integrate the evolving tools and data integration work completed by AFSC and PMEL.