ACLIM
The Alaska Climate Integrated Modeling project


Anne Hollowed, NOAA
Diana Stram, NPFMC
Jonathan Reum, UW
Kerim Aydin, NOAA
Al Hermann, UW
André Punt, UW
+ ACLIM Team

SSC, October 06, 2021

Kirstin Holsman, kirstin.holsman@noaa.gov
Alan Haynie, Alan.Haynie@noaa.gov
NOAA Alaska Fisheries Science Center

ACLIM Team

Lead PIs: Anne Hollowed, Kirstin Holsman, Alan Haynie, Jon Reum, Andre Punt, Kerim Aydin, Al Hermann

Co-Pis & Collaborators

Wei Cheng
Jim Ianelli
Kelly Kearney
Elizabeth McHuron
Daren Pilcher
Jeremy Sterling
Ingrid Spies
Paul Spencer
William Stockhausen
Cody Szuwalski
Sarah Wise
Ellen Yasumiishi

Andy Whitehouse
James Thorson
Peggy Sullivan
Amanda Faig
Steve Kasperski
Martin Dorn
Diana Evans
Ed Farely
Enrique Curchitser
Elliott Hazen
David Kimmel
Mike Jacox
Adam Hayes

Carol Ladd
Stan Kotwicki
Ivonne Ortiz
Kalei Shotwell
Rolf Ream
Elizabeth Siddon
Phyllis Stabeno
Charlie Stock
Chris Rooper
Jordan Watson
Diana Stram
Lauren Rogers
Ben Laurel

Building climate resilience through climate-informed Ecosystem Based Management

www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project

Outline of Today’s Presentation

1. Observed and projected climate change
2. Bering Sea most recent climate projections
3. Biological projections with fishing scenarios
4. ACLIM 2.0 harvest control rule and fishing example scenarios + requests for your input

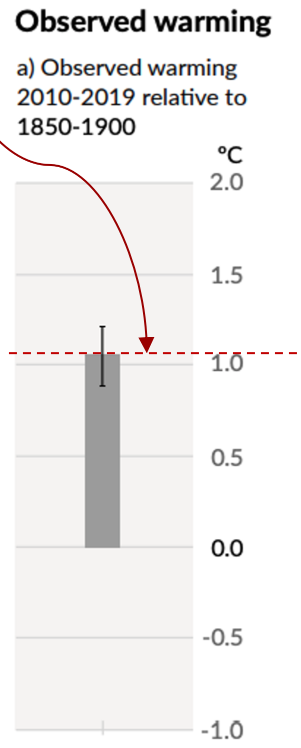
IPCC 6th Assessment Report (2021)

https://www.ipcc.ch/

Part 1

Climate change has already warmed the planet

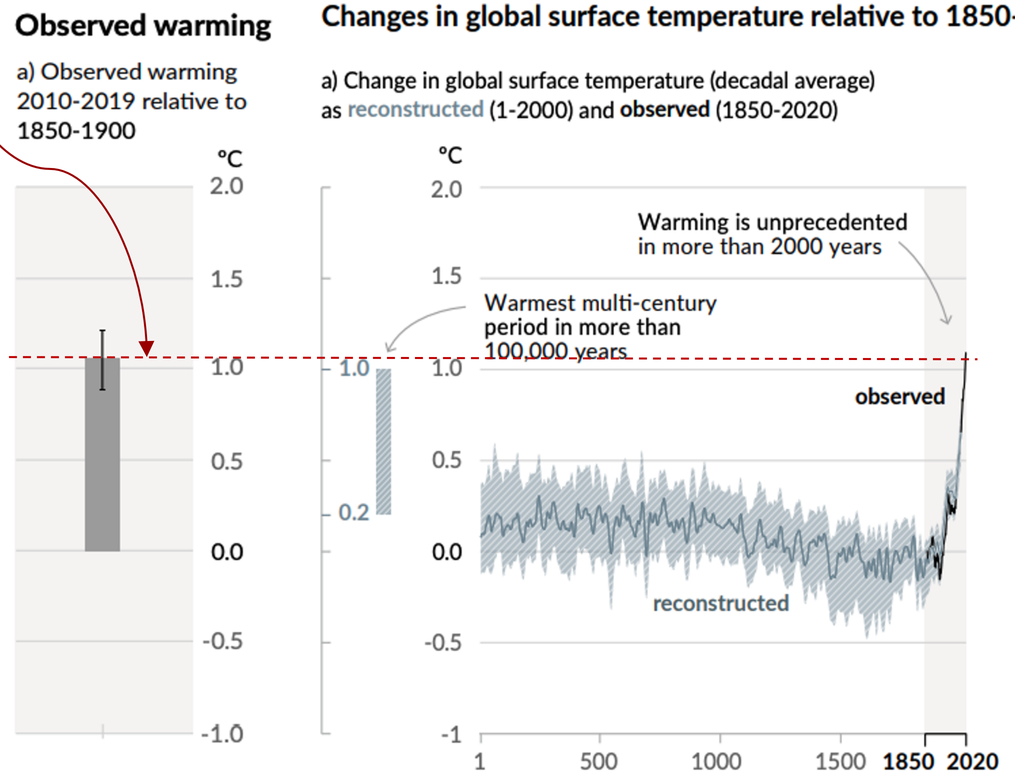
*"The likely range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is **0.8°C to 1.3°C, with a best estimate of 1.07°C.**"*
[IPCC 2021 6th Assessment Report, WG 1, SPM]



Part 1

Climate change has already warmed the planet

*"The likely range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is **0.8°C to 1.3°C, with a best estimate of 1.07°C.**"*
IPCC 2021 6th Assessment Report, WG 1, SPM

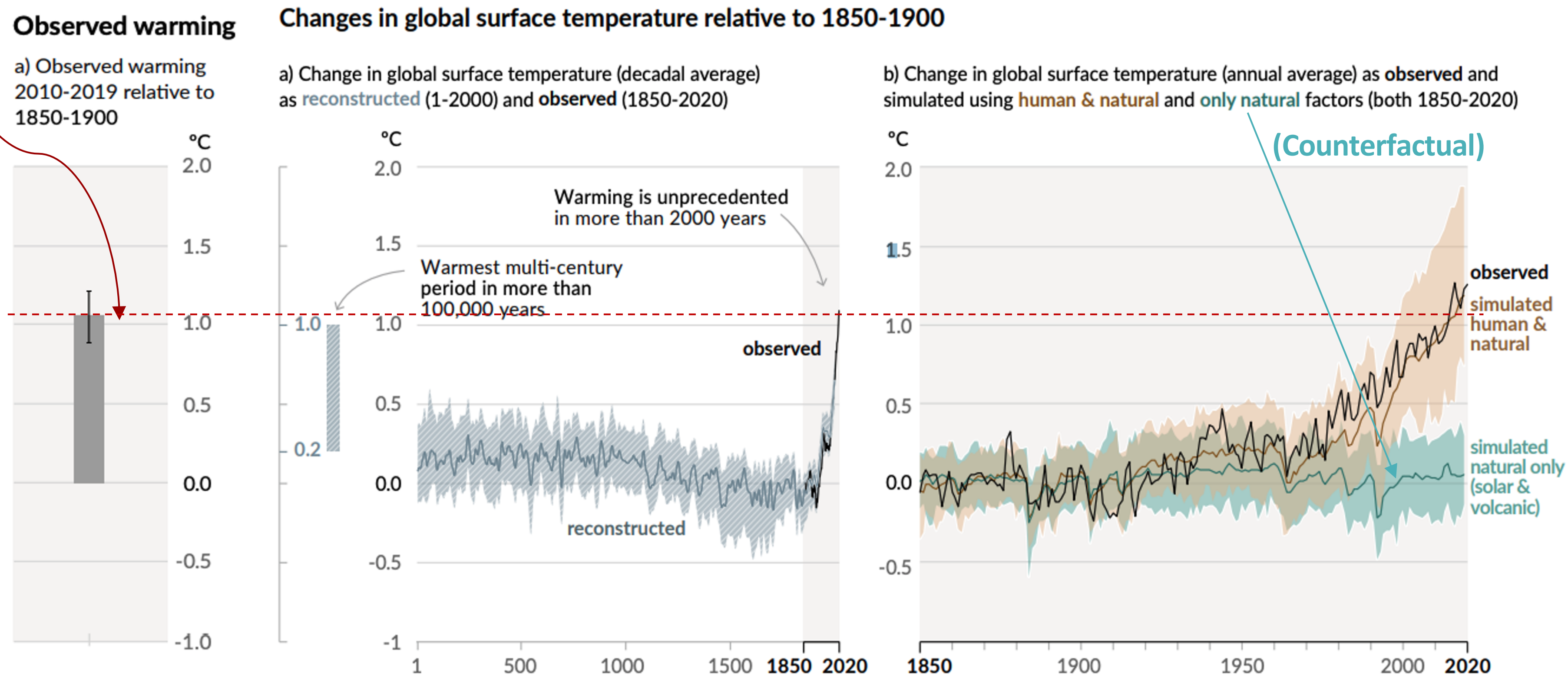


Recent Global Mean Warming is:

- Warmest period in more than 100,000 years
- Unprecedented warming in more than 2,000 years

Climate change has already warmed the planet

*"The likely range of total human-caused global surface temperature increase from 1850–1900 to 2010–2019 is **0.8°C to 1.3°C, with a best estimate of 1.07°C.**"*
IPCC 2021 6th Assessment Report, WG 1, SPM



Part 1

Warming in the Arctic is 2-3 x global average:

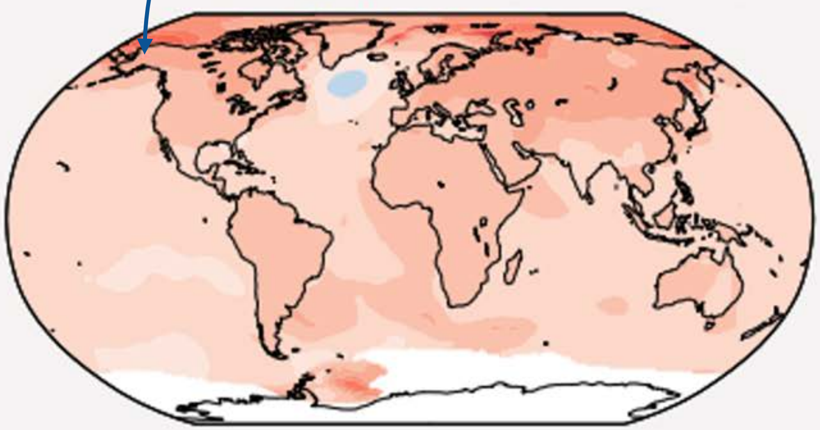
1.07^{o}C of "Global mean warming" = Warming of 2-3oC in the Arctic

"Arctic Amplification"

a) Annual mean temperature change (°C) at 1 °C global warming

Warming at 1 °C affects all continents and is generally larger over land than over the oceans in both observations and models. Across most regions, observed and simulated patterns are consistent.

Observed change per **1 °C** global warming

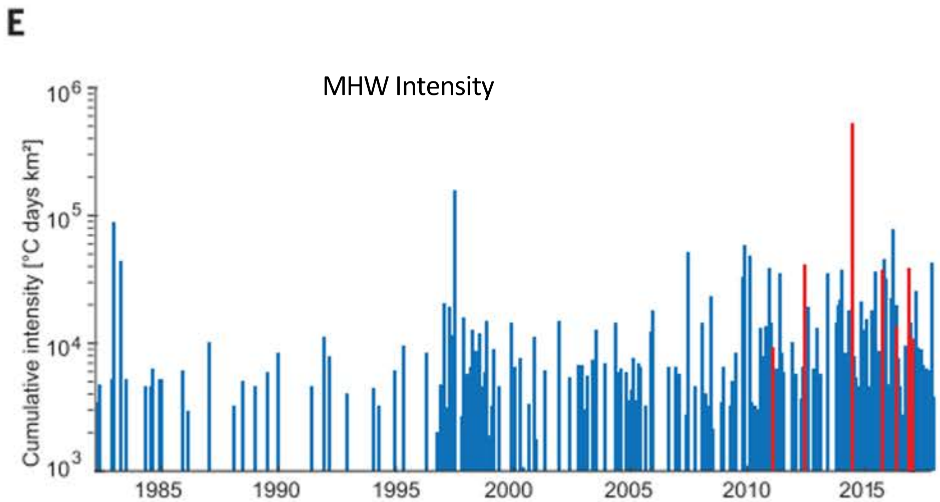


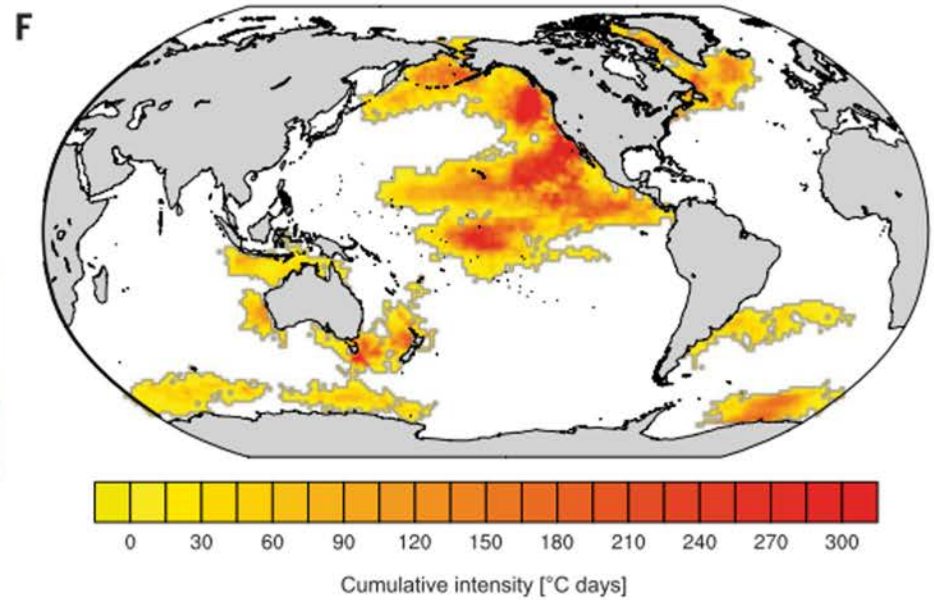
Figures from the IPCC AR6 WGI Summary for Policymakers: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

In Alaska climate change has already caused: Marine Heatwaves

"We show that the occurrence probabilities of the duration, intensity, and cumulative intensity of most documented, large, and **impactful MHWs have increased more than 20-fold as a result of anthropogenic climate change.**"

Pre-industrial (0°C global warming) = once every 100-1,000 y
1.5°C global warming = once every 10 - 100 y
3.0°C global warming = once every 1 - 10 y



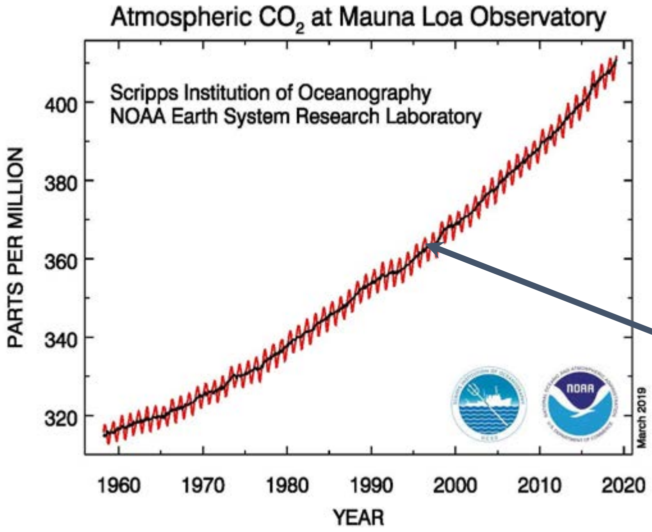


High-impact marine heatwaves attributable to human-induced global warming Laufkötter et al. Science 369 (6511), 1621-1625. DOI: 10.1126/science.aba0690

Part 1

In Alaska climate change has already caused: Loss of Sea Ice

- 2018 Bering Sea winter ice extent is **lowest in 5,500 yr record**
- Bering Sea ice extent lags atmospheric carbon concentrations **by 2 decades**
- Moderate to high global carbon mitigation preserves some winter EBS sea ice



685 ppmv = No EBS sea ice

Atmospheric Carbon in 1998... drives Sea Ice in 2018

https://www.noaa.gov/stories/unprecedented-2018-bering-sea-ice-loss-repeated-in-2019

Jones,et al. (2020). High sensitivity of Bering Sea winter sea ice to winter insolation and carbon dioxide over the last 5500 years. *Science Advances*, *6*(36), 1–10. https://doi.org/10.1126/sciadv.aaz9588

In Alaska climate change has already caused: Fishery losses

PeerJ

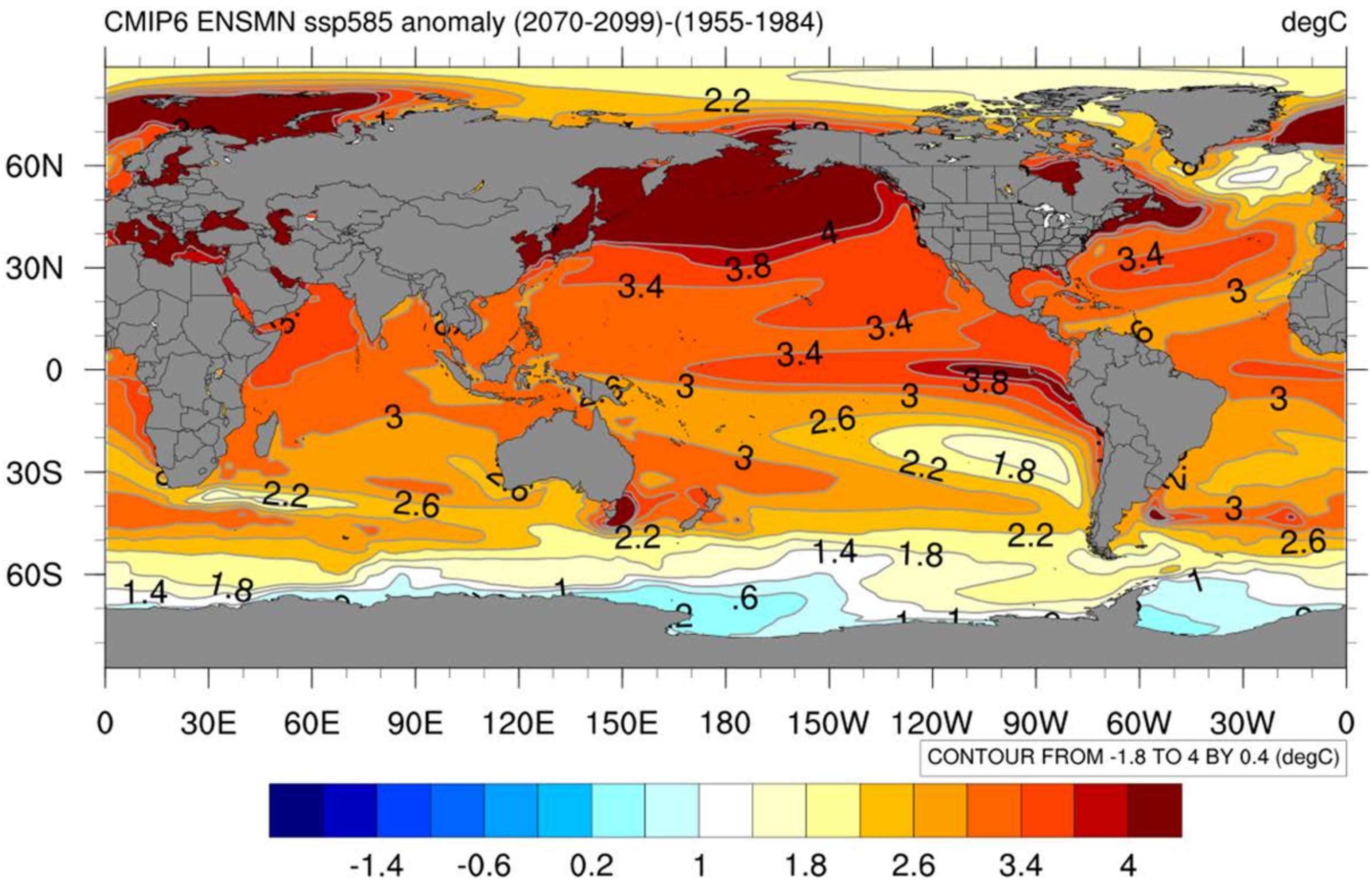
"Nationwide, 84.5% of fishery disasters were either partially or entirely attributed to extreme environmental events."

Table 2 **Total U.S. Congressional fishery disaster assistance (2019 USD) by cause and by federalfisheries management region.** One additional disaster had an allocation amount that was not reported, but the request letter cited economic impacts of $53.8-94.2M. Anthropogenic causes include pollution and overfishing; environmental causes include marine heatwaves, harmful algal blooms, hurricanes, extreme drought, etc.; and a combination includes both anthropogenic and environmental causes. Examples of fisheries being impacted by a combination of causes can be found in some Pacific northwest salmon fishery disasters, which were caused by low returns that resulted from marine heatwaves, drought, disease, habitat impacts, mismanagement, and overfishing.

Cause	Alaska	Greater Atlantic	Pacific Islands	Southeast	West Coast	To be determined	Total
Anthropogenic	$82,000,000	$132,996,669		$30,940,000	$7,600,000		$253,536,669
Environmental	$174,292,189	$41,572,622	$1,140,000	$505,938,343	$170,723,211		$893,666,365
Combination of Both	$75,588,349	$36,600,000		$37,098,200	$281,802,589		$431,089,138
To be determined						$414,103,069	$414,103,069
Total	$331,880,538	$211,169,291	$1,140,000	$573,976,543	$460,125,800	$414,103,069	$1,992,395,241

Bellquist et al. 2021. The rise in climate change-induced federal fishery disasters in the United States. https://peerj.com/articles/11186/

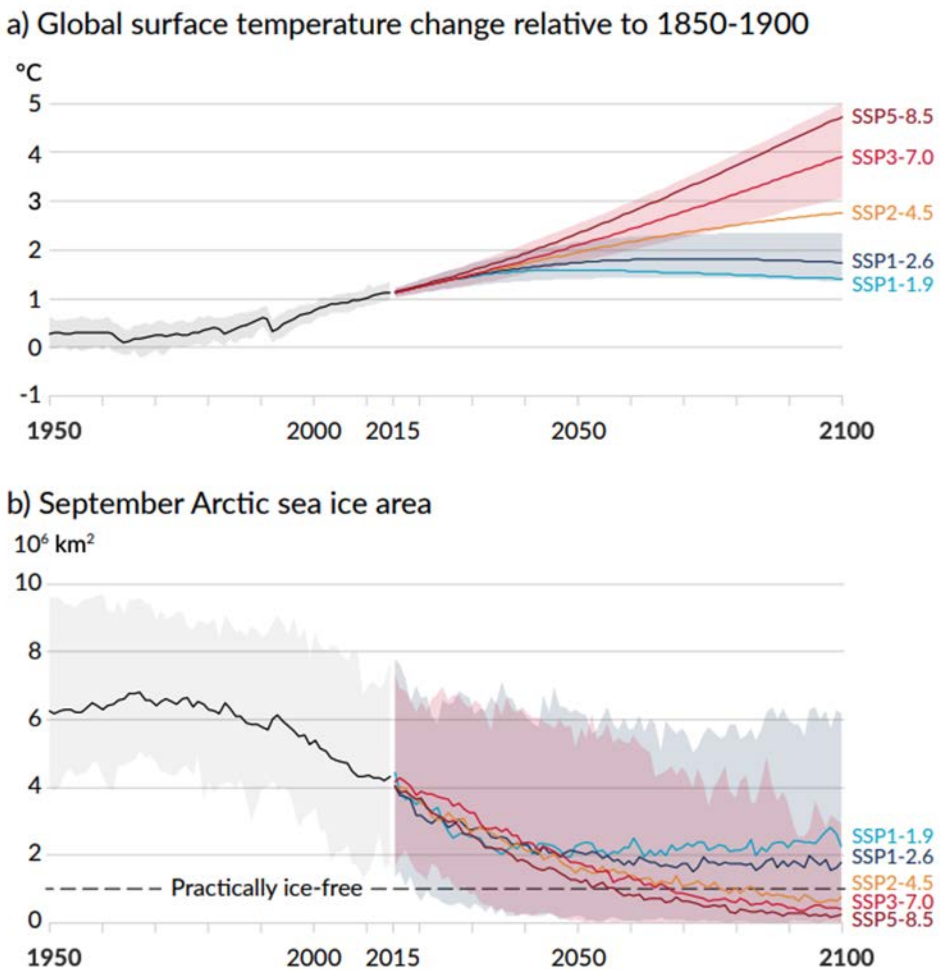
Climate change will continue to impact AK Ecosystems & fisheries



https://psl.noaa.gov/ipcc/cmip6/

Part 1

Climate change will continue to impact AK Ecosystems & fisheries

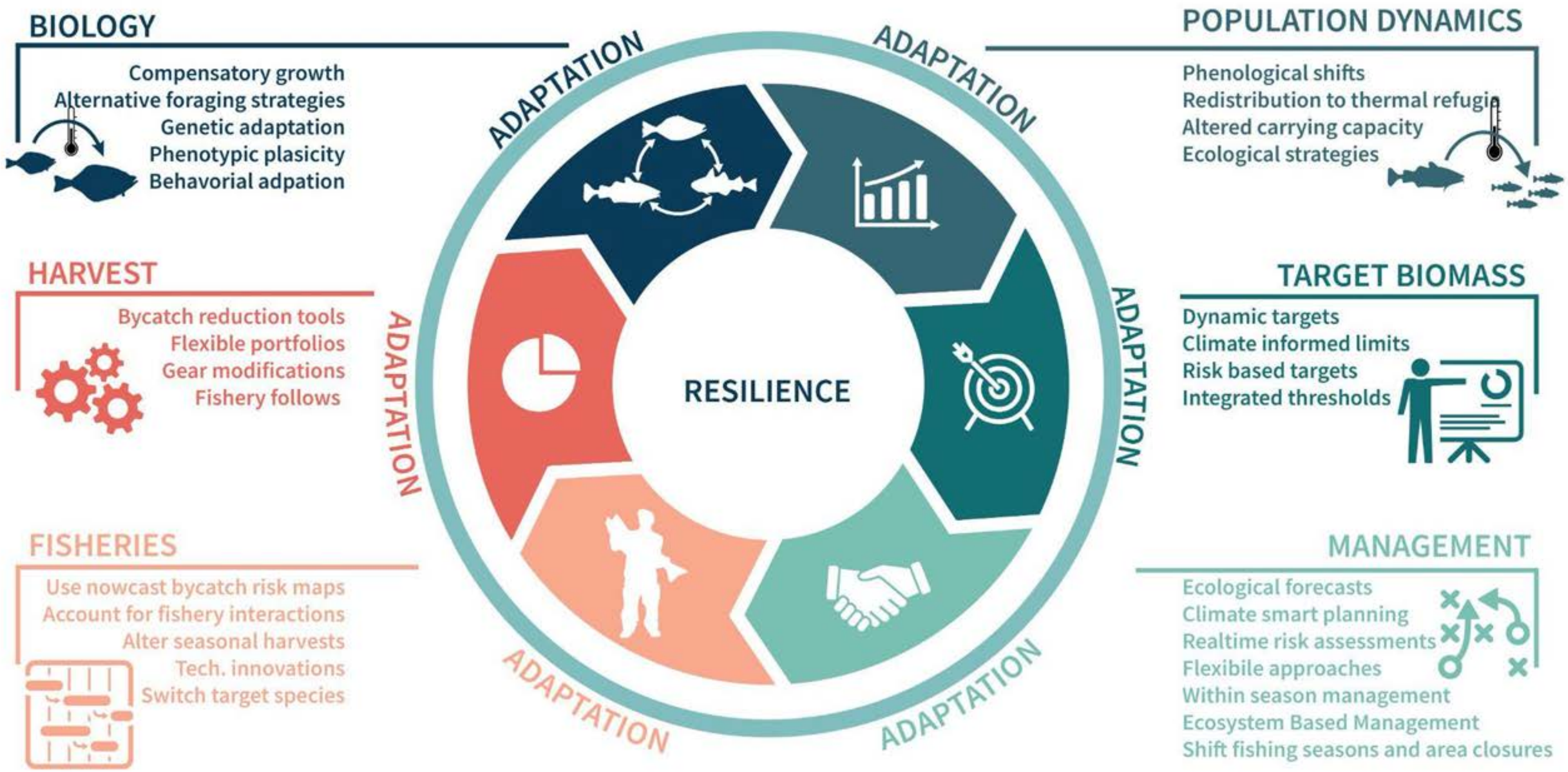


Warming will continue and is greater in scenarios with low carbon mitigation

Sea Ice will continue to decline, more so under scenarios with high global warming and low carbon mitigation

Figures from the IPCC AR6 WGI Summary for Policymakers: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM.pdf

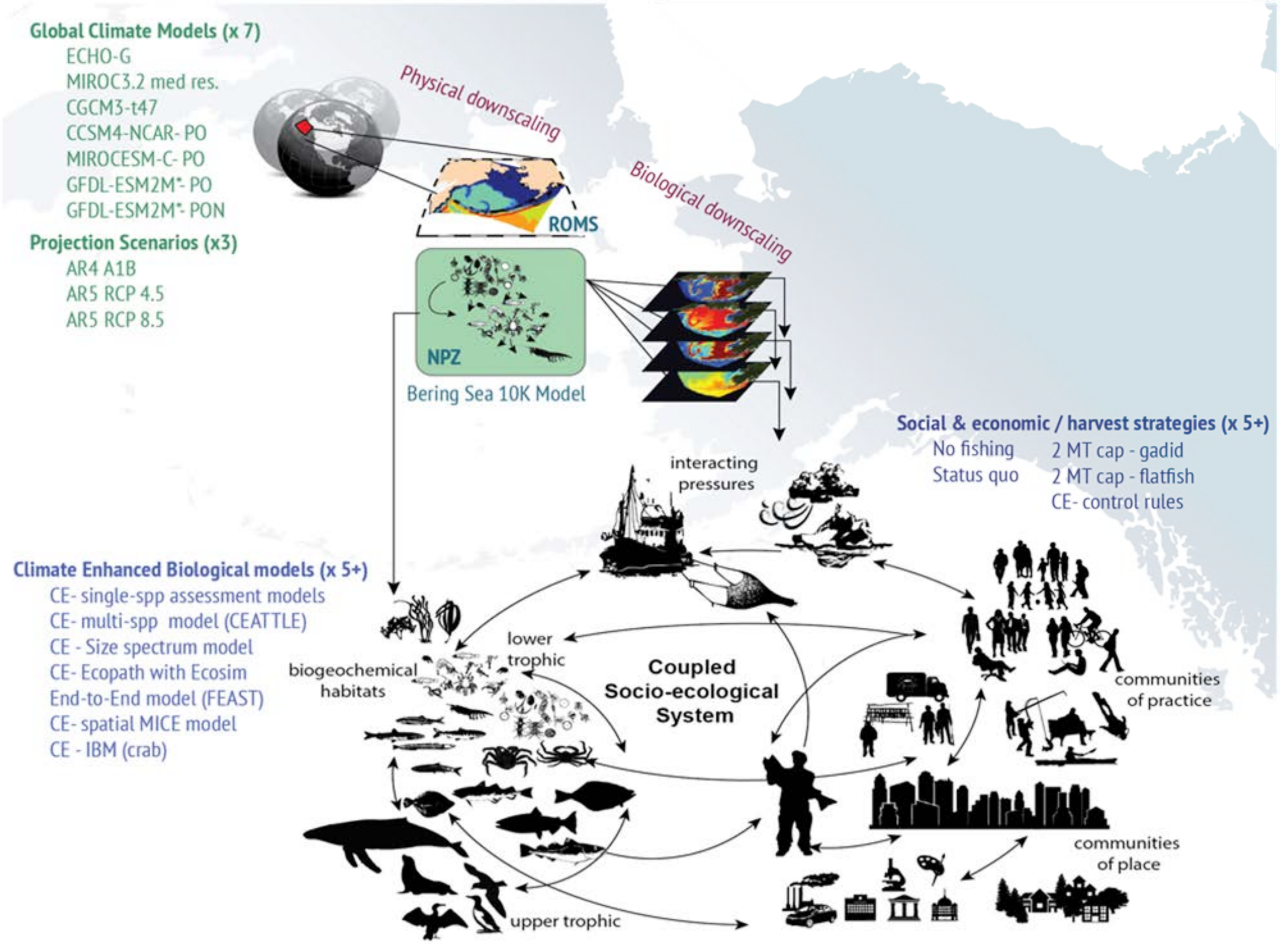
What can be done? Prediction, Planning, Preparing



Holsman et al. (in prep)

The Alaska Climate Integrated Modeling Project

www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project



Hollowed et al. 2020. Frontiers in Mar. Sci. doi: 10.3389/fmars.2019.00775

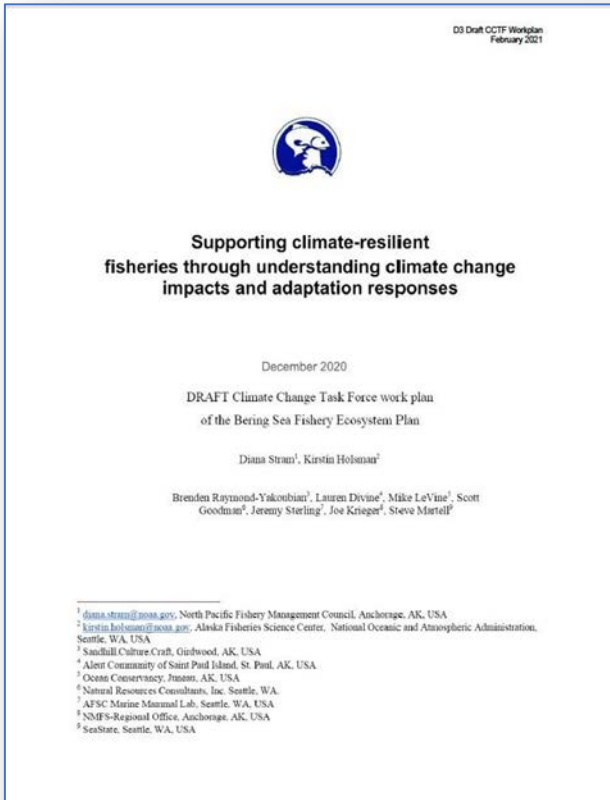
Part 1

ACLIM aims to address:

1. **What to expect?**
   Project physical and ecological conditions under levels of climate change (levels of global carbon mitigation)

2. **What can be done?**
   Evaluate effectiveness of adaptation actions including those supported by fisheries management

Provide tools and approaches to support climate informed management decisions


D3 Draft CCTF Workplan
February 2021

Supporting climate-resilient fisheries through understanding climate change impacts and adaptation responses

December 2020

DRAFT Climate Change Task Force work plan
of the Bering Sea Fishery Ecosystem Plan

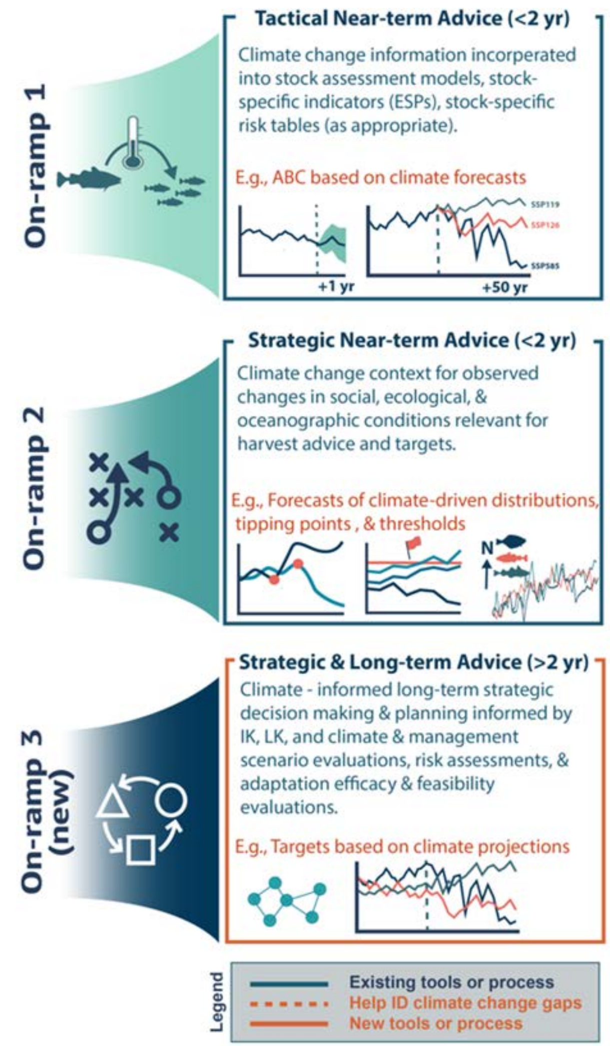
Diana Stram[1], Kirstin Holsman[2]

Brenden Raymond-Yakoubian[3], Lauren Divine[4], Mike LeVine[5], Scott Goodman[6], Jeremy Sterling[7], Joe Krieger[8], Steve Martell[9]

[1] diana.stram@noaa.gov, North Pacific Fishery Management Council, Anchorage, AK, USA
[2] kirstin.holsman@noaa.gov, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, Seattle, WA, USA
[3] Sandhill Culture Craft, Girdwood, AK, USA
[4] Aleut Community of Saint Paul Island, St. Paul, AK, USA
[5] Ocean Conservancy, Juneau, AK, USA
[6] Natural Resources Consultants, Inc. Seattle, WA
[7] AFSC Marine Mammal Lab, Seattle, WA, USA
[8] NMFS-Regional Office, Anchorage, AK, USA
[9] SeaState, Seattle, WA, USA

https://www.npfmc.org/climatechangetaskforce/
Stram et al. 2021

Climate information on ramps for fisheries management



Part 1

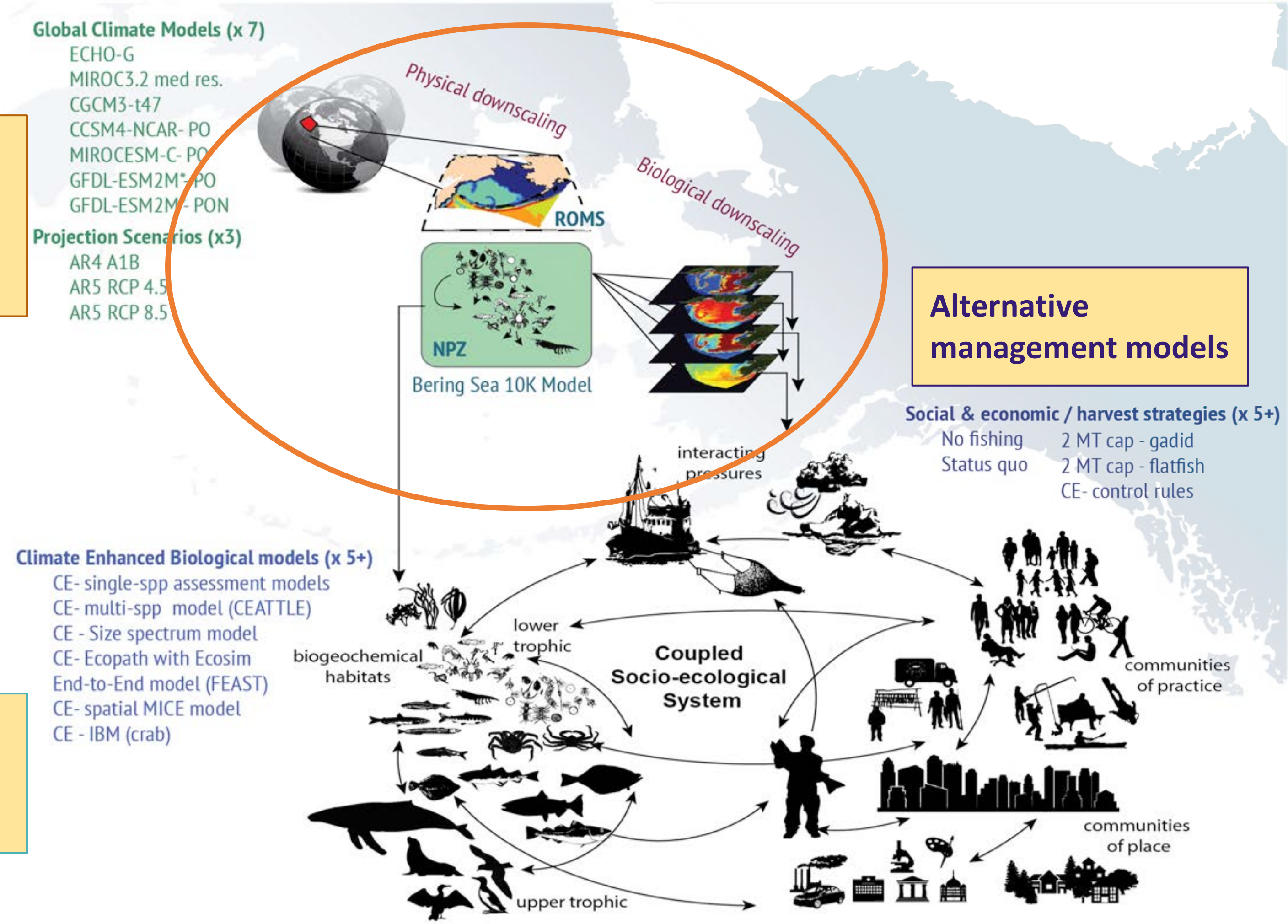
Bering Sea Oceanographic Projections

The Alaska Climate Integrated Modeling Project

High resolution realistic ocean projections under climate scenarios

Alternative management models

Climate driven changes to species & food-webs

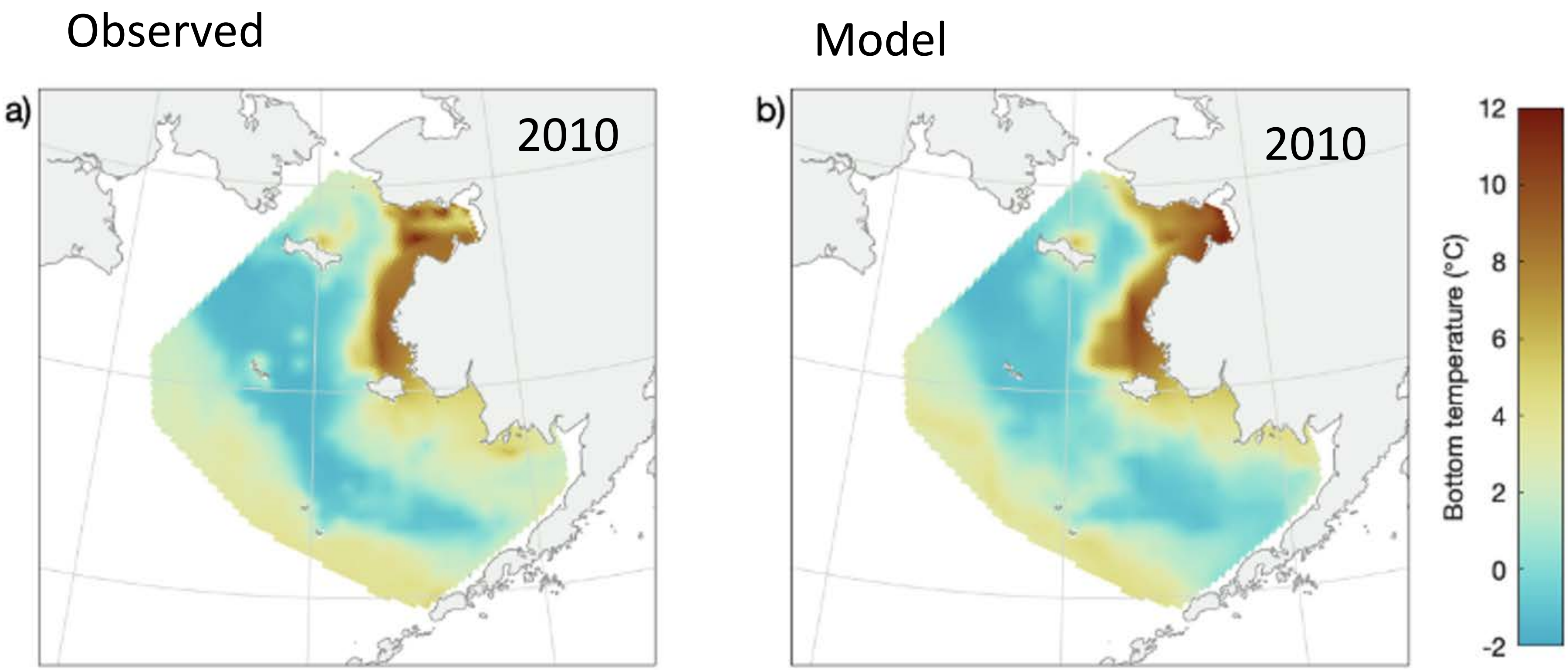


Hollowed et al. 2020. Frontiers in Mar. Sci. doi: 10.3389/fmars.2019.00775

Part 1

Part 2

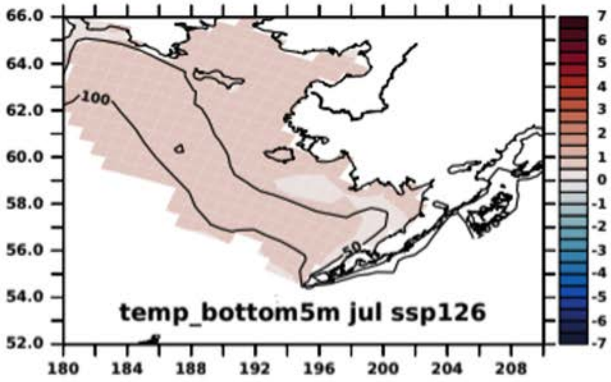
Bering10K ROMSNPZ reproduces the Bering Sea environment

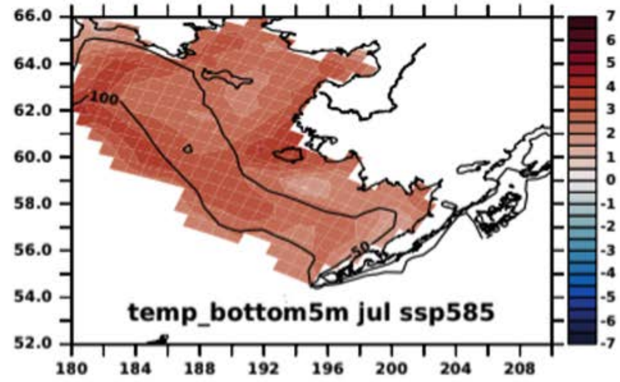


Kearney K (2021). Temperature data from the eastern Bering Sea continental shelf bottom trawl survey as used for hydrodynamic model validation and comparison. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-415, 40 p. link.

Increased warming & declines in Euphausiids expected

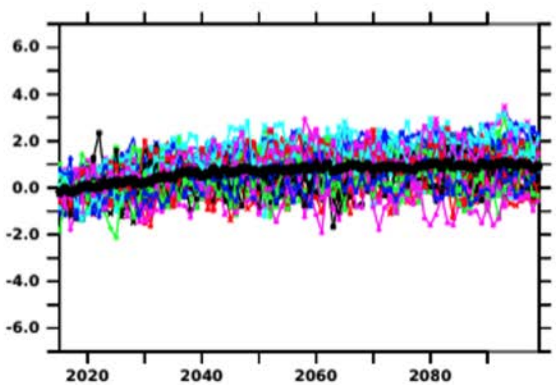
Bottom Temp.

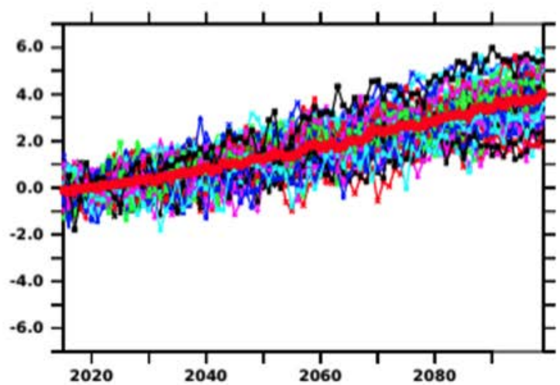




SSP126: High mitigation/ less warming.

SSP585: Low mitigation/ more warming





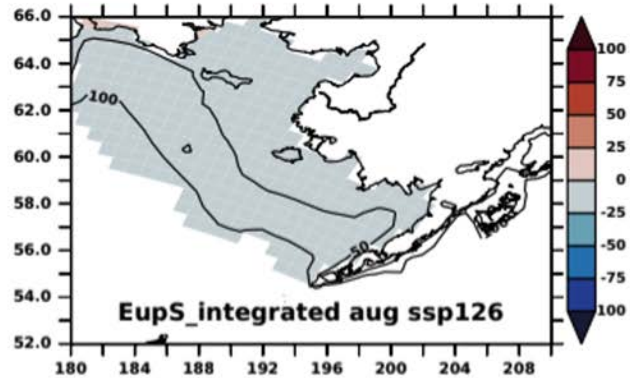
Hermann, et al. (in press)

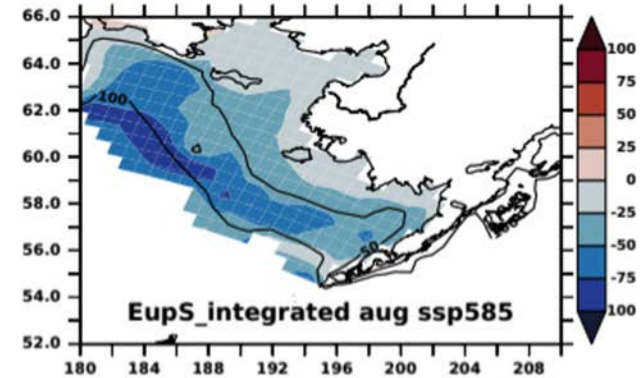
Part 1

Part 2

Increased warming & declines in Euphausiids expected

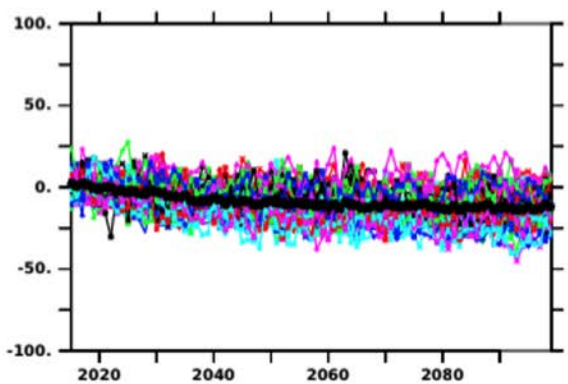
Euphausiid biomass

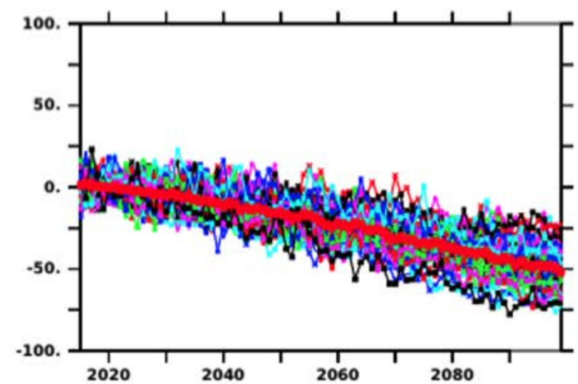




SSP126: High mitigation/ less warming

SSP585: Low mitigation/ more warming



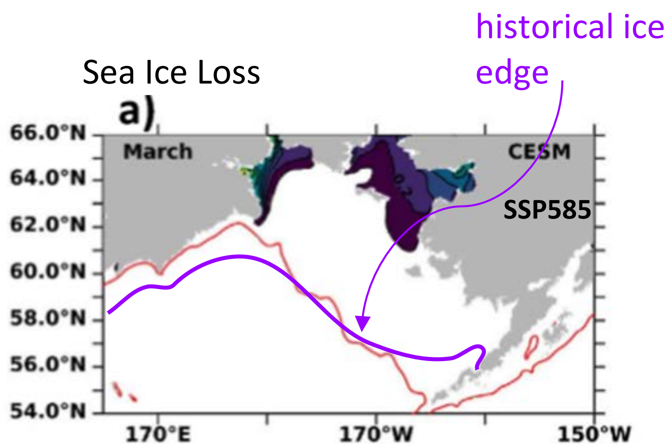


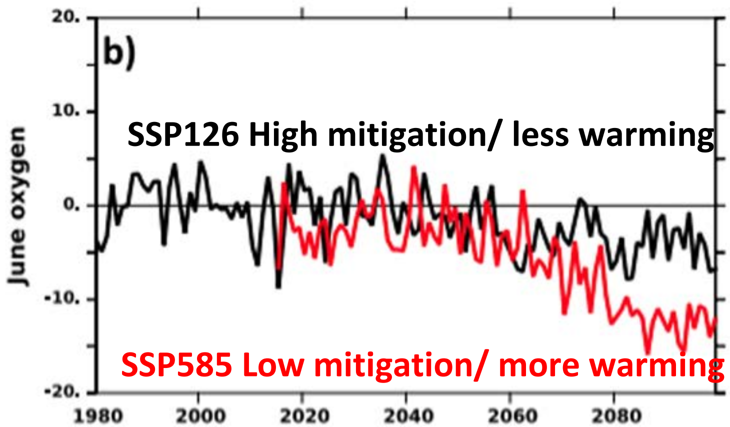
Hermann, et al. (in press)

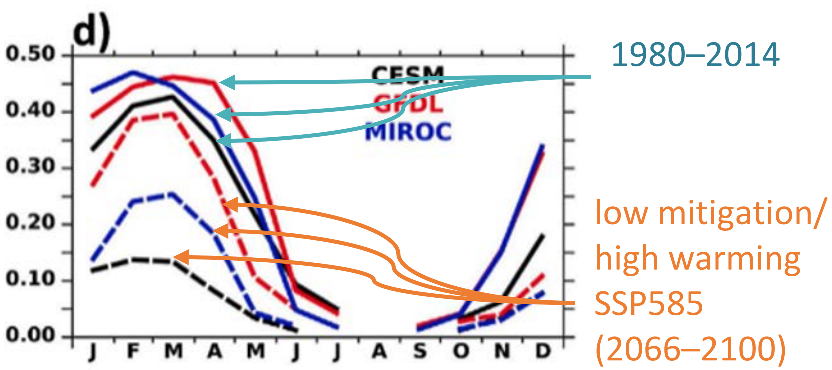
Part 1

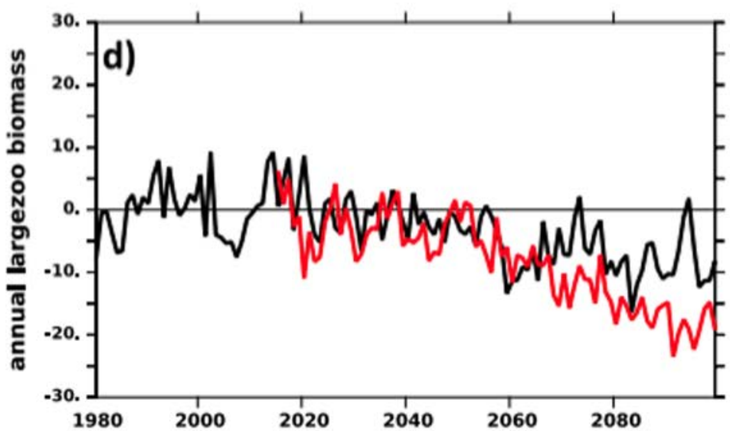
Part 2

Declines in Sea ice, O_2 & large Zooplankton expected





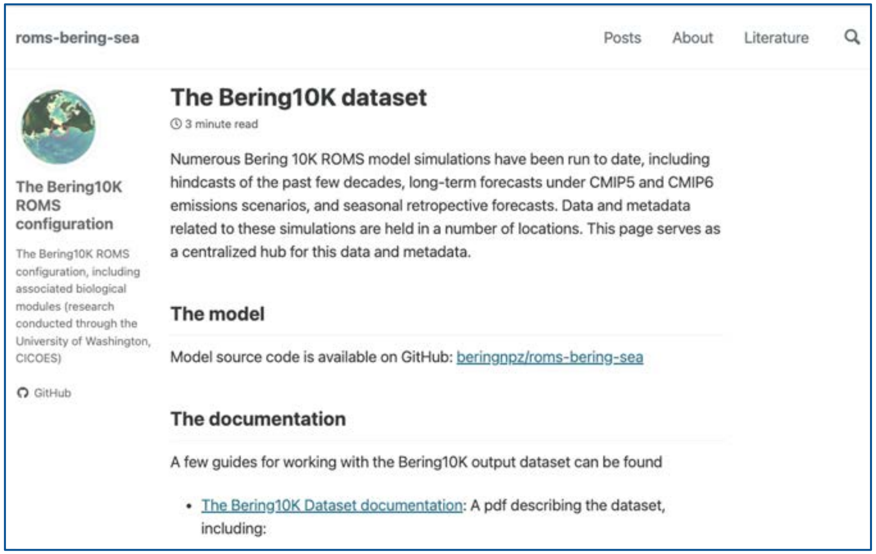




Cheng, et al. (in press) https://www.sciencedirect.com/science/article/pii/S0967064521000515

Learn More: BERING10K Data & Info portals

Learn More: https://beringnpz.github.io/roms-bering-sea/B10K-dataset-docs/



roms-bering-sea   Posts   About   Literature

The Bering10K ROMS configuration

The Bering10K ROMS configuration, including associated biological modules (research conducted through the University of Washington, CICOES)

GitHub

The Bering10K dataset

3 minute read

Numerous Bering 10K ROMS model simulations have been run to date, including hindcasts of the past few decades, long-term forecasts under CMIP5 and CMIP6 emissions scenarios, and seasonal retropective forecasts. Data and metadata related to these simulations are held in a number of locations. This page serves as a centralized hub for this data and metadata.

The model

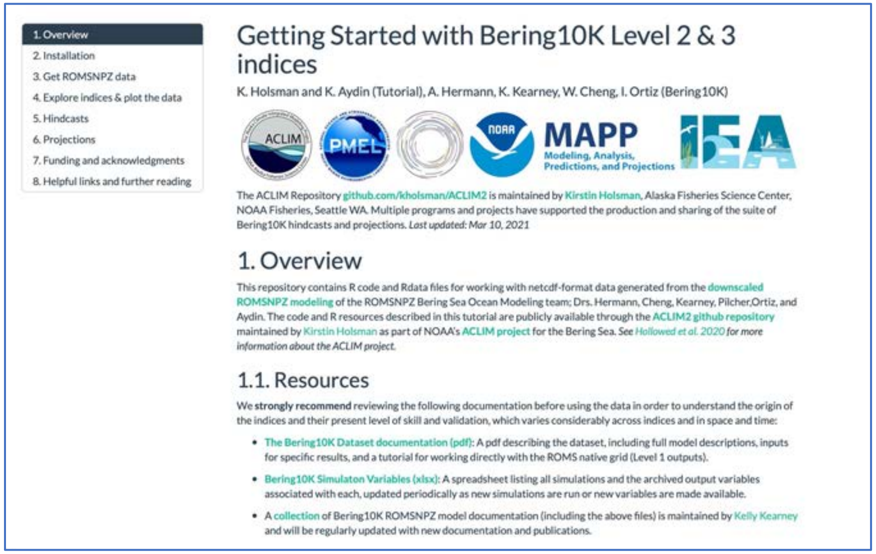
Model source code is available on GitHub: beringnpz/roms-bering-sea

The documentation

A few guides for working with the Bering10K output dataset can be found

- The Bering10K Dataset documentation: A pdf describing the dataset, including:

Explore the Data: https://github.com/kholsman/ACLIM2



1. Overview
2. Installation
3. Get ROMSNPZ data
4. Explore indices & plot the data
5. Hindcasts
6. Projections
7. Funding and acknowledgments
8. Helpful links and further reading

Getting Started with Bering10K Level 2 & 3 indices

K. Holsman and K. Aydin (Tutorial), A. Hermann, K. Kearney, W. Cheng, I. Ortiz (Bering10K)

ACLIM PMEL NOAA MAPP Modeling, Analysis, Predictions, and Projections IEA

The ACLIM Repository github.com/kholsman/ACLIM2 is maintained by Kirstin Holsman, Alaska Fisheries Science Center, NOAA Fisheries, Seattle WA. Multiple programs and projects have supported the production and sharing of the suite of Bering10K hindcasts and projections. *Last updated: Mar 10, 2021*

1. Overview

This repository contains R code and Rdata files for working with netcdf-format data generated from the downscaled ROMSNPZ modeling of the ROMSNPZ Bering Sea Ocean Modeling team; Drs. Hermann, Cheng, Kearney, Pilcher,Ortiz, and Aydin. The code and R resources described in this tutorial are publicly available through the ACLIM2 github repository maintained by Kirstin Holsman as part of NOAA's ACLIM project for the Bering Sea. *See Hollowed et al. 2020 for more information about the ACLIM project.*

1.1. Resources

We **strongly recommend** reviewing the following documentation before using the data in order to understand the origin of the indices and their present level of skill and validation, which varies considerably across indices and in space and time:

- The Bering10K Dataset documentation (pdf): A pdf describing the dataset, including full model descriptions, inputs for specific results, and a tutorial for working directly with the ROMS native grid (Level 1 outputs).
- Bering10K Simulaton Variables (xlsx): A spreadsheet listing all simulations and the archived output variables associated with each, updated periodically as new simulations are run or new variables are made available.
- A collection of Bering10K ROMSNPZ model documentation (including the above files) is maintained by Kelly Kearney and will be regularly updated with new documentation and publications.

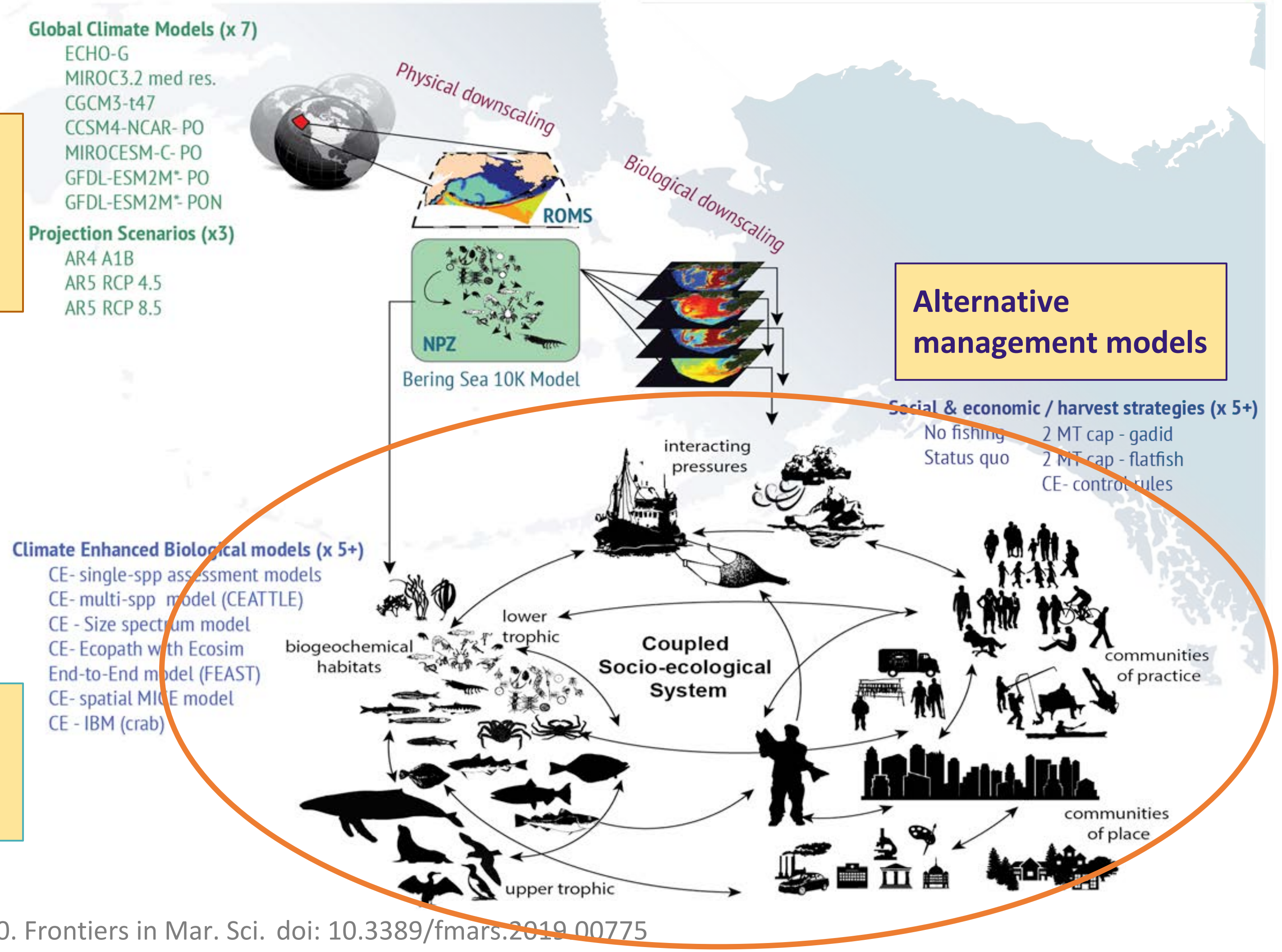
Climate + Biological + Management Modeling

The Alaska Climate Integrated Modeling Project

High resolution realistic ocean projections under climate scenarios

Climate driven changes to species & food-webs

Alternative management models



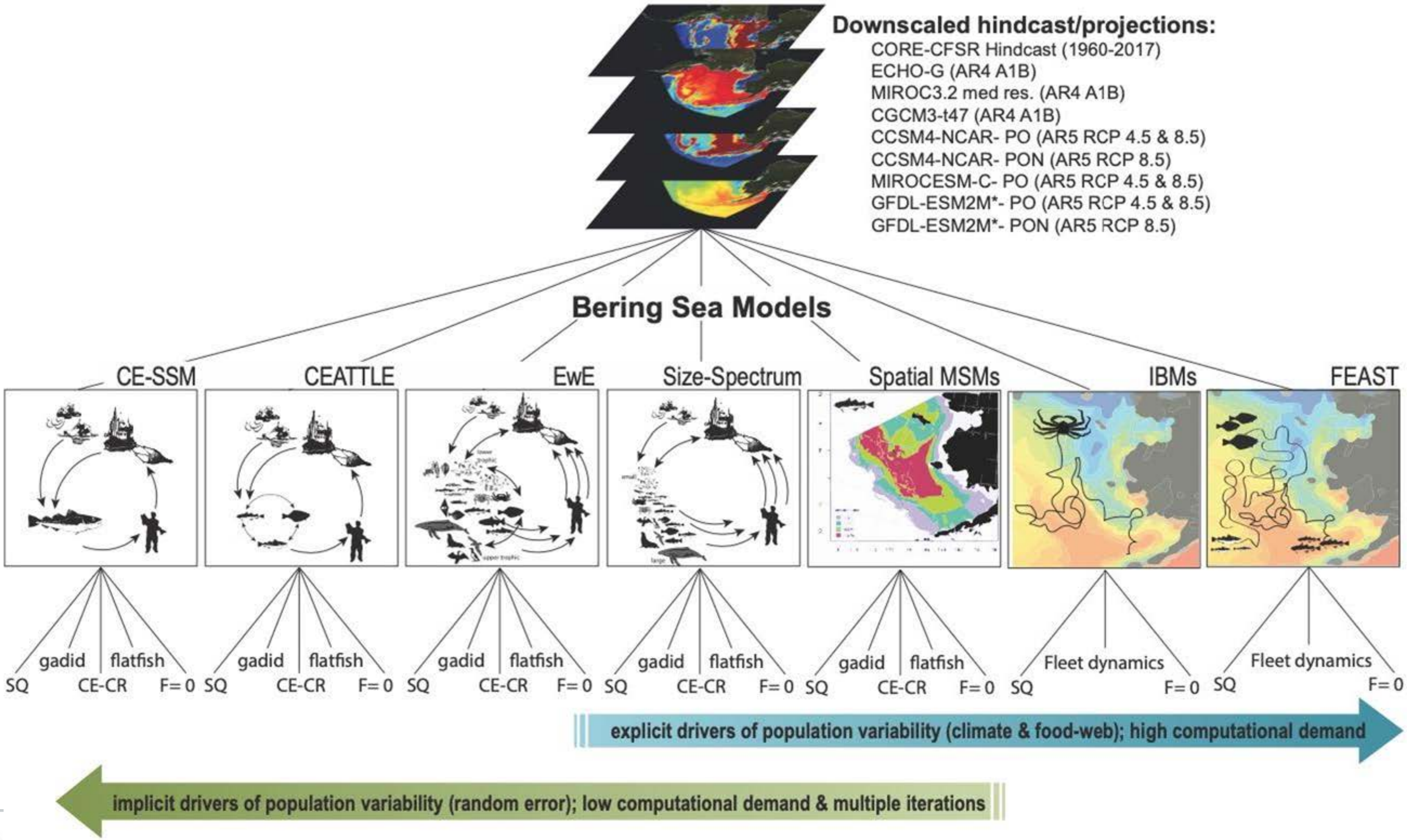
Hollowed et al. 2020. Frontiers in Mar. Sci. doi: 10.3389/fmars.2019.00775

Part 1 | Part 2 | Part 3

ACLIM Publications:

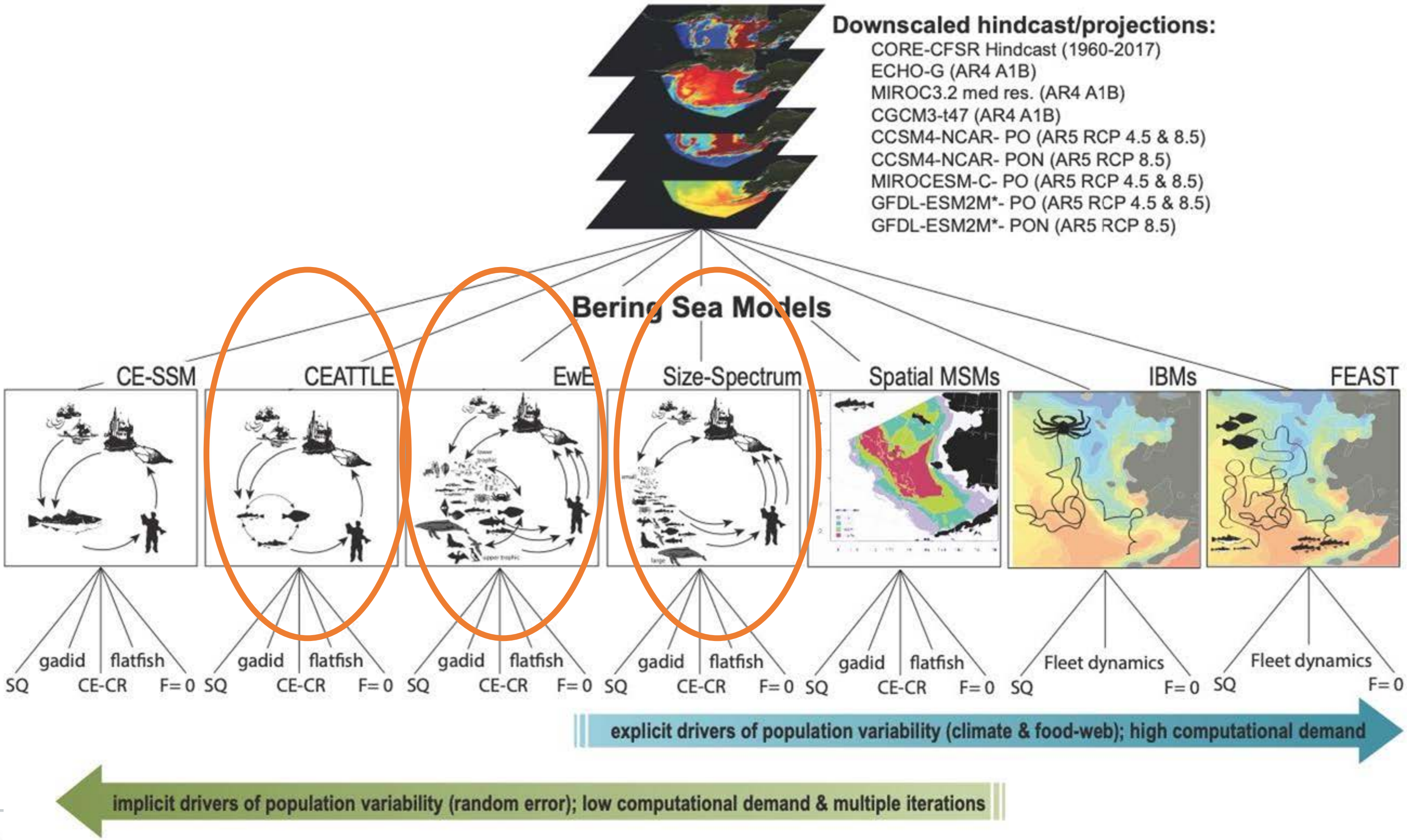
1. (in review) Torre, M. , W. T. Stockhausen, A. J. Hermann, W. Cheng, R. Foy, C. Stawitz, K. Holsman, C. Szuwalski, A. B. Hollowed. (In Review). Early life stage connectivity for snow crab, Chionoecetes opilio, in the eastern Bering Sea: evaluating the effects of temperature-dependent intermolt duration and vertical migration. Deep Sea Research II.
2. (2021) Whitehouse, G. A., K. Y. Aydin, A. B. Hollowed, K. K. Holsman, W Cheng, A. Faig, A. C. Haynie, A. J. Hermann, K. A. Kearney, A. E. Punt, and T. E. Essington. Bottom-up impacts of forecasted climate change on the eastern Bering Sea food web. Frontiers in Mar. Sci.
3. (2020) Holsman, K.K., A. Haynie, A. Hollowed, J. Reum, K. Aydin, A. Hermann, W. Cheng, A. Faig, J. Ianelli, K. Kearney, A. Punt. (2020) Ecosystem-based fisheries management forestalls climate-driven collapse. Nature Communications. DOI:10.1038/s41467-020-18300-3
4. (in review) Thorson, J., M. Arimitsu, L. Barnett, W. Cheng, L. Eisner, A. Haynie, A. Hermann, K. Holsman, D. Kimmel, M. Lomas, J. Richar, E. Siddon. Forecasting community reassembly using climate-linked spatio-temporal ecosystem models. Ecosphere
5. (Accepted) Szuwalski, W. Cheng, R. Foy, A. Hermann, A. Hollowed, K. Holsman, J. Lee, W. Stockhausen, J. Zheng. Climate change and the future productivity and distribution of crab in the Bering Sea. ICES JMS
6. (2020) Reum, J. C. P., J. L. Blanchard, K. K. Holsman, K. Aydin, A. B. Hollowed, A. J. Hermann, W. Cheng, A. Faig, A. C. Haynie, and A. E. Punt. 2020. Ensemble Projections of Future Climate Change Impacts on the Eastern Bering Sea Food Web Using a Multispecies Size Spectrum Model. Frontiers in Marine Science 7:1–17.
7. (2020) Hollowed, A. B., K. K. Holsman, A. C. Haynie, A. J. Hermann, A. E. Punt, K. Aydin, J. N. Ianelli, S. Kasperski, W. Cheng, A. Faig, K. A. Kearney, J. C. P. Reum, P. Spencer, I. Spies, W. Stockhausen, C. S. Szuwalski, G. A. Whitehouse, and T. K. Wilderbuer. 2020. Integrated Modeling to Evaluate Climate Change Impacts on Coupled Social-Ecological Systems in Alaska. Frontiers in Marine Science 6. https://doi.org/10.3389/fmars.2019.00775
8. (2019) Holsman, KK, EL Hazen, A Haynie, S Gourguet, A Hollowed, S Bograd, JF Samhouri, K Aydin, Toward climate-resiliency in fisheries management. ICES Journal of Marine Science. 10.1093/icesjms/fsz031
9. (2019) Hermann, A. J., G.A. Gibson, W. Cheng, I. Ortiz1, K. Aydin, M. Wang, A. B. Hollowed, and K. K. Holsman. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES Journal of Marine Science, fsz043, https://doi.org/10.1093/icesjms/fsz043
10. (2019) Reum, J., JL Blanchard, KK Holsman, K Aydin, AE Punt. Species-specific ontogenetic diet shifts attenuate trophic cascades and lengthen food chains in exploited ecosystems. Okios DOI: 10.1111/oik.05630
11. (2019) Reum, J., K. Holsman, KK, Aydin, J. Blanchard, S. Jennings. Energetically relevant predator to prey body mass ratios and their relationship with predator body size. Ecology and Evolution (9):201–211 DOI: 10.1002/ece3.4715

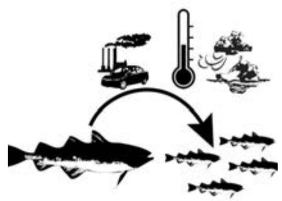
The Alaska Climate Integrated Modeling Project



Part 1 Part 2 Part 3

The Alaska Climate Integrated Modeling Project



	Climate-effects on food-webs	Sloping HCR	Multispecies effects of 2 MT Cap
			
No fishing	**X**		
No-cap	**X**	**X**	
Status quo	**X**	**X**	**X**

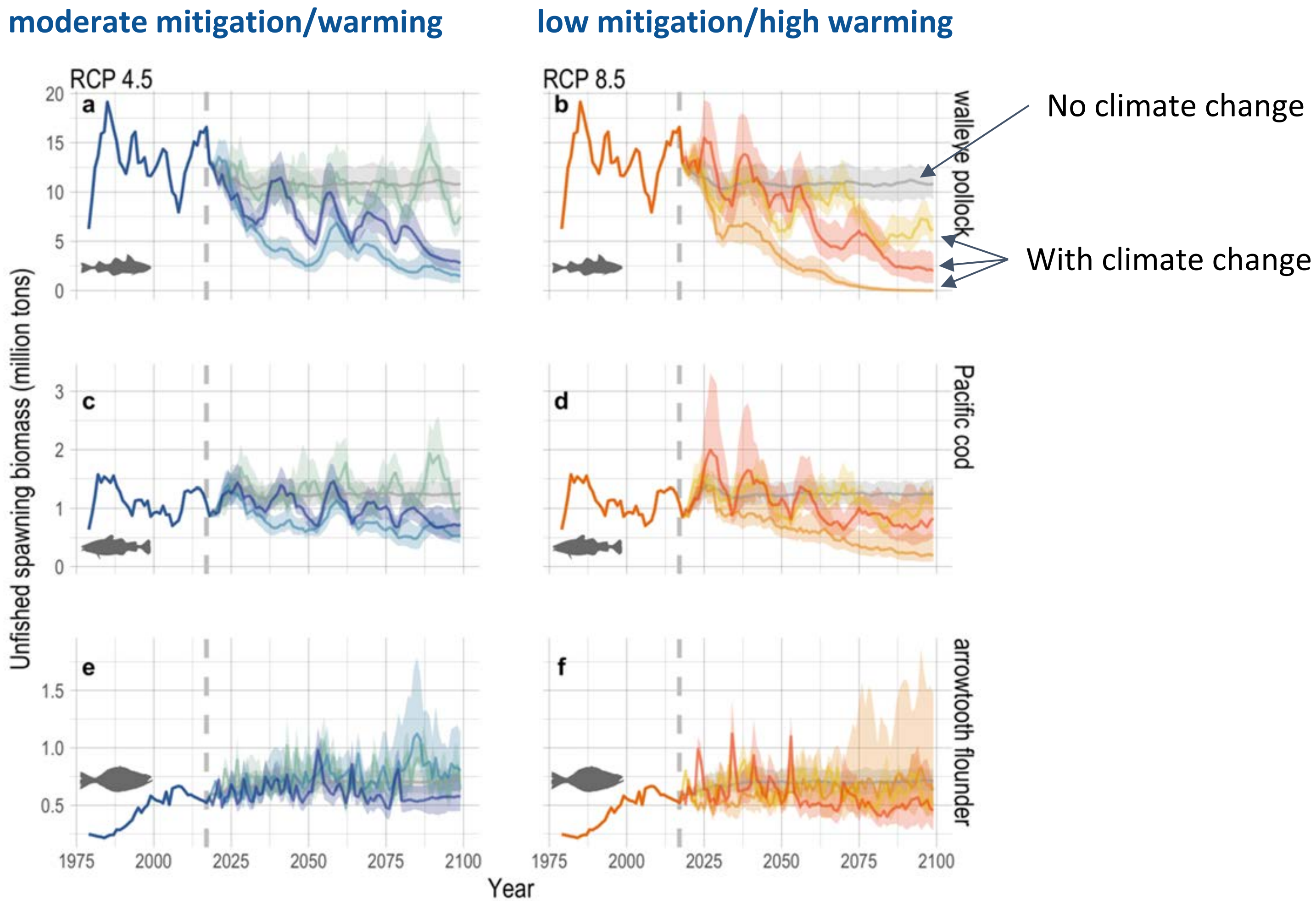
ATTACH Model (Faig & Haynie 2020): http://doi.org/10.5281/zenodo.3966545

CEATTLE: Unfished biomass (no harvest)

Assumes climate effects on recruitment, growth, & mortality

More warming =

- larger declines
- higher certainty of declines

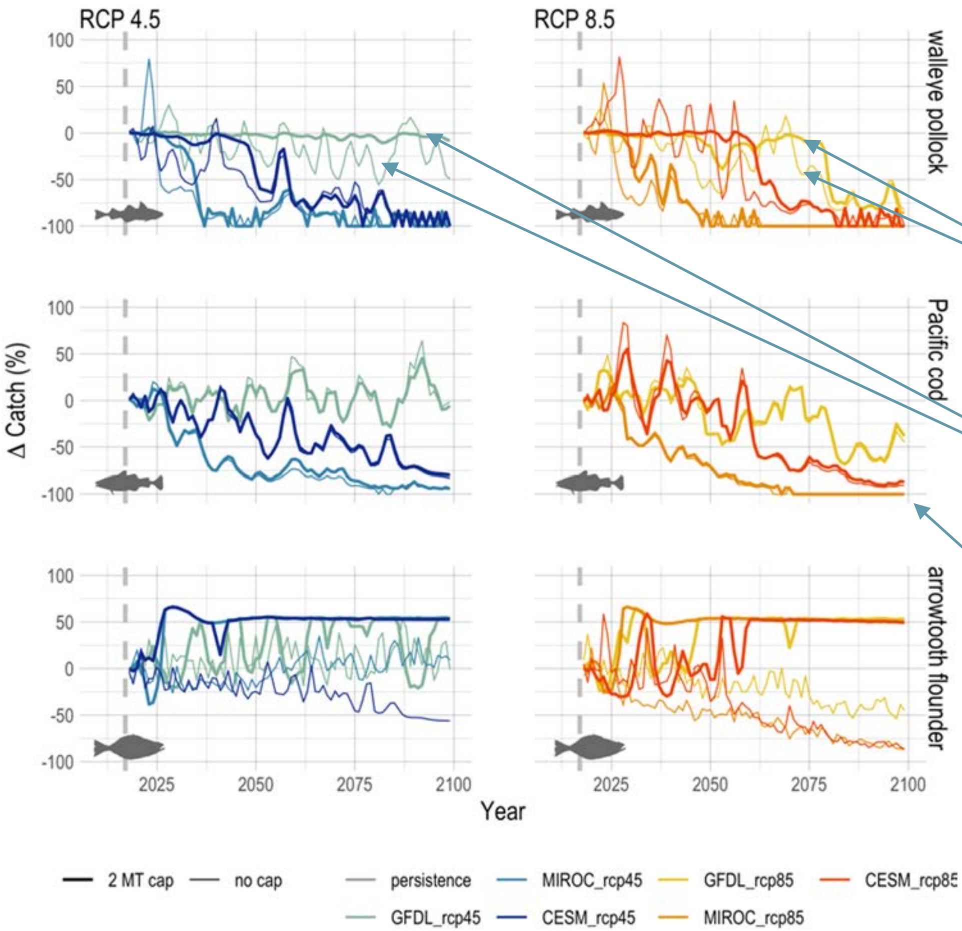


Holsman, K.K., Haynie, A.C., Hollowed, A.B. et al. Ecosystem-based fisheries management forestalls climate-driven collapse. Nat Commun 11, 4579 (2020). https://doi.org/10.1038/s41467-020-18300-3

CEATTLE: EBFM vs non-EBFM cap

Assumes climate effects on recruitment, growth, & mortality

EBFM = lowers risk of declines & collapse, although risk increases over time & with warming



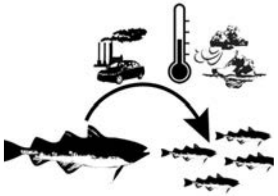
EBFM forestalled declines

EBFM stabilized catches

EBFM little effect on P. cod ($)

Holsman, K.K., Haynie, A.C., Hollowed, A.B. et al. Ecosystem-based fisheries management forestalls climate-driven collapse. Nat Commun 11, 4579 (2020). https://doi.org/10.1038/s41467-020-18300-3

The Alaska Climate Integrated Modeling Project

	Climate-effects on food-webs	Sloping HCR	Multispecies effects of 2 MT Cap
			
No fishing	**X**		
No-cap	**X**	**X**	
Status quo	**X**	**X**	**X**

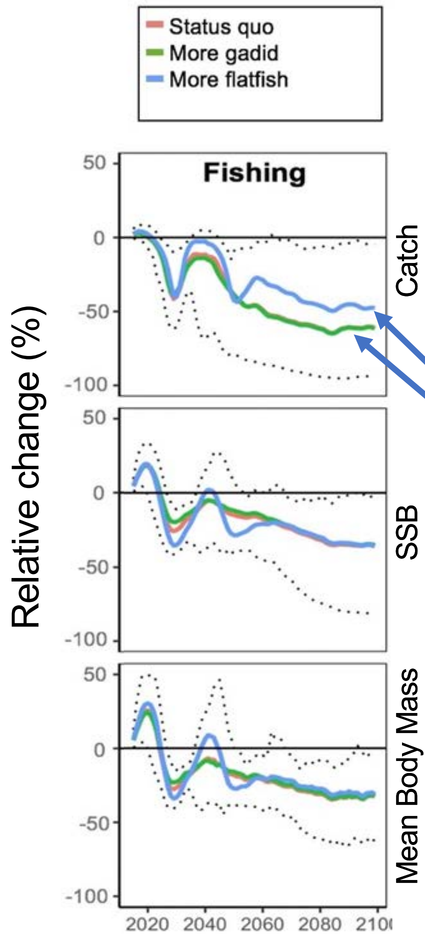
Flexibility sub-sets:
+10% more flatfish
+10% more gadid

ATTACH Model (Faig & Haynie 2020): http://doi.org/10.5281/zenodo.3966545

Part 1 Part 2 Part 3

Size-spectrum foodweb model (Reum et al. 2020)

Assumes food web dynamics are a function of size



Key Findings:

- Aggregate catch, SSB, and W decline with warming
- Species show mixed response
- Global carbon mitigation reduces declines
- Cumulative effects of Temperature on M and G are not additive
- Slight change in management flexibility can result in ~10% increase in catch over status quo

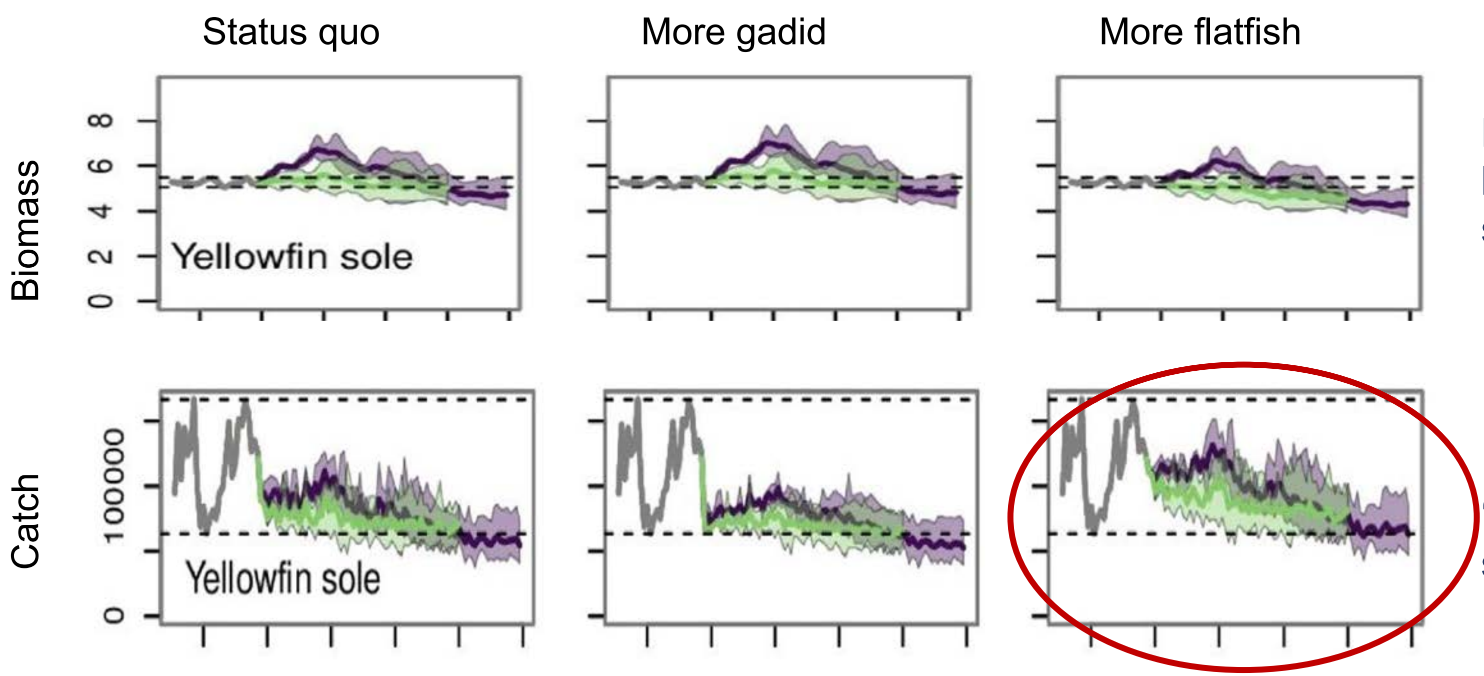
Incremental adjustments/flexibility can increase adaptive scope (slightly)

Reum, et al. 2020. Ensemble Projections of Future Climate Change Impacts on the Eastern Bering Sea Food Web Using a Multispecies Size Spectrum Model. Frontiers in Marine Science 7:1–17.

Rpath() / EwE (Whitehouse et al. 2021)

Assumes food web dynamics are a function of biomass

YFS fishing scenarios



No difference between fishing scenarios

Higher catch for 'more flatfish scenario"

Incremental adjustments/flexibility can increase adaptive scope (slightly)

Whitehouse, et al. 2021. Bottom-up impacts of forecasted climate change on the eastern Bering Sea food web. Front. Mar. Sci., 03 February 2021 | https://doi.org/10.3389/fmars.2021.624301

Rpath() / EwE (Whitehouse et al. 2021)

Assumes food web dynamics a function of biomass

General declines in seabirds

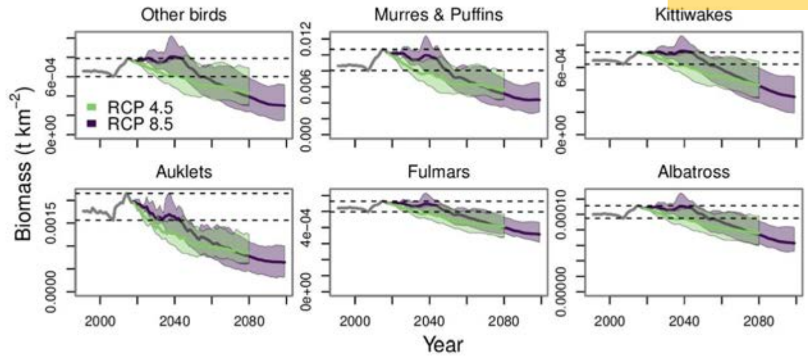


FIGURE 8 | Biomass projections for seabird functional groups. The gray line from 1991 to 2017 indicates the historical period. The purple and green poly indicate the minimum and maximum range for the three earth system models run under each RCP. The purple and green lines indicate the mean of the th each RCP. The dashed lines indicate the minimum and maximum values from the historical period.

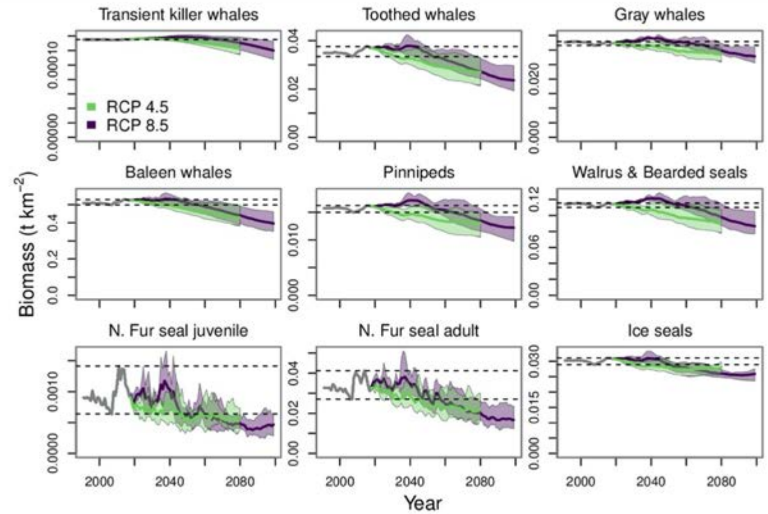


FIGURE 7 | Biomass projections for marine mammal functional groups. The gray line from 1991 to 2017 indicates the historical period. The purple and green polygons indicate the minimum and maximum range for the three earth system models run under each RCP. The purple and green lines indicate the mean of the three runs for each RCP. The dashed lines indicate the minimum and maximum values from the historical period.

General declines in marine mammals

Whitehouse, et al. 2021. Bottom-up impacts of forecasted climate change on the eastern Bering Sea food web. Front. Mar. Sci., 03 February 2021 | https://doi.org/10.3389/fmars.2021.624301

Downscaling is needed

Projections based on global climate models may underestimate future variance. Variability among GCMs is large so select multiple scenarios to downscale.

Multiple models of biological & socioeconomic dynamics are needed

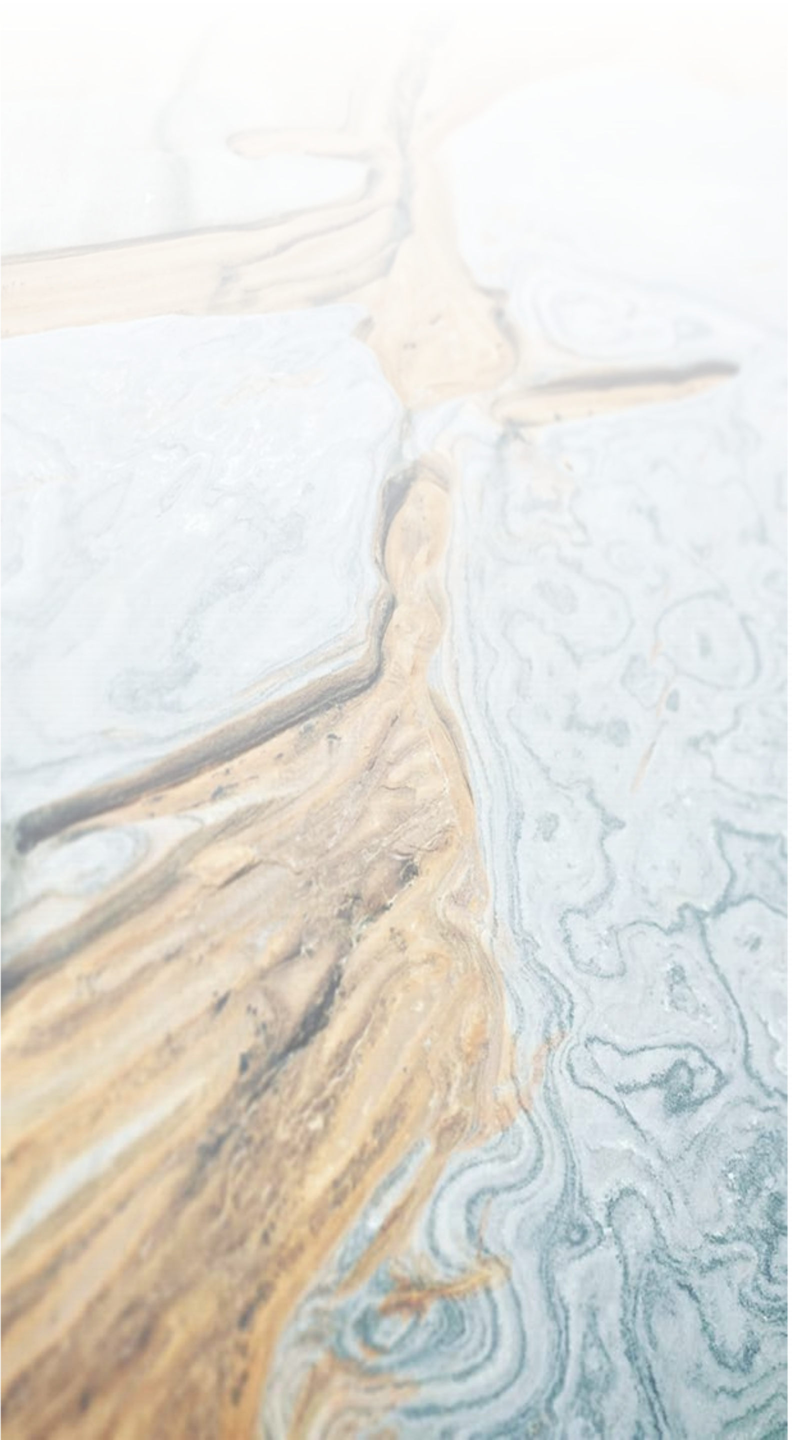
Accounting for predation changed the direction of projections from increases (single-sp model) to declines (multi-sp). Modeling management response and adaptation is needed to understand tipping points in the system. Climate impacts are non-additive and dynamics of the social-ecological system may attenuate or amplify impacts. Multiple integrated models are needed to evaluate structural uncertainty.

Mitigation is lower risk

Changes in productivity may induce large declines in fish and crab. Most pollock and cod scenarios crashed under business as usual (RCP8.5) by 2100; carbon mitigation (RCP 4.5) represents a lower risk scenario.

Adaptation through fisheries management

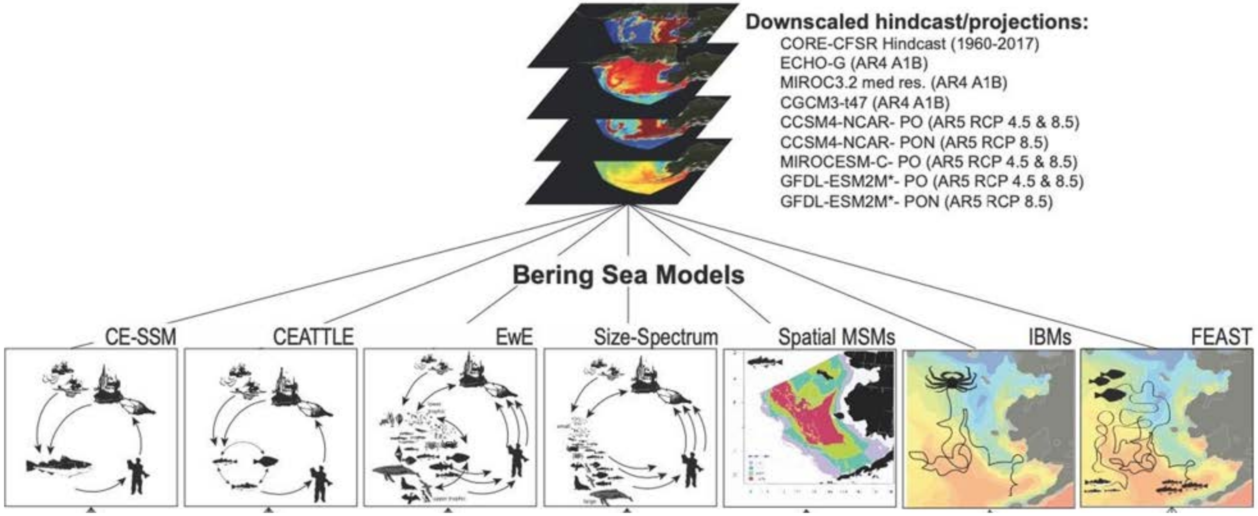
Changing harvest rates through management can help lessen climate impacts, to a point. EBFM can forestall climate declines and provide critical time to adapt.



ACLIM 2.0 Next Directions

- EBS Social- ecological system climate risk analysis
- Expanded management scenarios
- Co-production of knowledge, community workshops, and social network modeling.
- Spatial distribution models & EBS
- Expanded protected species analyses (marine mammals!)
- Expanded OA and O2 modeling
- Expanded lower trophic and YOY modeling
- *GOA through Northern Bering ACLIM via GOA-CLIM*

Diverse socioeconomic models are being coupled with the integrated physical / biological models



ACLIM 2.0 uses economic / management models of different complexity to match the needs of biological models.

- Council TAC-setting
- Effort response to abundance
- Bycatch & price sensitivities
- Spatial models of fleets

Why ACLIM 2.0 Socioeconomic Scenarios?

- Provide a tractable number of fisheries responses to projected changes in the ecosystem
- Evaluate how management strategies interact with environmental changes
  - Estimate the catch, environmental impacts, revenue, profit, and impacts on fishing communities
- Are there management changes that would improve the projected future health and productivity of the North Pacific?

The Context for Tradeoffs: U.S. National Standards

1. **Optimum Yield**
2. **Scientific Information**
3. **Management Units**
4. **Allocations**
5. **Efficiency**
6. **Variations and Contingencies**
7. **Costs and Benefits**
8. **Communities**
9. **Bycatch**
10. **Safety of Life at Sea**

U.S. marine fisheries are scientifically monitored, regionally managed, and legally enforced under a number of requirements, including ten national standards.

The National Standards are principles that must be followed in any fishery management plan (FMP) to ensure sustainable and responsible fishery management.

As mandated by the Magnuson-Stevens Fishery Conservation and Management Act, NOAA Fisheries has developed guidelines for each National Standard.

When reviewing FMPs, FMP amendments, and regulations, the Secretary of Commerce must ensure that they are consistent with the National Standard guidelines.

Photo: Alan Haynie

ACLIM 1.0 Four- Scenario Comparison

Based on Council input on the challenges of setting TACs under the 2 million ton cap, these 4 scenarios were used in analyses in ACLIM 1.0.

1. No Fishing
2. Current Ecosystem Management (Status Quo)
3. Increased Pollock-cod share of total allowable catch– max 10% increase under the cap
4. Increased Flatfish share of total allowable catch (Flatfish Dominated) – Lg. flatfish increase

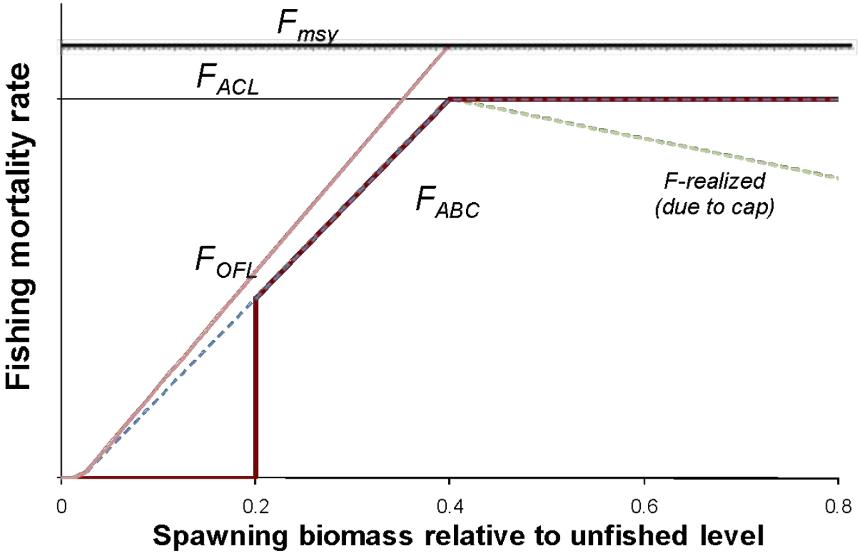
Photo: Alan Haynie

In light of climate change, what are the trade-offs of different Harvest Control Rules (HCRs)?

Boreal ecosystems are exposed to highly variable environmental conditions (seasonal, interannual and decadal).

- Over evolutionary time boreal species have adapted life history characteristics to sustain populations through perturbations.
- Sustainable fisheries policies are designed to estimate the average production necessary to replace spawners over time. Assumes some fraction of the surplus production can be harvested sustainably.
- If characteristics of emerging climate impacted ecosystem differ from those experienced in evolutionary time then knowledge of the range of reproductive potential of the population informs actions to sustain populations.

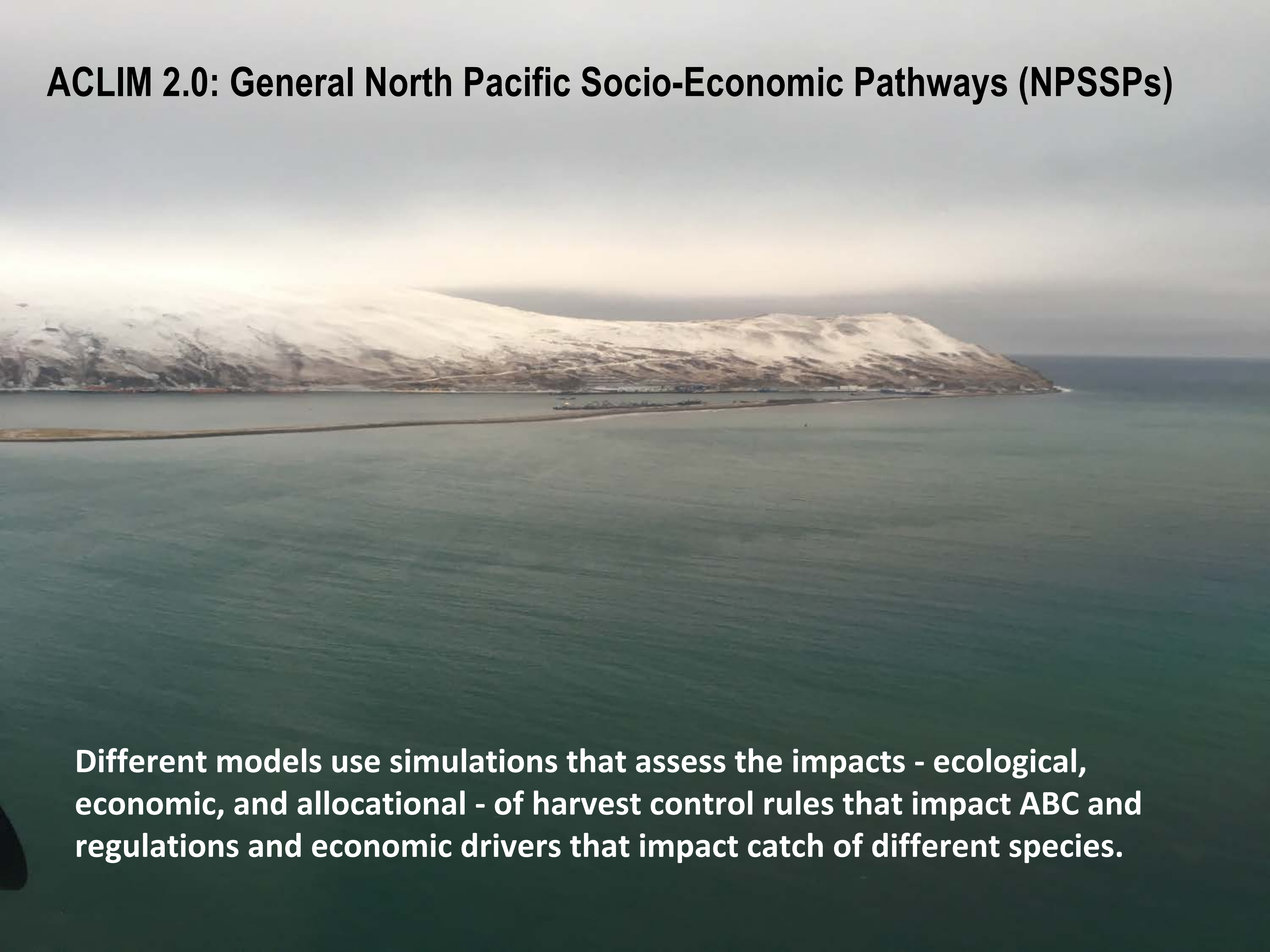
North Pacific Fishery Management Council - Pollock



Punt et al. 2010

ACLIM 2.0: General North Pacific Socio-Economic Pathways (NPSSPs)

ACLIM 2.0: General North Pacific Socio-Economic Pathways (NPSSPs)



Different models use simulations that assess the impacts - ecological, economic, and allocational - of harvest control rules that impact ABC and regulations and economic drivers that impact catch of different species.

ACLIM 2.0: General North Pacific Socio-Economic Pathways (NPSSPs)

<u>Other dimensions</u>

- Monitoring impacts
- Ecosystem models
- Emissions scenarios / models
- Diverse regulations

Note: there are additional complexities, too!

Different models use simulations that assess the impacts - ecological, economic, and allocational - of harvest control rules that impact ABC and regulations and economic drivers that impact catch of different species.

ACLIM 2.0: General North Pacific Socio-Economic Pathways (NPSSPs)

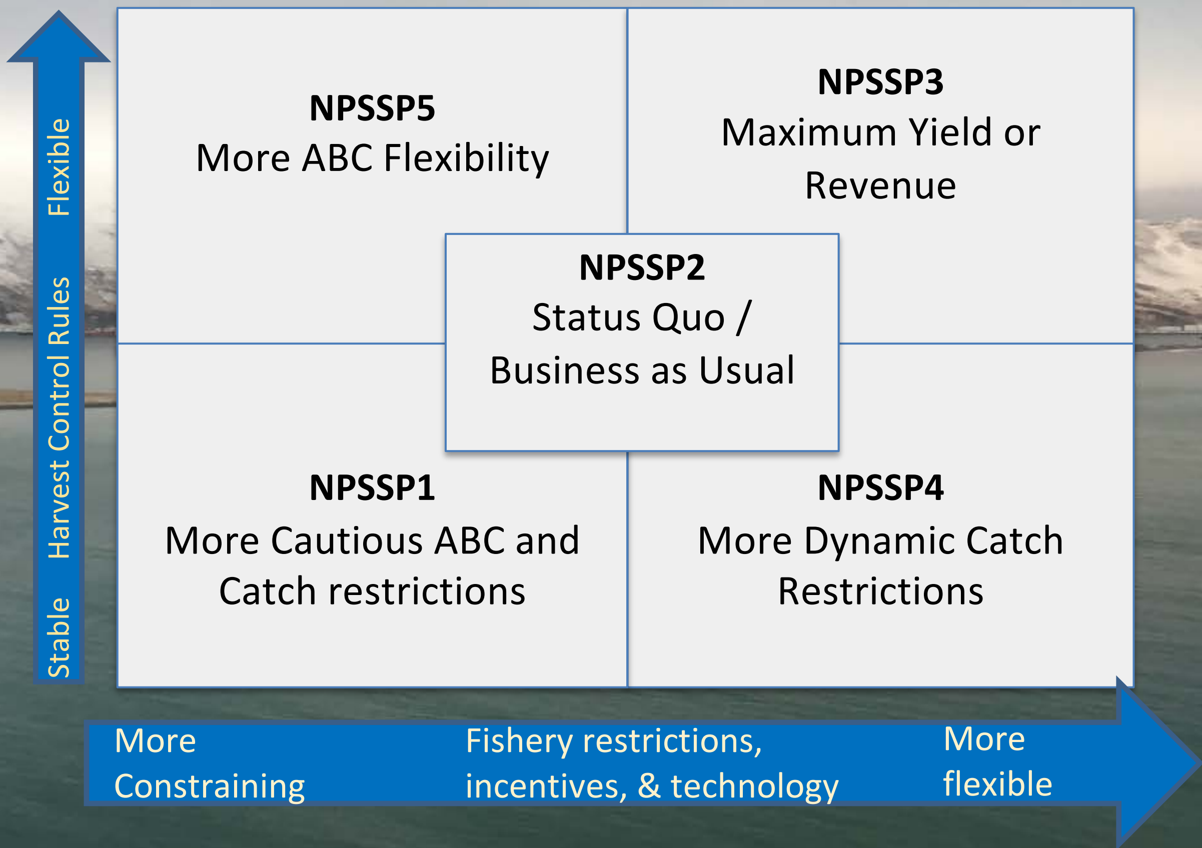
<u>Other dimensions</u>

- Monitoring impacts
- Ecosystem models
- Emissions scenarios / models
- Diverse regulations

Note: there are additional complexities, too!

Different models use simulations that assess the impacts - ecological, economic, and allocational - of harvest control rules that impact ABC and regulations and economic drivers that impact catch of different species.

ACLIM 2.0: General North Pacific Socio-Economic Pathways (NPSSPs)



<u>Other dimensions</u>

- Monitoring impacts
- Ecosystem models
- Emissions scenarios / models
- Diverse regulations

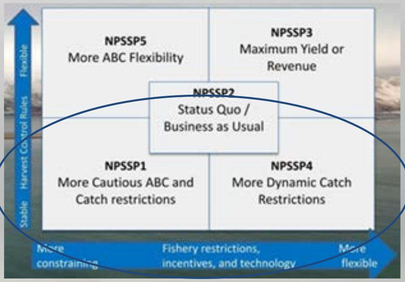
Note: there are additional complexities, too!

Different models use simulations that assess the impacts - ecological, economic, and allocational - of harvest control rules that impact ABC and regulations and economic drivers that impact catch of different species.

Caveats on Socioeconomic Scenarios

- Scenarios demonstrate trade-offs - there may be different trade-offs and priorities in the future.
- Some trade-offs may be shown beyond MSA rules - for example, understanding the impacts of loosening single-species annual catch limits in multi-species fisheries.
- Policy trade-offs examined - these are not recommendations.

Examples:



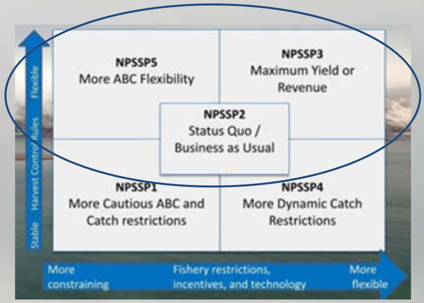
More <u>cautious / stable ABC</u> Measures

Strategy and Rationale of these measures:
Examine the impacts of scenarios that include more stable ABC policies to adjust ABC / Harvest Control Rules (HCR) with climate.

Example ABC / Harvest Control Rule (HCR) Features:

- **Thermal or ocean acidification (OA) thresholds for buffer increase to F50%, age diversity minimums**
- **climate linked M, climate linked R, climate linked growth, climate linked maturity**
- **Allow reset of HCRs to adjust for production regimes, allow time varying q for trawl fisheries due to movement out of SEBS, adjust HCR to account for shift to earlier maturation**

Examples:

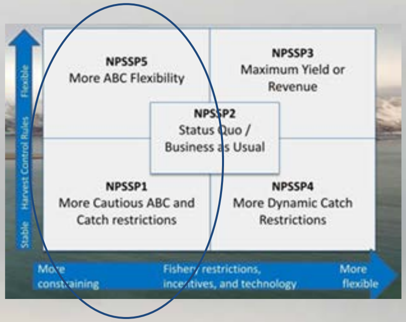


More <u>flexible ABC </u>Measures

Strategy and Rationale of these measures:
Examine the impacts of scenarios that include more flexible ABC policies to adjust ABC / Harvest Control Rules (HCR) with climate and stock changes.

Example ABC / Harvest Control Rule (HCR) Features:

- **Allow multi-year ABC averages.**
- **Remove B20 rule.**
- **Climate- or regime-specific B0 & B40.**
- **Utilize ecosystem models to explore harvest levels that would increase overall sustainable catch and/or revenue.**
- **Explore measure that would increase stability of community access to resources.**



Examples:

More <u>restrictive </u>cap, catch restrictions, incentives, and technology

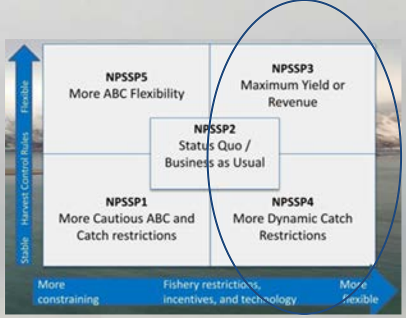
Strategy and Rationale of these measures:

- Examine the impacts of scenarios that include measures that lower the cap or reduce the catch of different species.

Example Fishery Features:

- Impact of 1.6 MMT or climate-linked Ecosystem Cap / Optimum yield
- Additional Spatial management related to protected species.
- Additional bycatch challenges that (further) limit harvest of some species.
- Increases in fishing costs or lack of growth in fish prices, leading to reduced incentives or ability to harvest as much of some species.

Examples:



More <u>flexible</u> cap, catch restrictions, incentives, and technology

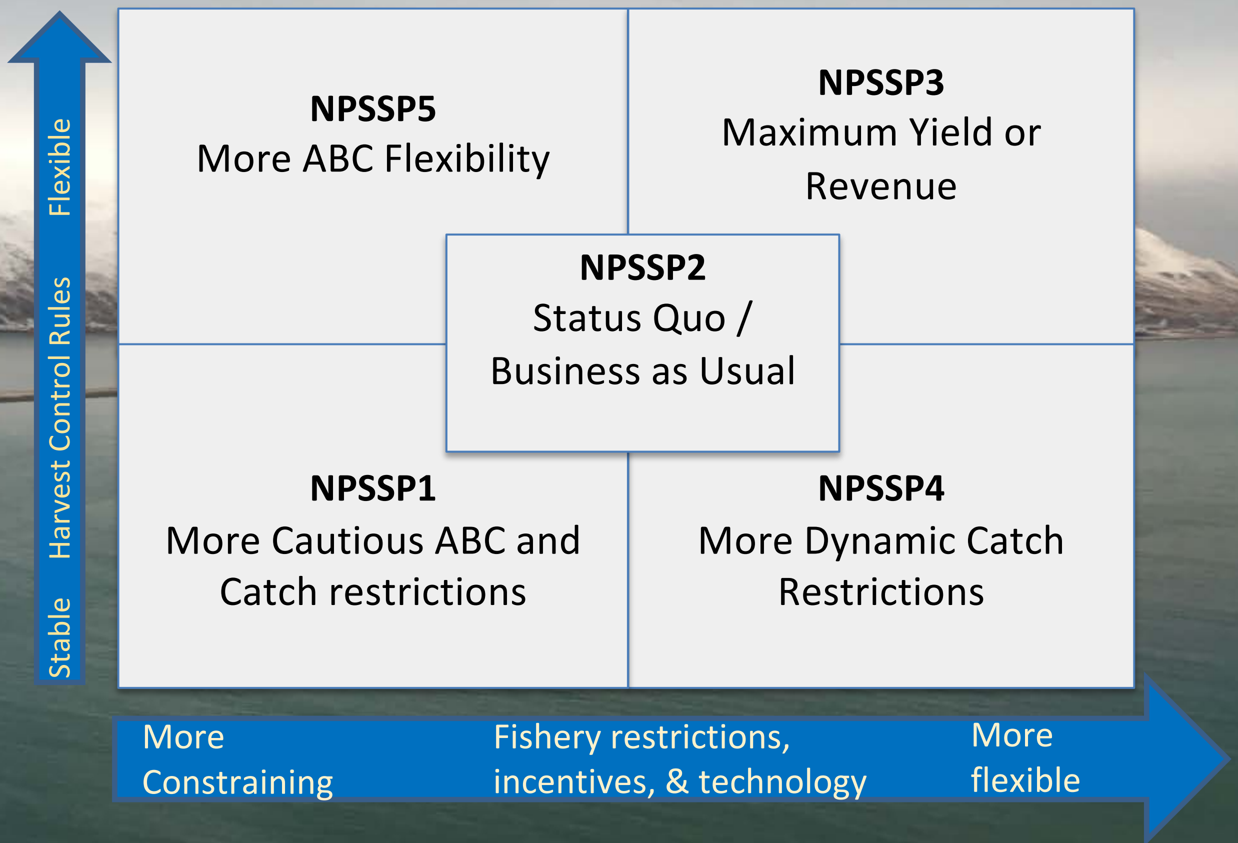
Strategy and Rationale of these measures:

- Examine the impacts and trade-offs of scenarios that include factors that lead to more flexible catch restrictions and/or greater catch.

Example Fishery Features:

- Impact of 2.4 MMT (or other) Ecosystem Cap / Optimum Yield.
- Reduced Spatial management measures when PSC quotas in place.
- Additional fishing flexibility in the Northern Bering Sea.
- Greater quota or bycatch flexibility (e.g., expanded Flatfish flexibility).
- Higher prices or improved fishing technology leading to greater catch.

ACLIM 2.0: General North Pacific Socio-Economic Pathways (NPSSPs)



The combinations of HCR and Fishery measures will be combined to explore the trade-offs that result.

Putting it all together...

Better and more realistic models

Expanded socioeconomic scenarios with input from Council and diverse communities and stakeholders

= Best available science about the trade-offs of management alternatives.

\+ An integrated system that will be continuously improved.

Photo: Alan Haynie

Input welcome today or anytime

- Input welcome from the SSC and Council now or anytime.
- Working hard now to build and integrate models.
- The sooner that we have suggestions for research directions, the more quickly we can begin to consider how to address and prioritize various concerns, but ...
- There will opportunities to give input in 2022 and beyond.
  – Including April Council Meeting.

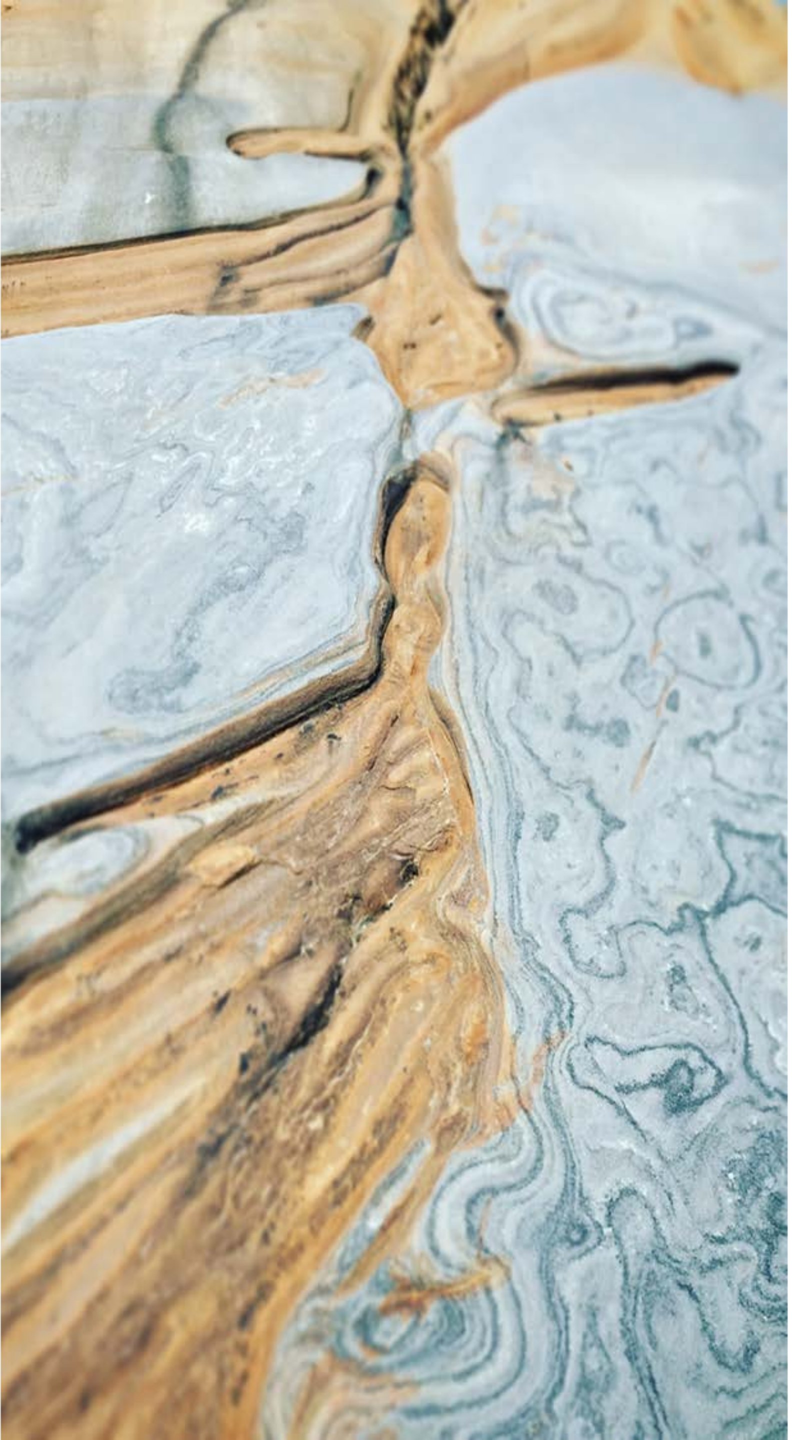
Photo: Alan Haynie

How to get involved

- Join an ACLIM 2.0 Workgroup (see next slide)
- Communicate with an of us anytime- Kirstin Holsman (Kirstin.Holsman@noaa.gov), Alan Haynie (Alan.Haynie@noaa.gov) or reach out to your favorite ACLIM member.
- NPFMC Climate Change Task Force
  - ACLIM WG11: PI Communication coordination: management, on ramps to Council and international coordination and communication
- Fishery Ecosystem Plan (FEP)

ACLIM 2.0 Working Groups:
Cross-organizational teams created to couple new ACLIM 2.0 activities with existing research and projects.

1. Ensemble modeling
2. Climate downscaling and ocean modeling
3. Spatial Modeling
4. Social, economic, and fishery modeling
5. Climate enhanced Stock Assessment Models and HCRs
6. Food web models
7. Ecophysiology, energetics, IBMs, & early life history working
8. Marine mammals
9. Indicators for ESRs and ESP
10. Post-docs / students across ACLIM and GOA-CLIM
11. PI Communication coordination: management, on ramps to Council and international coordination and communication



Thanks!

- ACLIM 1.0 funding:
  - Fisheries & the Environment (FATE)
  - Stock Assessment Analytical Methods (SAAM)
  - Climate Regimes & Ecosystem Productivity (CREP)
  - NMFS Economics and Human Dimensions Program
  - NOAA Integrated Ecosystem Assessment Program (IEA)
  - NOAA Research Transition Acceleration Program (RTAP)
  - Alaska Fisheries Science Center
- ACLIM 2.0 funding:
  - NOAA's Coastal and Ocean Climate Applications (COCA) Climate and Fisheries Program
  - NOAA Integrated Ecosystem Assessment Program (IEA)
  - Alaska Fisheries Science Center

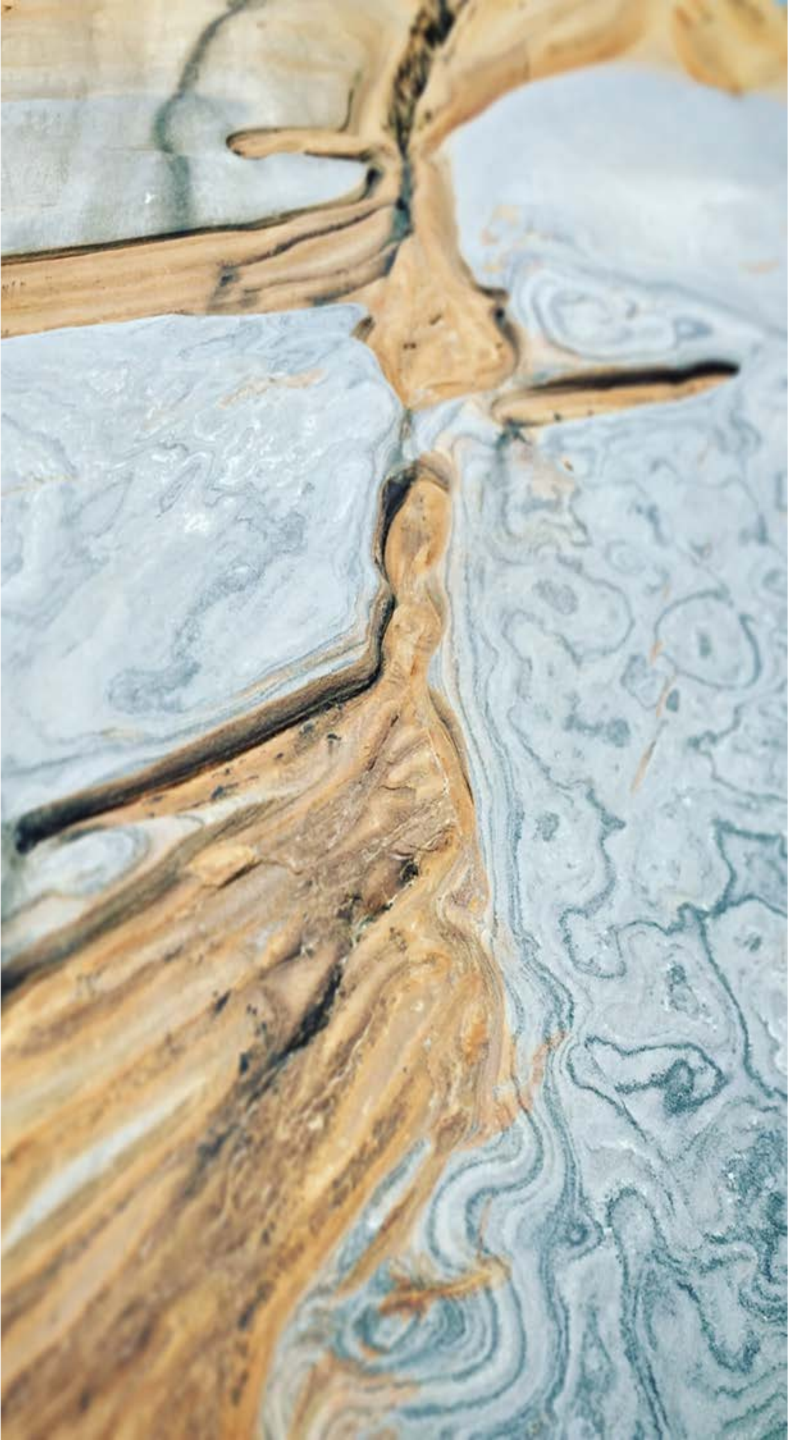
Collaboration support:

- NPRB & BSIERP Team
- GOA-CLIM Team
- AFSC REEM, REFM, RACE
- ICES PICES Strategic Initiative on climate change and marine ecosystems (SICCME/S-CCME)
- NPFMC Climate change task force, the Ecosystem Committee of the NPFMC
- FAO
- MAPP

QUESTIONS?


kirstin.holsman@noaa.gov


Alan.Haynie@noaa.gov



Glossary of Terms

- IPCC : United Nations Intergovernmental Panel on Climate Change
- NOAA : National Oceanic and Atmospheric Administration
- NMFS : National Marine Fisheries Service
- Council : North Pacific Fisheries Management Council
- CE - : "Climate Enhanced" -
- GCM : General Circulation Model (Global in scale)
- RCP : Representative (carbon) Concentration Pathway
- FEP : Fisheries Ecosystem Plan
- ROMS : Regional Ocean Modeling System
- NPZ : Nutrient Phytoplankton Zooplankton Model
- CEATTLE : Climate Enhanced Assessment with Temperature and Trophic Linkages & Energetics Model
- FEAST : Forage and Euphausiid Assessment in Space and Time model
- SES : coupled Social-Ecological System