ACLIM : Lessons learned from coupled climate-ecosystem-socioeconomic models

BECI workshop June 2022

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NOAA Alaska Fisheries Science Center

ACLIM Team

Supporting climate resilience through climate-informed Ecosystem Based Management advice

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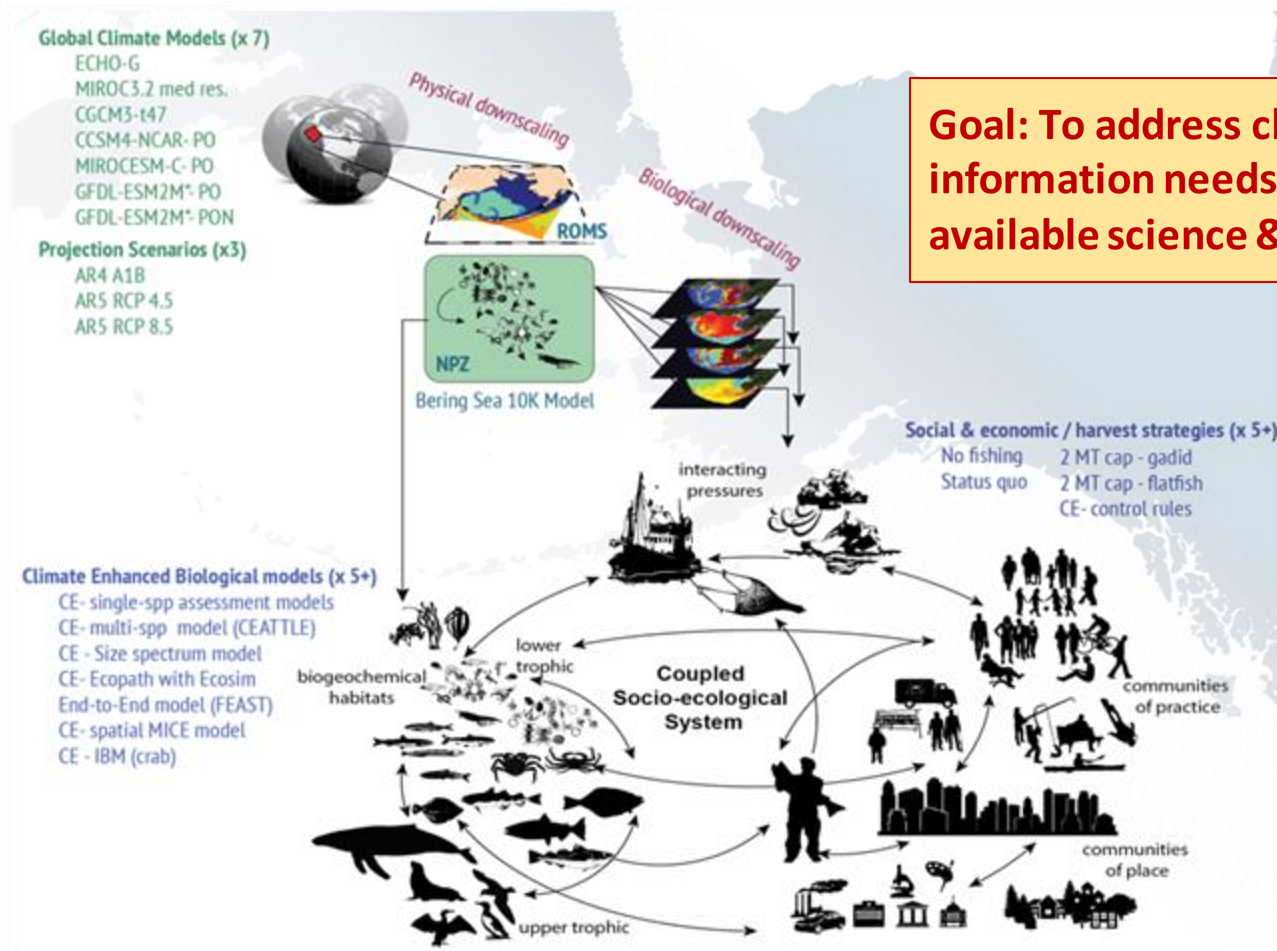
Lauren Rogers
Ben Laurel

The Alaska Climate Integrated Modeling Project

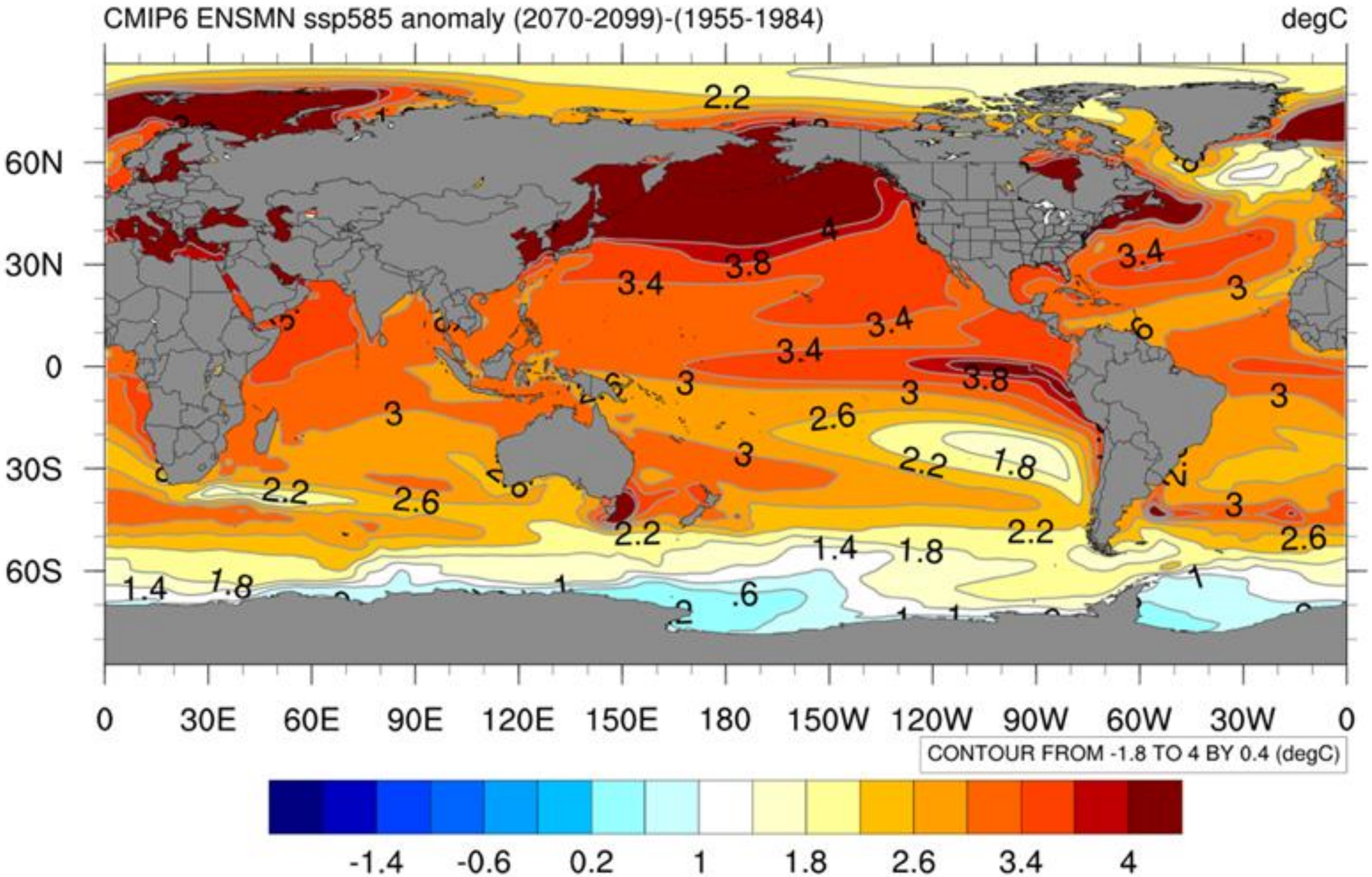
www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project



Goal: To address climate information needs with best available science & tools

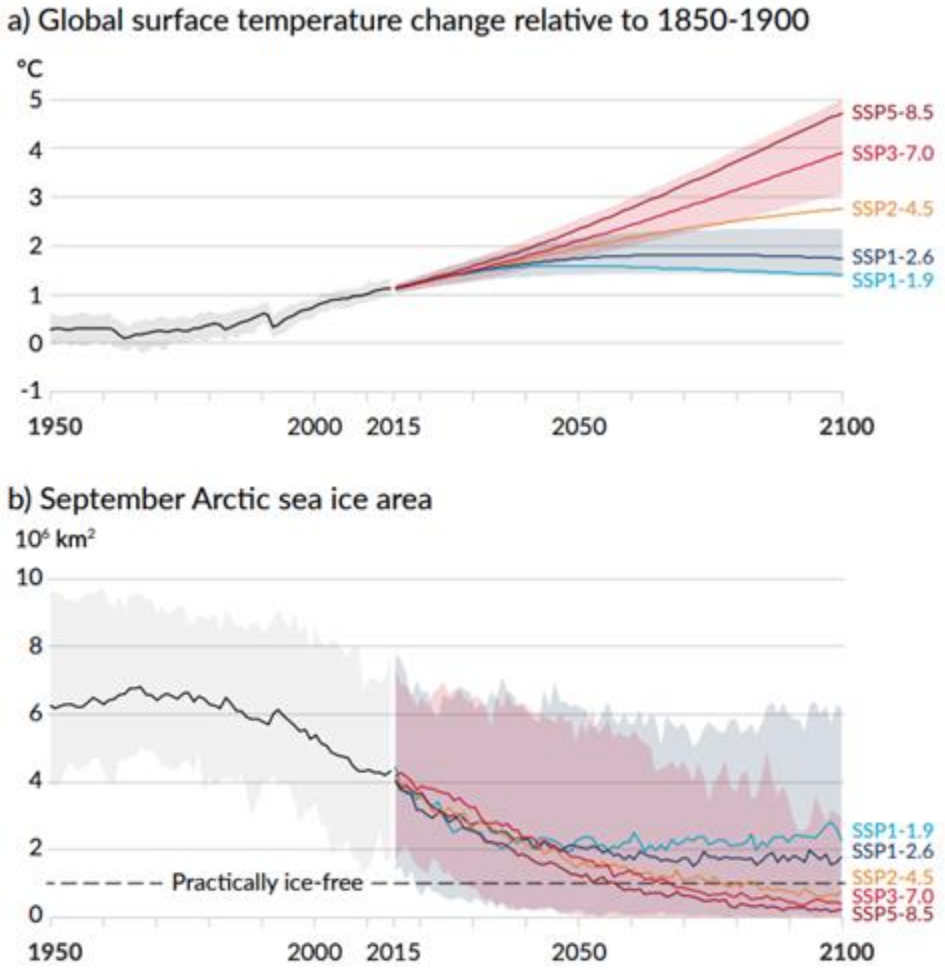
UNIVERSITY *of* WASHINGTON
SAFS School of Aquatic and Fishery Sciences
PMEL
JISAO
Joint Institute for the Study of the Atmosphere and Ocean
IEA INTEGRATED ECOSYSTEM ASSESSMENT
NOAA FISHERIES

Climate change is expected to continue to impact AK Ecosystems & Fisheries



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

Climate change is expected to continue to impact AK Ecosystems & Fisheries



Carbon Emission Scenarios

"plausible descriptions of how the future may evolve with respect to a range of variables…they are not meant to be policy prescriptive, (i.e. no likelihood or preference is attached to any of the individual scenarios of the set)"

van Vuuren et al. 2011

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

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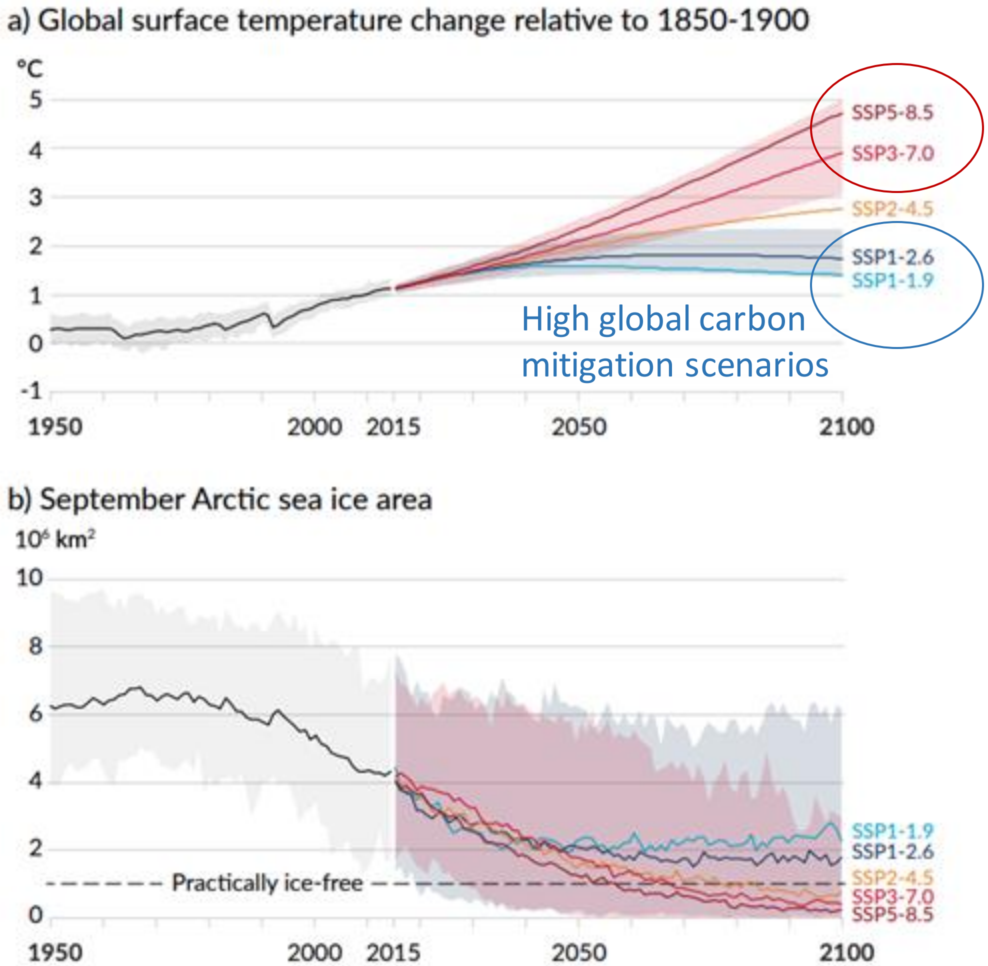

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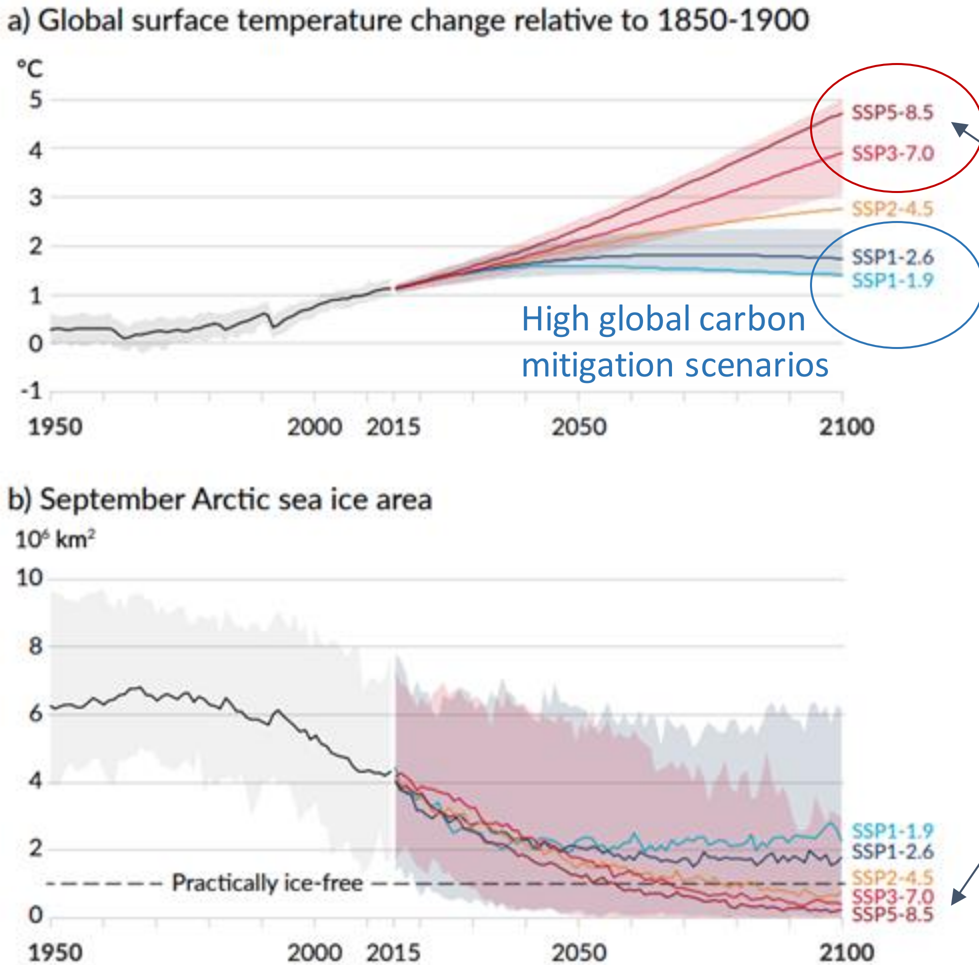
Climate change is expected to continue to impact AK Ecosystems & Fisheries



Low carbon mitigation scenarios

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

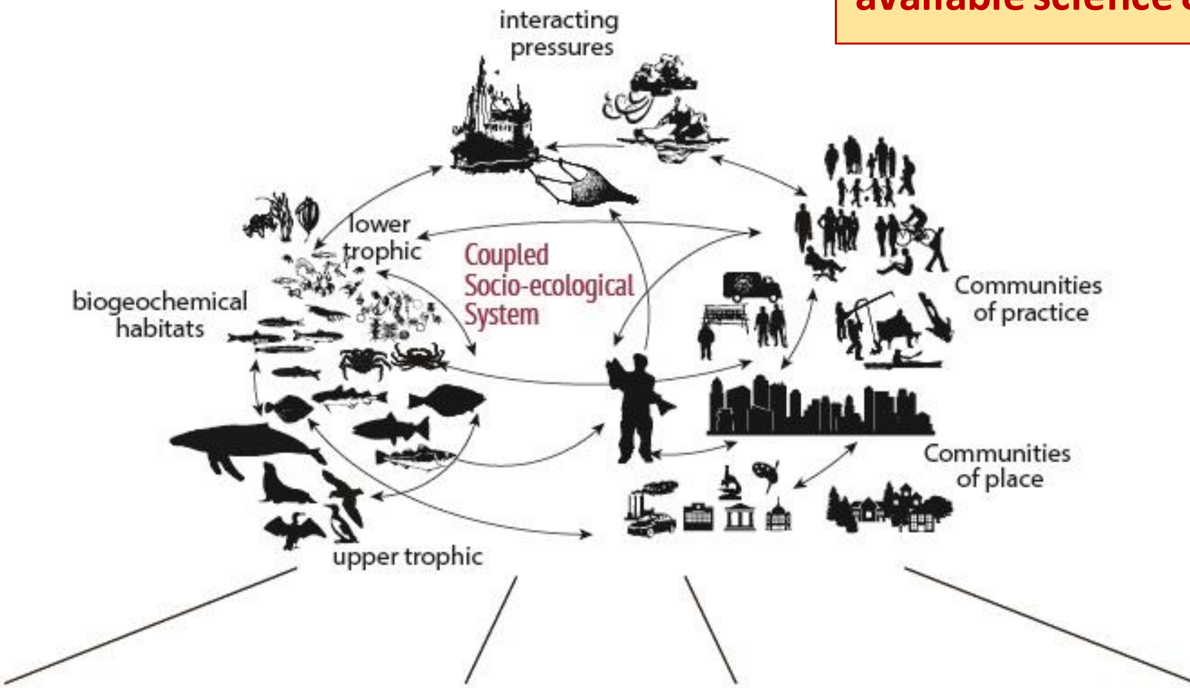
ACLIM aims to address:

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

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

The Alaska Climate Integrated Modeling Project

Goal: To address climate information needs with best available science & tools



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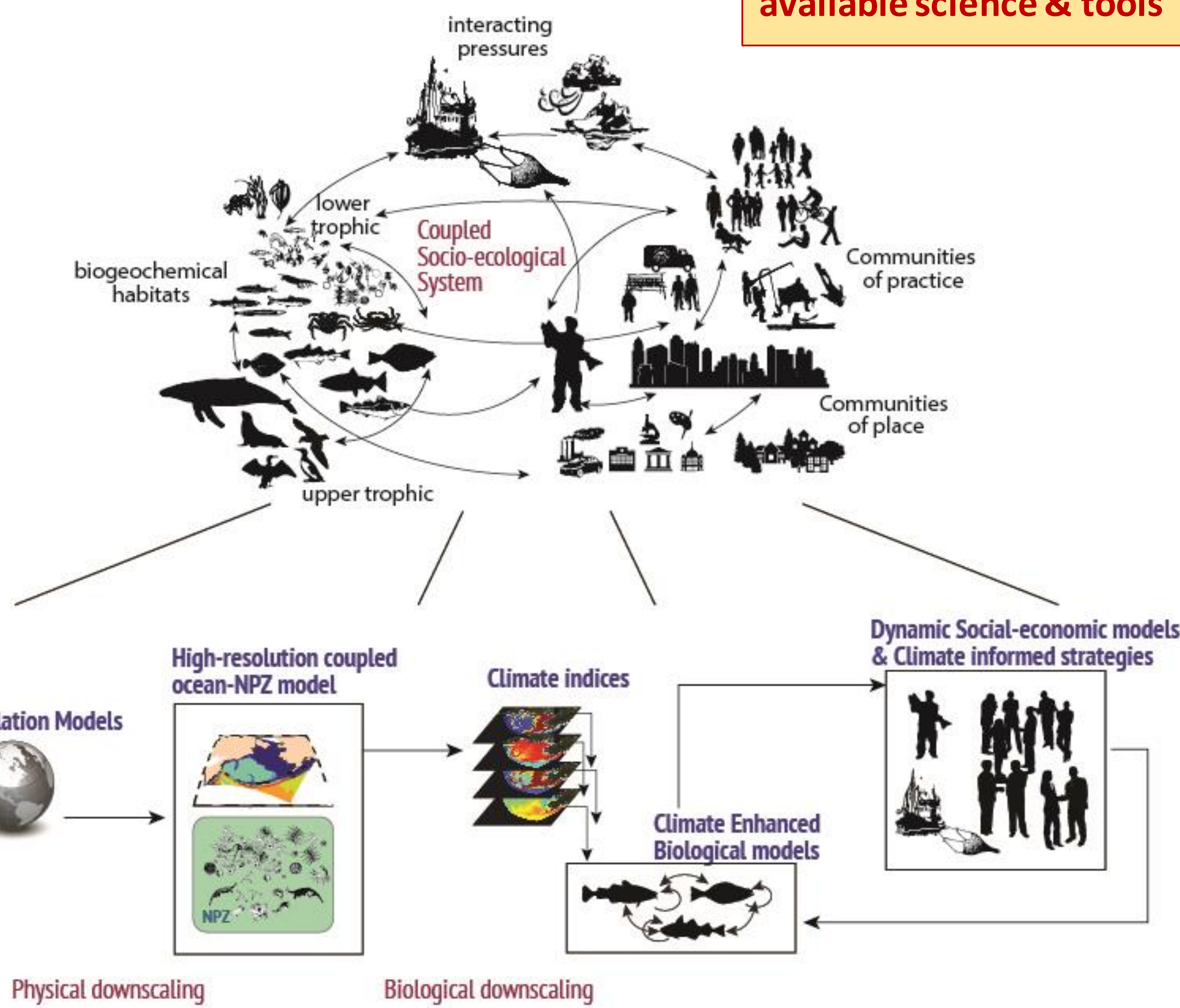
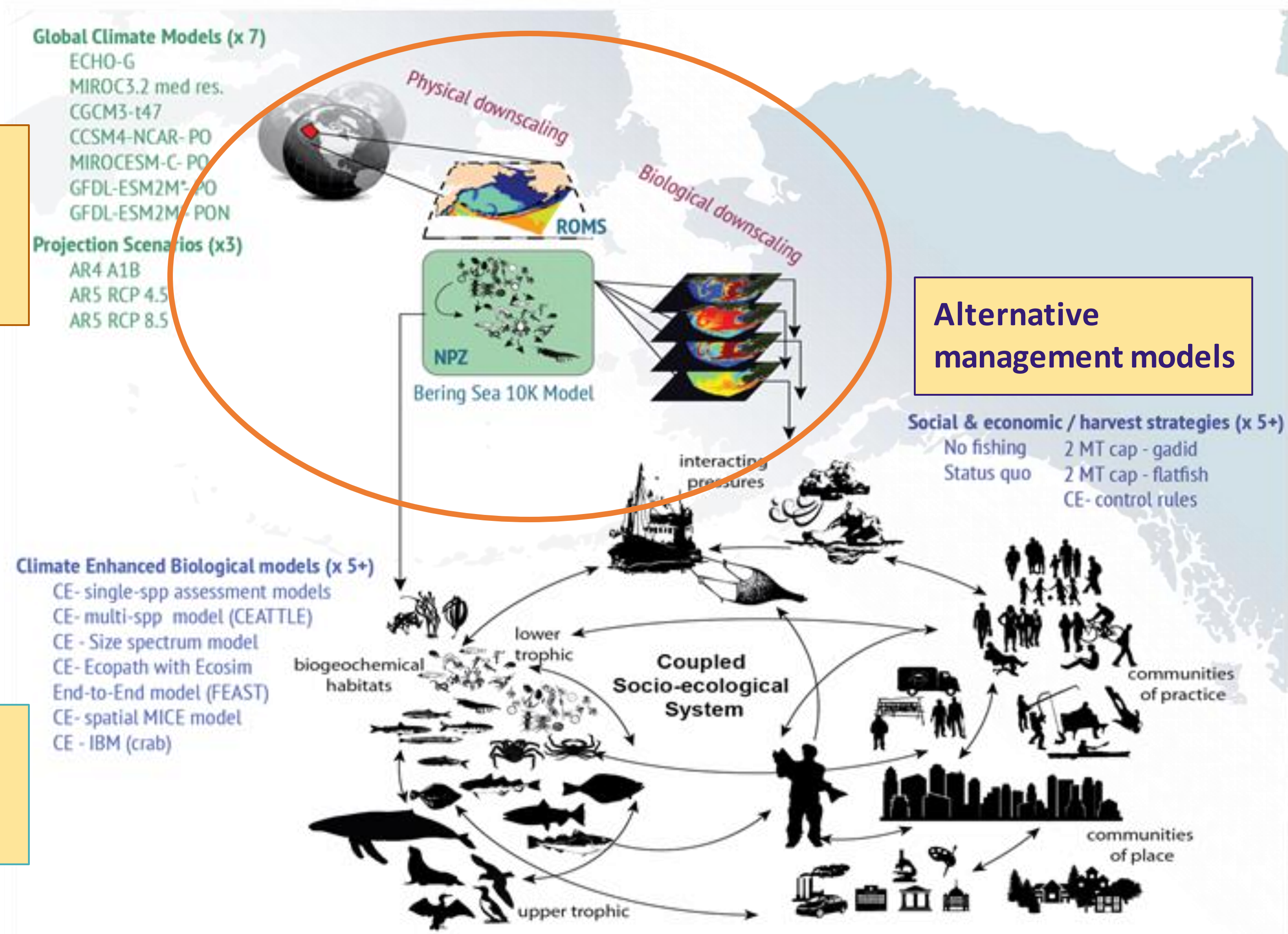


Bering Sea Oceanographic Projections

The Alaska Climate Integrated Modeling Project

High resolution realistic ocean projections under climate scenarios

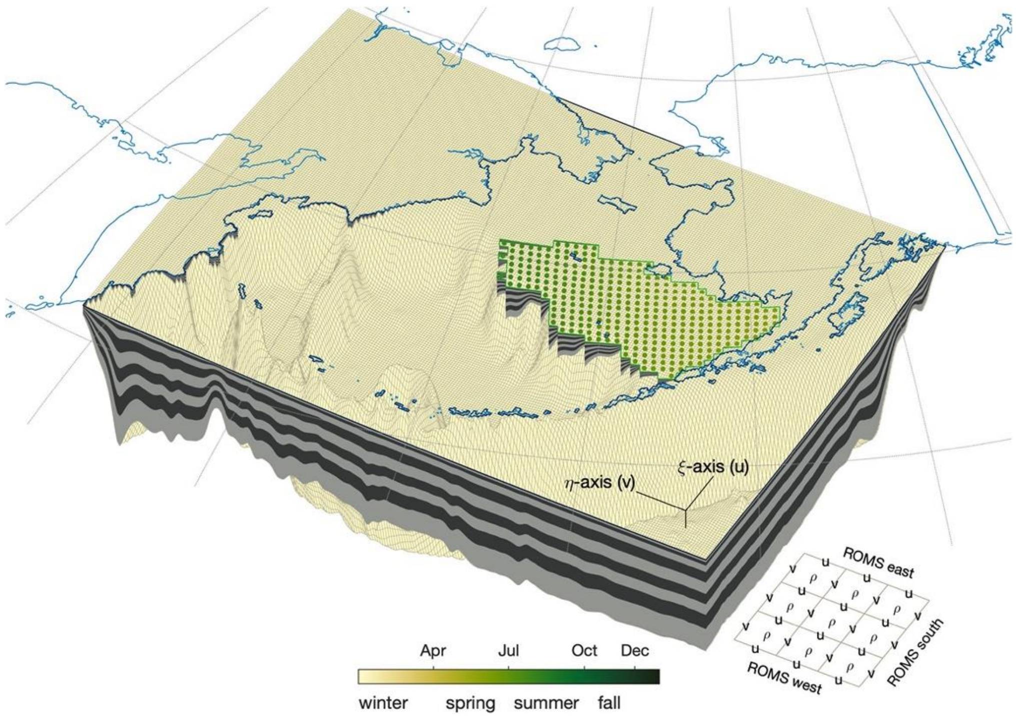


Alternative management models

Climate driven changes to species & food-webs

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

Bering 10K ROMSNPZ model



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Hermann et al. 2013,2016, 2019; Kearney et al. 2020; Hollowed et al. 2020. Frontiers in Mar. Sci. doi: 10.3389/fmars.2019.00775

High-res model reproduces the Bering Sea environment

OBSERVATIONS ROMSNPZ (downscaled) GLOBAL MODEL

2003

2009

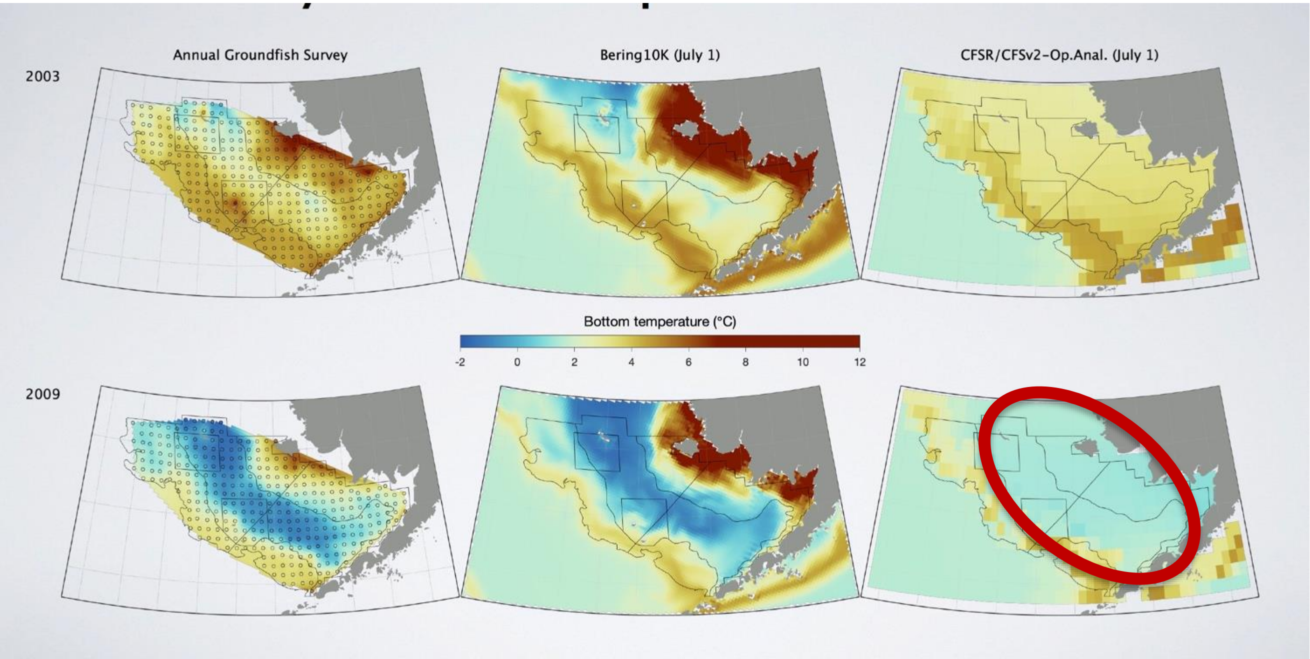
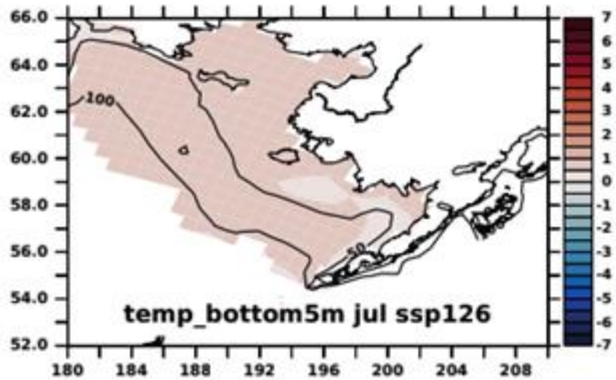


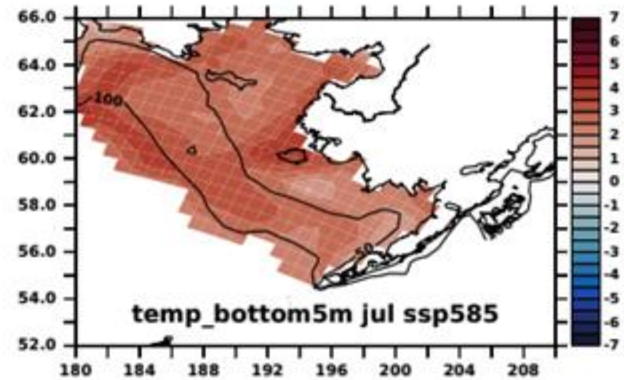
Image: Kelly Kearney

Downscaling is needed

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 expected

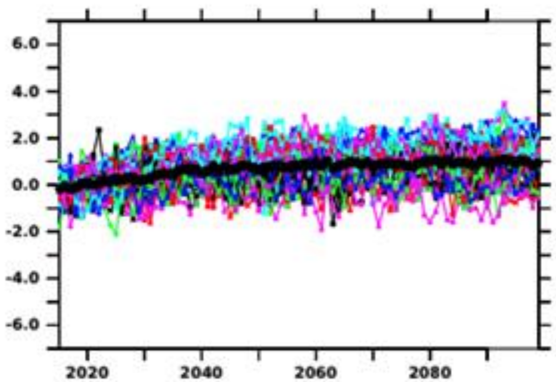




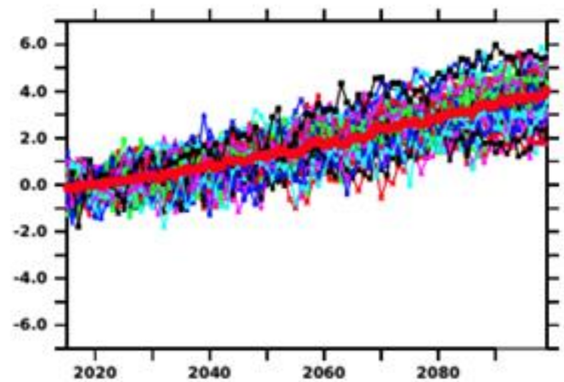
Bottom Temp. (^oC)

SSP126: High CO2 mitigation (less warming)

SSP585: Low CO2 mitigation (high warming)



Up to + 2 ^oC

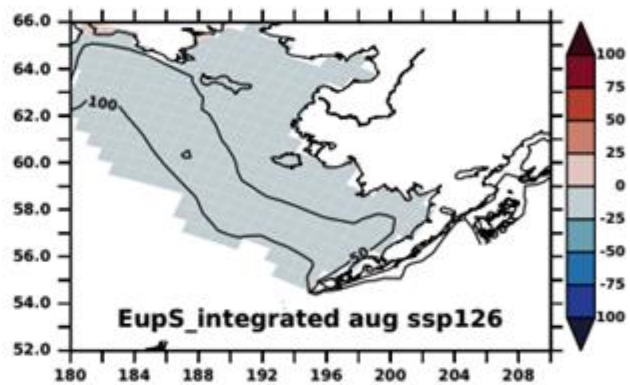


Up to + 6 ^oC

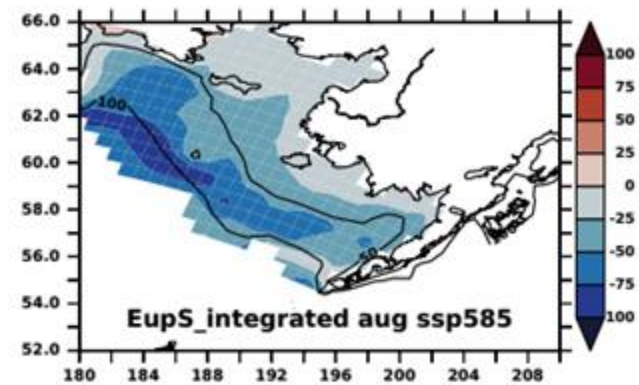
Hermann, et al. (2021). Coupled modes of projected regional change in the Bering Sea from a dynamically downscaling model under CMIP6 forcing. Deep-Sea Research Part II: Topical Studies in Oceanography, 194 (Dec), 104974. https://doi.org/10.1016/j.dsr2.2021.104974

Declines in Euphausiids expected

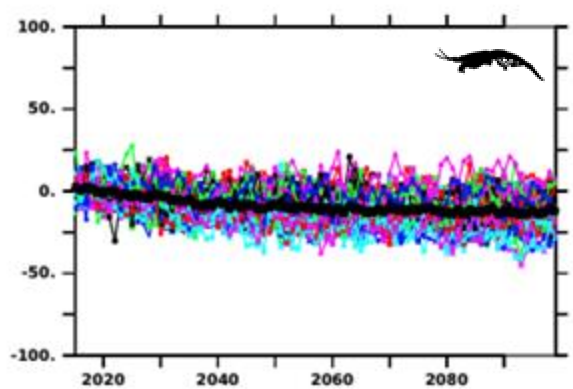
Euphausiid biomass

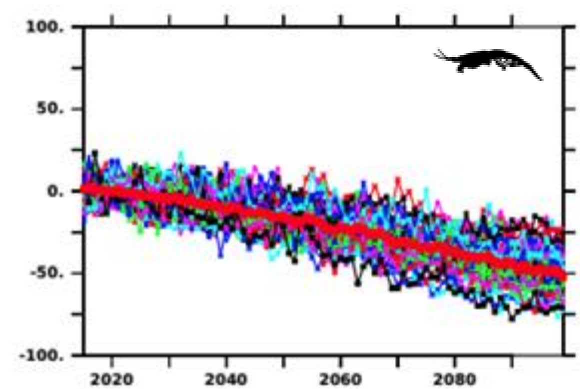


SSP126: High CO2 mitigation (less warming)



SSP585: Low CO2 mitigation (high warming)





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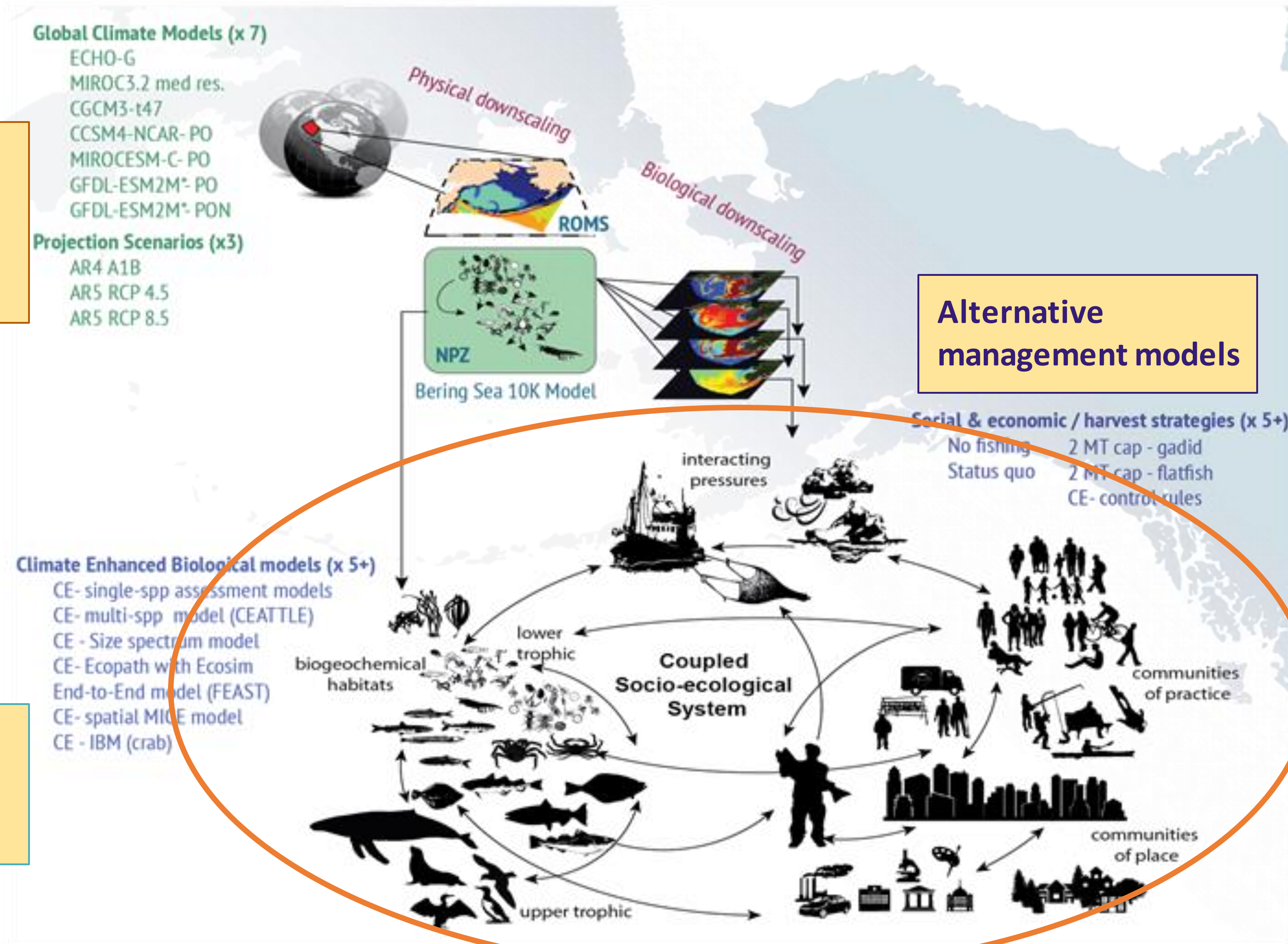
Climate + Biological + Management Modeling

The Alaska Climate Integrated Modeling Project

High resolution realistic ocean projections under climate scenarios

Alternative management models

Climate driven changes to species & food-webs



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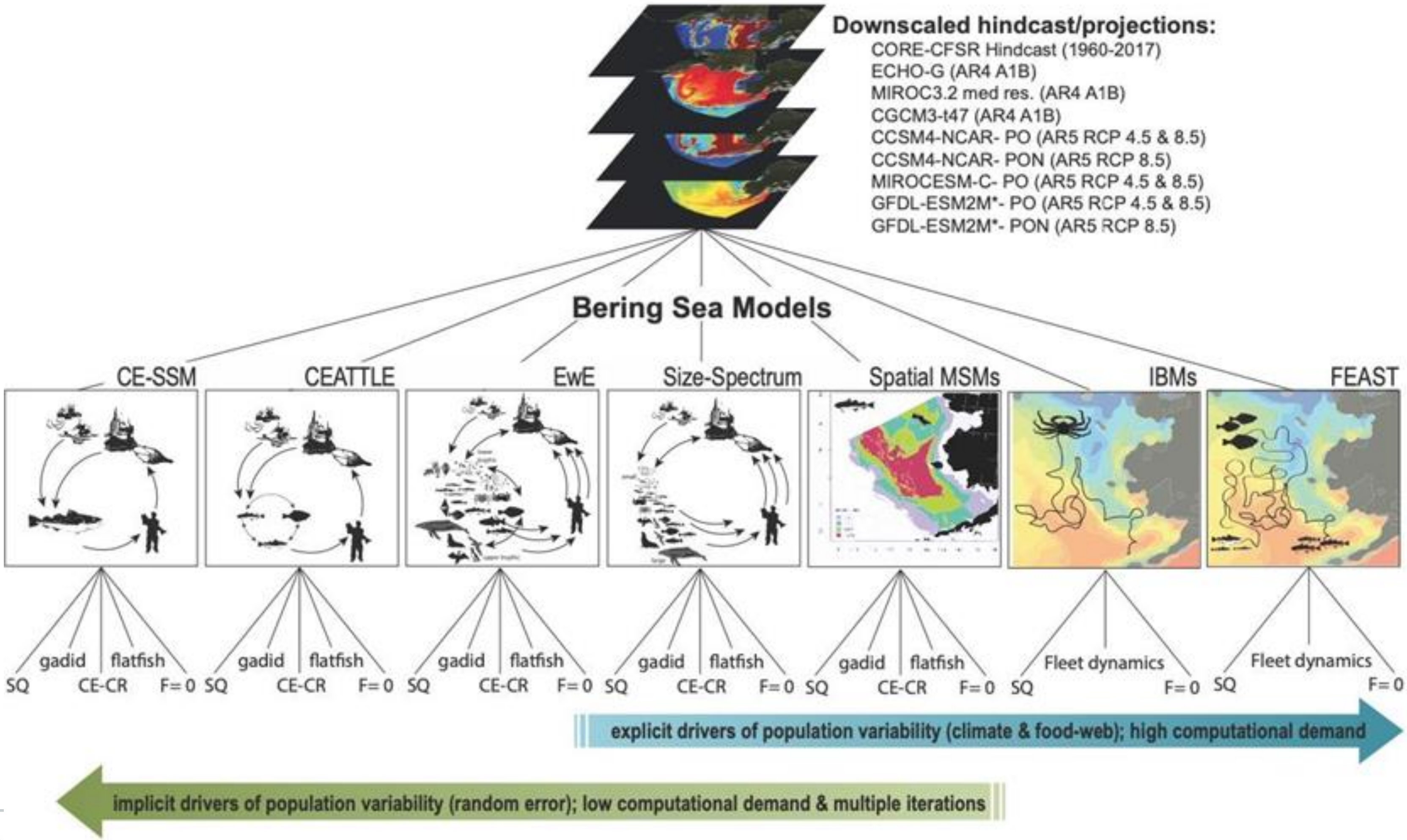
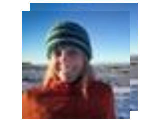
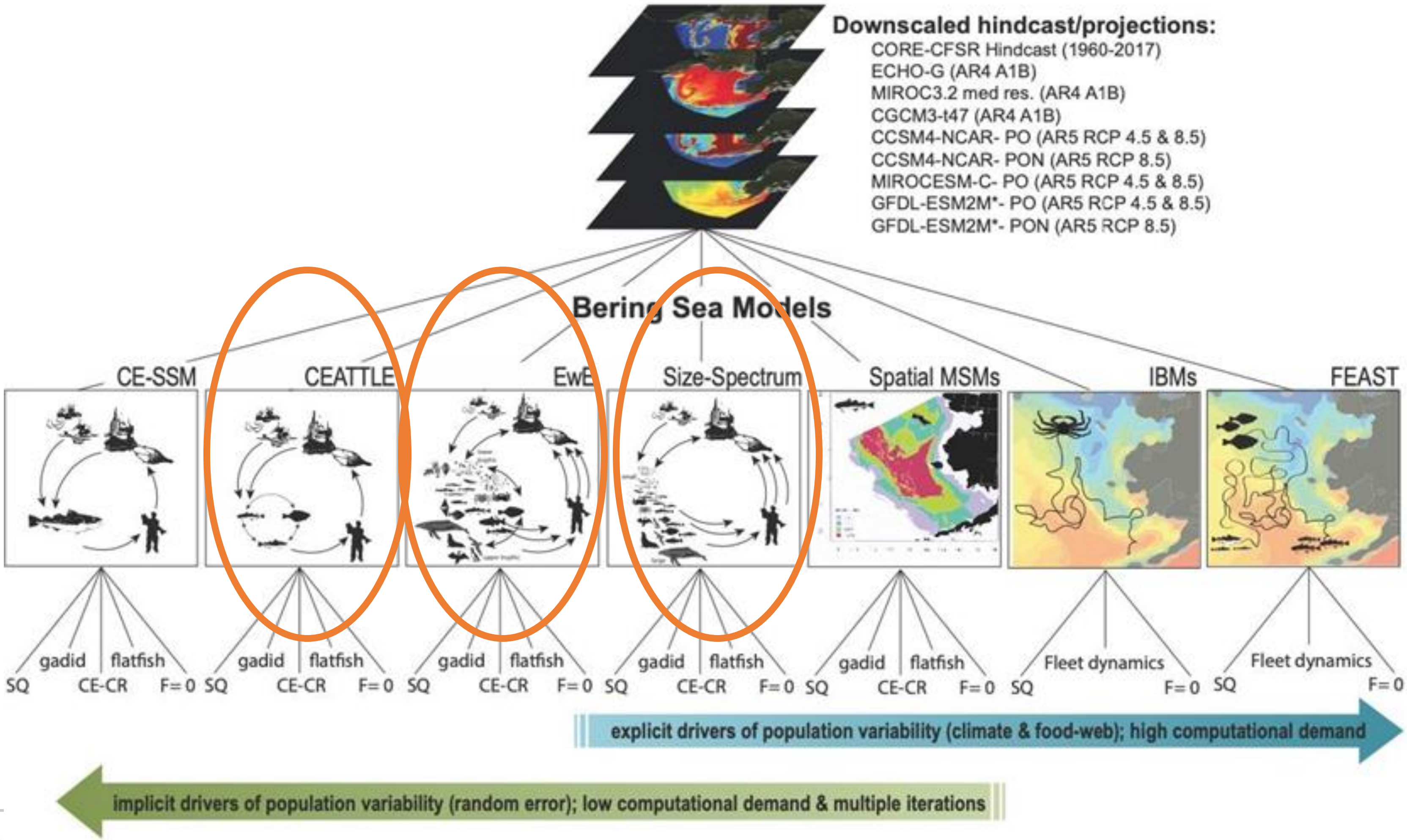
The Alaska Climate Integrated Modeling Project

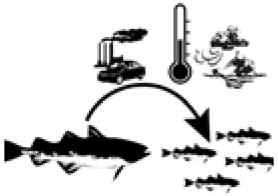


The Alaska Climate Integrated Modeling Project





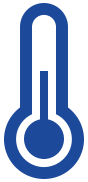
The Alaska Climate Integrated Modeling Project

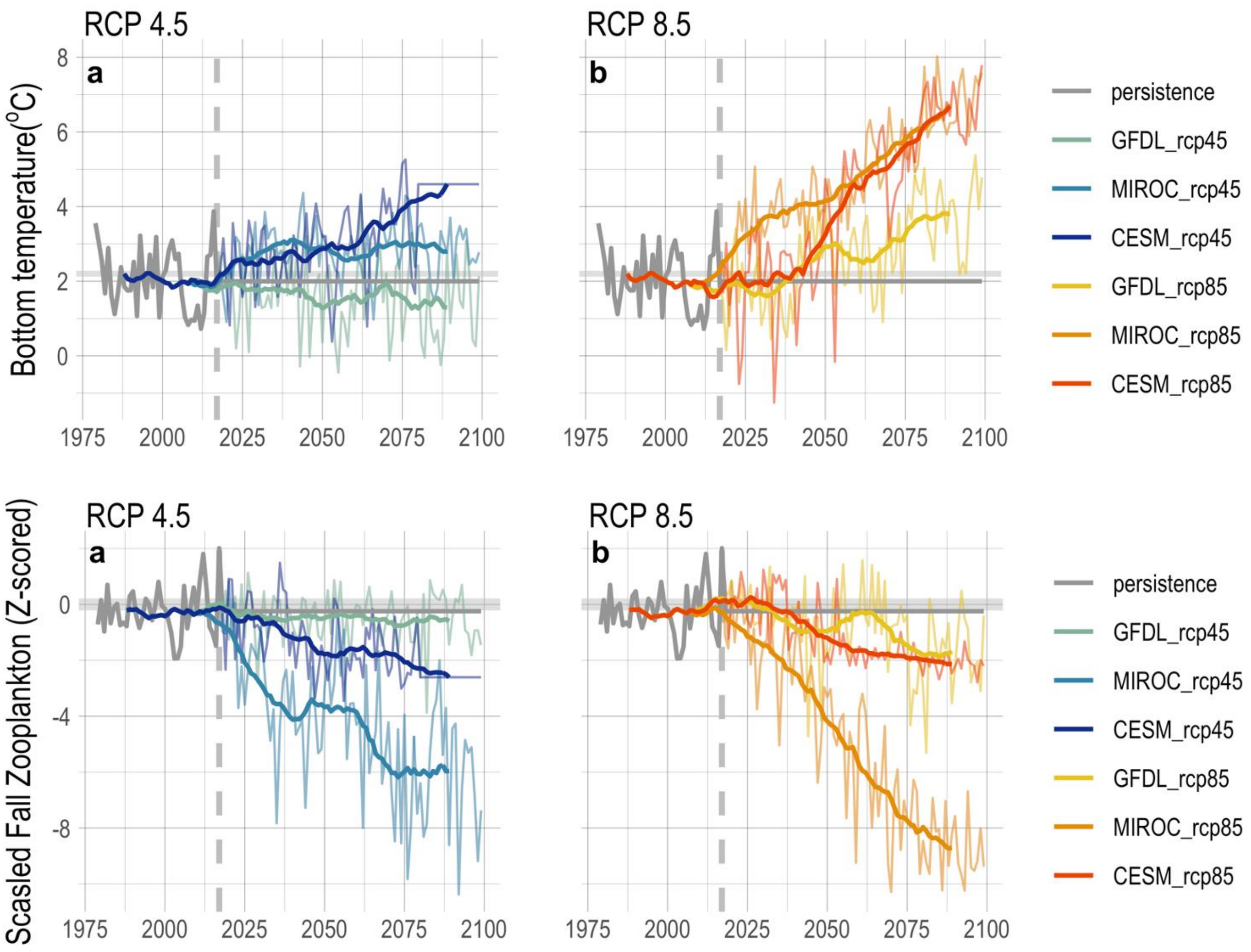
	Climate-effects on food-webs	Sloping HCR	Multispecies effects of 2 MT Cap
			
No fishing	**X**		
No-cap	**X**	**X**	
Status quo	**X**	**X**	**X**

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

CEATTLE: Unfished biomass (no harvest)

Assumes climate effects on recruitment, growth, & mortality





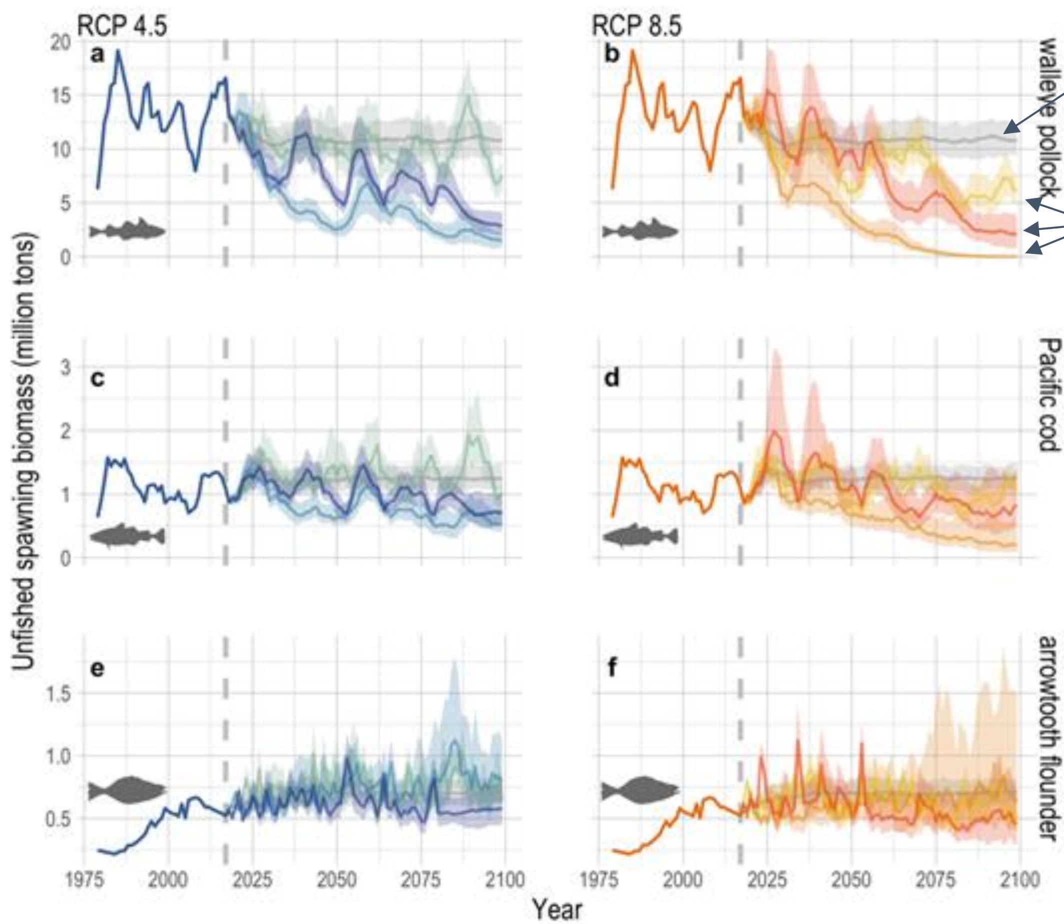
Holsman, K.K., Haynie, A.C., Hollowed, A.B. et al. Ecosystem-based fisheries management forestalls climate-driven collapse. Nat Commun 11, 4579 (2020). https://doi.org/10.1038/s41467-020-18300-3

CEATTLE: Unfished biomass (no harvest)

Assumes climate effects on recruitment, growth, & mortality

More warming =
- larger declines
- higher agreement of declines

moderate mitigation/warming | **low mitigation/high warming**



No climate change

With climate change

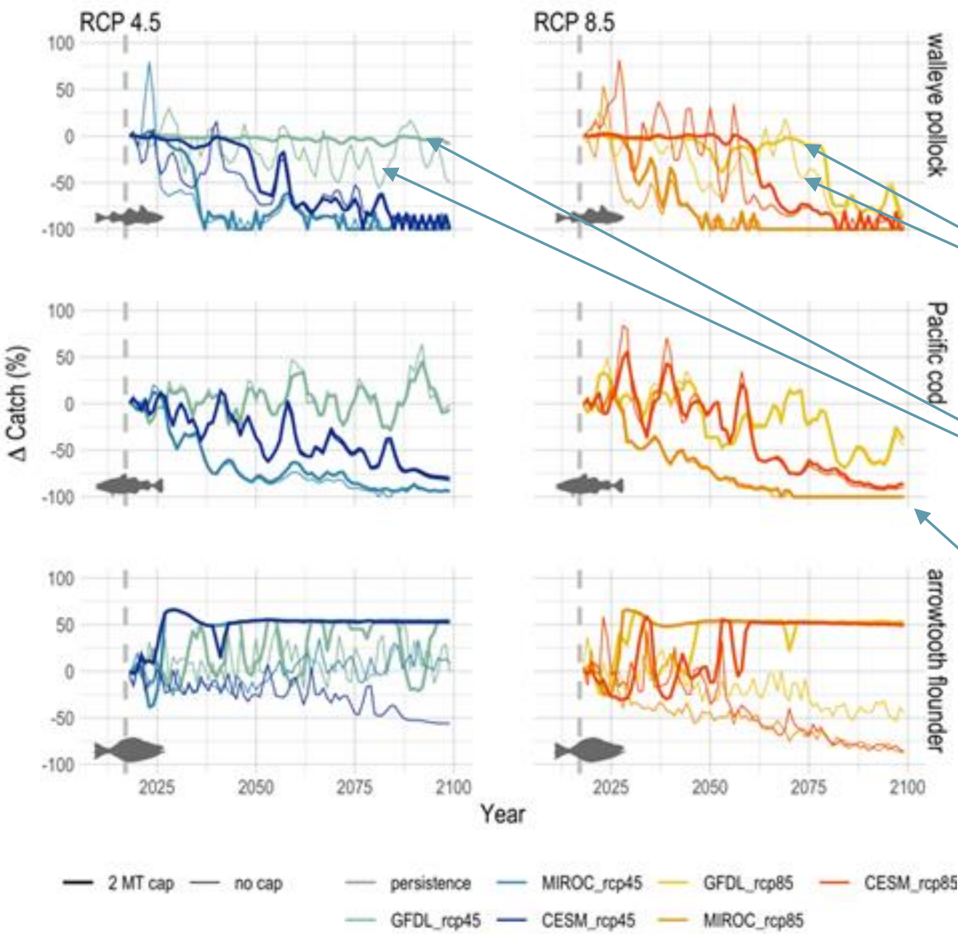
Holsman, K.K., Haynie, A.C., Hollowed, A.B. et al. Ecosystem-based fisheries management forestalls climate-driven collapse. Nat Commun 11, 4579 (2020). https://doi.org/10.1038/s41467-020-18300-3

CEATTLE: EBFM vs non-EBFM cap

Assumes climate effects on recruitment, growth, & mortality

EBFM = lower risk of declines & collapse

although risk increases over time & with warming



EBFM cap forestalled declines

EBFM cap stabilized catches

EBFM cap had 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

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The Alaska Climate Integrated Modeling Project

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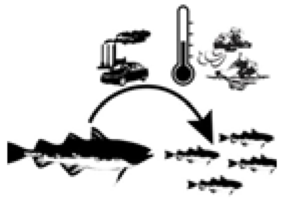
			
No fishing	X		
No-cap	X	X	
Status quo	**X**	**X**	**X**

Flexibility sub-sets:

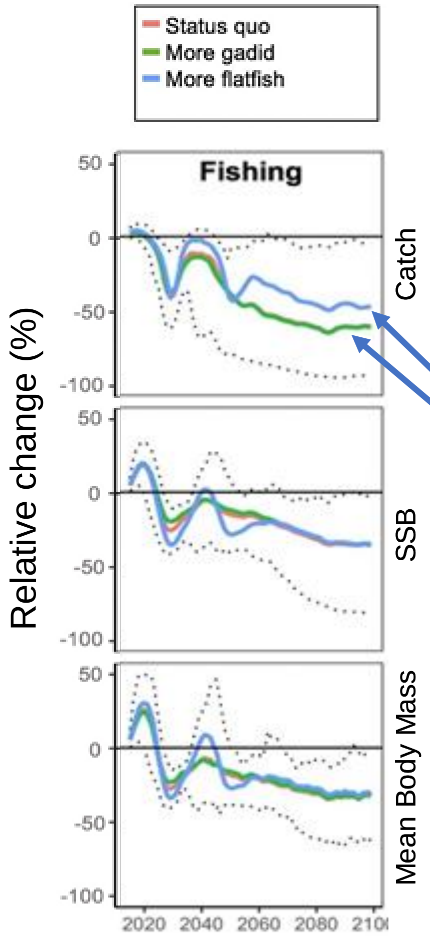
+10% more flatfish

+10% more gadid

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

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.

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

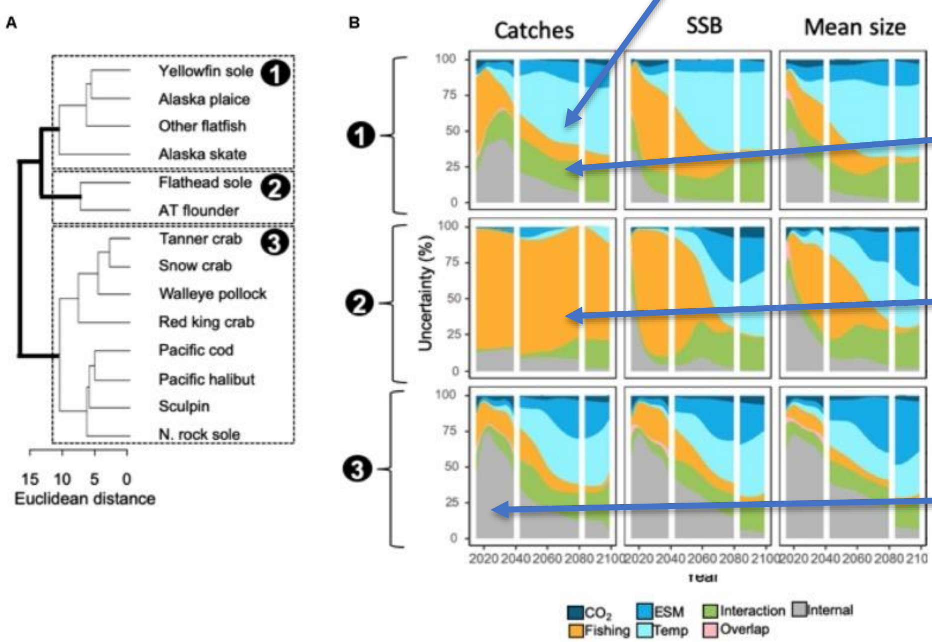
Assumes food web dynamics are a function of size

Uncertainty driven by the nature of the climate coupling

More research on interactions & processes would reduce uncertainty

Strong potential for adaptation through management (changing fishing approaches changes outcome)

“Random noise”



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

General declines in seabirds

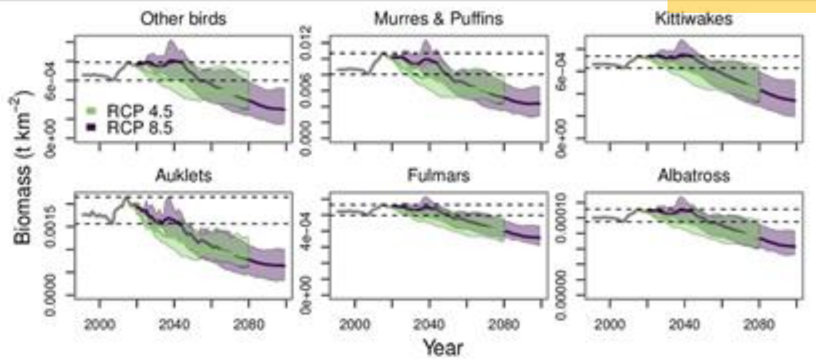


FIGURE 8 | Biomass projections for seabird functional groups. The gray line from 1991 to 2017 indicates the historical period. The purple and green poly indicate the minimum and maximum range for the three earth system models run under each RCP. The purple and green lines indicate the mean of the th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

General declines in marine mammals

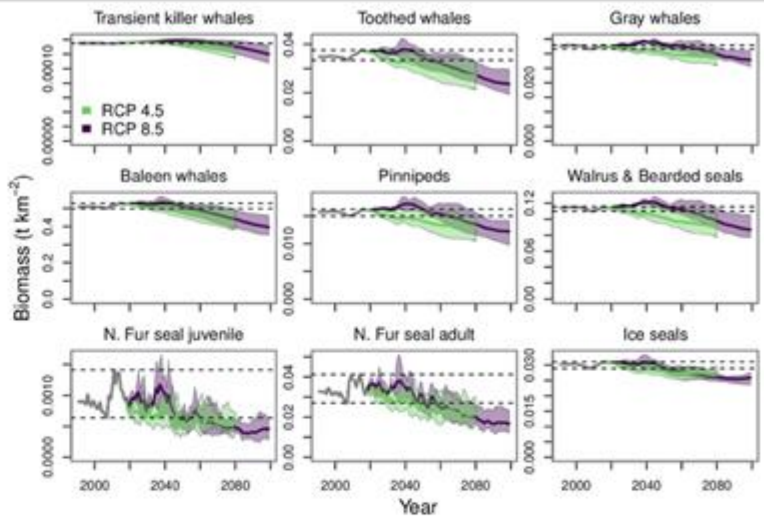


FIGURE 7 | Biomass projections for marine mammal functional groups. The gray line from 1991 to 2017 indicates the historical period. The purple and green polygons indicate the minimum and maximum range for the three earth system models run under each RCP. The purple and green lines indicate the mean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

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

What we found in ACLIM1.0

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

Modeling ecological and social-economic 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

Climate induced changes in productivity caused large declines in fish and crab that are greatest in low mitigation scenarios. Most pollock and cod scenarios declined 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.

1. What do you know?

- What does your work show regarding current foodweb conditions?
- What do you recommend as indicators of change?

→ Physical changes drive ecosystem responses: change in biomass, catch, and recruitment
→ Changes in predation and survival

2. What don't you know?

- What gaps has your work identified in understanding foodweb conditions?

→ Spatial overlap
→ Human community & fishery response

3. What is to be done to address these gaps?

- What are your recommendations on a path forward?

→ Refinement and additional biological and social-econ modeling

ACLIM 2.0 Next Directions

EBS social-ecological system climate risk analysis

Expanded management scenarios

Community workshops and network modeling

Spatial distribution models & NEBS

Expanded protected species analyses (marine mammals)

Expanded Ocean Acidification (OA) and dissolved oxygen modeling

Expanded lower trophic and young of year modeling

GOA ← → Northern Bering ACLIM via GOA-CLIM

QUESTIONS?

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ACLIM Publications:

1. Hermann, et al. (2021). Coupled modes of projected regional change in the Bering Sea from a dynamically downscaling model under CMIP6 forcing. Deep-Sea Research Part II: Topical Studies in Oceanography, 194 (Dec), 104974. https://doi.org/10.1016/j.dsr2.2021.104974
2. Cheng, W., A. Hermann, A. Hollowed, K. Holsman, K. Kearney, D. Pilcher, C Stock, K Aydin. (2021) Bering Sea dynamical downscaling: Environmental and lower trophic level responses to climate forcing in CMIP6. Deep Sea Res II.
3. (in revision) 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.
4. (2021) Punt, A., M G Dalton, W Cheng, A Hermann, K Holsman, T Hurst, J Ianelli, K Kearney, C McGilliard, D Pilcher, M Véron. Evaluating the impact of climate and demographic variation on future prospects for fish stocks: An application for northern rock sole in Alaska. Deep Sea Research Part II: Topical Studies in Oceanography 189–190:104951.
5. (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. Front. Mar. Sci., 03 February 2021 | https://doi.org/10.3389/fmars.2021.624301
6. (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
7. (2021) 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 44: 1–14, doi: 10.1111/ecog.05471
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9. (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.
10. (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
11. (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
12. (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
13. (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
14. (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