Climate Change Scenario Planning

A brief overview

Dr. Kirstin Holsman
NOAA AFSC, Seattle, usa
CSW 2024

NOAA FISHERIES

Warming in the Arctic is 2-3 x global average

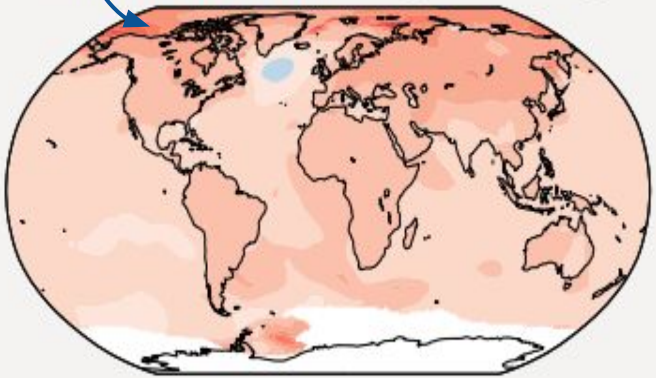
1.07°C of "Global mean warming" = Warming of 2-3°C in the Arctic

"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



https://www.nature.com/articles/s43247-022-00498-3

lobal average

“Arctic Amplification”

communications
earth & environment

ARTICLE

https://doi.org/10.1038/s43247-022-00498-3 OPEN

Check for updates

The Arctic has warmed nearly four times faster than the globe since 1979

Mika Rantanen[1✉], Alexey Yu. Karpechko[1], Antti Lipponen[2], Kalle Nordling[1,3], Otto Hyvärinen[1], Kimmo Ruosteenoja[1], Timo Vihma[1] & Ari Laaksonen[1,4]

In recent decades, the warming in the Arctic has been much faster than in the rest of the world, a phenomenon known as Arctic amplification. Numerous studies report that the Arctic is warming either twice, more than twice, or even three times as fast as the globe on average. Here we show, by using several observational datasets which cover the Arctic region, that during the last 43 years the Arctic has been warming nearly four times faster than the globe, which is a higher ratio than generally reported in literature. We compared the observed Arctic amplification ratio with the ratio simulated by state-of-the-art climate models, and found that the observed four-fold warming ratio over 1979-2021 is an extremely rare occasion in the climate model simulations. The observed and simulated amplification ratios are more consistent with each other if calculated over a longer period; however the comparison is obscured by observational uncertainties before 1979. Our results indicate that the recent four-fold Arctic warming ratio is either an extremely unlikely event, or the climate models systematically tend to underestimate the amplification.

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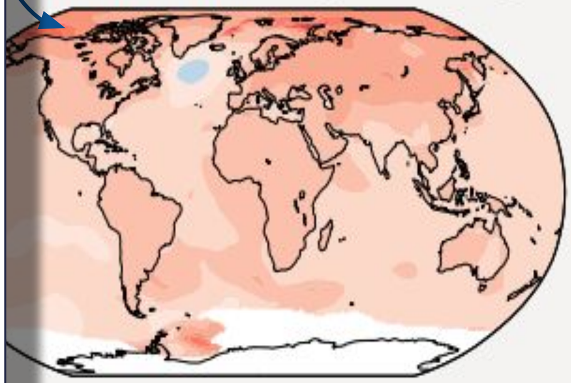


https://www.nature.com/articles/s43247-022-00498-3

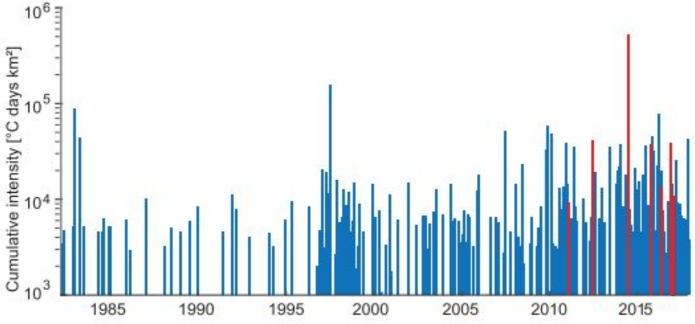
Climate change : Marine Heatwaves

"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 GWL) = 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

E

MHW Intensity



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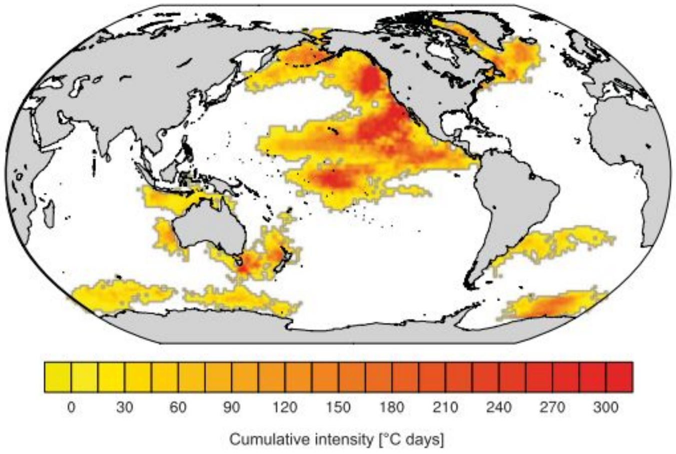

High-impact marine heatwaves attributable to human-induced global warming Laufkötter et al. Science 369 (6511), 1621-1625. DOI: 10.1126/science.aba0690

[*supporting effective adaptation*]

"to climate change depends on
society's ability & willingness to anticipate the change,
recognise its effects,
plan to accommodate its consequences,
& implement a coordinated portfolio of informed solutions"

-- IPCCWGII Chp.3

Why do scenario planning now?

To gather & organize the information, tools, & support for navigating future change

What can be done? **Prediction, Planning, Preparing**

Holsman et al. in prep.

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Scenario planning can help support effective climate change adaptation

Scenario planning can help support effective climate change adaptation

https://www.indeed.com/career-advice/career-development/scenario-planning

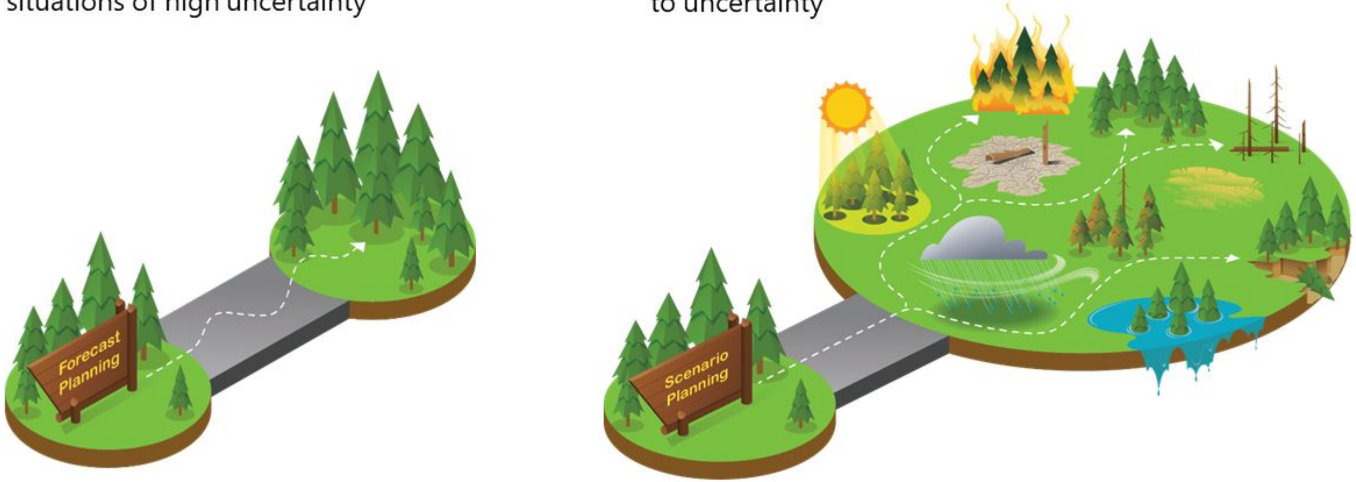
What is Scenario Planning?

- "Scenario planning is a strategy organizations use to **consider possible future events so they can develop effective and relevant long-term plans.**"
- "Scenario planning differs from forecasting because it considers trend analyses and **qualitative** data in addition to examining **quantitative** data and past events."
- "Regular and consistent scenario planning can help organizations **allocate resources successfully, mitigate risks** and decrease production costs."

Scenario planning (figure from NPS)

Traditional planning
- Assumes the future will resemble the past
- Assumes high certainty in our ability to accurately predict the future
- Encourages a precise characterization of the future
- Leaves managers vulnerable to surprises in situations of high uncertainty

Scenario planning
- Assumes the future will likely differ from the past
- Recognizes uncertainty and asks "what might happen?" in a rigorous and structured way
- Encourages broad and open-minded exploration of future possibilities and surprises
- Helps managers identify strategies that are robust to uncertainty

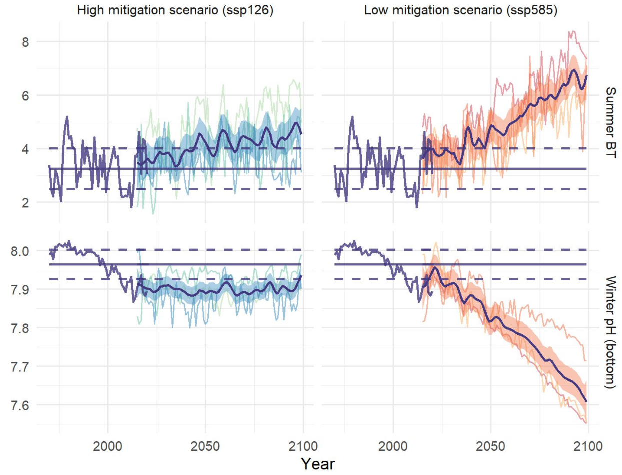


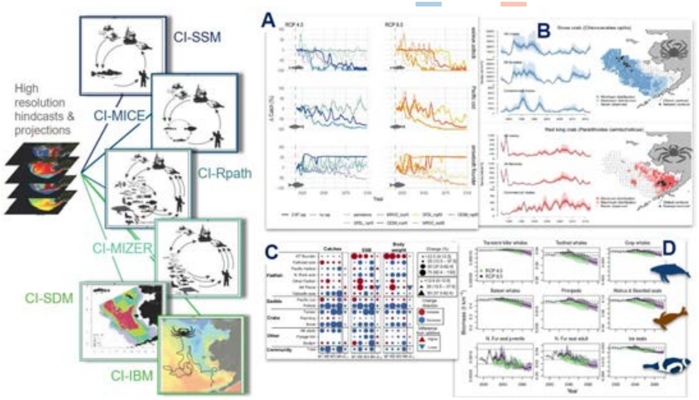
https://www.nps.gov/articles/000/overcoming-analysis-paralysis-through-better-climate-change-scenario-planning.htm

Types of scenario planning:

- **Quantitative scenarios:** The quantitative scenario approach looks at the best and worst cases by altering variables, assuming that key variables identified have fixed relationships.
- **Operational scenarios:** Operational, or event-driven, scenarios look at the effects a circumstance may have on an organization.
- **Normative scenarios:** Normative scenarios are a goal-oriented type of scenario planning often used to help organizations reach their desired operation.
- **Strategic management scenarios:** Also referred to as "alternative futures," this type of scenario focuses on the environment where decisions are made.
- **Probability-based scenarios:** Probability-based scenarios look at trends to determine the likelihood an event may occur.
- **Interactive scenarios:** Interactive scenarios describe the interaction with select variables or parties in a competitive "gaming" atmosphere.

BEST WORST





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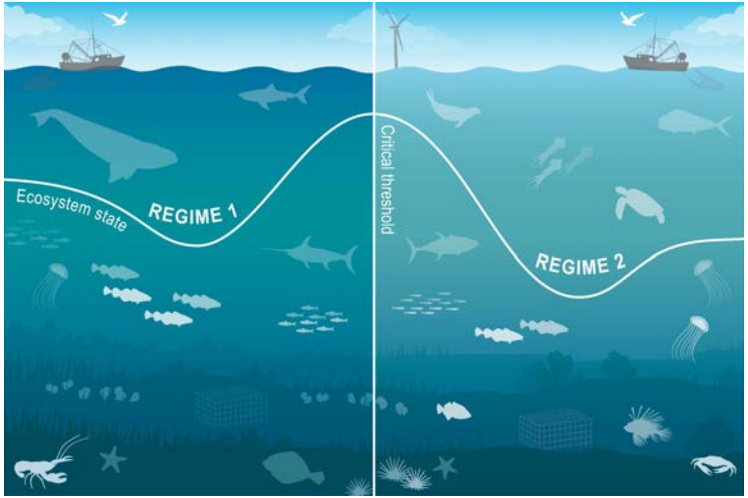
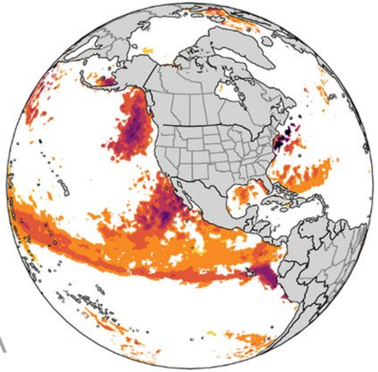


https://noaa-edab.github.io/presentations/20210310_MAFMC_SSC_Gaichas.html#6

What if ?



NOAA

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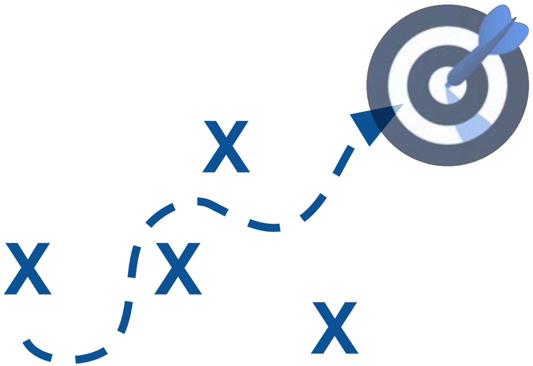

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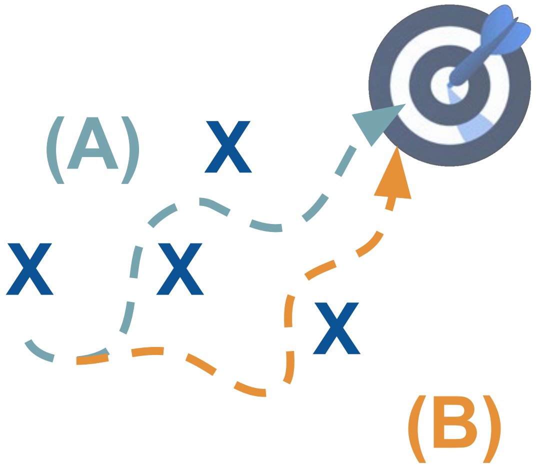
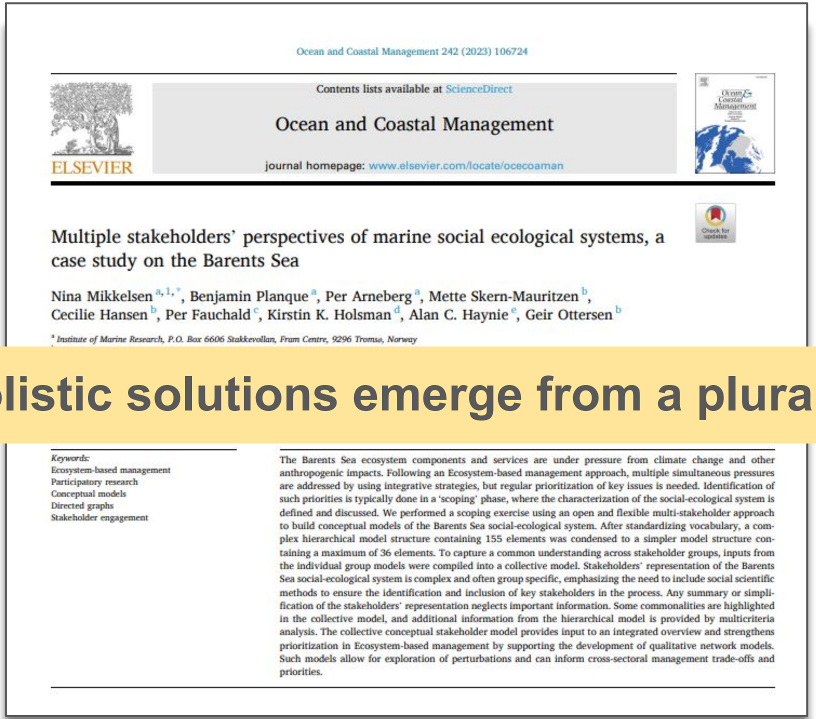
Given different futures…

How do we get to our target(s)?



Participatory and inclusive approaches


Ocean and Coastal Management 242 (2023) 106724

Contents lists available at ScienceDirect

Ocean and Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

ELSEVIER

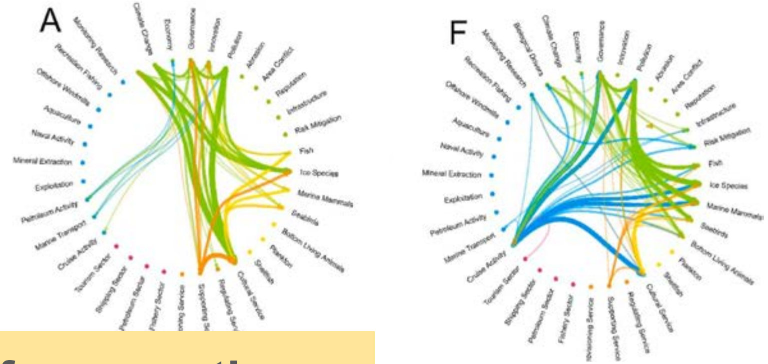
Multiple stakeholders' perspectives of marine social ecological systems, a case study on the Barents Sea

Nina Mikkelsen[a,1,*], Benjamin Planque[a], Per Arneberg[a], Mette Skern-Mauritzen[b], Cecilie Hansen[b], Per Fauchald[c], Kirstin K. Holsman[d], Alan C. Haynie[e], Geir Ottersen[b]

[a] Institute of Marine Research, P.O. Box 6606 Stakkevollan, Fram Centre, 9296 Tromsø, Norway

Keywords:
Ecosystem-based management
Participatory research
Conceptual models
Directed graphs
Stakeholder engagement

The Barents Sea ecosystem components and services are under pressure from climate change and other anthropogenic impacts. Following an Ecosystem-based management approach, multiple simultaneous pressures are addressed by using integrative strategies, but regular prioritization of key issues is needed. Identification of such priorities is typically done in a 'scoping' phase, where the characterization of the social-ecological system is defined and discussed. We performed a scoping exercise using an open and flexible multi-stakeholder approach to build conceptual models of the Barents Sea social-ecological system. After standardizing vocabulary, a complex hierarchical model structure containing 155 elements was condensed to a simpler model structure containing a maximum of 36 elements. To capture a common understanding across stakeholder groups, inputs from the individual group models were compiled into a collective model. Stakeholders' representation of the Barents Sea social-ecological system is complex and often group specific, emphasizing the need to include social scientific methods to ensure the identification and inclusion of key stakeholders in the process. Any summary or simplification of the stakeholders' representation neglects important information. Some commonalities are highlighted in the collective model, and additional information from the hierarchical model is provided by multicriteria analysis. The collective conceptual stakeholder model provides input to an integrated overview and strengthens prioritization in Ecosystem-based management by supporting the development of qualitative network models. Such models allow for exploration of perturbations and can inform cross-sectoral management trade-offs and priorities.



Holistic solutions emerge from a plurality of perspectives

- Explore multiple conceptualizations of the system
- Don't aim for consensus
- No need to "drop" information
- Can be used to identify maladaptation
- Shared solutions emerge

Mikkelsen et al. in 2023 https://doi.org/10.1016/j.ocecoaman.2023.106724

Scenario Planning

Scenario Planning: An Introduction for Fishery Managers

Kathryn M. Frens and Wendy E. Morrison

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OSF-9
July 2020

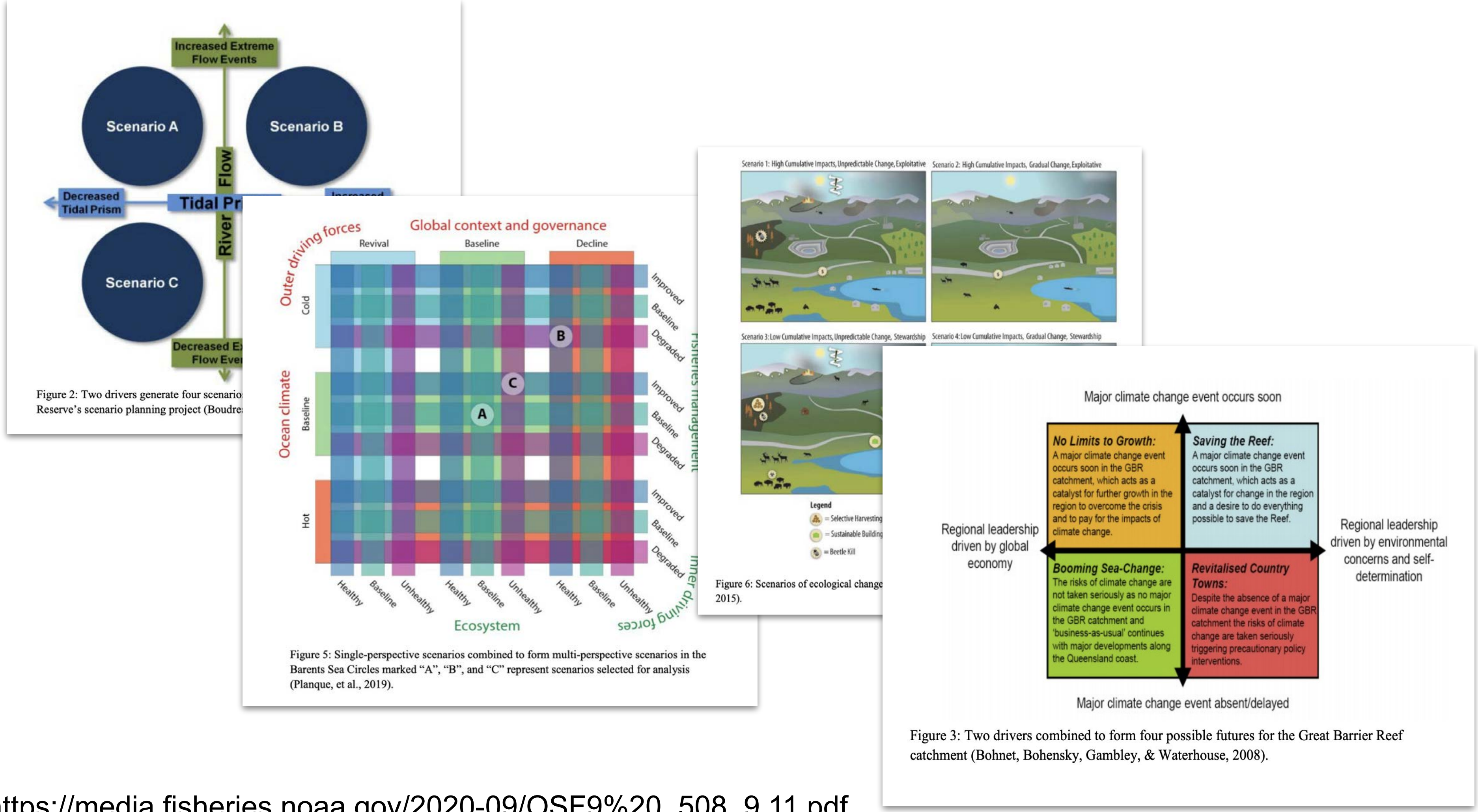
"Scenario planning is a flexible tool that has potential to help fisheries managers plan for a future that is full of uncertainty by **working with the uncertainty** rather than attempting to reduce it."

"**Stakeholder engagement** is at the core of scenario planning, and **confers benefits that transcend the planning process.**"

"Inclusion of a **diverse group of stakeholders contributes a broad knowledge base** to the project and helps open lines of communication to various groups in the community."

"The ongoing nature of implementation means that all the **results of a scenario planning project may not be realized for a long time.** Scenario planning should be viewed as a long-term investment in resources management."

https://media.fisheries.noaa.gov/2020-09/OSF9%20_508_9.11.pdf



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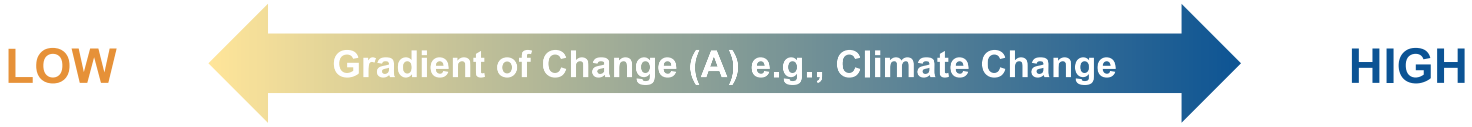
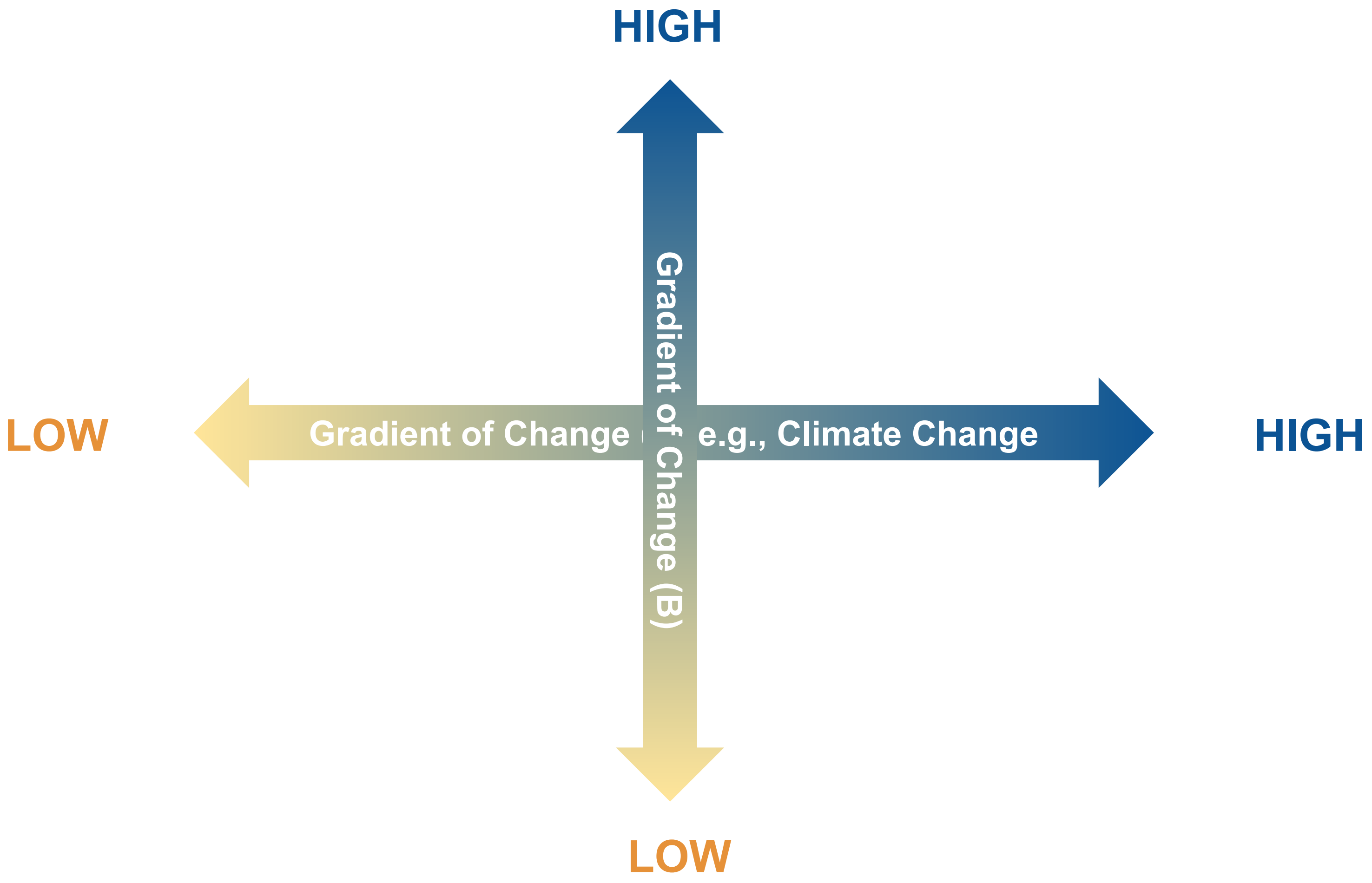
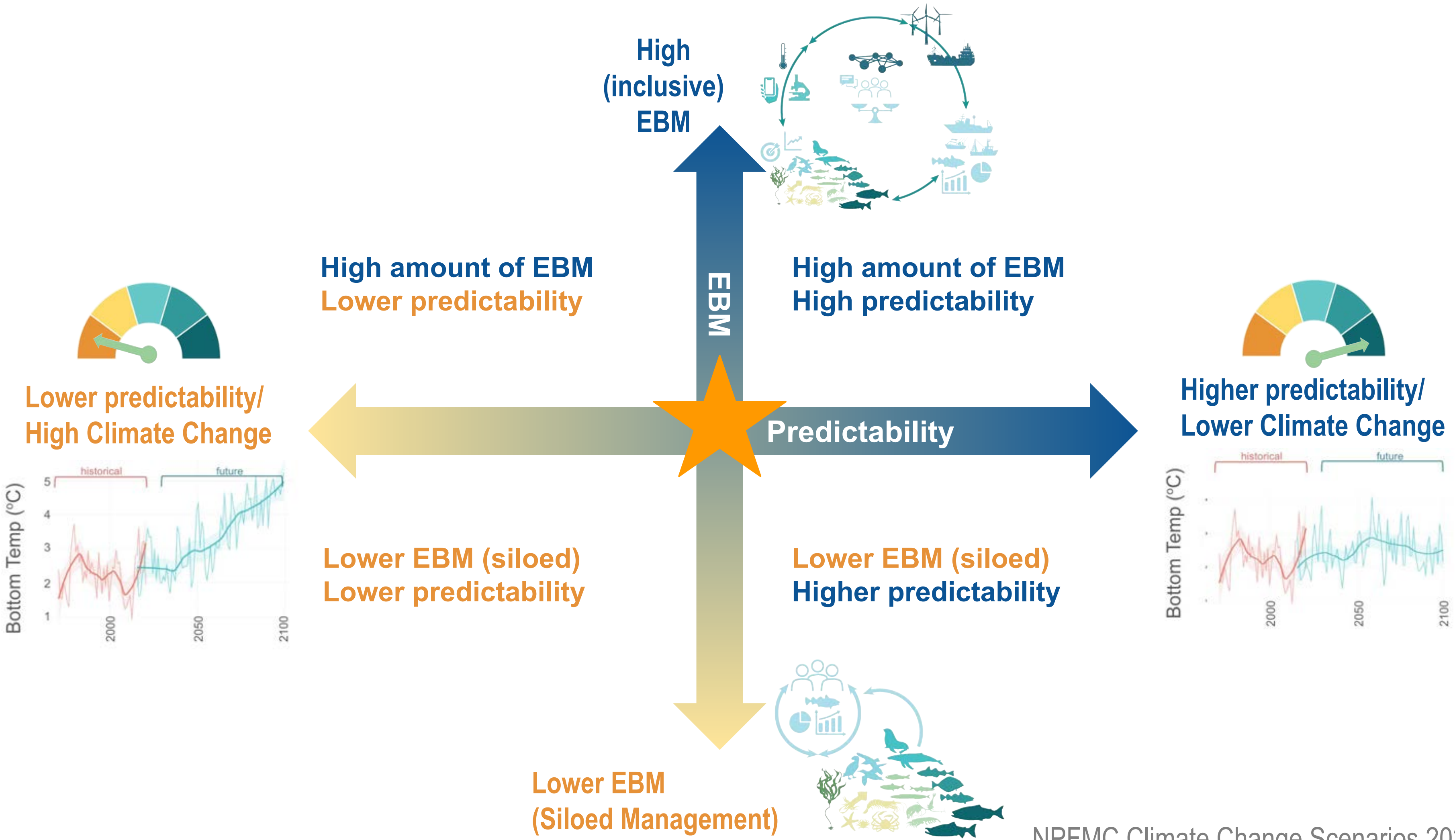
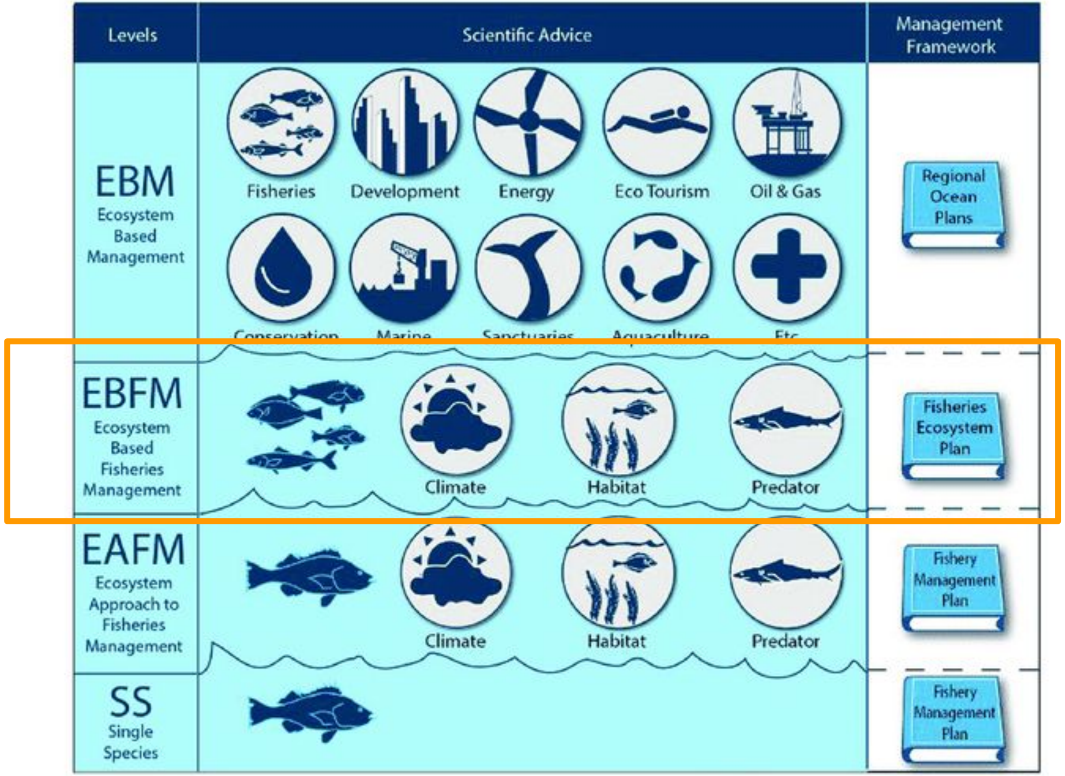

LOW
Gradient of Change (A) e.g., Climate Change
HIGH

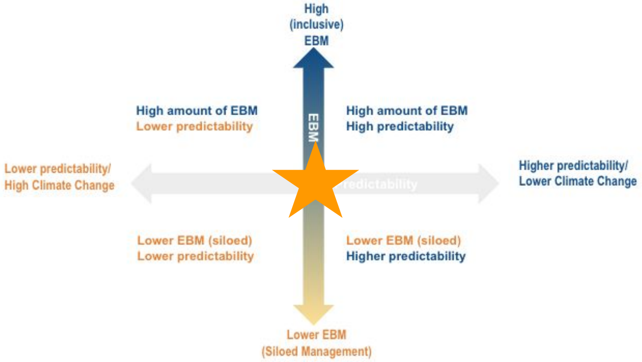

HIGH
Gradient of Change (B)
LOW
Gradient of Change
e.g., Climate Change
HIGH
LOW



NPFMC Climate Change Scenarios 2024

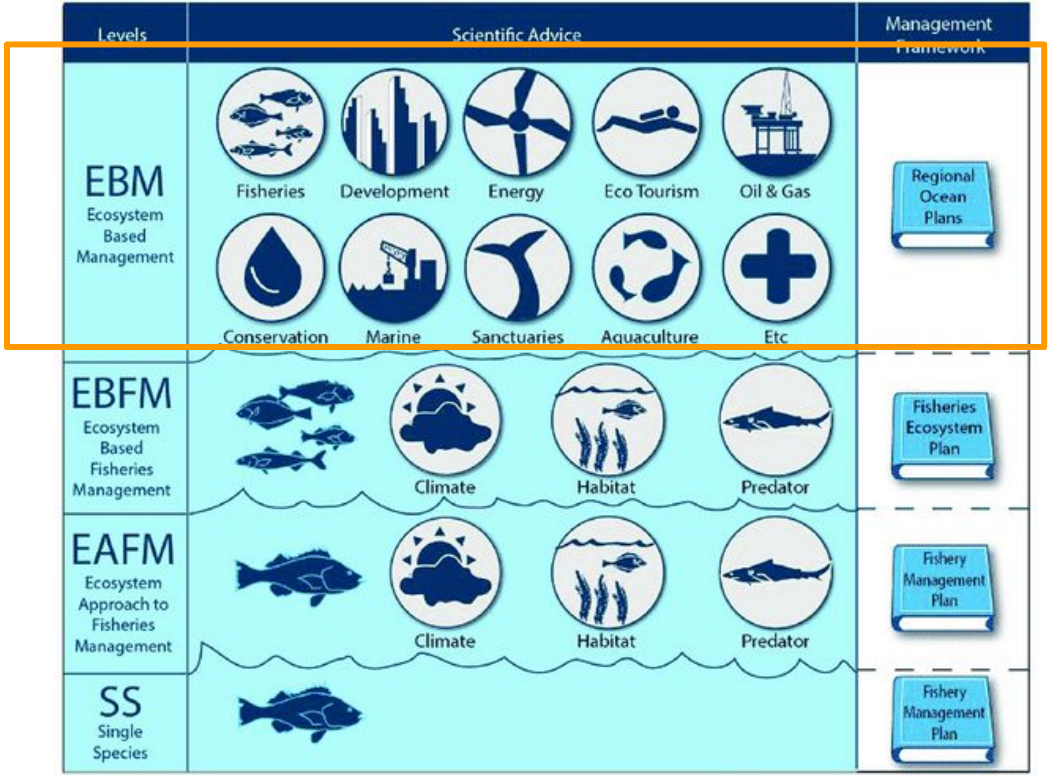
Ecosystem Based Management

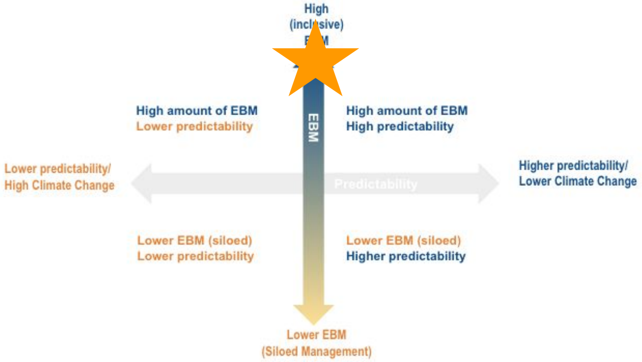


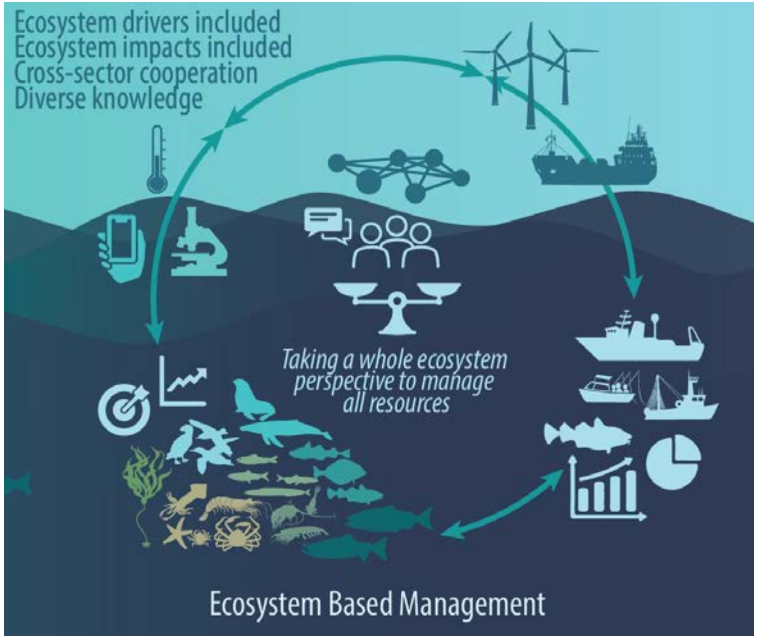


Dolan et al. 2016 https://doi.org/10.1093/icesjms/fsv242

Ecosystem Based Management







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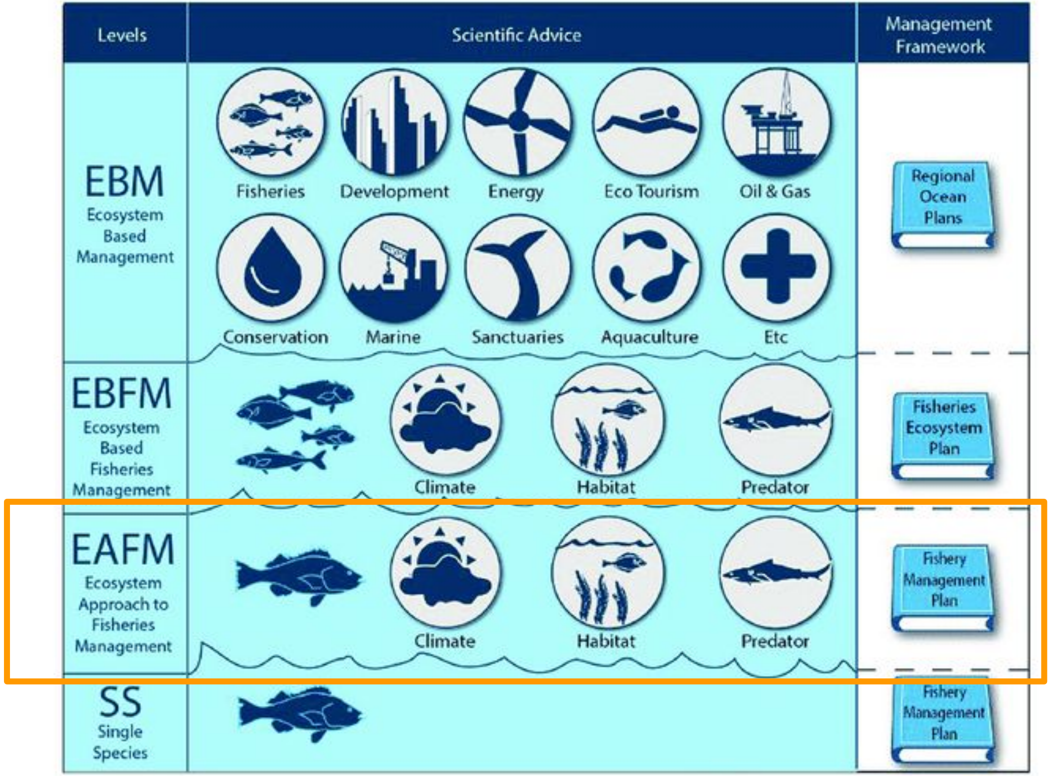
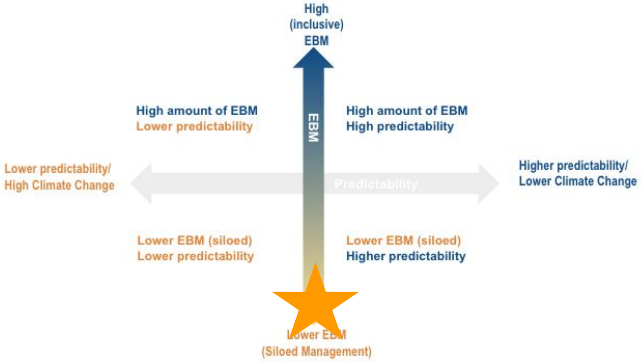
Ecosystem Based Management





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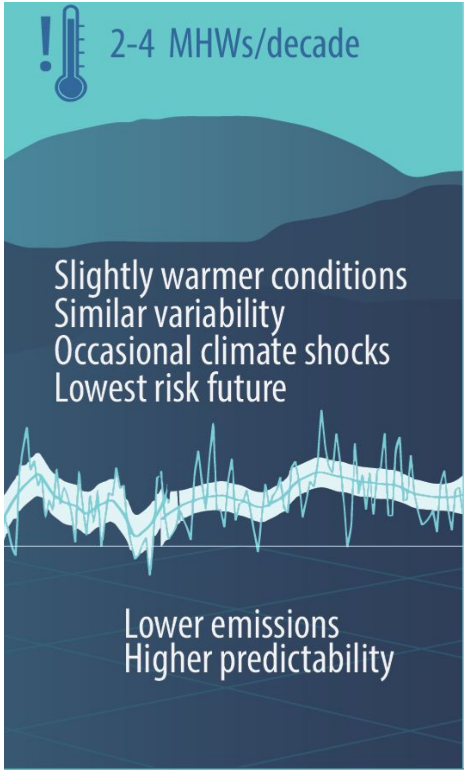
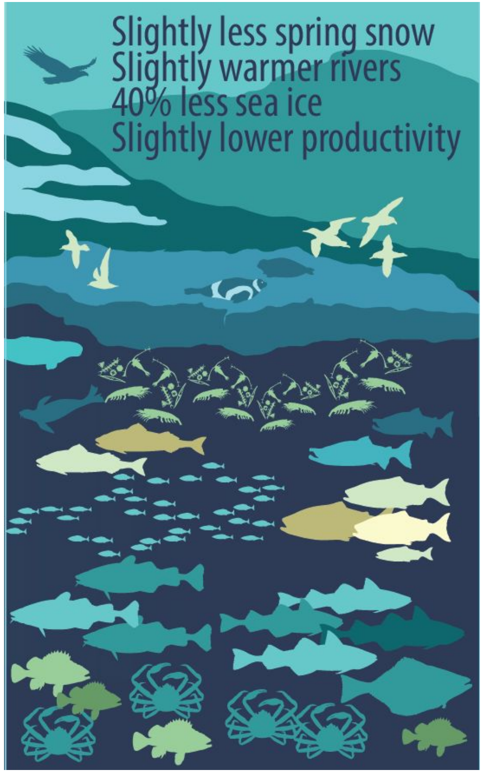
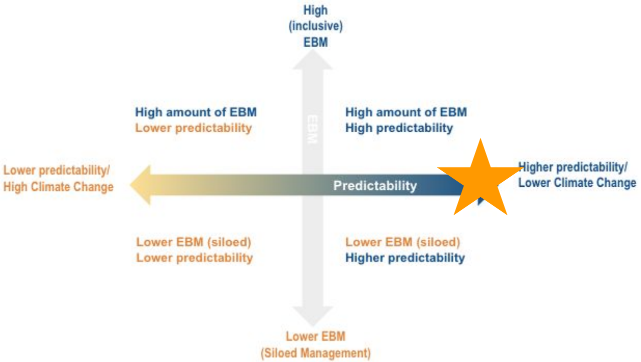
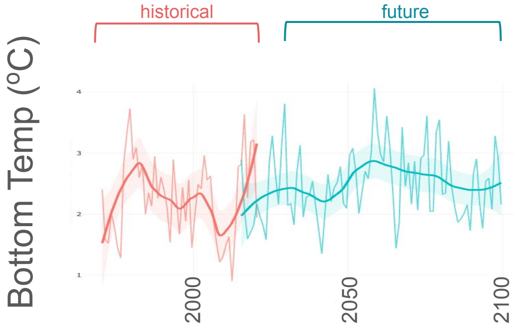
Future climate conditions





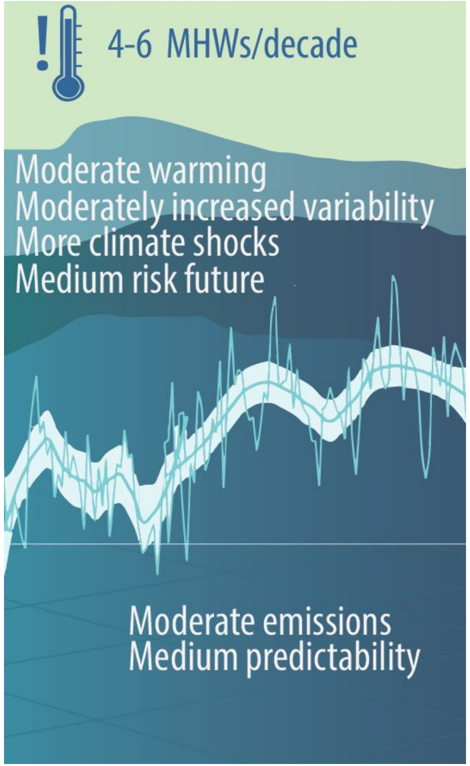


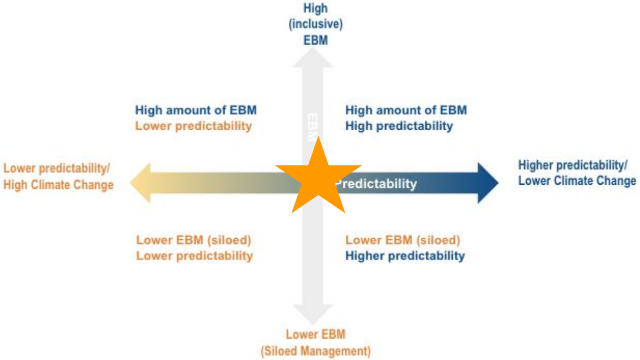


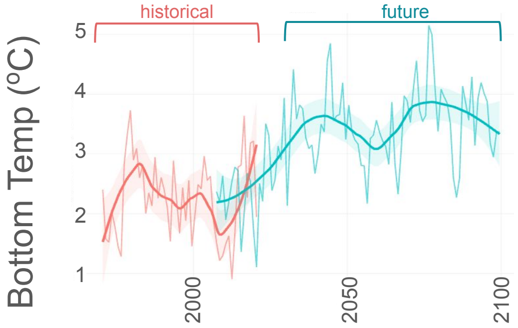
Lower warming (SSP126)
& higher predictability

https://kkh2022.shinyapps.io/ACLIM2_indices/

Future climate conditions



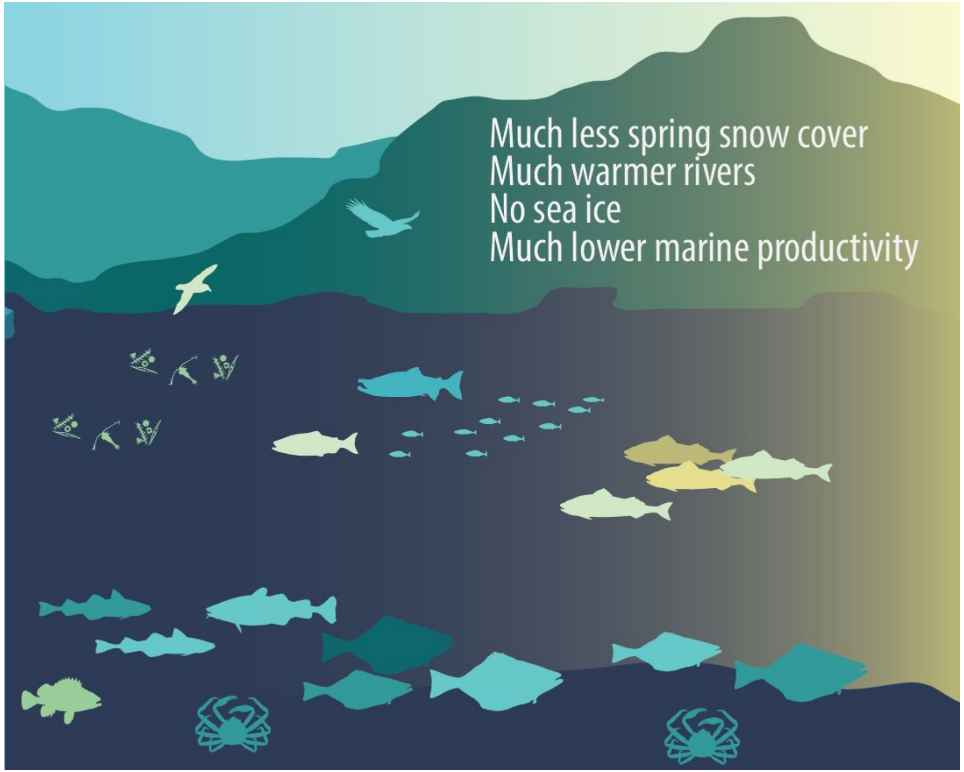


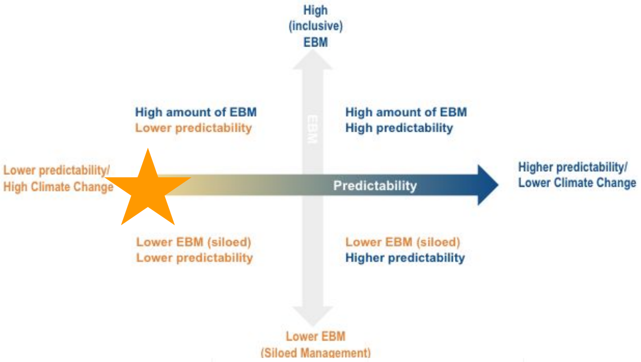


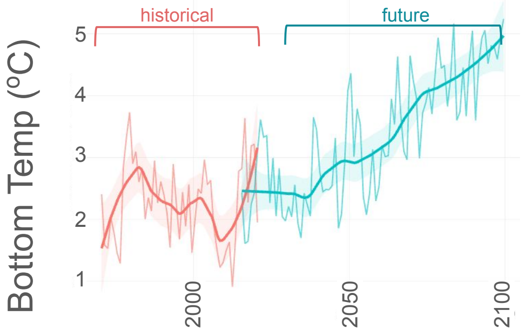
Med. warming (RCP45)
& medium predictability

https://kkh2022.shinyapps.io/ACLIM2_indices/

Future climate conditions







High warming (SSP585)
& lower predictability

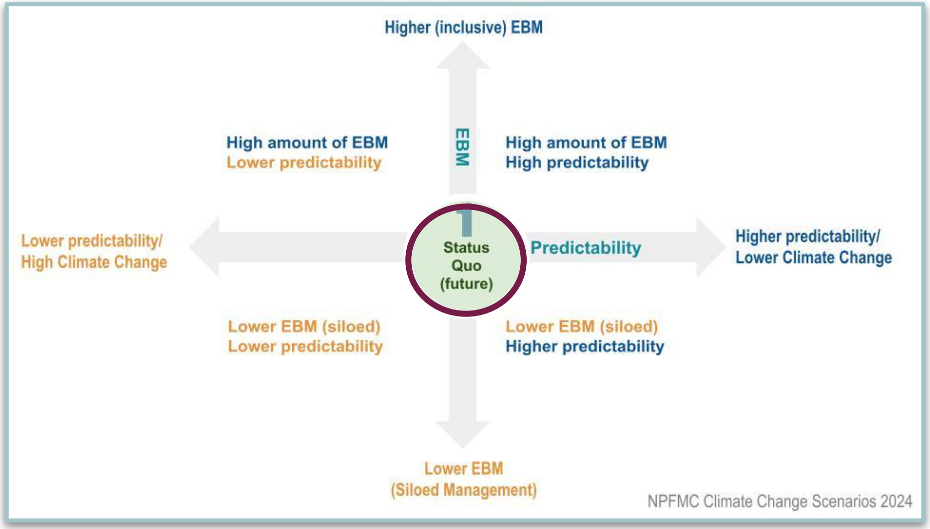
https://kkh2022.shinyapps.io/ACLIM2_indices/

Step 1:
Start here

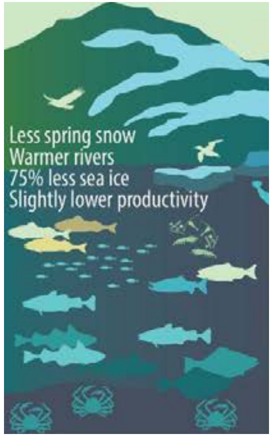
Scenario 1: Current trajectory

Some progress toward ecosystem-based fisheries management (EBFM), significant climate change impacts, and moderate predictive capabilities

Climate change continues to disrupt ecosystems and fisheries. The management tools and policies in place are similar to those used in 2024. Forecasting and planning improve but capacity for adaptation varies widely across fisheries.



Medium predictability



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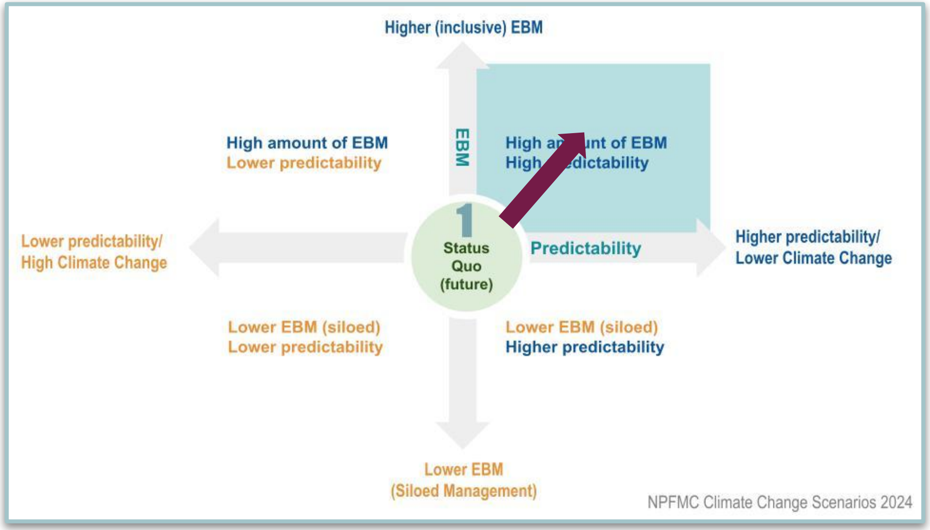
Step 2: Consider the best case scenario...

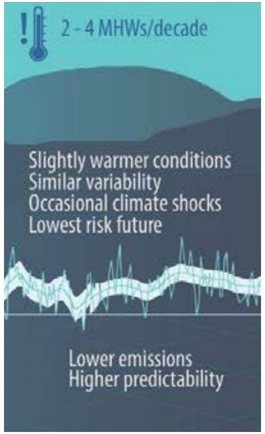
Scenario 2: Best of both worlds

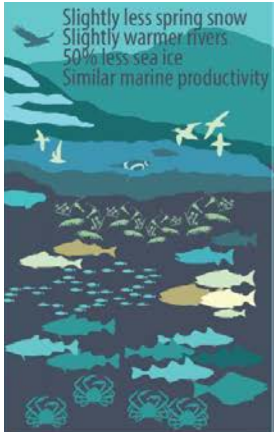
Highly effective and inclusive ecosystem-based management (EBM), lowest potential climate change impacts, and strong predictive capabilities

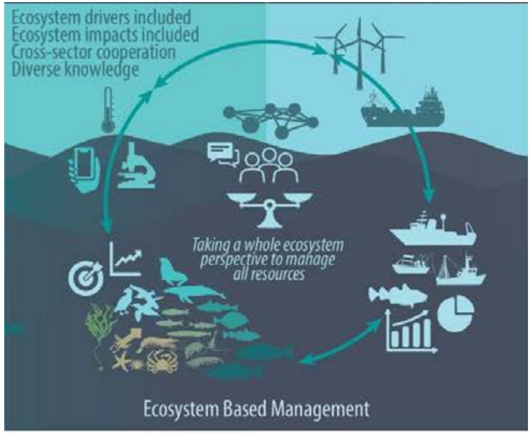
While there are periodic climate shocks and extreme events, there are strong predictive capabilities, effective consideration of interactions between stocks and ocean users, and more lead time for planning.



Higher predictability







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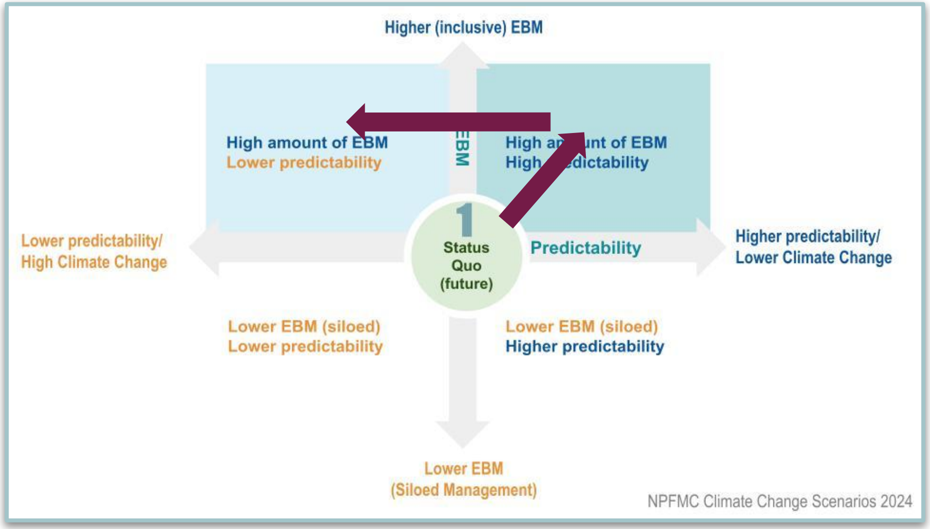
Step 3: Now, consider if climate change impacts are severe...

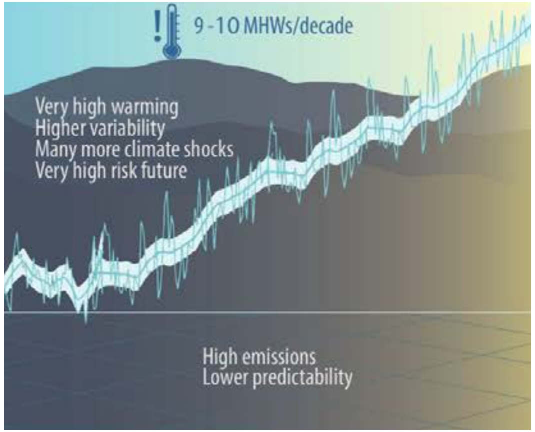
Scenario 3: EBM and rapid change

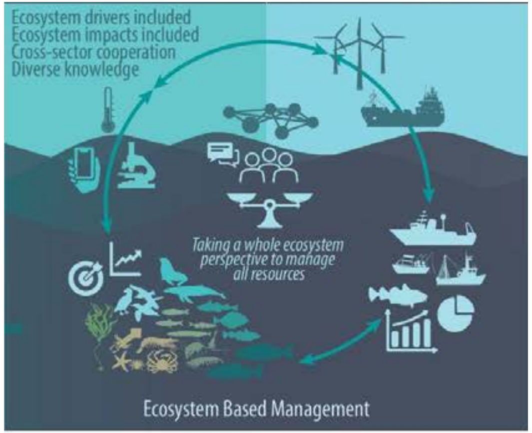
Highly effective and inclusive ecosystem-based management (EBM), high climate change impacts, and low predictive capabilities

Managers are able to practice effective ecosystem-based management but climate change impacts are more severe than in Scenario 2. As a result, predictive capabilities are low and management is reactive.



Lower predictability





Step 1: Start here

Scenario 1: Current trajectory

Some progress toward ecosystem-based fisheries management (EBFM), significant climate change impacts, and moderate predictive capabilities

Climate change continues to disrupt ecosystems and fisheries. The management tools and policies in place are similar to those used in 2024. Forecasting and planning improve but capacity for adaptation varies widely across fisheries.

Step 2: Consider the best case scenario...

Scenario 2: Best of both worlds

Highly effective and inclusive ecosystem-based management (EBM), lowest potential climate change impacts, and strong predictive capabilities

While there are periodic climate shocks and extreme events, there are strong predictive capabilities, effective consideration of interactions between stocks and ocean users, and more lead time for planning.

Step 3: Now, consider if climate change impacts are severe...

Scenario 3: EBM and rapid change

Highly effective and inclusive ecosystem-based management (EBM), high climate change impacts, and low predictive capabilities

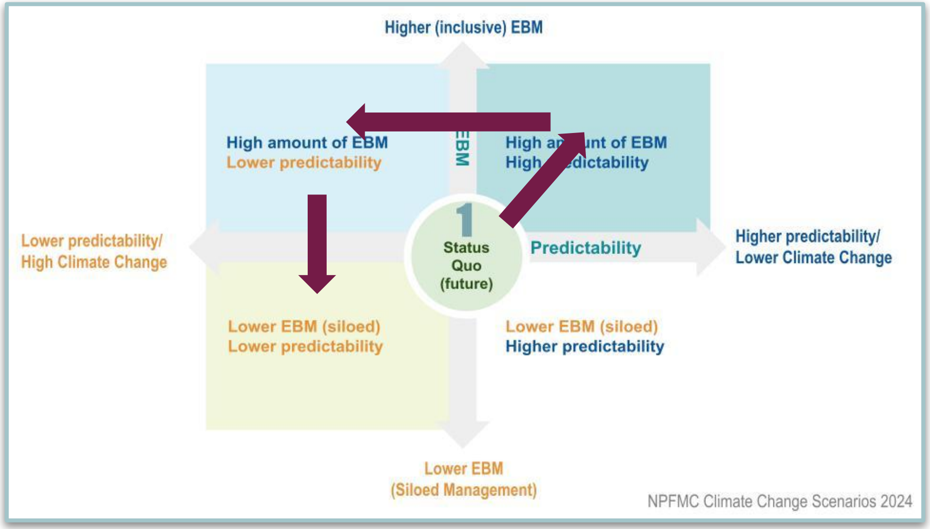
Managers are able to practice effective ecosystem-based management but climate change impacts are more severe than in Scenario 2. As a result, predictive capabilities are low and management is reactive.

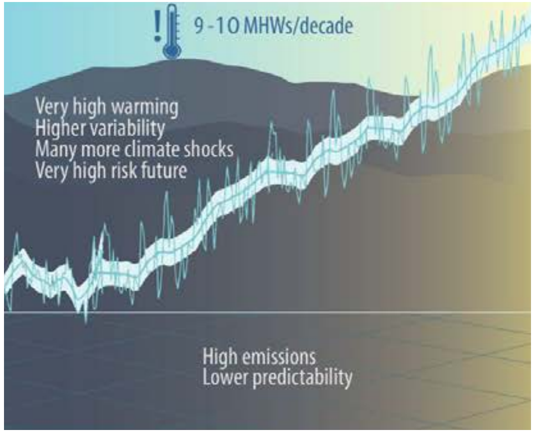
Step 4: Now, consider if management is siloed...

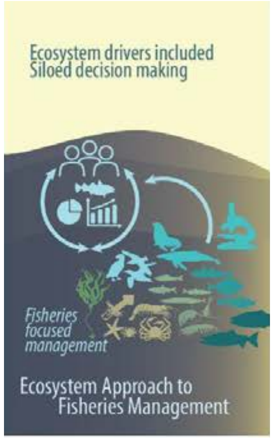
Scenario 4: Siloed management and high challenges

Sector and stock specific management focus, extreme climate change impacts, and low predictive capabilities

Extreme climate events and market shocks are common and predictive capabilities are low. Management is reactive and focused on individual stocks, sectors, and fleets. The rapid rate of change creates instability for fisheries and communities.







How should I prepare?

- **Bring your personal expertise and experiences** to the workshop.

- **Come ready to share** ideas, brainstorm, listen to others, and connect dots in terms of possible mutual challenges and shared solutions.

- **Plan to generate a diversity of considerations and responses** (consensus is not the goal) to inform tradeoffs and design.

Discussion questions during the workshop:

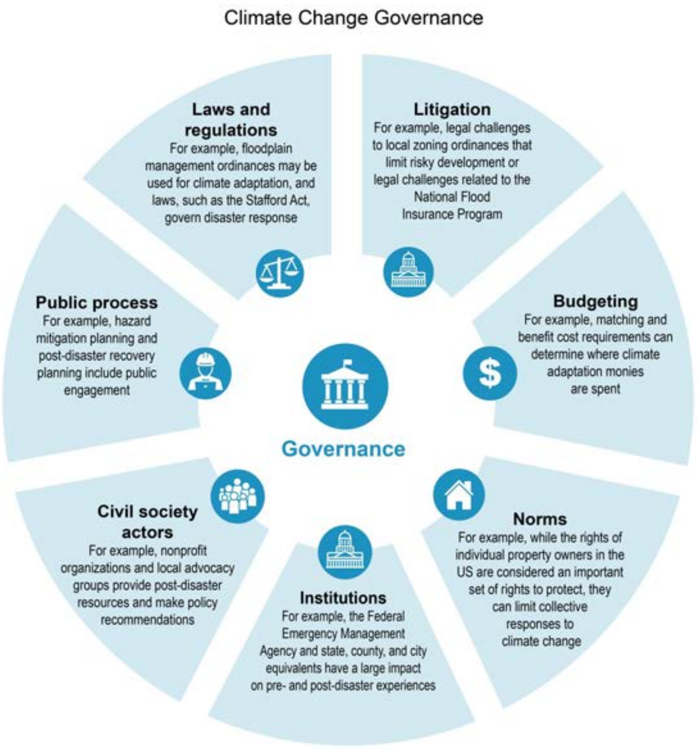
(From your perspective)

1. What does climate resilience look like in each scenario?
2. What are the challenges to climate resilience?
3. What management tools and approaches could help?
4. What scientific tools and information could help?
5. What other assets and opportunities could help support climate resilience? (E.g., diverse knowledge sources, collaborative approaches, community and industry-led initiatives).
6. How can the Council support a robust and inclusive process for climate readiness planning?

https://meetings.npfmc.org/CommentReview/DownloadFile?p=8e6125f5-7062-416d-aa00-66971dcf6c8b.pdf&fileName=Scenarios%20and%20Discussion%20Guide.pdf

What will we do with the outcomes?

- The results of discussions will be used to **help connect dots and map out tools, policies, and information resources** to help respond to and plan for climate change (from emergency response to long-term portfolio planning).
- With information organized for the Council (management), Agency, Fisheries, Communities, Individuals/families



https://nca2023.globalchange.gov/all-figures/#10

Types of Management Actions

Catch Quotas: Specify overfishing limits (OFL), allowable biological catch levels (ABC), and total allowable catch (TAC)

Gear Types and Seasons: identification of legal gear types, and seasons to distribute harvest in time to avoid ger conflicts, reduce bycatch and marine mammal interactions

Bycatch and PSC: Bycatch and prohibited species catch limits, time/ area/ gear type closures

Protected Resources: Time and area closures to protect critical areas, prey species limitations

Habitat: Description and identification of essential fish habitat for all managed species, gear/area closures to protect key areas

Community Protections: Harvest quota set asides for communities, regional delivery restrictions

Limited Access Privileges: Create limited access programs, sector allocations, rationalization privileges

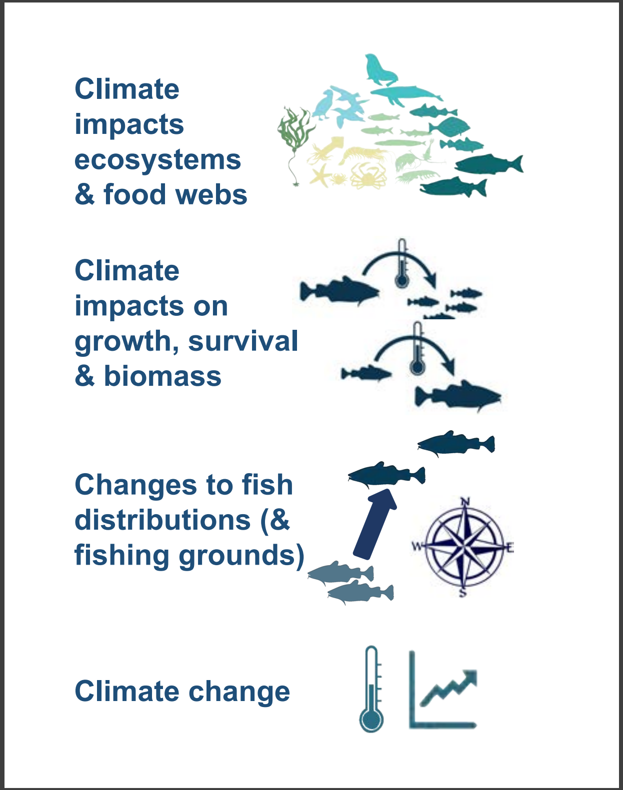
https://www.npfmc.org/how-we-work/management-policies/

Types of Management Actions

- Catch Quotas
- Gear Types and Seasons
- Bycatch and PSC Limits
- Protected Resources
- Habitat
- Community Protections
- Limited Access Privileges

https://www.npfmc.org/how-we-work/management-policies/

Types of Management Actions



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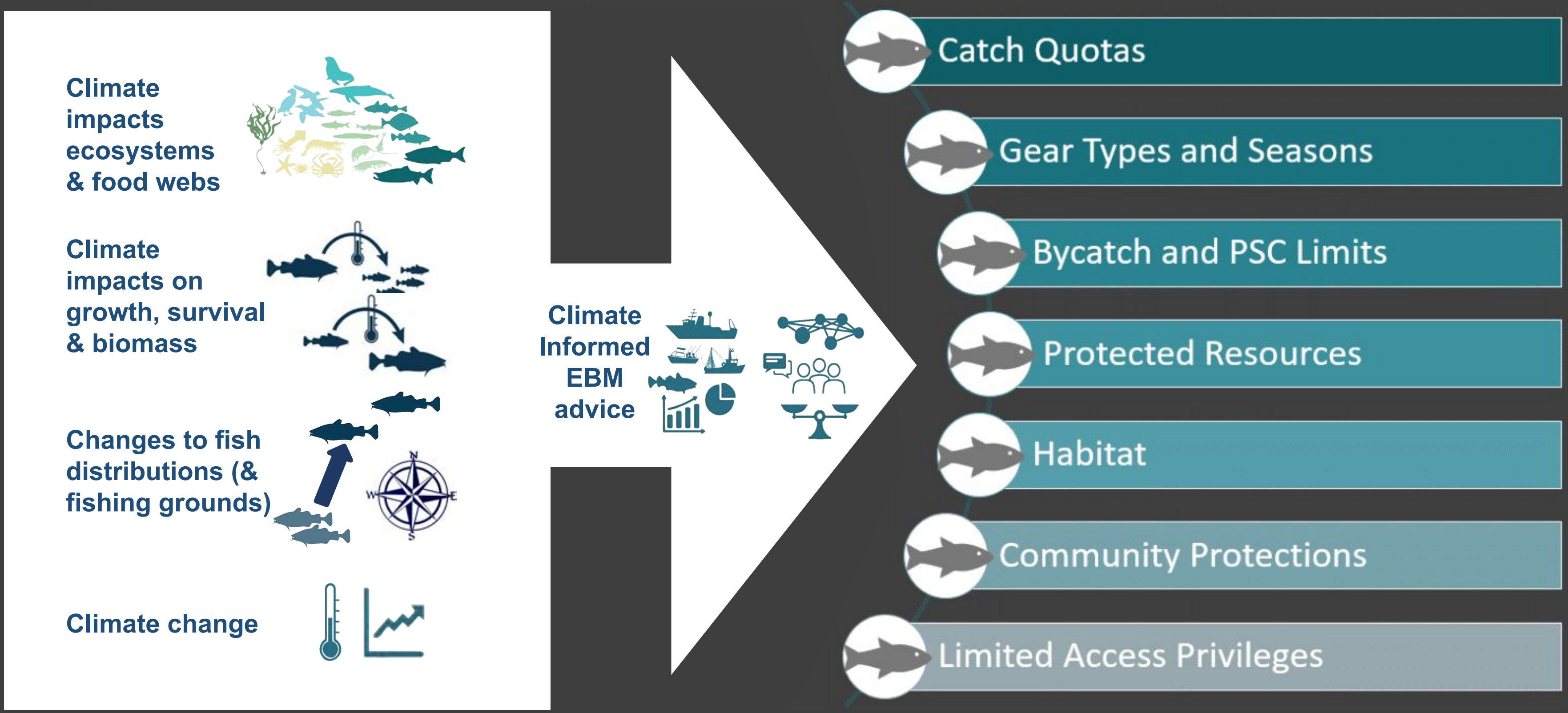
https://www.npfmc.org/how-we-work/management-policies/

Types of Management Actions



https://www.npfmc.org/how-we-work/management-policies/

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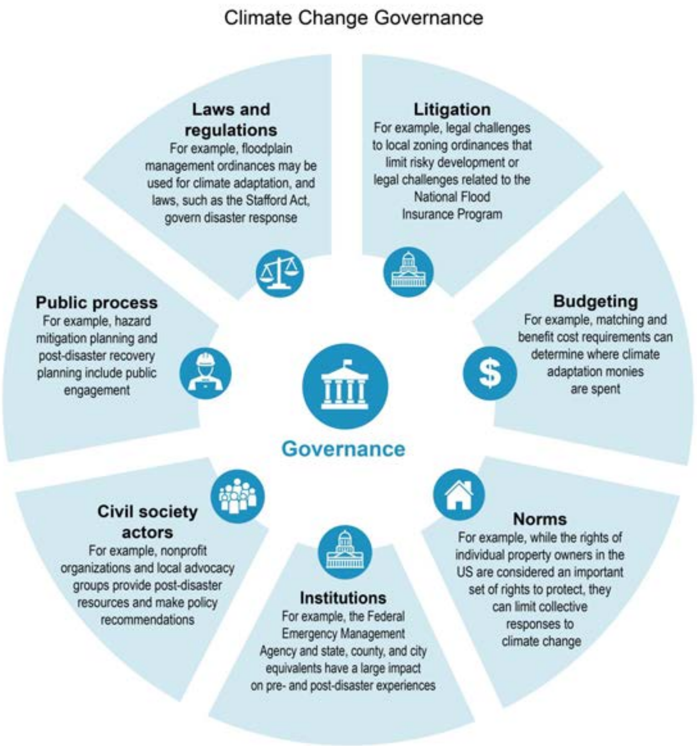
Types of info. that may be identified may include (not limited to):

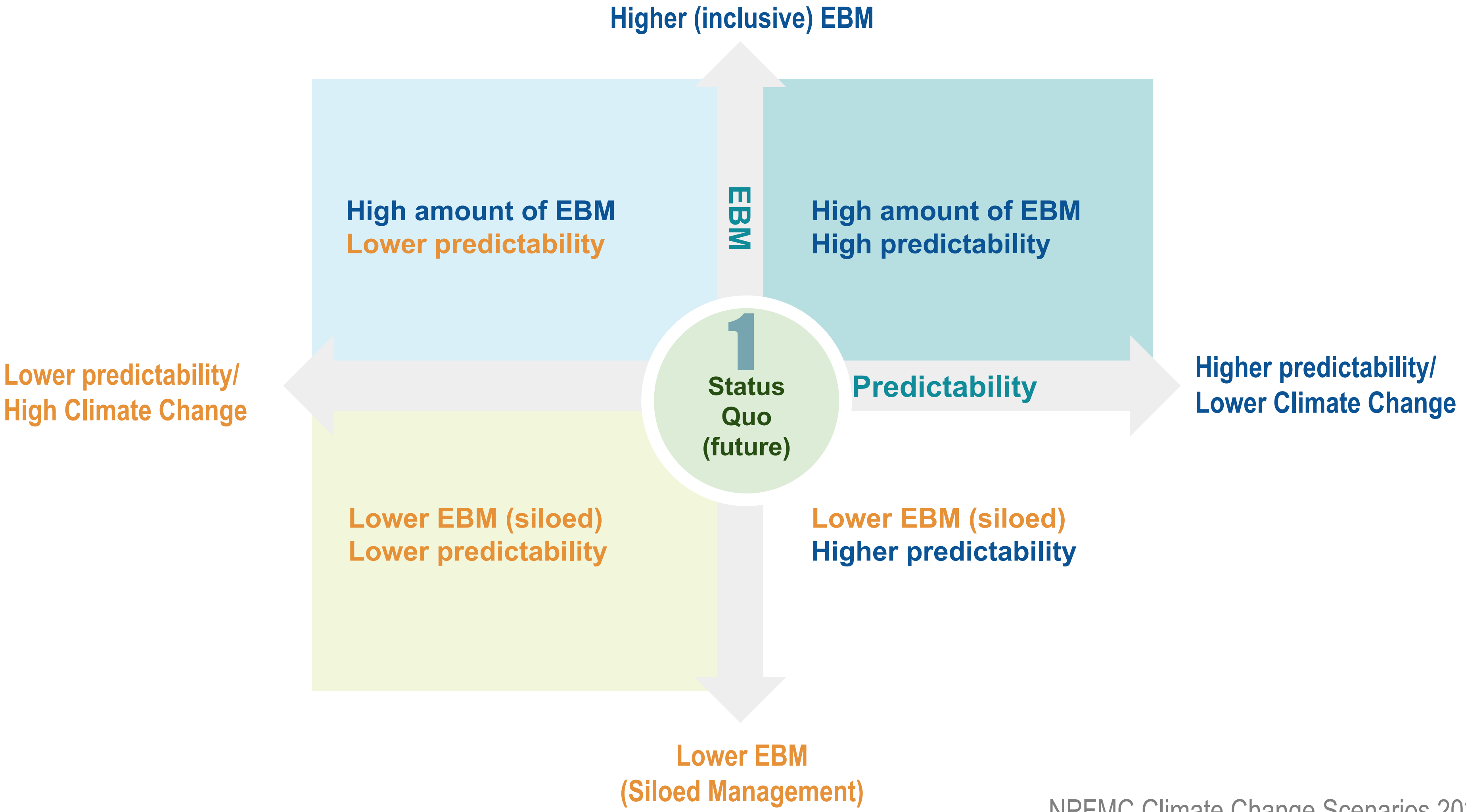
- **Information on-ramps** to enhance response and predictability
- **Management measures** to increase flexibility
- **Scientific tools** to increase predictability and characterize risks or benefits of alternative actions
- **Governance, and teams to increase inclusive discussions** and navigate climate shocks and potential climate conflicts
- Communication & processes to **increase information exchange**
- **Financing tools** to increase flexibility & response & help navigate climate shocks



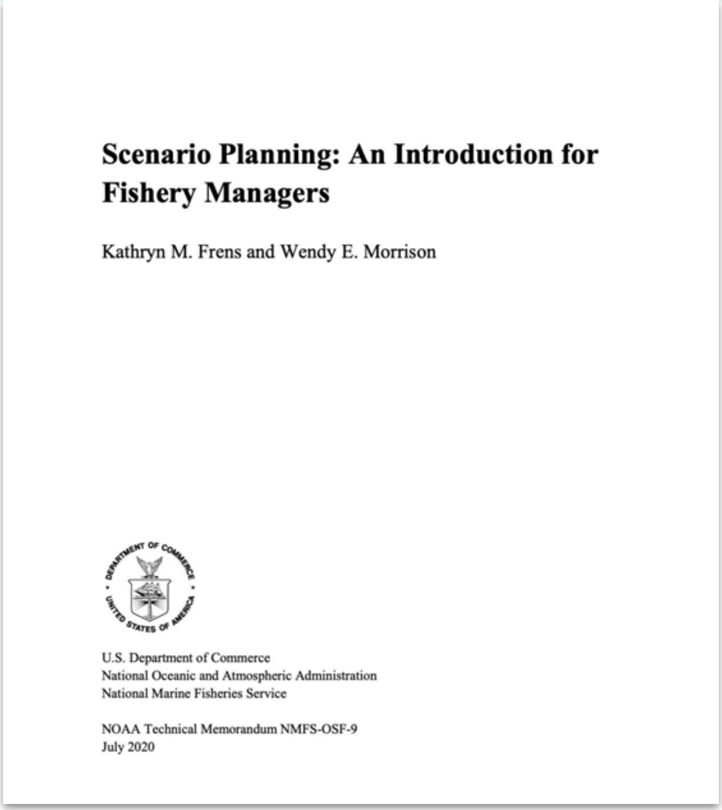
https://nca2023.globalchange.gov/all-figures/#10

QUESTIONS?

EXTRA SLIDES


Higher (inclusive) EBM
High amount of EBM
Lower predictability
EBM
High amount of EBM
High predictability
Lower predictability/
High Climate Change
1
Status
Quo
(future)
Predictability
Higher predictability/
Lower Climate Change
Lower EBM (siloed)
Lower predictability
Lower EBM (siloed)
Higher predictability
Lower EBM
(Siloed Management)

EXAMPLES OF SCENARIO PLANNING FRAMEWORKS



Scenario Planning: An Introduction for Fishery Managers

Kathryn M. Frens and Wendy E. Morrison

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-OSF-9
July 2020

https://media.fisheries.noaa.gov/2020-09/OSF9%20_508_9.11.pdf

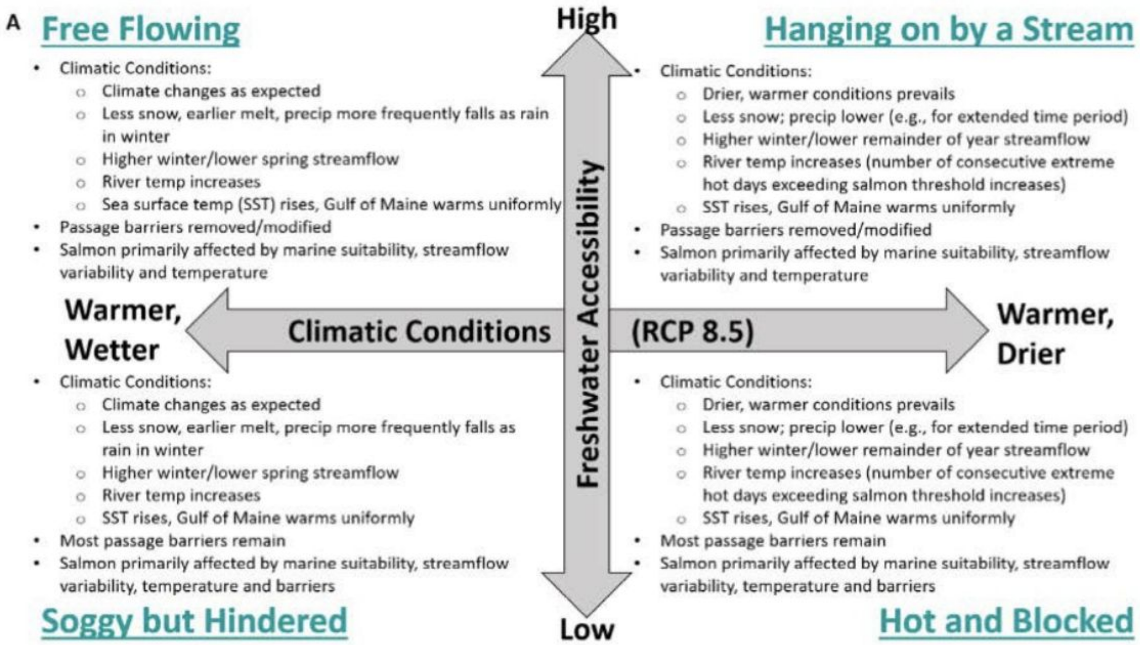


Figure 7: Climate conditions combined with freshwater accessibility produce four scenarios for Gulf of Maine salmon (Borgaard, et al., 2019).

https://media.fisheries.noaa.gov/2020-09/OSF9%20_508_9.11.pdf

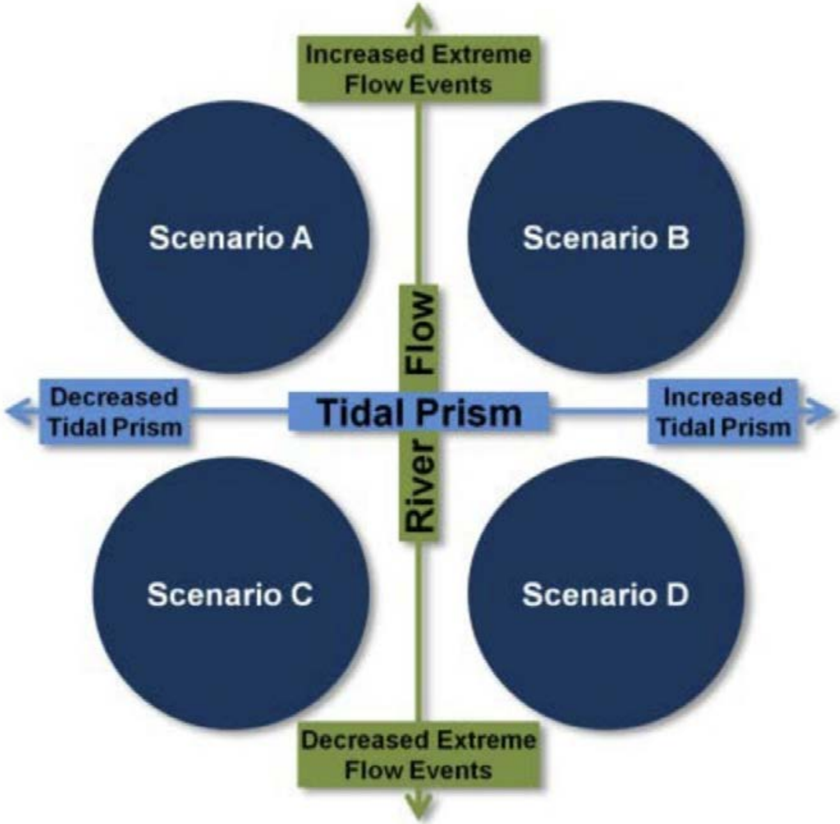


Figure 2: Two drivers generate four scenarios for Tijuana National Estuarine Research Reserve's scenario planning project (Boudreau, Crooks, Goodrich, & Lorda, 2016).

https://media.fisheries.noaa.gov/2020-09/OSF9%20_508_9.11.pdf

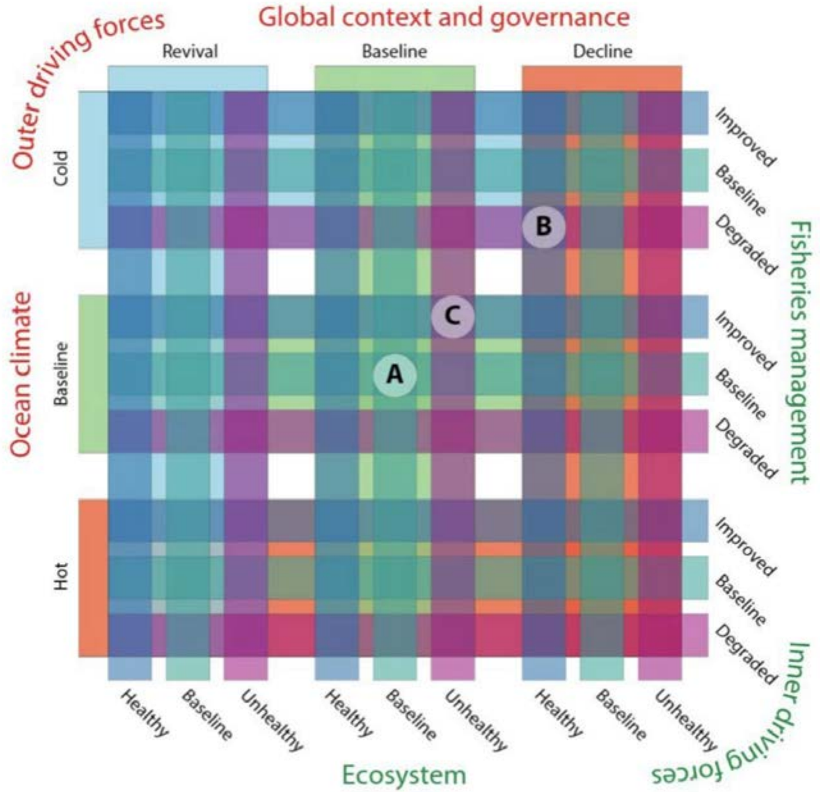


Figure 5: Single-perspective scenarios combined to form multi-perspective scenarios in the Barents Sea Circles marked "A", "B", and "C" represent scenarios selected for analysis (Planque, et al., 2019).

https://media.fisheries.noaa.gov/2020-09/OSF9%20_508_9.11.pdf

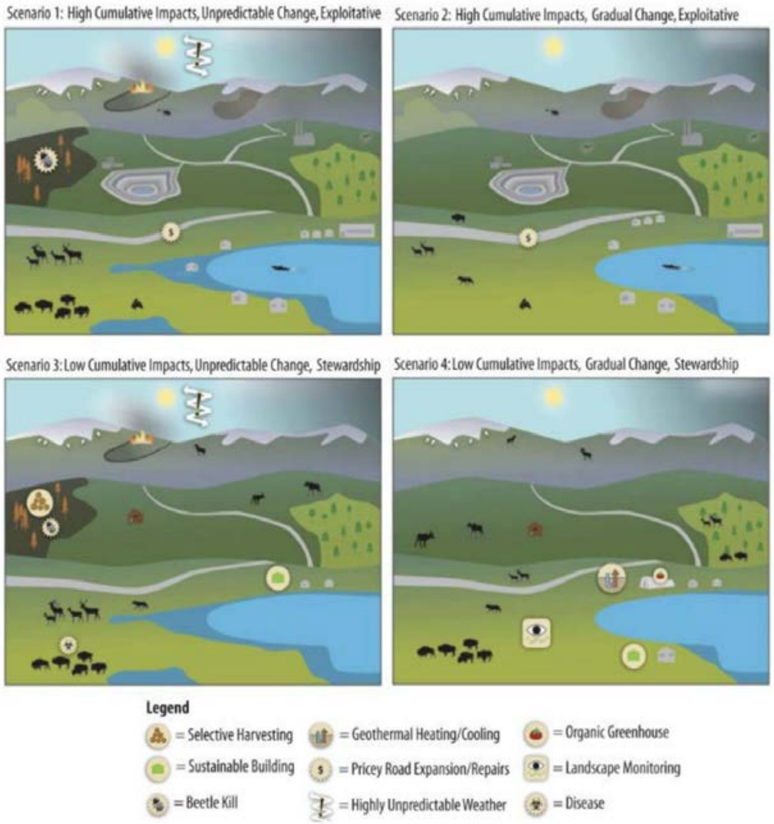


Figure 6: Scenarios of ecological change selected for analysis in the Yukon (Beach & Clark, 2015).

https://media.fisheries.noaa.gov/2020-09/OSF9%20_508_9.11.pdf

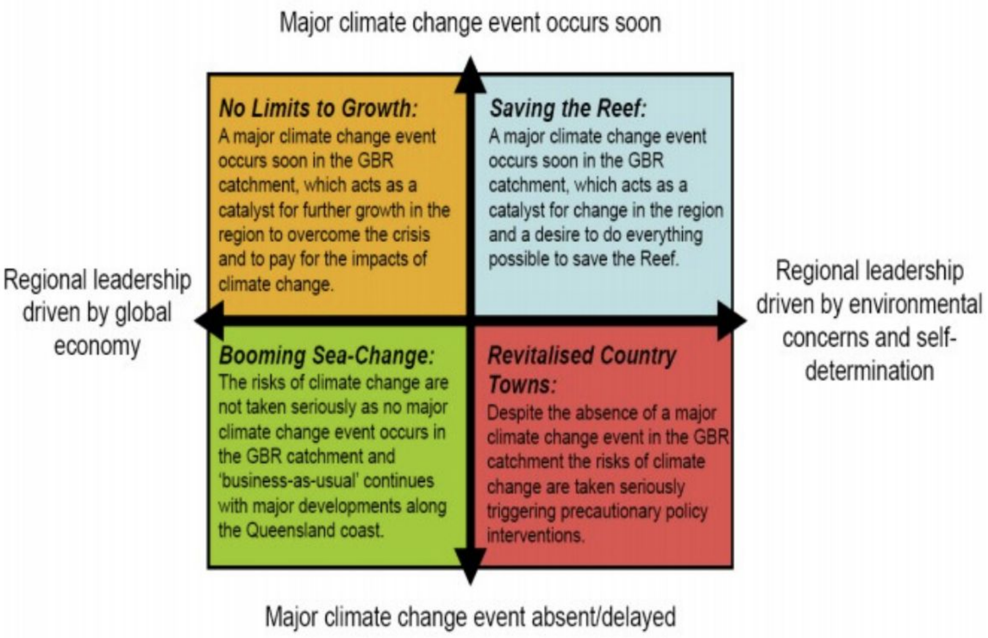
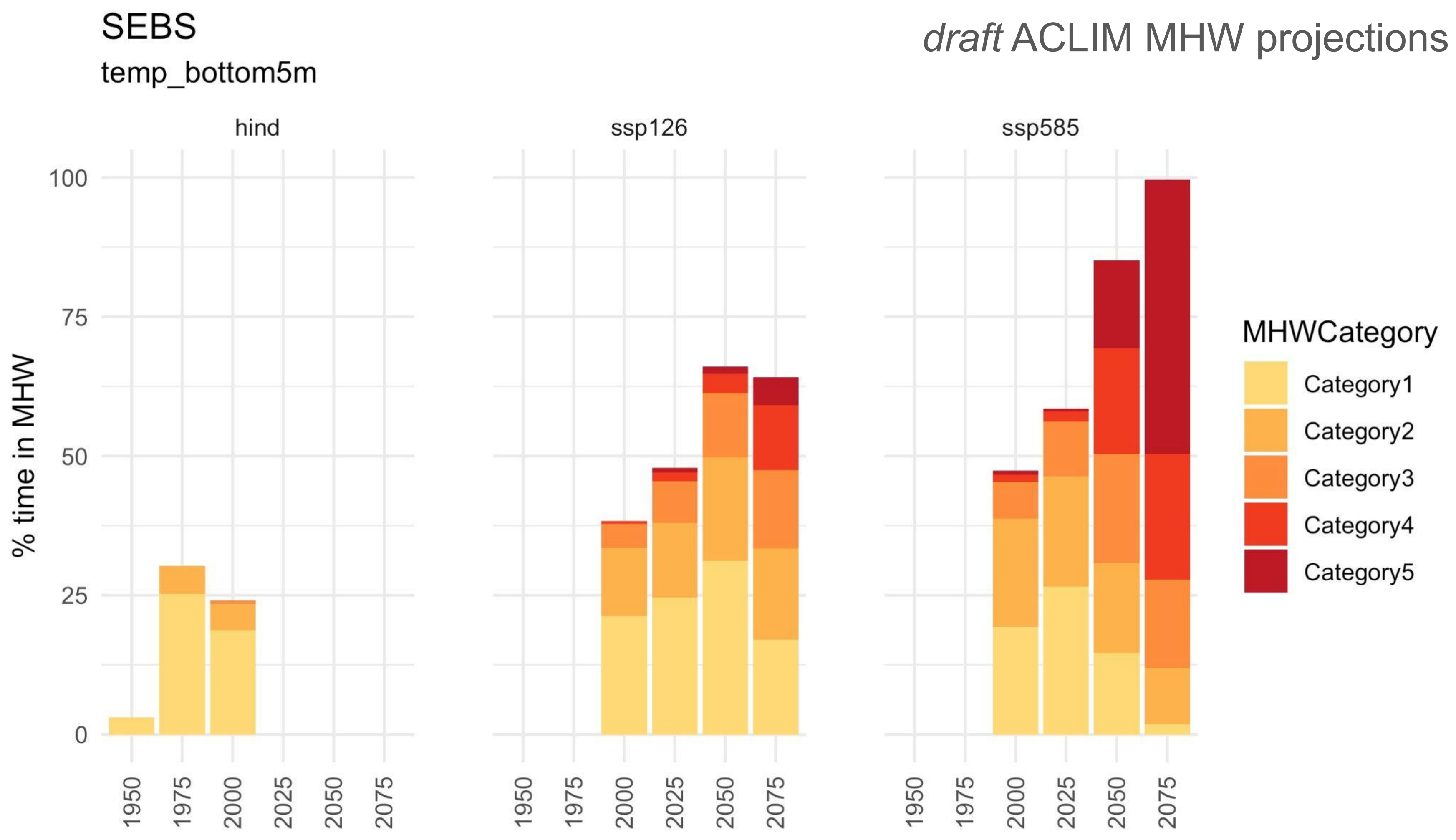


Figure 3: Two drivers combined to form four possible futures for the Great Barrier Reef catchment (Bohnet, Bohensky, Gambley, & Waterhouse, 2008).

https://media.fisheries.noaa.gov/2020-09/OSF9%20_508_9.11.pdf


SEBS
temp_bottom5m
draft ACLIM MHW projections
hind
ssp126
ssp585
% time in MHW
100
75
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1950
1975
2000
2025
2050
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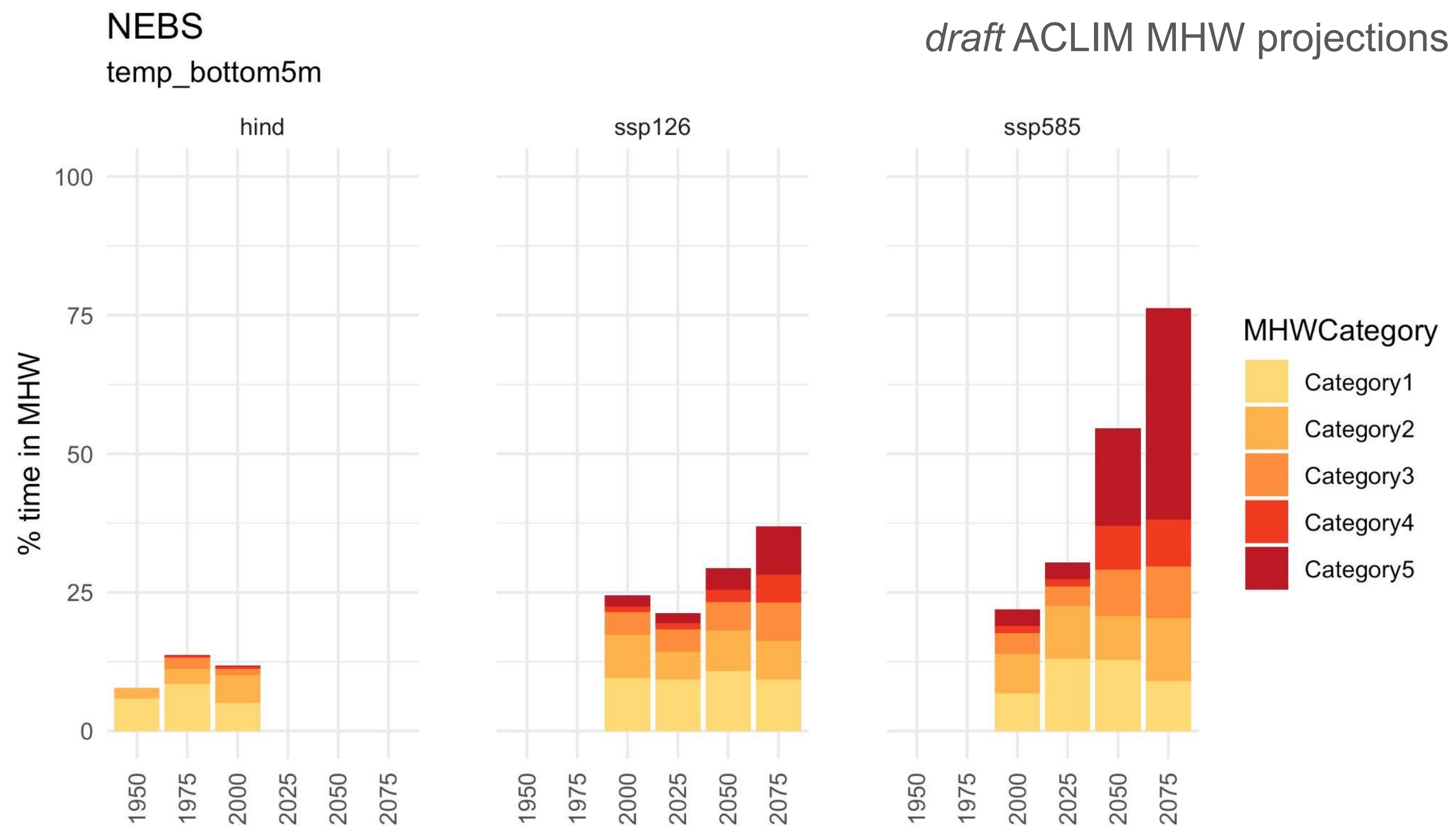
MHWCategory
Category1
Category2
Category3
Category4
Category5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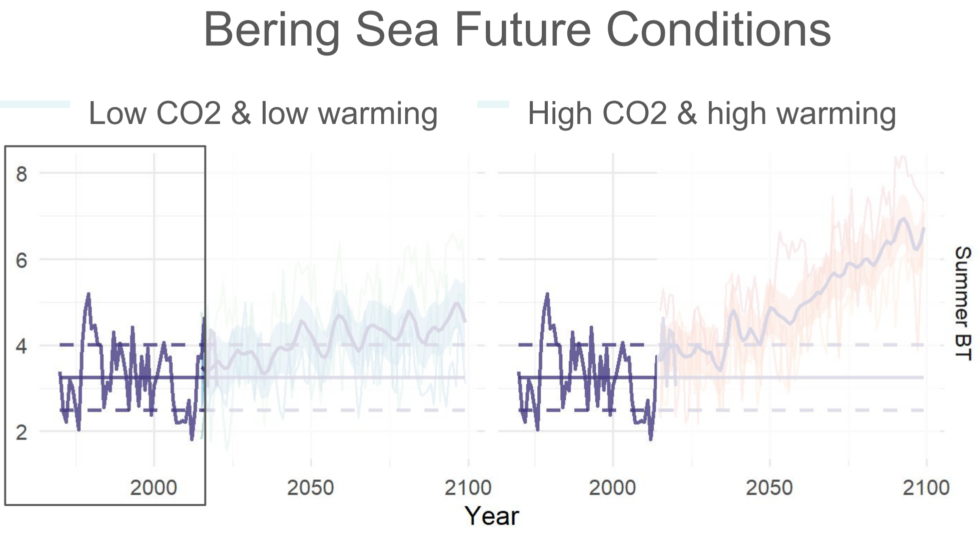
2025
2050
2075
MHWCategory
Category1
Category2
Category3
Category4
Category5

Future Change : EBS

From EBS Ecosystem Status Report

Bottom Temperature

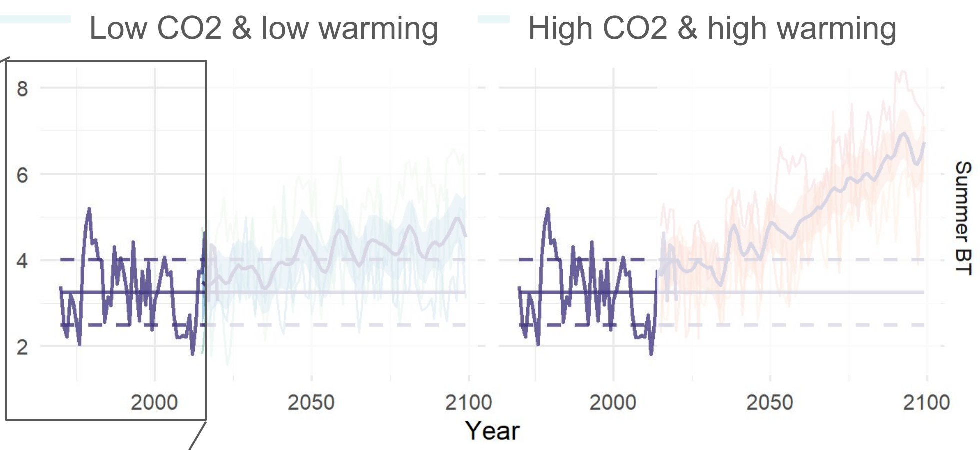


Operational hindcasts: AK IEA | Projections: ACLIM2 | Model: Bering10K 30-layer

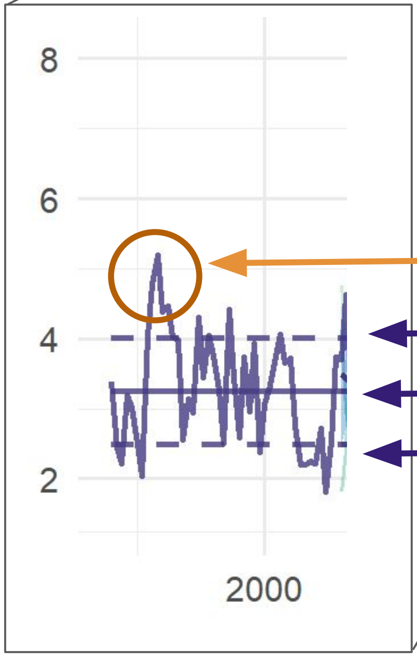
Future Change : EBS

From EBS Ecosystem Status Report

Bering Sea Future Conditions



Bottom Temperature



“Warm anomaly” or Marine Heat Wave

Upper range of “normal” ~4.0 deg C

Average bottom temperature ~3.2 deg C

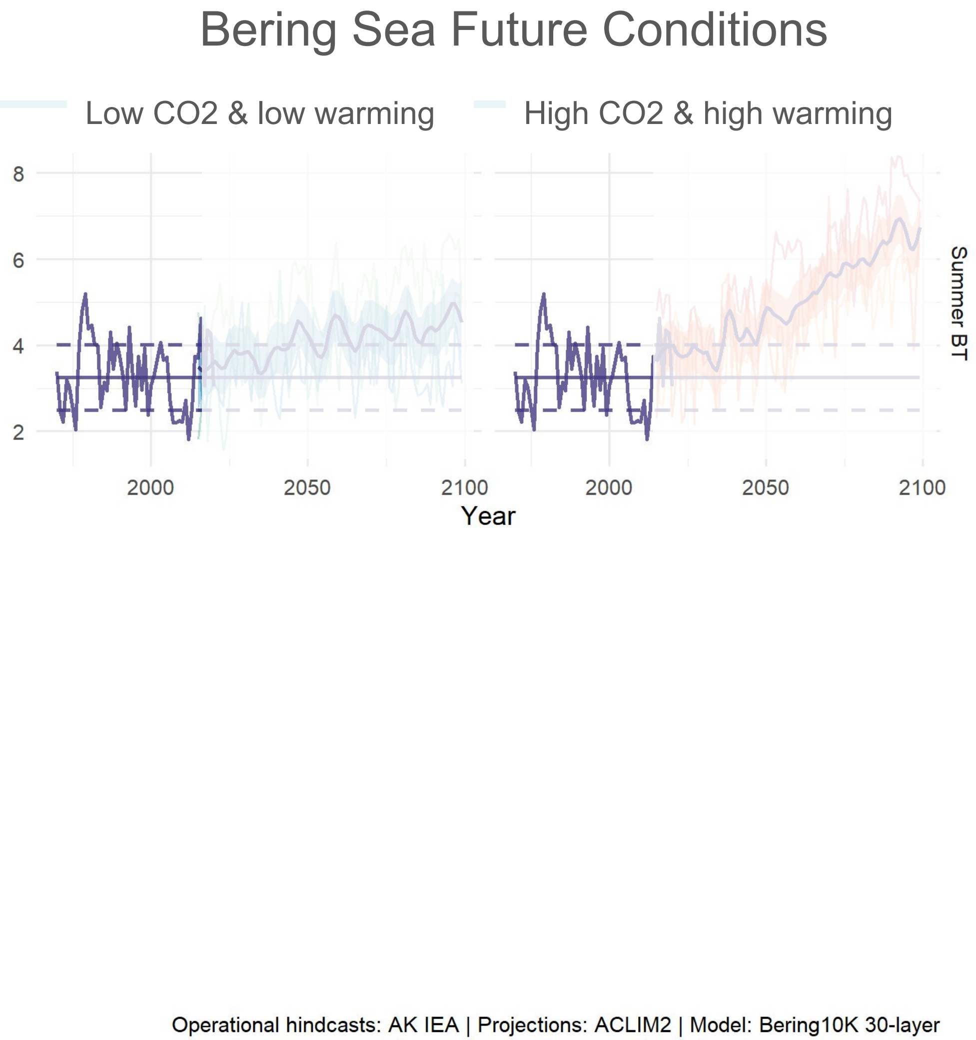
Lower range of “normal” ~2.6 deg C

Operational hindcasts: AK IEA | Projections: ACLIM2 | Model: Bering10K 30-layer

Future Change : EBS

From EBS Ecosystem Status Report

Bottom Temperature



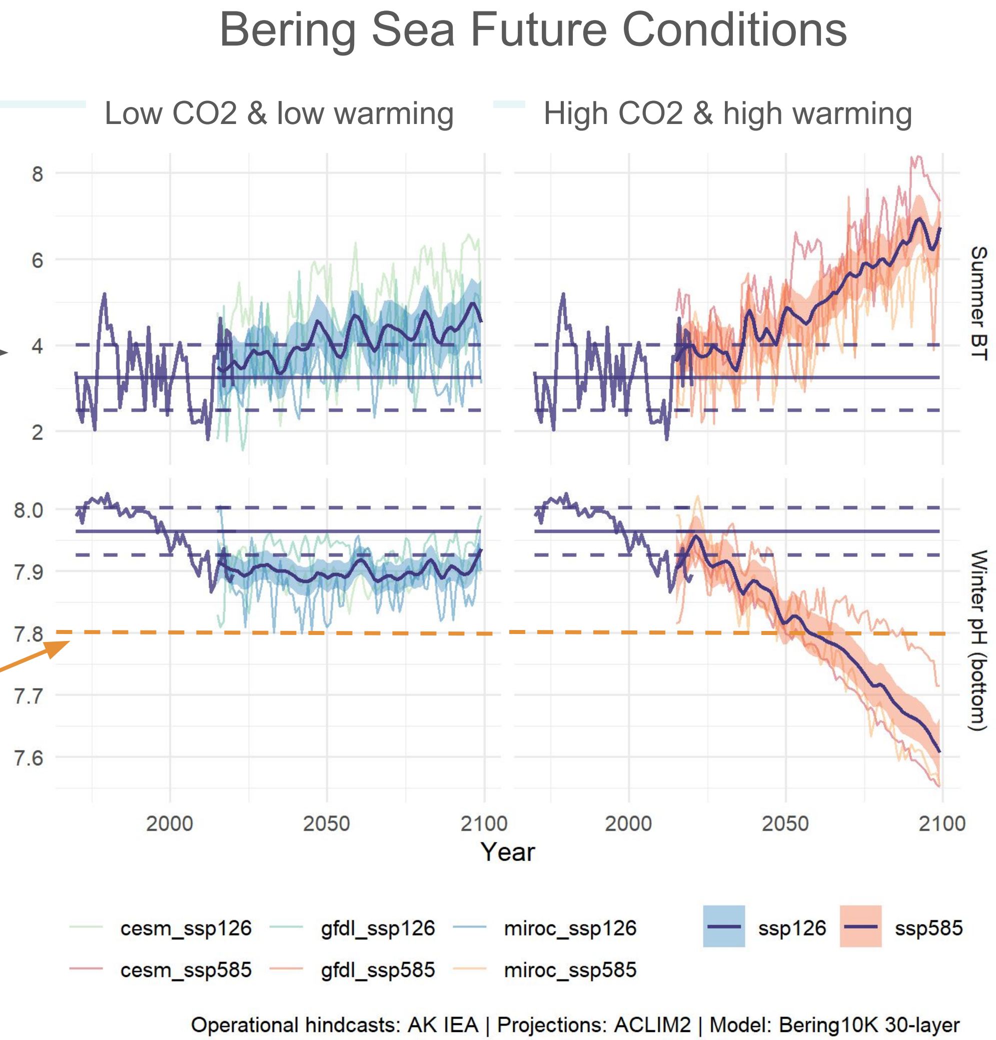
Future Change : EBS

From EBS Ecosystem Status Report

Bottom Temperature

Ocean pH

Critical threshold for shellfish growth & survival



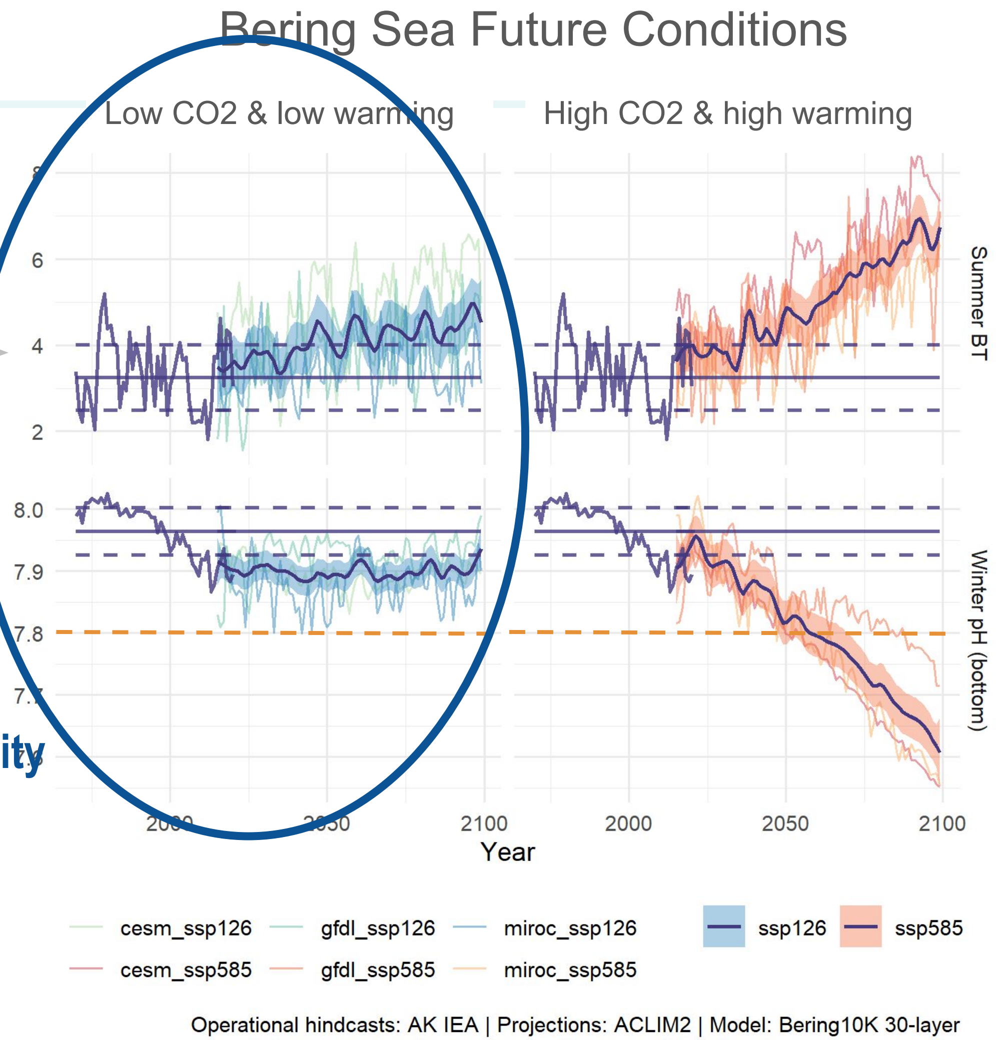
Future Change : EBS

From EBS Ecosystem Status Report

Bottom Temperature

Ocean pH

Lower warming & higher predictability

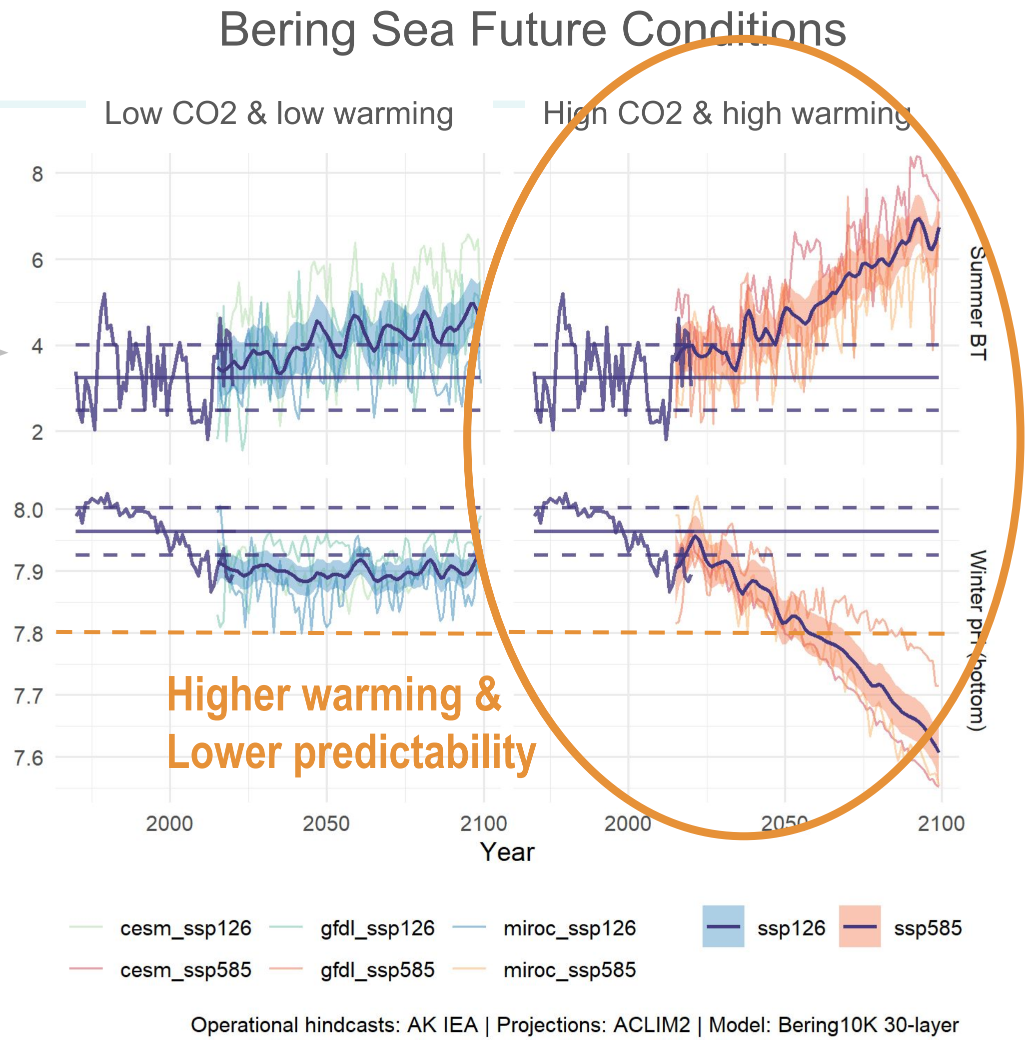


Future Change : EBS

From EBS Ecosystem Status Report

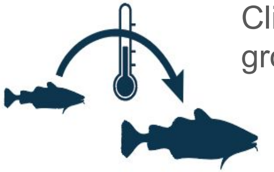
Bottom Temperature

Ocean pH



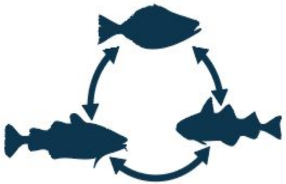
Future Change : EBS

BSAI Multispp. Assessment



Climate effects on growth

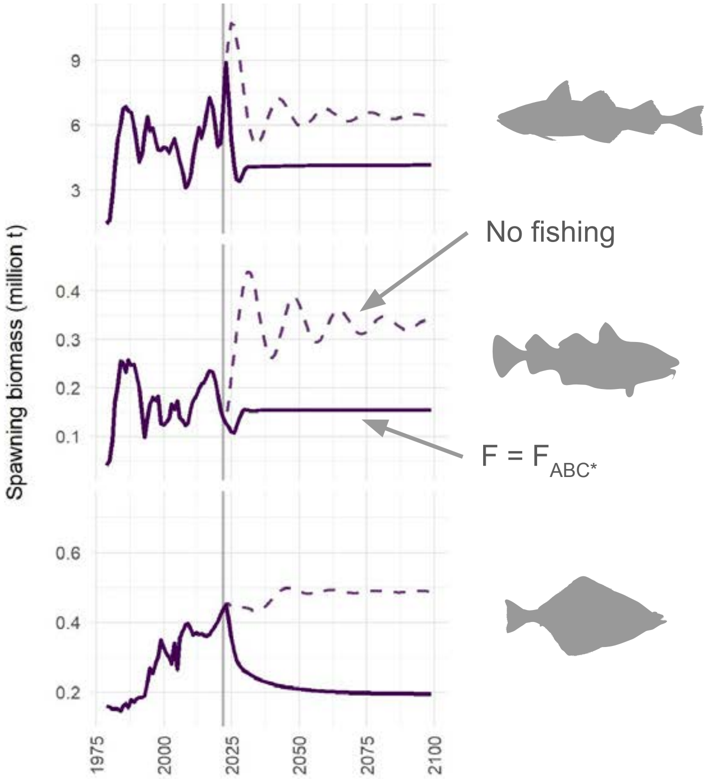
Climate effects on survival



Climate effects on recruitment

Bering Sea Spawning Biomass

Future = No change in climate

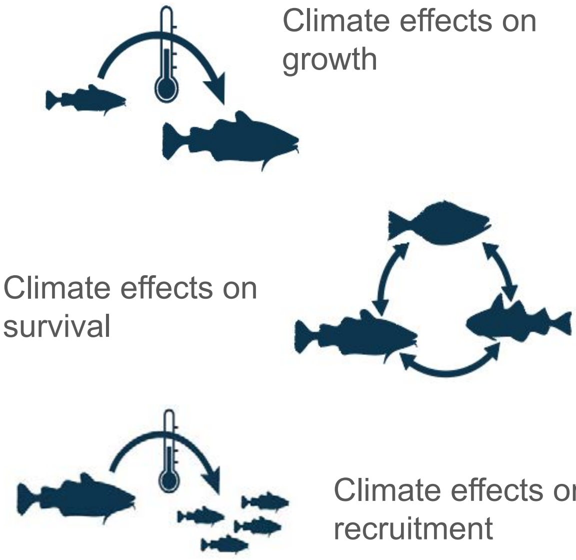


Holsman et al. 2022. Multispecies stock assessment for the EBS. NPFMC
https://apps-afsc.fisheries.noaa.gov/Plan_Team/2022/EBSmultispp.pdf

Future Change : EBS

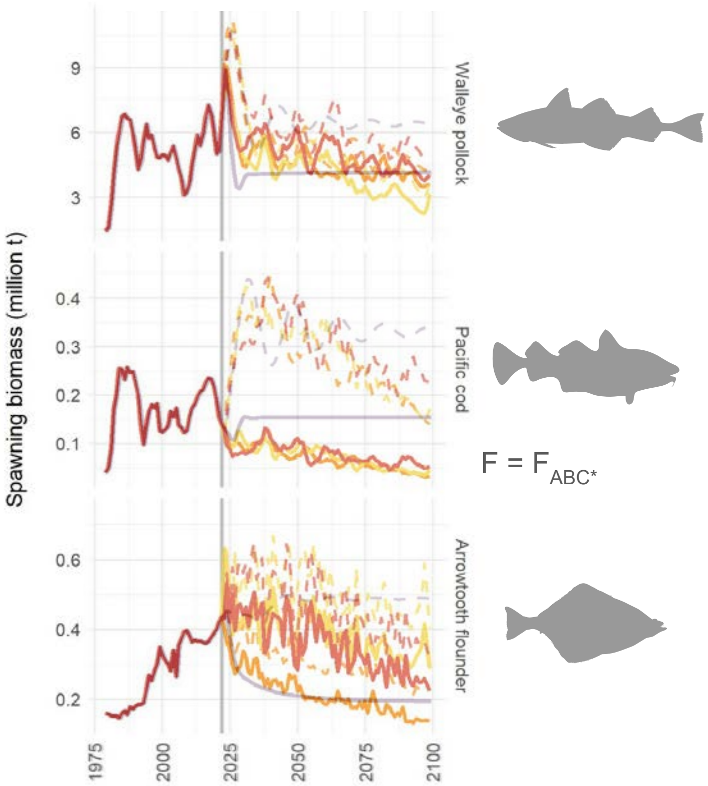
Bering Sea Spawning Biomass

BSAI Multispp. Assessment



Assumes no adaptation in fish or fishery (status quo)

High CO2 & high warming



$F = F_{ABC*}$

Holsman et al. 2022. Multispecies stock assessment for the EBS. NPFMC
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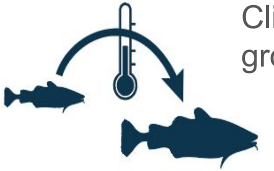
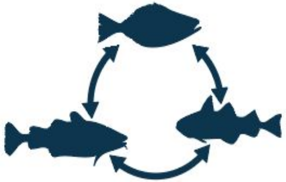
Future Change : EBS

Bering Sea Spawning Biomass

BSAI Multispp. Assessment

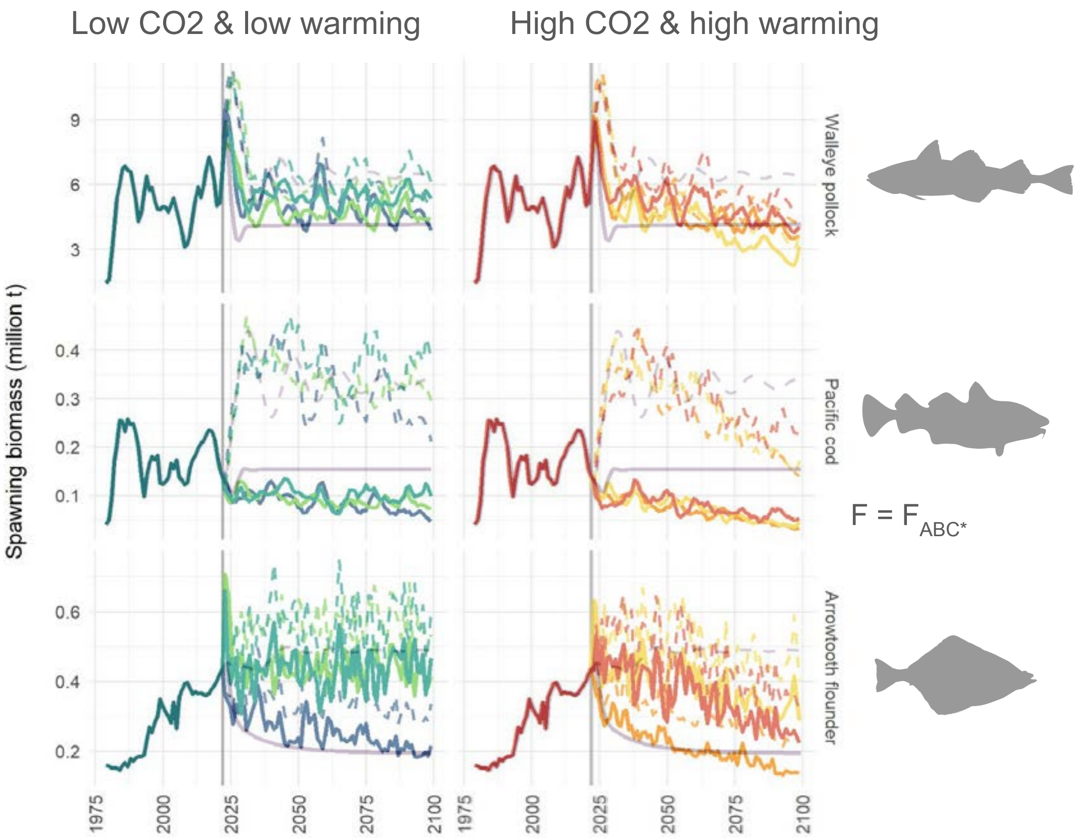


Climate effects on growth



Climate effects on survival

Climate effects on recruitment



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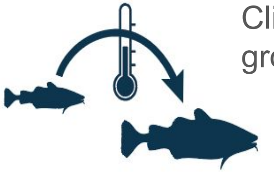
Holsman et al. 2022. Multisp
https://apps-afsc.fisheries.no

Future Change : EBS

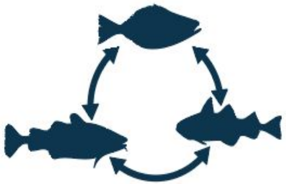
Bering Sea Spawning Biomass

BSAI Multispp. Assessment



Climate effects on growth

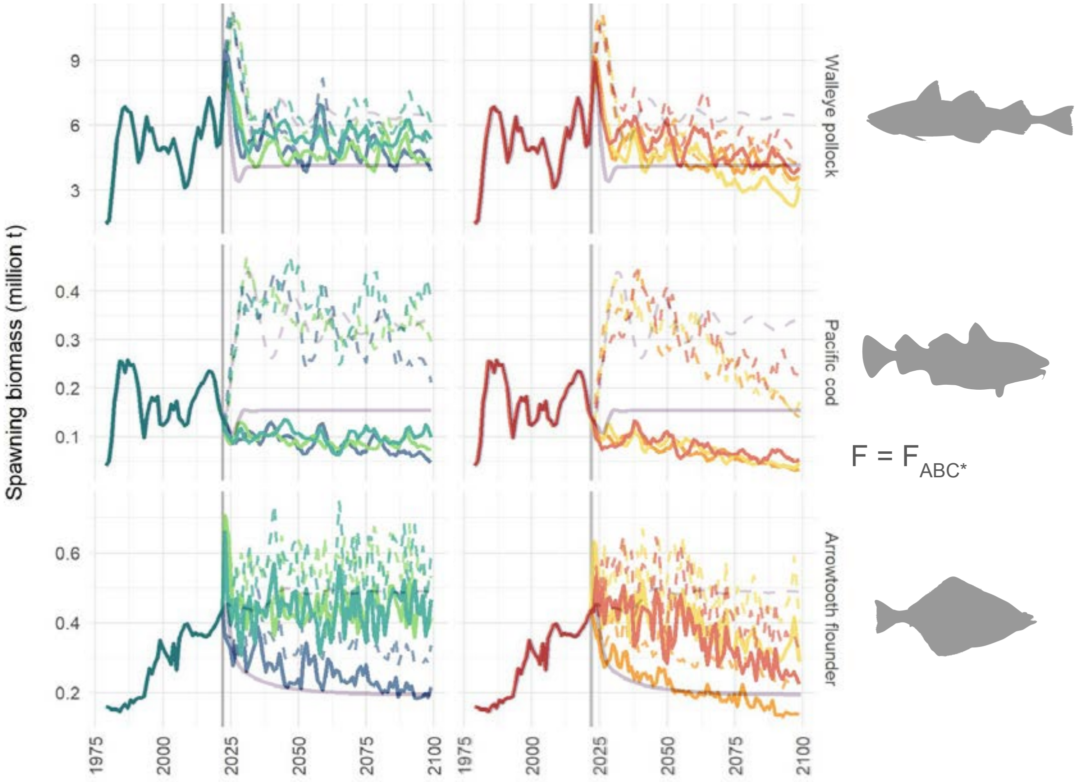
Climate effects on survival



Climate effects on recruitment

Low CO2 & low warming

High CO2 & high warming



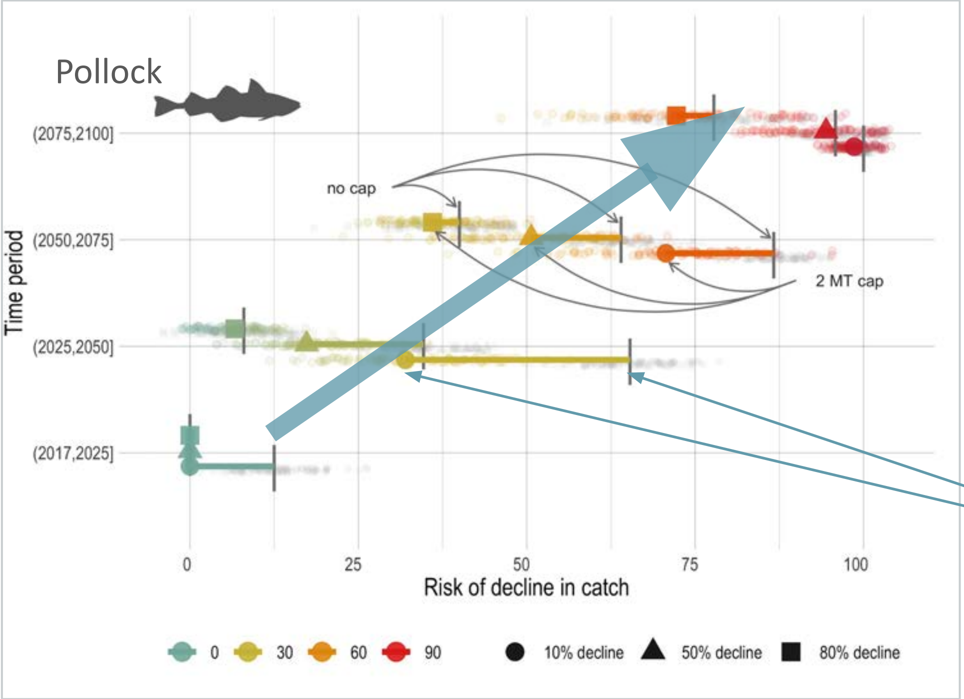
$F = F_{ABC*}$

Assumes no adaptation in fish or fishery (status quo)

Holsman et al. 2022. Multisp
https://apps-afsc.fisheries.no

CEATTLE: EBFM vs non-EBFM cap

Assumes no adaptation in fish or fishery



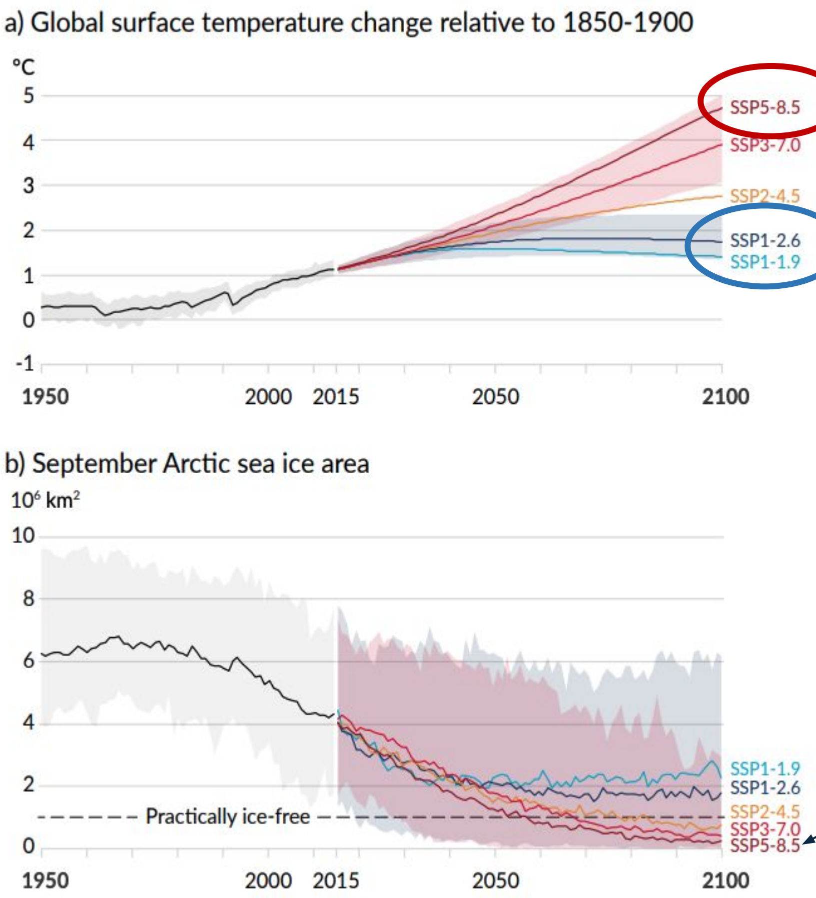
How does the 2mt/yr EBM cap on total groundfish yield perform under climate change?

Risk of declines & collapse is lower with EBFM cap

Risk increases with warming (overtime)

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

Climate change is expected to increasingly impact oceans



Low CO_2 mitigation scenario

High CO_2 mitigation scenarios

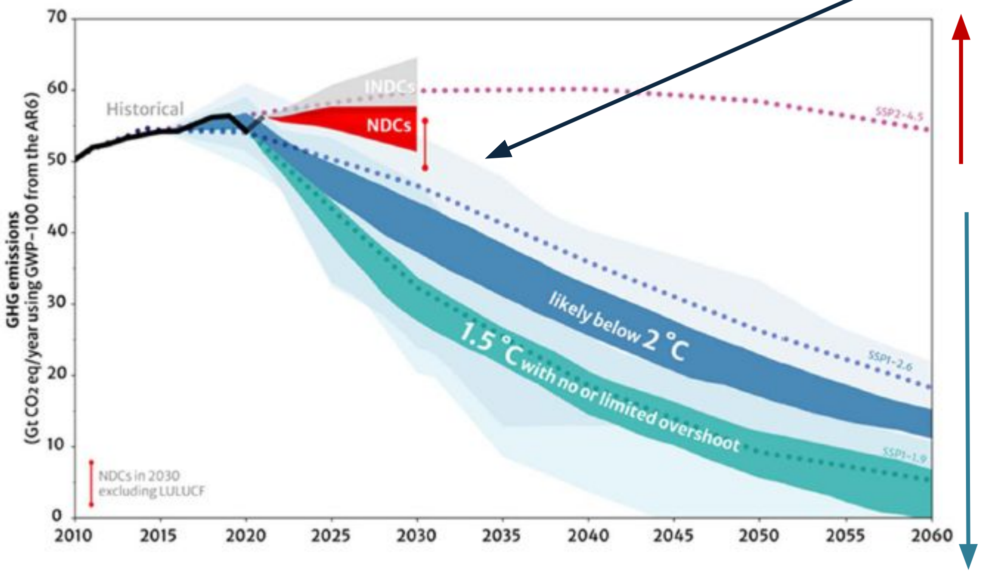
Warming will continue and is greater in scenarios with low CO_2 mitigation

Sea Ice will continue to decline, more so under scenarios with high global warming and low CO_2 mitigation

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

UNFCC 2022 NDC Synthesis report

Revised NDCs

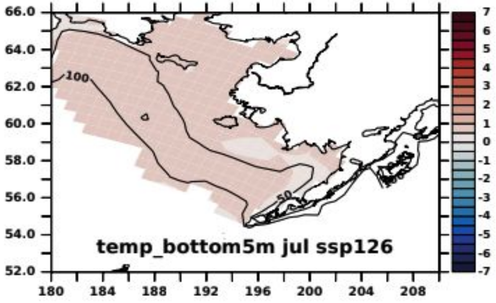


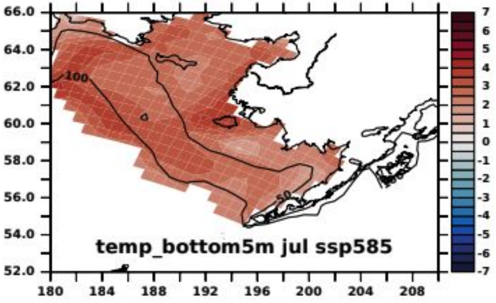
ACLIM found higher risk above this (SSP585, RCP8.5)

ACLIM found lower risk below this (RCP4.5, SSP126)

https://unfccc.int/ndc-synthesis-report-2022

Increased warming expected (July BT [2070–2099]-[2015-2044])



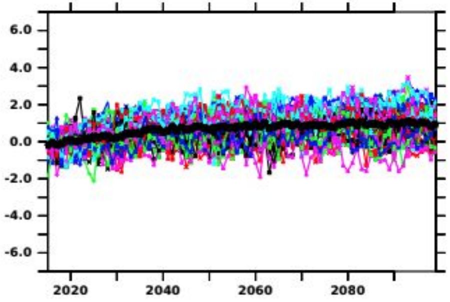


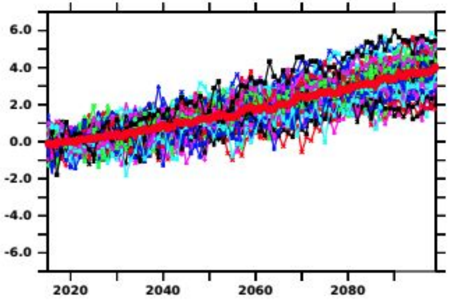
Bottom Temp.

(degrees C)

SSP126
High mitigation/ less warming

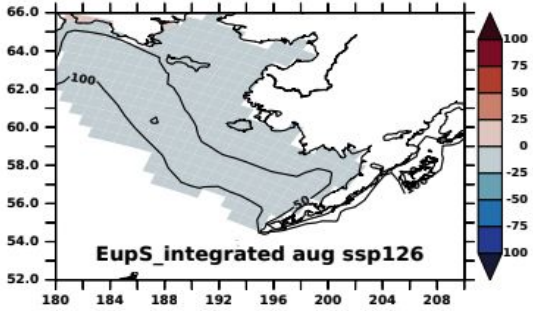
SSP585
Low mitigation/ more warming

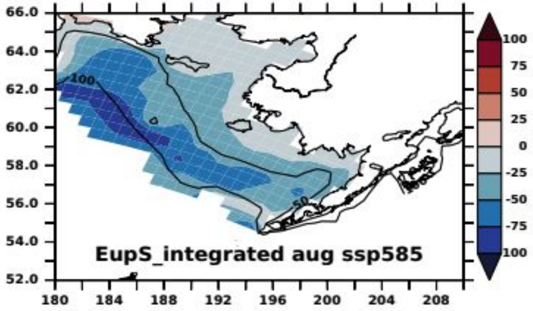




(2021) Hermann, A. J., Kearney, K., Cheng, W., Pilcher, D., Aydin, K., Holsman, K. K., & Hollowed, A. B.. Coupled modes of projected regional change in the Bering Sea from a dynamically downscaling model under CMIP6 forcing. Deep-Sea Research Part II: Topical Studies in Oceanography, 194 (Dec), 104974. https://doi.org/10.1016/j.dsr2.2021.104974

Declines in Euphausiids expected (July [2070–2099]-[2015-2044])

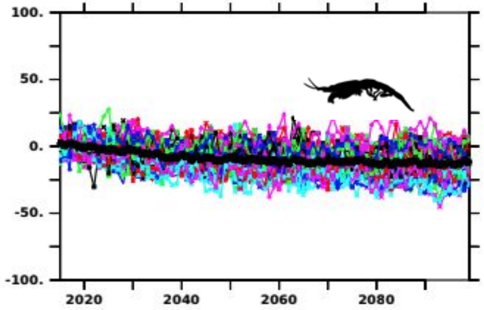




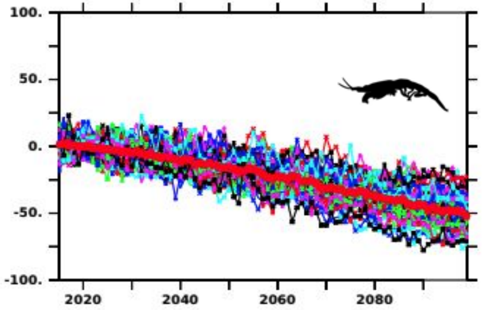
Euphausiid biomass

EupS, mg C m-2

SSP126
High mitigation/ less warming



SSP585
Low mitigation/ more warming

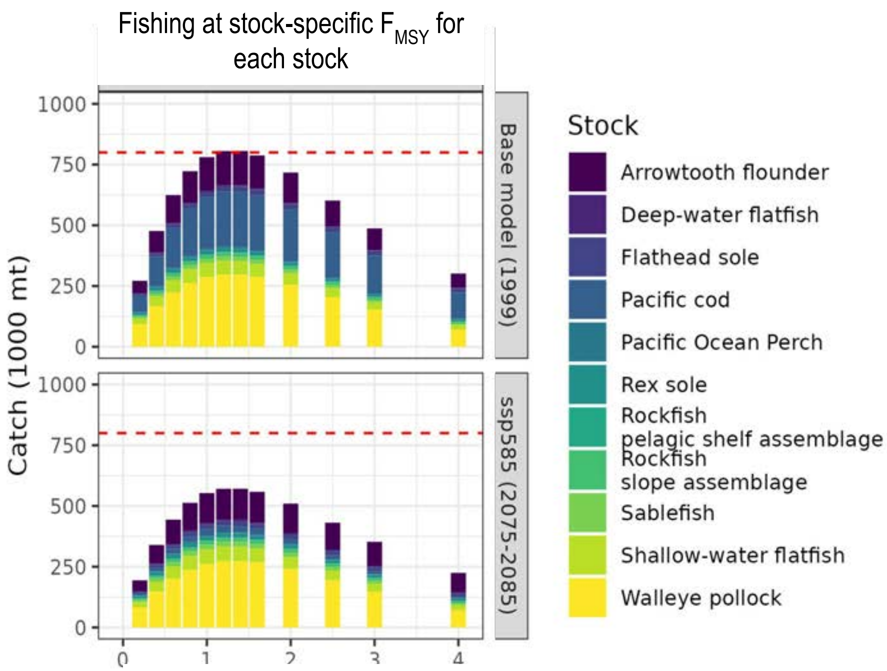


(2021) Hermann, A. J., Kearney, K., Cheng, W., Pilcher, D., Aydin, K., Holsman, K. K., & Hollowed, A. B.. Coupled modes of projected regional change in the Bering Sea from a dynamically downscaling model under CMIP6 forcing. Deep-Sea Research Part II: Topical Studies in Oceanography, 194 (Dec), 104974. https://doi.org/10.1016/j.dsr2.2021.104974

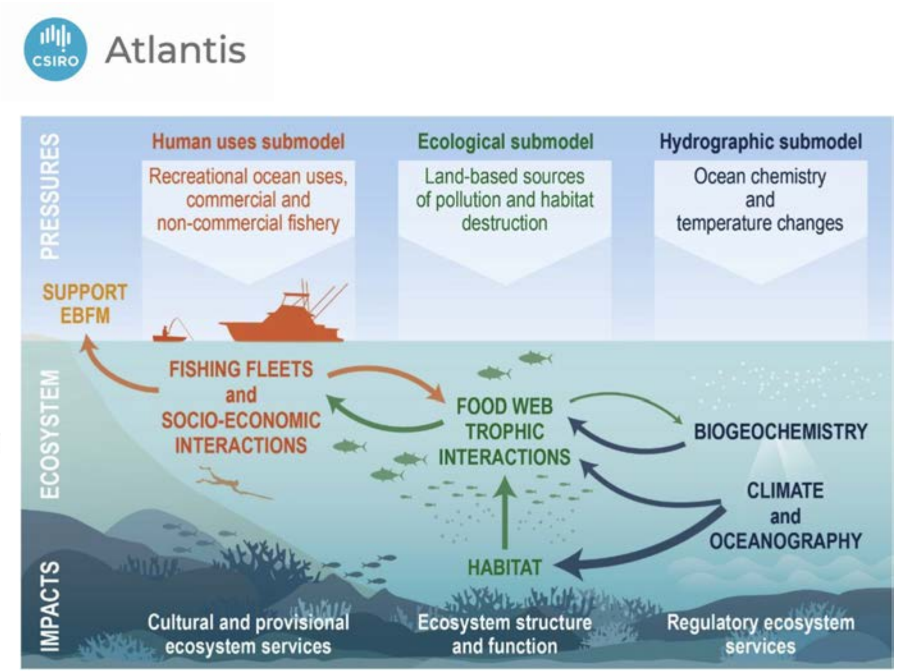
Strategic advice for EBM

GOACLIM

How does climate impact aggregate yield across species?



Multi-species optimum yield multiplier



Slide from Alberto Rovellini – Optimum Yield under climate change

Salmon & Communities

Goal: Identify candidate ROMS/NPZ indicators for Yukon River Chinook salmon survival based on scientific and traditional knowledge.

H1: Ocean temperatures during the 1st and 2nd year at sea impacts growth & survival.

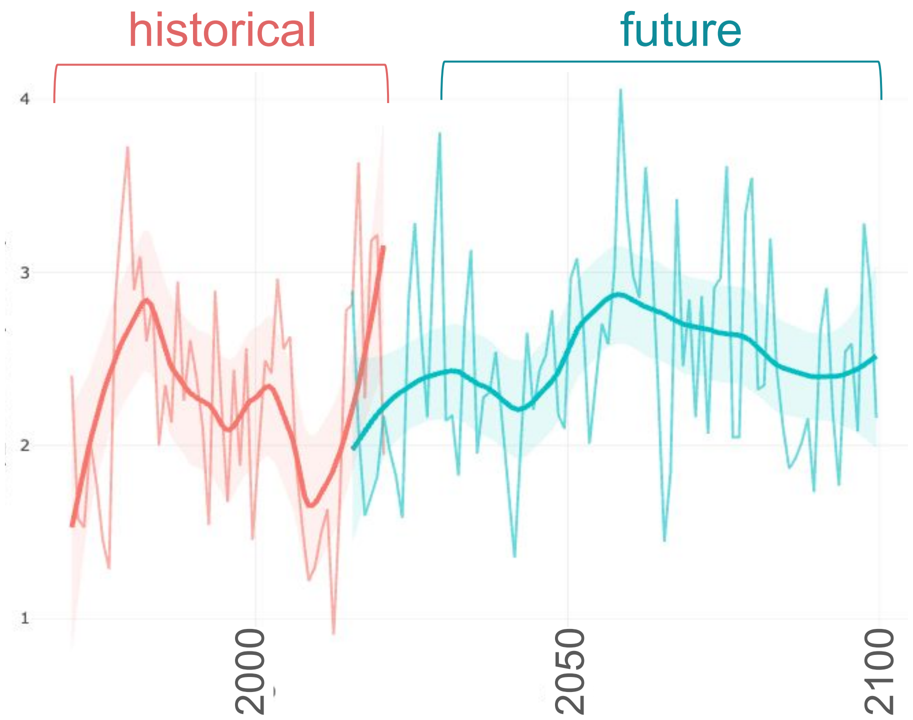
Spring 2023 trip to Lower Yukon LTK:
Good for salmon returns: Strong north winds, high river water, ice break up but not thaw, & yellow butterflies. (wish list indicators)

→ **Produce recruitment projections under different climate & emission scenarios at various lags**

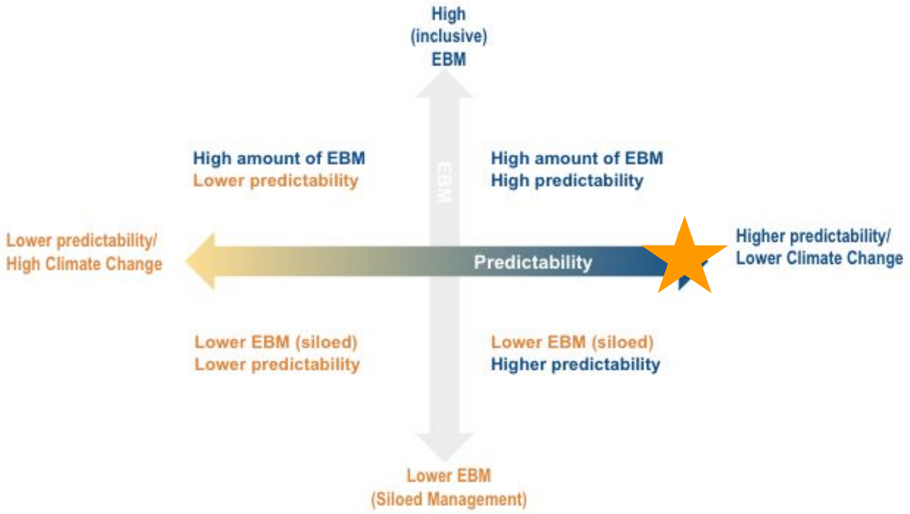
Slide Courtesy of S. Wise, E. Yasumiishi, J. Reynolds (AFSC-NOAA)

Future climate conditions

Bottom temperature in the SEBS (deg C)

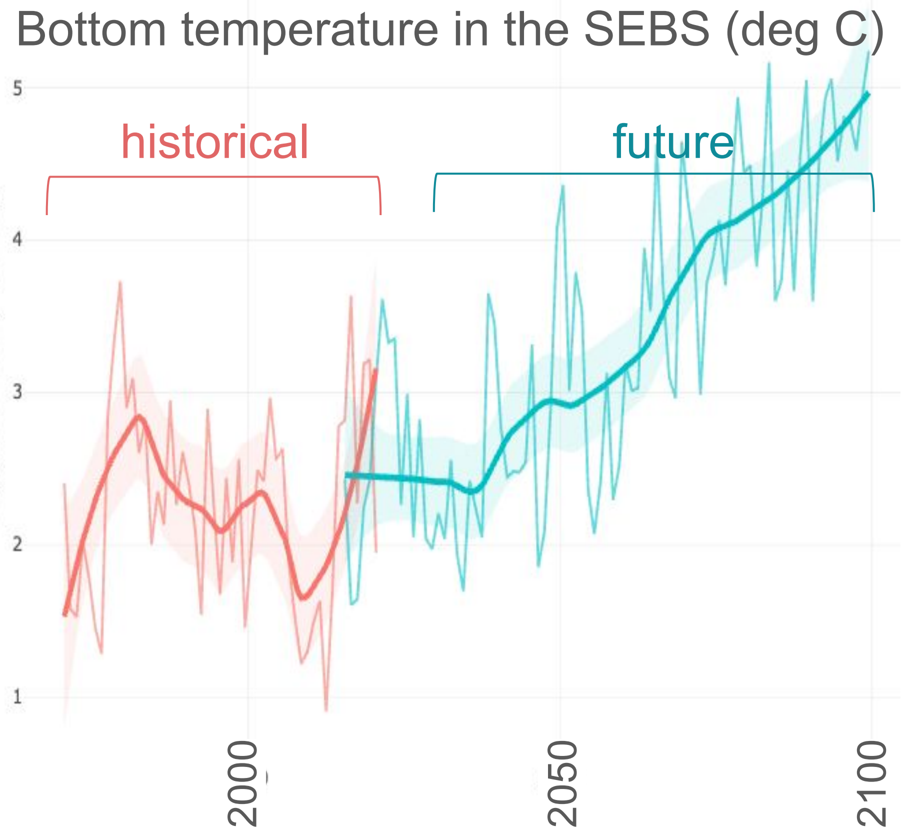


Lower warming (SSP126)
& higher predictability

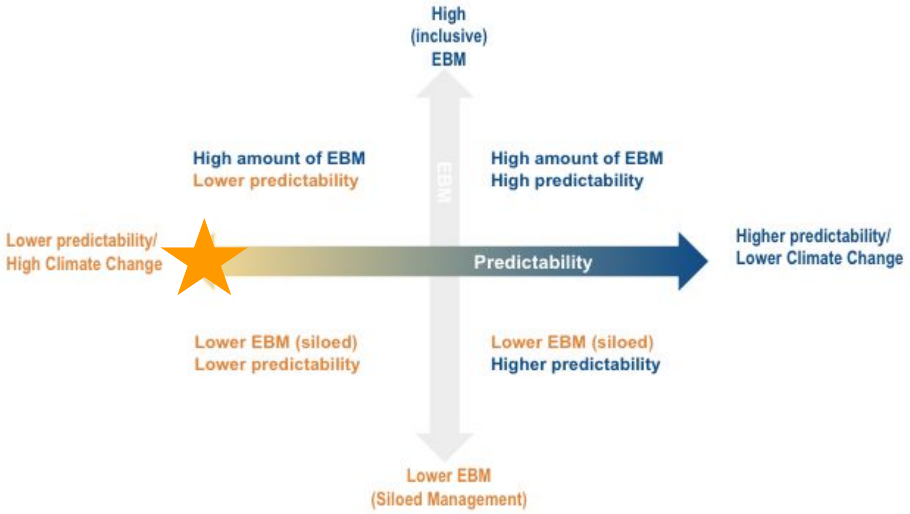


https://kkh2022.shinyapps.io/ACLIM2_indices/

Future climate conditions



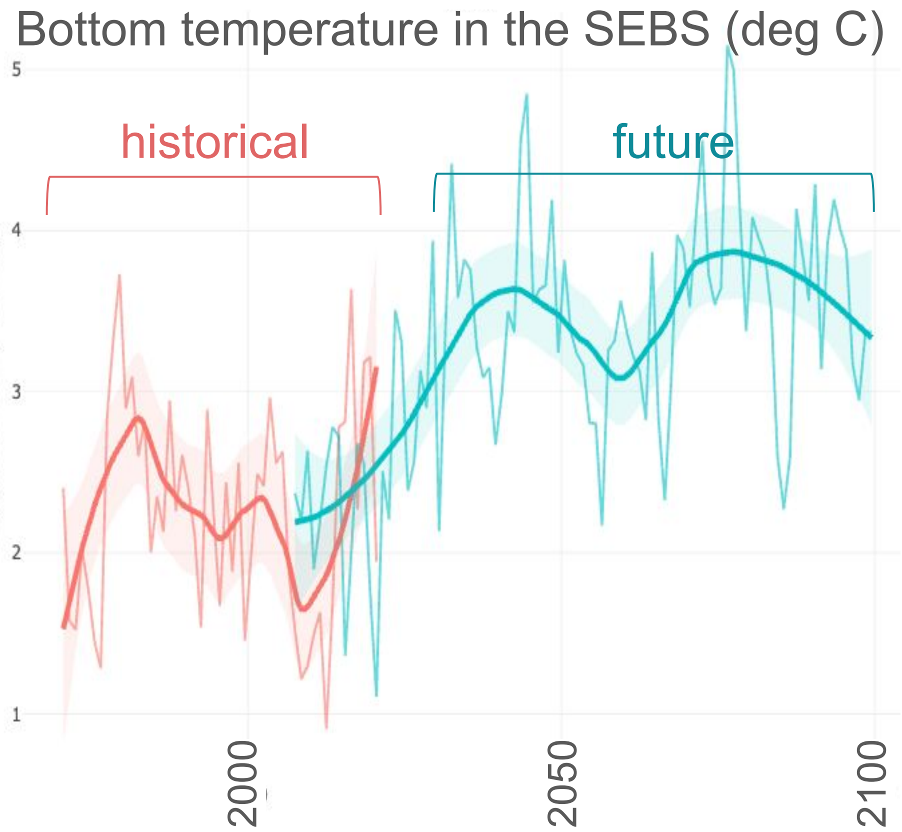
High warming (SSP585)
& lower predictability

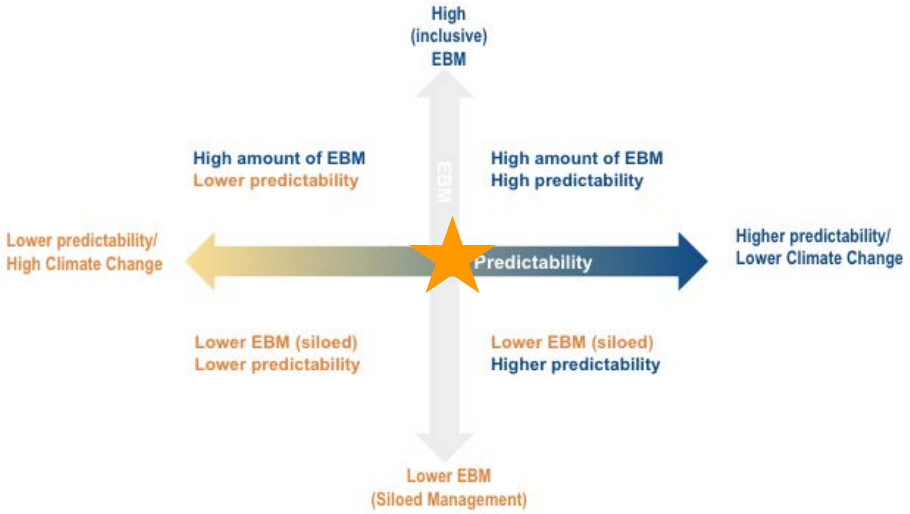


https://kkh2022.shinyapps.io/ACLIM2_indices/

Future climate conditions

Med. warming (RCP45)
& medium predictability





https://kkh2022.shinyapps.io/ACLIM2_indices/