Alternative HCRs & cap evaluations

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Thanks to :

ACLIM and GOACLIM
CEFI - Alaska
ICES/PICES S-CCME/ SICCME

Outline for today's talk

a) Overview of Council Actions [Stram] 10 mins

b) Overview of ACLIM & GOACLIM HCRs [Holsman] 10mins

    i) SSC Workshop

        1) Stage 1 HCRs (4)
        2) Cap evalations
        3) Simulation evaluation criteria
        4) Stage 1 focal species

a) Next steps & feedback towards a workplan [Stram & Holsman 5 mins]

Credit: Kirstin Holsman

GOAL TODAY

- Update PTs on HCR and Cap analyses presently underway through ACLIM & GOACLIM
- PT feedback on key questions and considerations
- Use that to help inform a council work plan (draft in Feb 2026 (T), potential approval June 2026)

Credit: Mark Holsman

CCTF Timeline

CCTF Start

Council Motion

2020 — **Climate On-ramps**

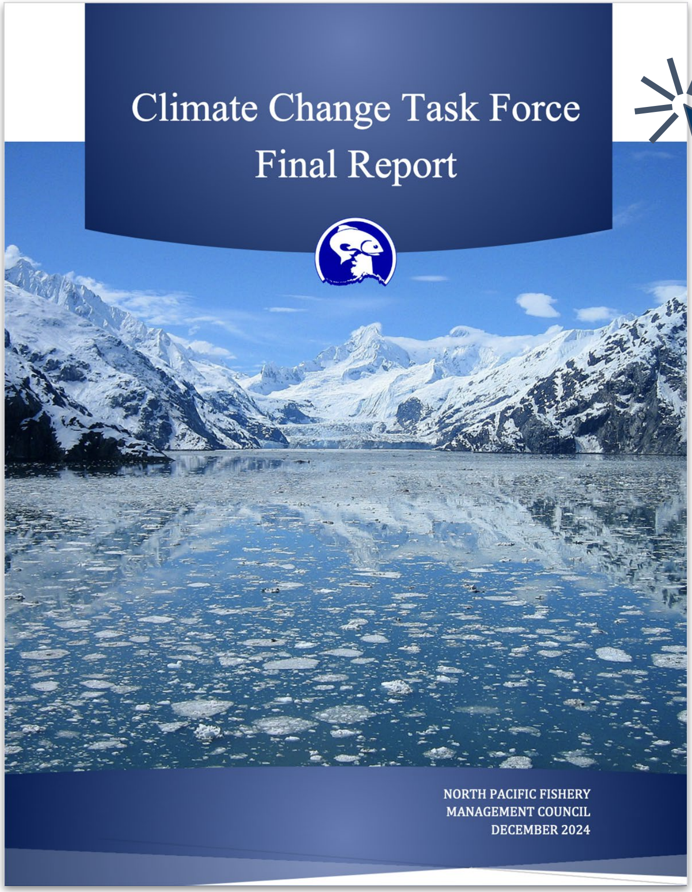
2021 — **CCTF work plan**
Adaptation & Resilience definitions

2022 — **Climate Readiness Synthesis Report**

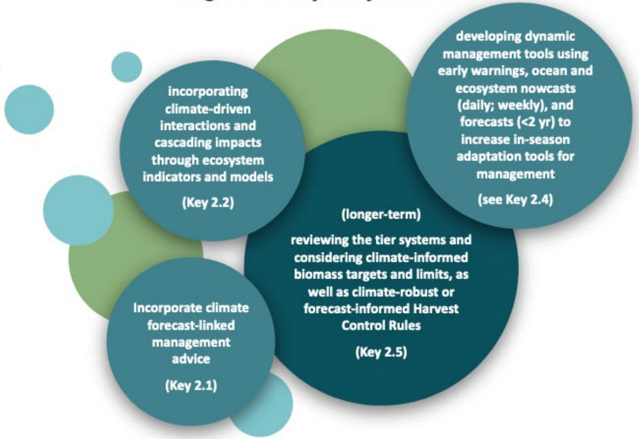
2023 — **Climate Scenarios Workshop proposal**
Reviewed FEP goals and indicators & research priorities

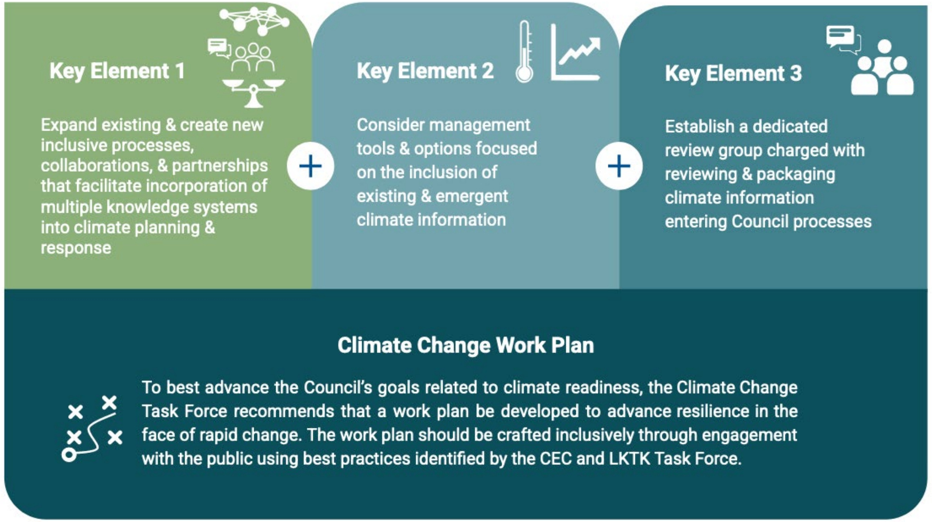
2024 — **CCTF Final Report**

NPFMC CCTF

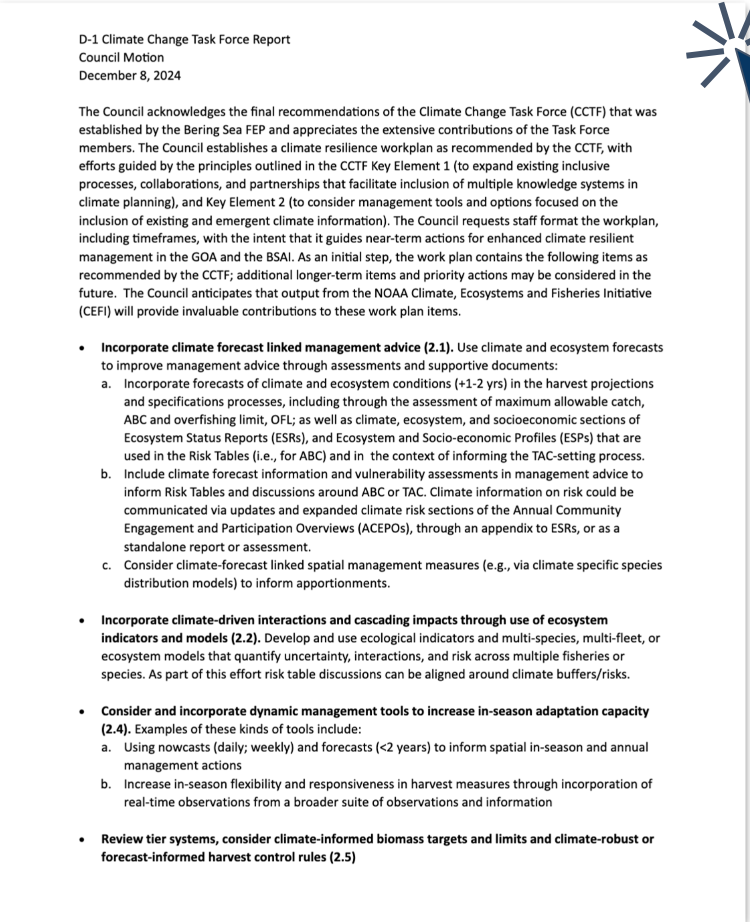


High Priority Key Elements





NPFMC Dec. 2024 Motion


D-1 Climate Change Task Force Report
Council Motion
December 8, 2024

The Council acknowledges the final recommendations of the Climate Change Task Force (CCTF) that was established by the Bering Sea FEP and appreciates the extensive contributions of the Task Force members. The Council establishes a climate resilience workplan as recommended by the CCTF, with efforts guided by the principles outlined in the CCTF Key Element 1 (to expand existing inclusive processes, collaborations, and partnerships that facilitate inclusion of multiple knowledge systems in climate planning), and Key Element 2 (to consider management tools and options focused on the inclusion of existing and emergent climate information). The Council requests staff format the workplan, including timeframes, with the intent that it guides near-term actions for enhanced climate resilient management in the GOA and the BSAI. As an initial step, the work plan contains the following items as recommended by the CCTF; additional longer-term items and priority actions may be considered in the future. The Council anticipates that output from the NOAA Climate, Ecosystems and Fisheries Initiative (CEFI) will provide invaluable contributions to these work plan items.

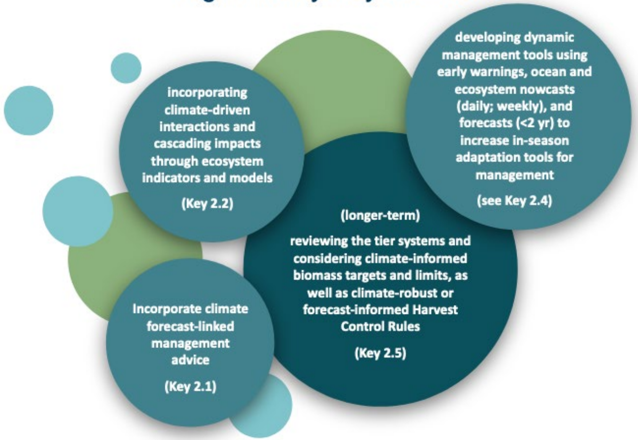
- **Incorporate climate forecast linked management advice (2.1).** Use climate and ecosystem forecasts to improve management advice through assessments and supportive documents:
  a. Incorporate forecasts of climate and ecosystem conditions (+1-2 yrs) in the harvest projections and specifications processes, including through the assessment of maximum allowable catch, ABC and overfishing limit, OFL; as well as climate, ecosystem, and socioeconomic sections of Ecosystem Status Reports (ESRs), and Ecosystem and Socio-economic Profiles (ESPs) that are used in the Risk Tables (i.e., for ABC) and in the context of informing the TAC-setting process.
  b. Include climate forecast information and vulnerability assessments in management advice to inform Risk Tables and discussions around ABC or TAC. Climate information on risk could be communicated via updates and expanded climate risk sections of the Annual Community Engagement and Participation Overviews (ACEPOs), through an appendix to ESRs, or as a standalone report or assessment.
  c. Consider climate-forecast linked spatial management measures (e.g., via climate specific species distribution models) to inform apportionments.

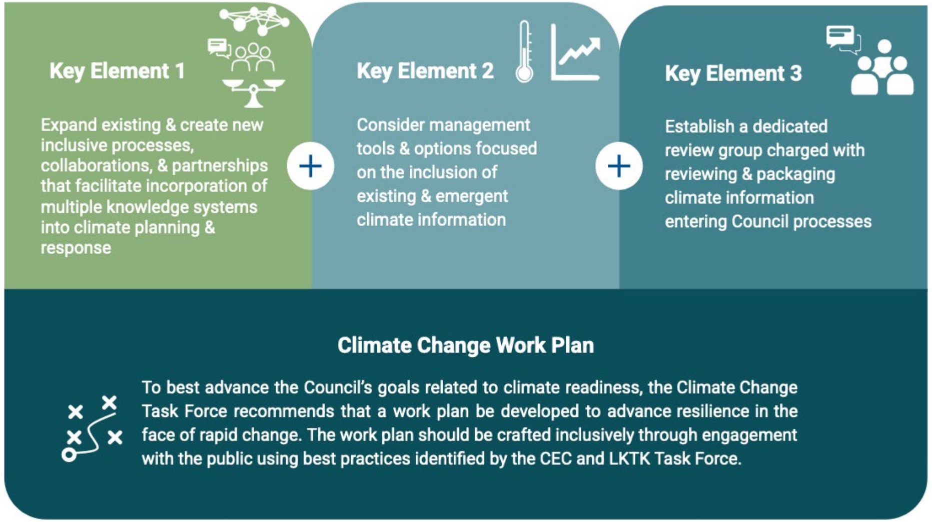
- **Incorporate climate-driven interactions and cascading impacts through use of ecosystem indicators and models (2.2).** Develop and use ecological indicators and multi-species, multi-fleet, or ecosystem models that quantify uncertainty, interactions, and risk across multiple fisheries or species. As part of this effort risk table discussions can be aligned around climate buffers/risks.

- **Consider and incorporate dynamic management tools to increase in-season adaptation capacity (2.4).** Examples of these kinds of tools include:
  a. Using nowcasts (daily; weekly) and forecasts (<2 years) to inform spatial in-season and annual management actions
  b. Increase in-season flexibility and responsiveness in harvest measures through incorporation of real-time observations from a broader suite of observations and information

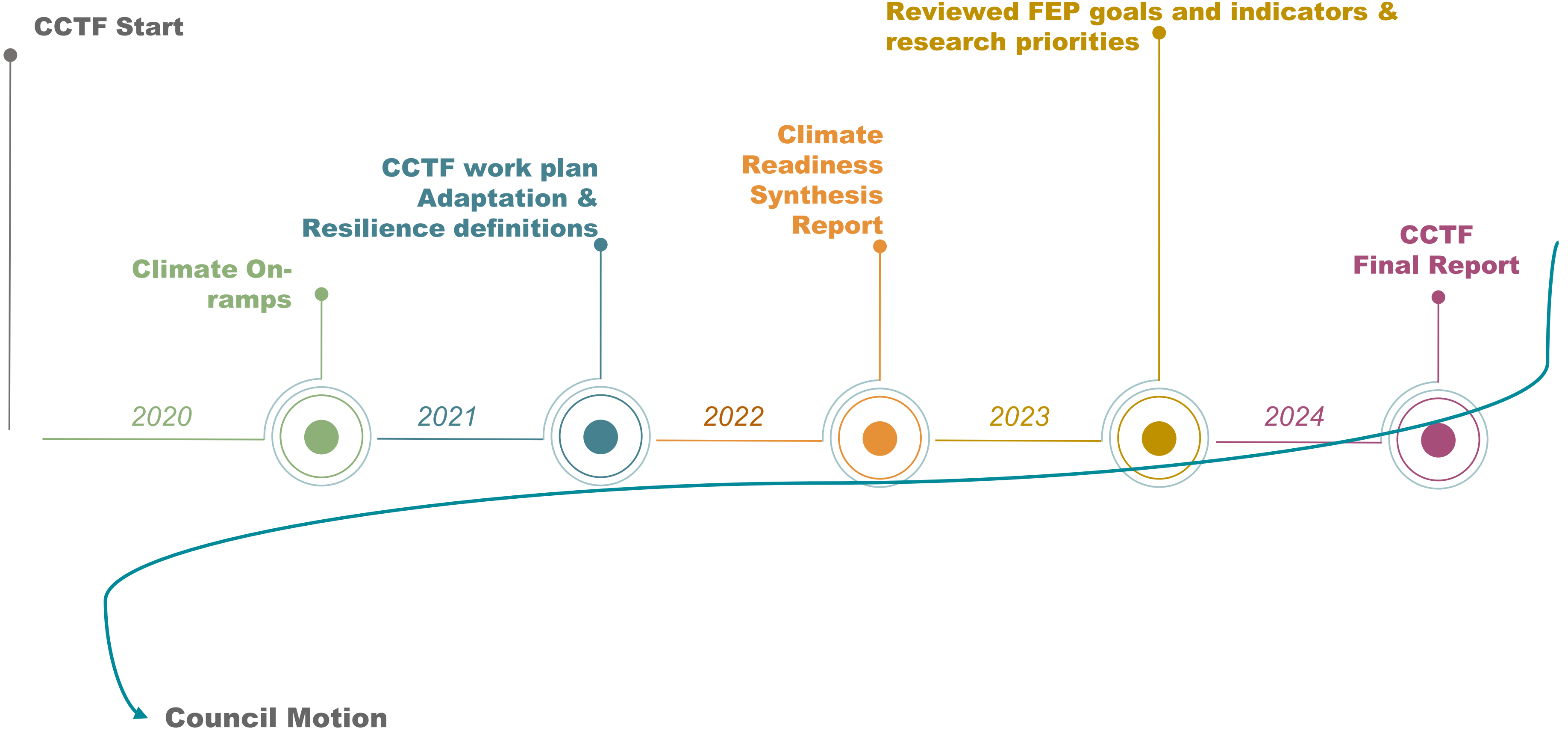
- **Review tier systems, consider climate-informed biomass targets and limits and climate-robust or forecast-informed harvest control rules (2.5)**

High Priority Key Elements

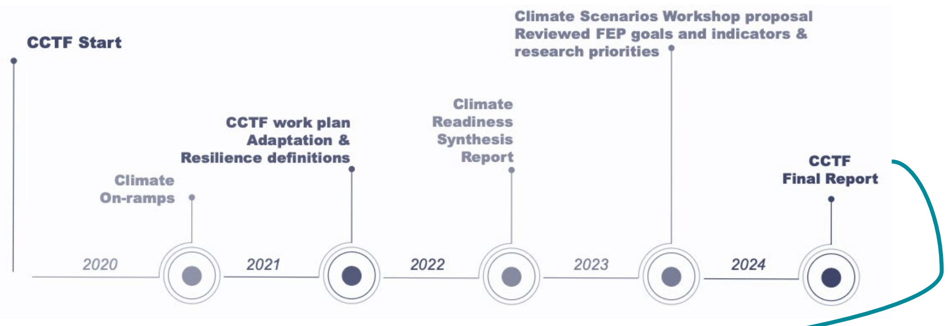


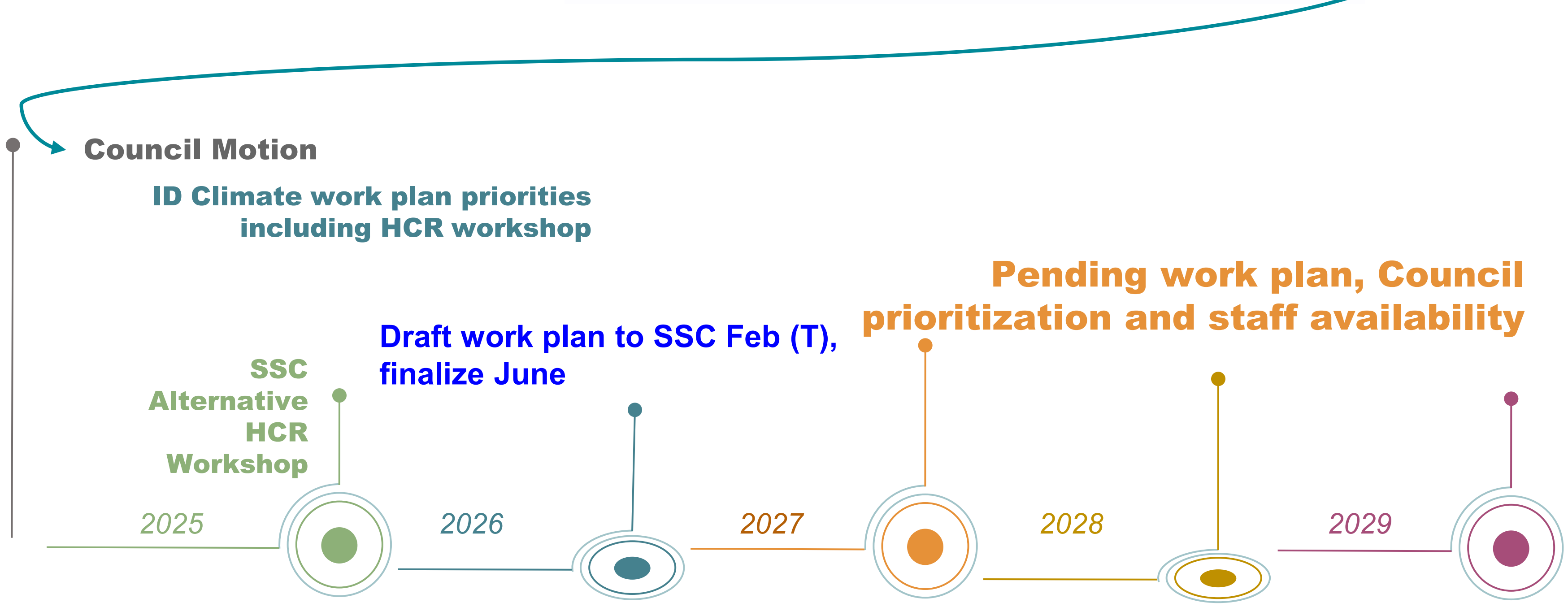


CCTF Timeline



Council Workplan



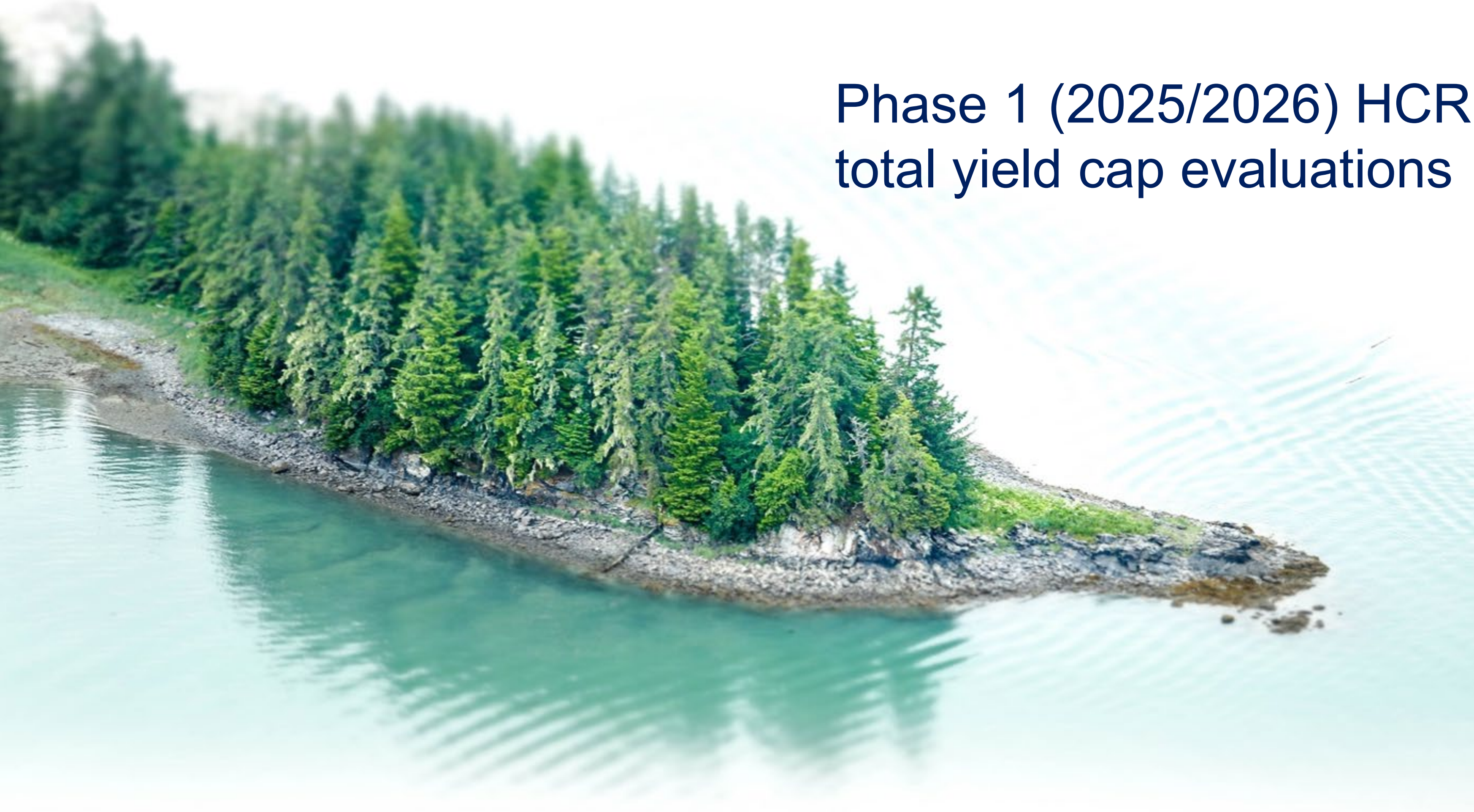


Workplan goals/needs

could focus on answering questions such as:

- Which stocks are most sensitive?
  - SSC suggestion to consider P cod, pollock (BSAI and GOA), AK sablefish, snow crab, BBRKC
  - Plan team feedback?
- Which if any should use an alternative HCR?
- What are options for alternative HCRs?
- How do the caps x HCR interact?

Phase 1 (2025/2026) HCR & total yield cap evaluations



Credit: Kirstin Holsman

AFSC Integrated Climate Modeling Projects

The Alaska Climate Integrated Modeling Project
ACLIM
Eastern Bering Sea
NOAA Alaska Fisheries Science Center

The GOA Climate Integrated Modeling Project
GOA-CLIM
Gulf of Alaska
NOAA Alaska Fisheries Science Center

ACLIM & GOACLIM Overviews in eAgenda

frontiers in Marine Science

ORIGINAL RESEARCH
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Integrated Modeling to Evaluate Climate Change Impacts on Coupled Social-Ecological Systems in Alaska

Anne Babcock Hollowed[1*], Kirstin Kari Holsman[1], Alan C. Haynie[1], Albert J. Hermann[2,3], Andre E. Punt[4], Kerim Aydin[1], James N. Ianelli[1], Stephen Kasperski[1], Wei Cheng[2,3], Amanda Faig[2,4], Kelly A. Kearney[1,2], Jonathan C. P. Reum[1,5], Paul Spencer[1], Ingrid Spies[1], William Stockhausen[1], Cody S. Szuwalski[1], George A. Whitehouse[2,4] and Thomas K. Wilderbuer[1]

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The Alaska Climate Integrated Modeling (ACLIM) project represents a comprehensive, multi-year, interdisciplinary effort to characterize and project climate-driven changes to the eastern Bering Sea (EBS) ecosystem, from physics to fishing communities. Results from the ACLIM project are being used to understand how different regional fisheries management approaches can help promote adaptation to climate-driven changes to sustain fish and shellfish populations and to inform managers and fishery dependent communities of the risks associated with different future climate scenarios. The project relies on iterative communications and outreaches with managers and fishery-dependent communities that have informed the selection of fishing scenarios. This iterative approach ensures that the research team focuses on policy relevant scenarios that explore realistic adaptation options for managers and communities. Within each iterative cycle, the interdisciplinary research team continues to improve: methods for downscaling climate models, climate-enhanced biological models, socio-economic modeling, and management strategy evaluation (MSE) within a common analytical framework. The evolving nature of the ACLIM framework ensures improved understanding of system responses and feedbacks are considered within the projections and that the fishing scenarios continue to reflect the management objectives of the regional fisheries management bodies. The multi-model approach used for projection of biological responses, facilitates the quantification of the relative contributions of climate forcing scenario, fishing scenario, parameter, and structural uncertainty with and between models. Ensemble means and variance within and between models inform risk assessments under different future scenarios. The first phase of projections of climate conditions to the end of the 21st century is complete,

Gulf of Alaska Climate Integrated Modeling (GOA-CLIM) Project

Meaghan Bryan[1], Carey McGilliard[1], Alberto Rovellini[2], Bia Dias[1], Bridget Ferriss[1], Szymon Surma[3], Kerim Aydin[1], Grant Adams[1], Cheryl Barnes[4], Chang Seung[1], Andre Punt[2], Martin Dorn[2]

[1] NOAA Fisheries, Alaska Fisheries Science Center
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[3] University of British Columbia, Institute for Ocean and Fisheries
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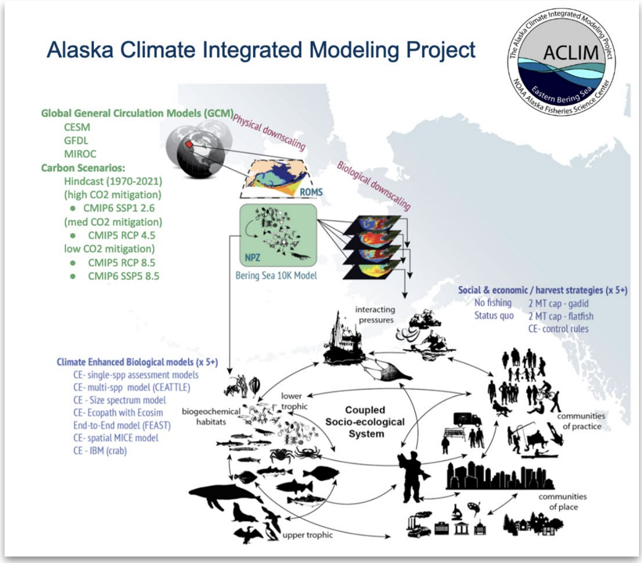
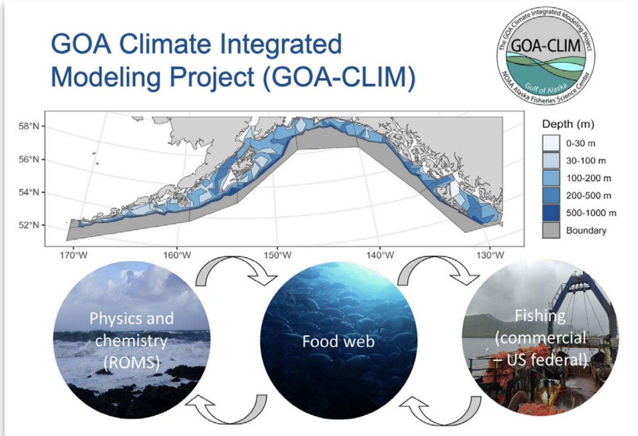
The Gulf of Alaska Climate Integrated Modeling (GOA-CLIM) project is an integrated research program that is closely aligned with the Alaska Climate Integrated Modeling (ACLIM) project. This is a multiphase project where the first phase focused on (1) the development, calibration, and skill testing of an end-to-end Atlantis model for the GOA, (2) development of two Ecopath with Ecosim models splitting the GOA into eastern and western portions, (3) refinement of other multispecies models (e.g., Rceattle), (4) synthesizing datasets for the ensemble of models, (5) linking continuous Regional Ocean Modeling System (ROMS) simulations from the present to 2100 to ecosystem and stock assessment models, and (6) evaluating the performance of management strategies under different environmental scenarios (e.g., system level optimum yield). The main goals of the current phase, phase two, are to refine the ensemble of environment coupled models (e.g., refine modeling of top predators, refine the fleet structure in Atlantis) and develop a multispecies size spectrum model to include in the ensemble. The ensemble of models will be used to evaluate the performance of harvest control rules and ecosystem caps and will be linked to regional economic models to assess the impacts of environmental scenarios and fisheries management measures on GOA communities.

The purpose of this document is to provide a brief description of the ensemble of component models that have been developed or are under development, along with highlights of their model assumptions. The models include Atlantis, Ecopath with Ecosim/Rpath, Rceattle (as a multi-species model and as an extended single-species stock assessment model), a bioeconomics community impact model linked to Rceattle, and a multispecies size spectrum model. Though Rceattle has utility as a production assessment model in single-species form, the use of all of the GOA-CLIM models for projecting under environmental and harvest scenarios is intended for exploring long-term outcomes and corresponding uncertainty.

Atlantis is a deterministic ecosystem simulation model that comprises physical, food web, and fishery sub-models. The GOA Atlantis model spans the GOA shelf from 170W (NMFS area 610) to Northern BC, using 109 depth-stratified spatial polygons. The physical sub-model is forced using temperature, salinity, and currents output from ROMS for the Northeast Pacific, available for the historical period (1980-2020) and as three CO_2 emission scenarios through 2100. The food web sub-model captures 78 functional groups, including age-structured fish populations representing the FMP groundfish stocks and stock complexes, as well as key predators such as Steller sea lions and seabirds. Model functional groups are connected via trophic interactions, and recruitment of fish populations follow Beverton-Holt stock-recruit relationships. The fishery sub-model allows modeling species-specific fishing mortality, either as fixed rates or as determined dynamically by harvest control rules. Various harvest control rule forms can be reproduced, including the ramped fishing mortality (status quo) control rules used for GOA groundfish, as well as alternative formulations. A notable feature is the ability to model the Optimum Yield cap on FMP groundfish removals, allowing users to evaluate different cap values and species prioritization schemes when rescaling harvest specifications if aggregate projected catch exceeds the cap.

Hollowed et al. 2020





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

What to expect?

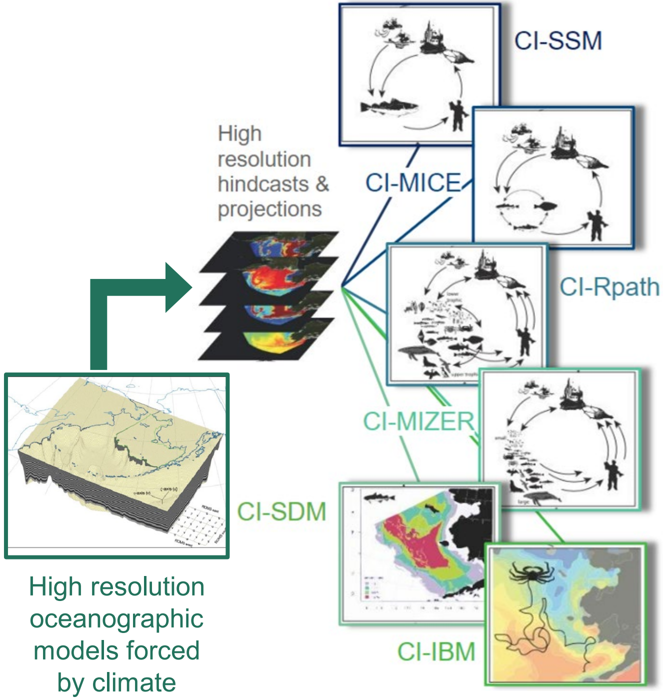
- Project physical and ecological conditions under alternative levels of global carbon mitigation
- Characterize uncertainty

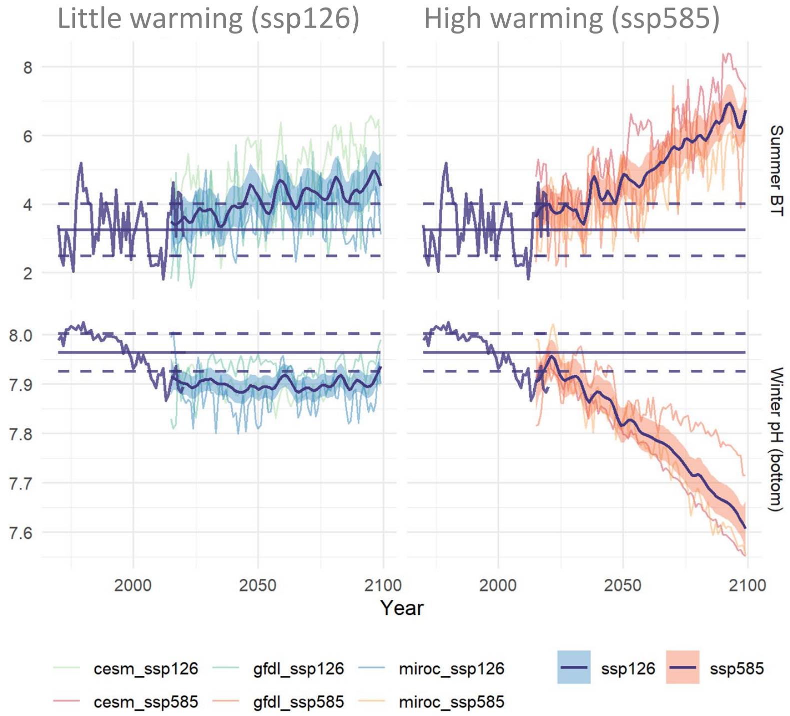
What can be done?

- Evaluate effectiveness of adaptation actions including those supported by fisheries management

Scenarios form the basis for comparative simulations & Management Strategy Evaluations

CLIM Models & Simulations

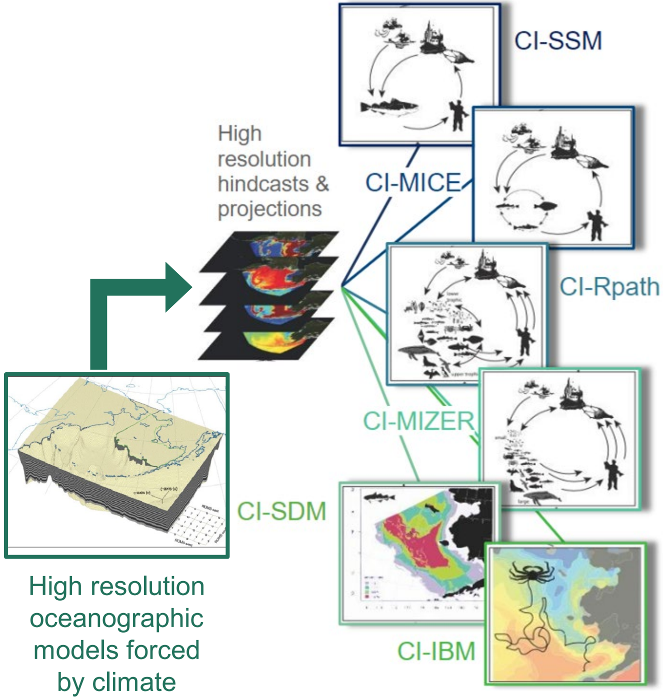




Supporting Publications

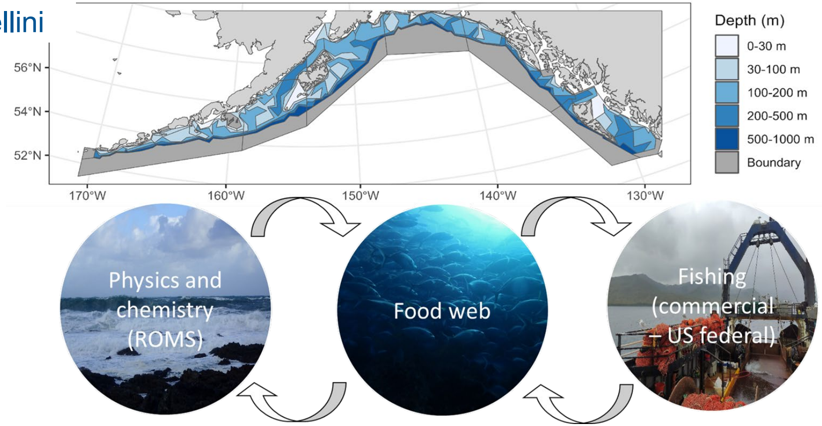
Goodman et al. (2024), Punt et al. (2023), Szuwalski et al. (2023), Olmos et al. (2023), McHuron et al. (2024), Barnes et al. (2022), Thorson et al. (2021), Whitehouse et al. (2021), Kearney et al (2020), Pilcher et al. (2022), Hollowed et al. (2020), Roveliini et al. 2024

CLIM Models & Simulations




A. Rovellini

GOA-CLIM Atlantis



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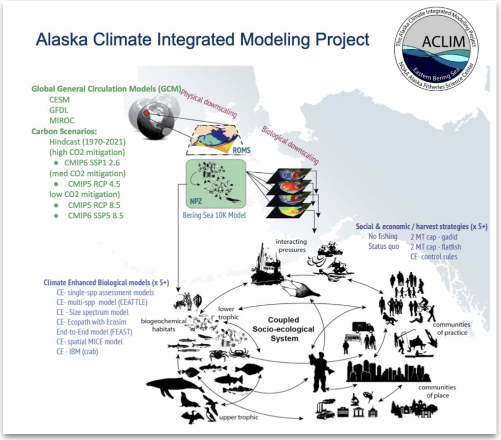
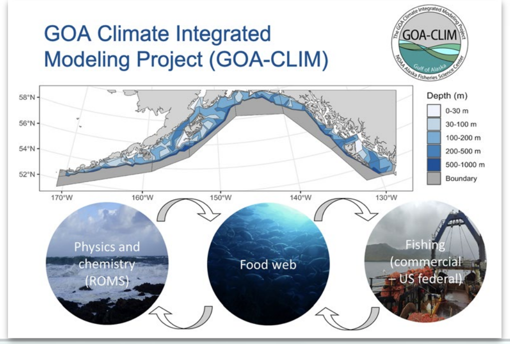
Strategic foresight & predictions

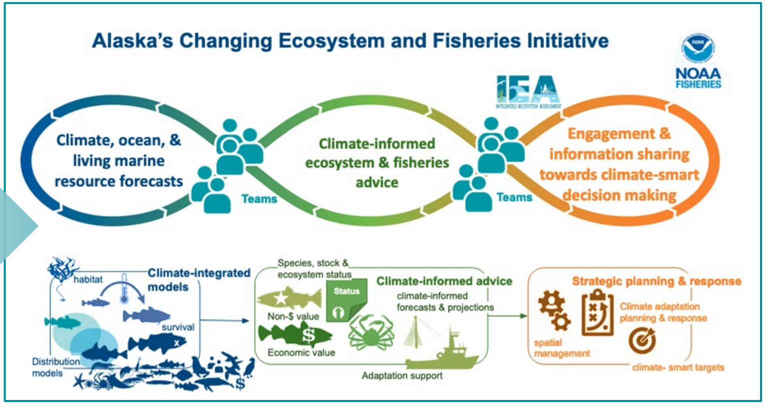
Research & development



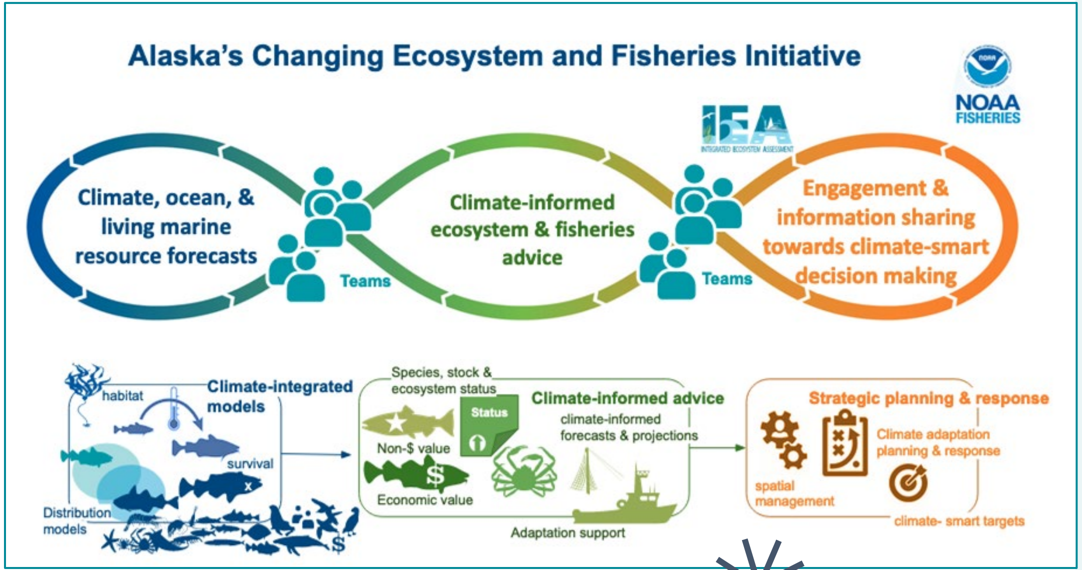


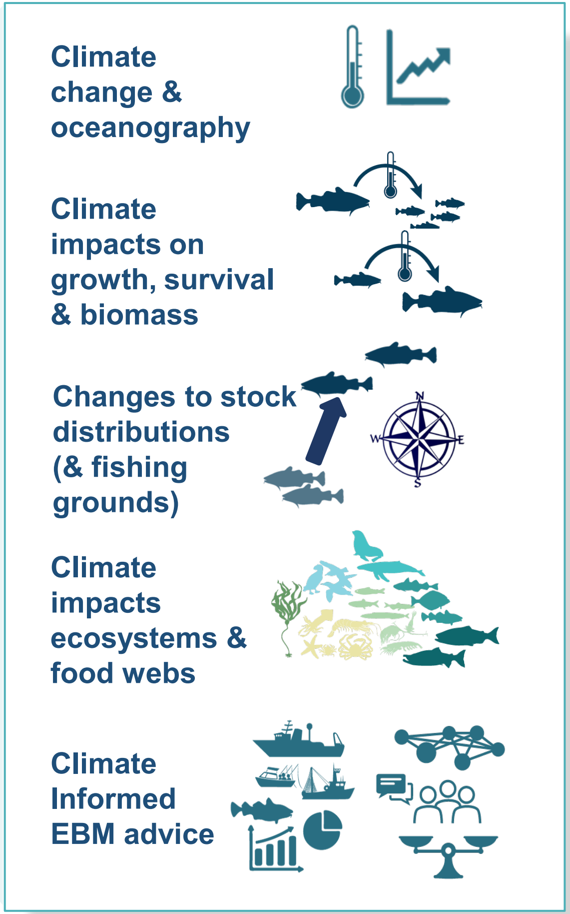
Climate & Ecological (CE) forecasts
CE assessment & foodweb models
CE informed SDMs
CE informed EBM advice
Robust alternative HCRs & CAPs
CE planning support & scenarios

Long-term operational support



Strategic foresight & predictions

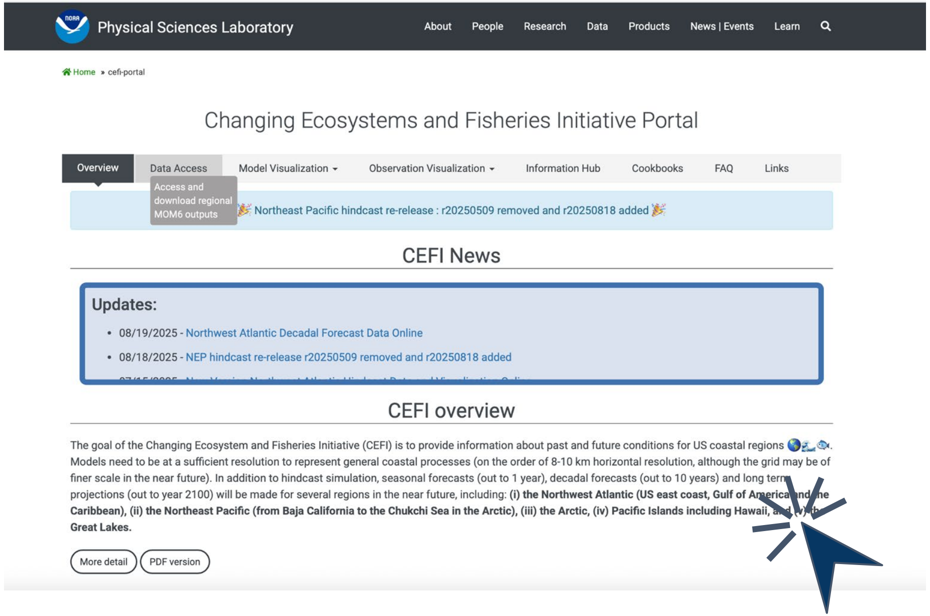




https://www.fisheries.noaa.gov/science-data/changing-ecosystems-and-fisheries-initiative-regional-activities#alaska

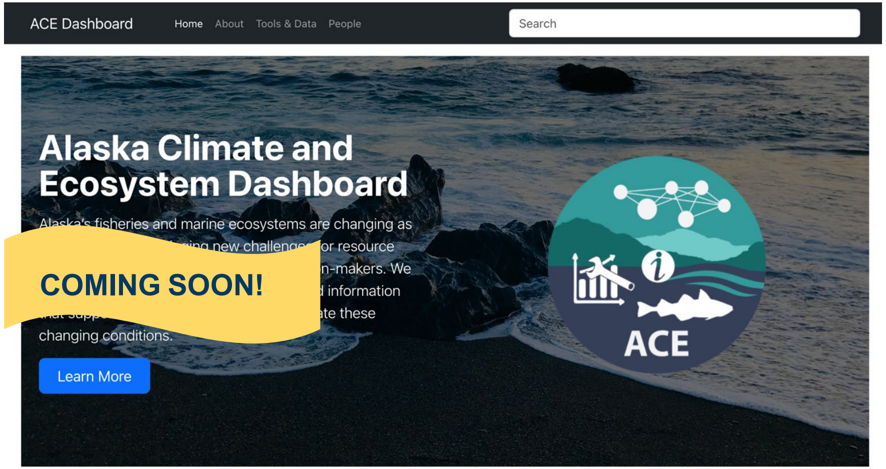
CEFI: Operational CE-informed Decision Support

National CEFI Data Portal

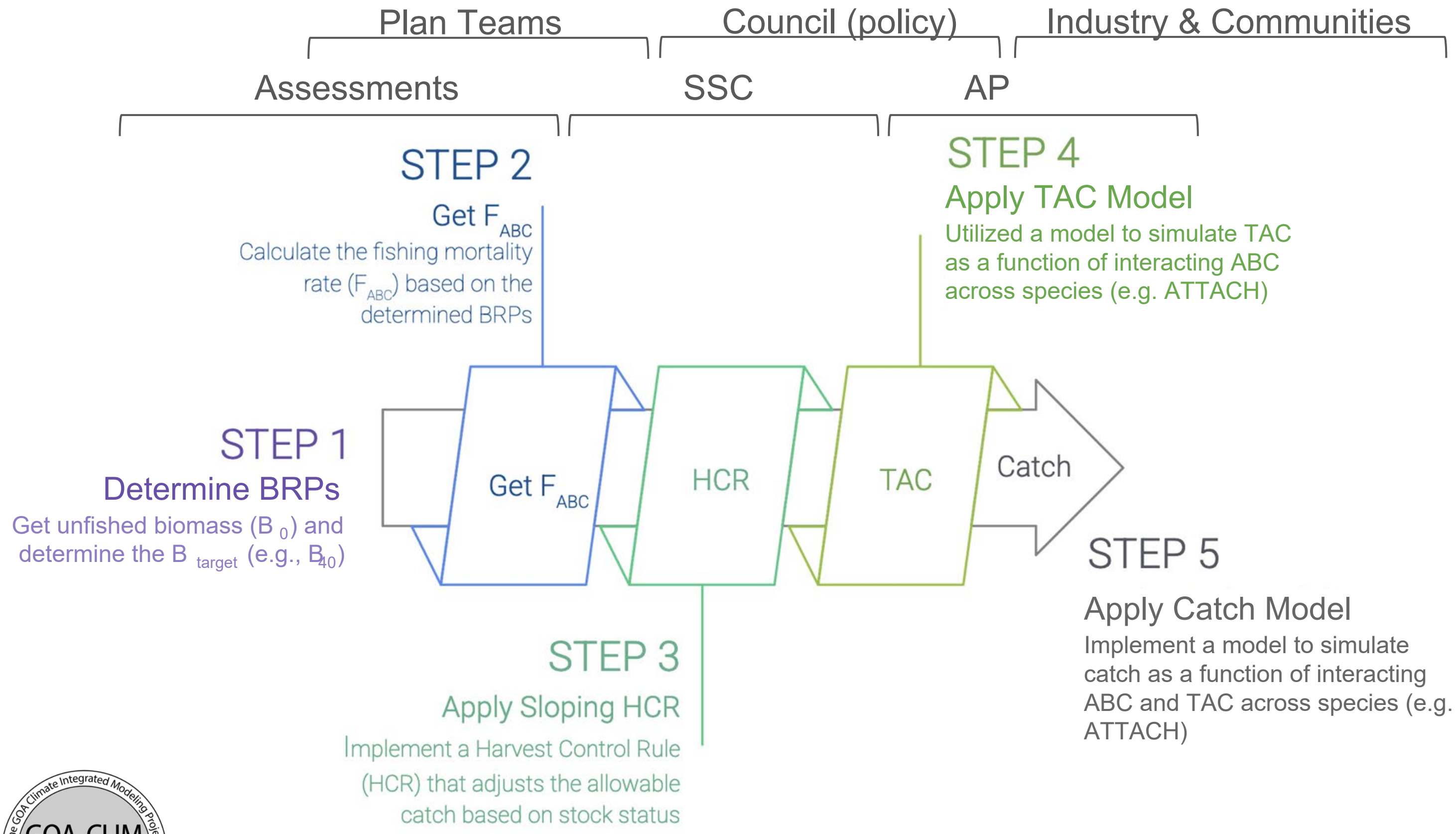


https://psl.noaa.gov/cefi_portal/

Regional (AK specific) decision support tools (via ACE dashboard)



ACLIM & GOACLIM HCR simulation process



SSC HCR Workshop Whitepaper

An Overview of Stage 1 (2025-2026) Alternative HCR Evaluations Through ACLIM and GOACLIM

Prepared by:
K Holsman, M. Bryan, C. McGilliard, A. Rovellini, A. Hollowed and D. Stram

Contents

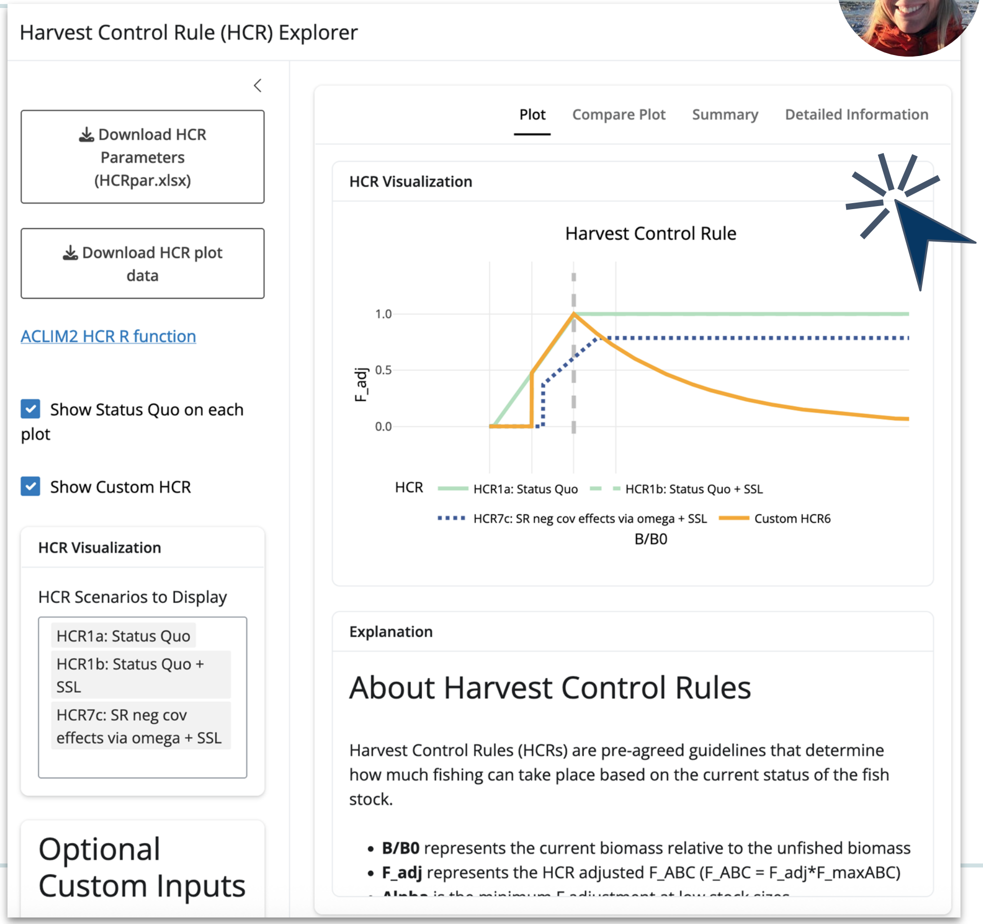
Table 1: Overview of ACLIM and GOACLIM 2025 HCR options. "Stage 2" denotes the HCRs that are not being evaluated as part of the Council's request following the June SSC workshop, but have been or are being evaluated as part of the ACLIM and GOACLIM work.

HCR	Name	Detail	HCR Stage
HCR 1	Status quo	This HCR is the baseline sloping harvest control rule used for groundfish in Alaska	1
HCR 5	Maximize productivity/ increased reserve (buffer shocks)	HCR 5 is designed to maximize ecosystem and spawning biomass productivity by increasing reserves, creating a buffer against environmental shocks and enhancing long-term sustainability.	1
HCR 7	Risk Table Bridging, R/S variability covariate adjusted HCR	This HCR provides a way to transition from qualitative risk tables to a more explicit, analytical approach for species whose productivity is known to vary with environmental conditions.	1
HCR 10	Maximize productivity/increased reserve, linear version (1/ B_target) with offset	This HCR builds on HCR 5 by applying a proportional reduction in fishing mortality based on biomass levels, further enhancing stock and environmental productivity through strengthening the buffer against environmental shocks.	1
	(Stage 2 HCRs Below)		
HCR 2	Lagged recovery to estimate emergency relief financing needs	Simulations with this HCR will mimic economic-driven fishery closures and delayed recovery in order to estimate emergency relief needs.	2
HCR 3	Long-term resilience (stronger reserve) B_target	This HCR aims to enhance long-term stock resilience by adjusting B_target (as a proportion of unfished biomass)	2
HCR 4	Environmental index informed sloping rate, e.g., MHW category alpha	Simulations with this HCR will assess whether adjusting harvest intensity based on poor forecasted conditions—such as marine heatwaves—can accelerate stock recovery following climate or environmental disturbances.	2
HCR 6	Combination of MHW (HCR4) + Maximize productivity (HCR5)	This HCR combines the approaches of HCR 4 and HCR 5 to address both immediate and long-term environmental impacts.	2
HCR 8	Adjust effective spawning biomass (simulate adjusted B_target)	This HCR adjusts the effective spawning biomass instead of the target biomass threshold, serving as a sensitivity approach to explore variability in spawning stock biomass (SSB) estimates within a given assessment year or to evaluate alternative B_target	2

Interactive HCR explorer tool

https://kholsman.shinyapps.io/HCRshiny/

Research question:
Are there alternative HCRs that can perform better than status quo under alternative future scenarios?



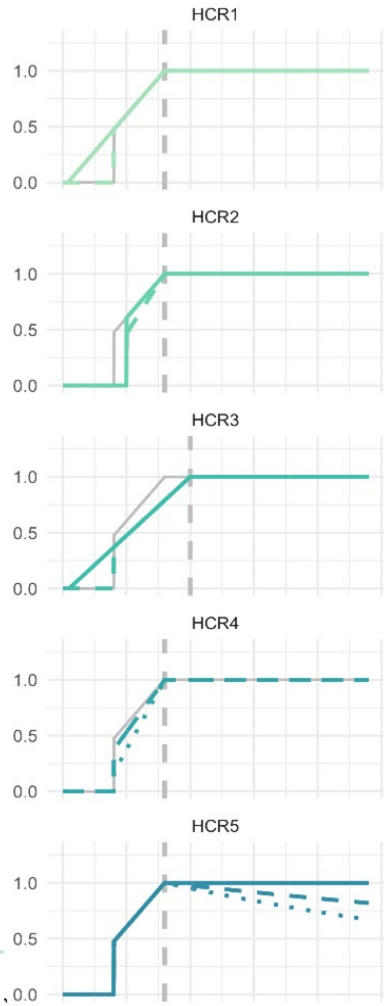
The Alaska Climate Integrated Modeling Project ACLIM Eastern Bering Sea NOAA Alaska Fisheries Science Center

The GOA Climate Integrated Modeling Project GOA-CLIM Gulf of Alaska NOAA Alaska Fisheries Science Center

HCR Scenarios

ACLIM2

HCR	Name
ABC+HCR 1	Status quo
ABC+HCR 2	Lagged recovery to estimate emergency relief financing needs
ABC+HCR 3	Long-term resilience (stronger reserve) B_target
ABC+HCR 4	Environmental index informed sloping rate, e.g., MHW category alpha
ABC+HCR 5	Maximize productivity/ increased reserve (buffer shocks)



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; **accepted:** 21 February 2024
Advance access publication date: 29 March 2024
Stories from the front lines

ICES CIEM
International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

Development of climate informed management scenarios for fisheries in the eastern Bering Sea

Anne Babcock Hollowed [1,*], Kirstin K. Holsman [2], Sarah P. Wise[2], Alan C. Haynie [3], Wei. Cheng[4,5], Diana C. K. Evans[6], Albert J. Hermann[4,5], James N. Ianelli[2], Kelly A. Kearney [2], Andre E. Punt[1], Jonathan C. P. Reum [2], Diana L. Stram[6], Cody S. Szuwalski[2]

Hollowed et al. (2025) https://doi.org/10.1093/icesjms/fsae034

ACLIM
The Alaska Climate Integrated Modeling Project
Eastern Bering Sea
NOAA Alaska Fisheries Science Center

GOA-CLIM
The GOA Climate Integrated Modeling Project
Gulf of Alaska
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HCR Scenarios

ACLIM2

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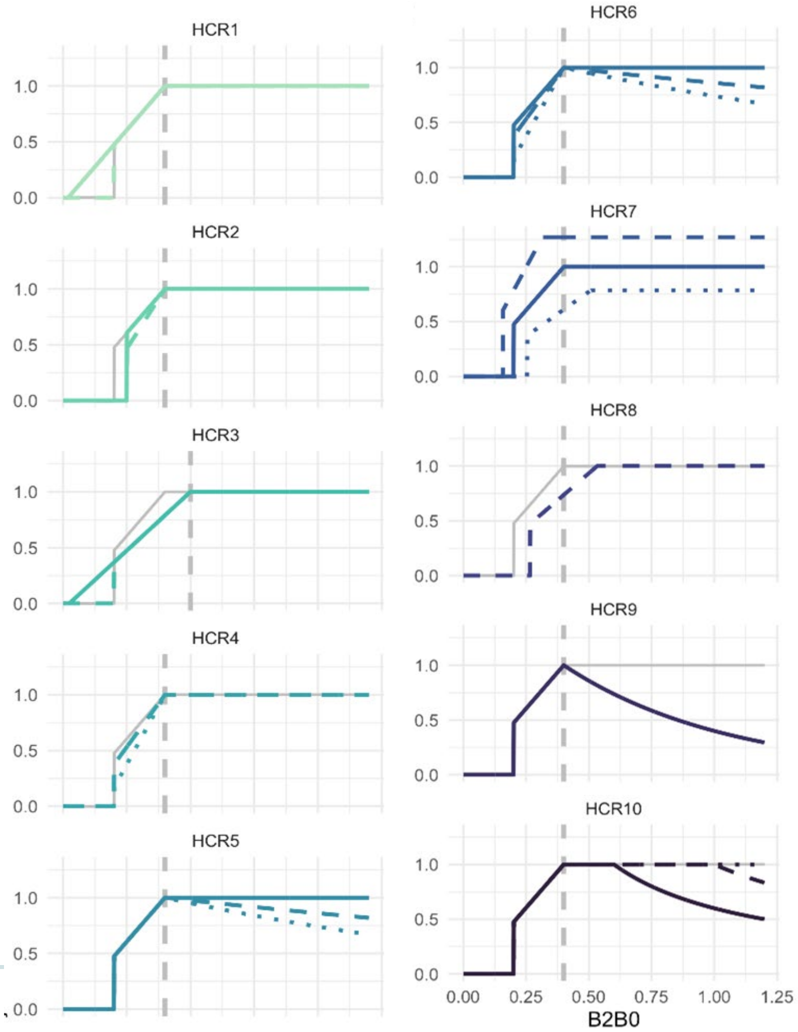
ABC+HCR 6	Combination of MHW (HCR4) + Maximize productivity (HCR5)
ABC+HCR 7	Risk Table Bridging, R/S variability covariate adjusted HCR
ABC+HCR 8	Adjust effective spawning biomass (simulate adjusted B_target)
ABC+HCR 9	Forecast informed version of HCR 5
ABC+HCR 10	Maximize productivity/increased reserve (HCR5), linear version (1/ B_target) with offset



HCR Scenarios

ACLIM2

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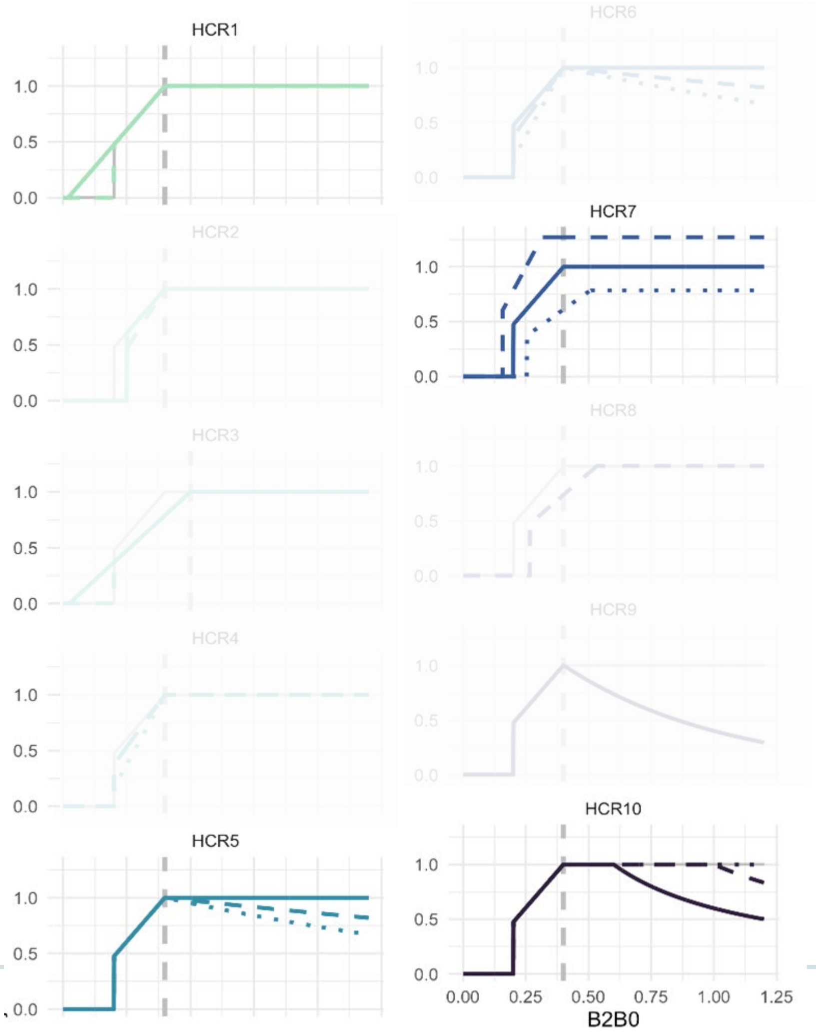
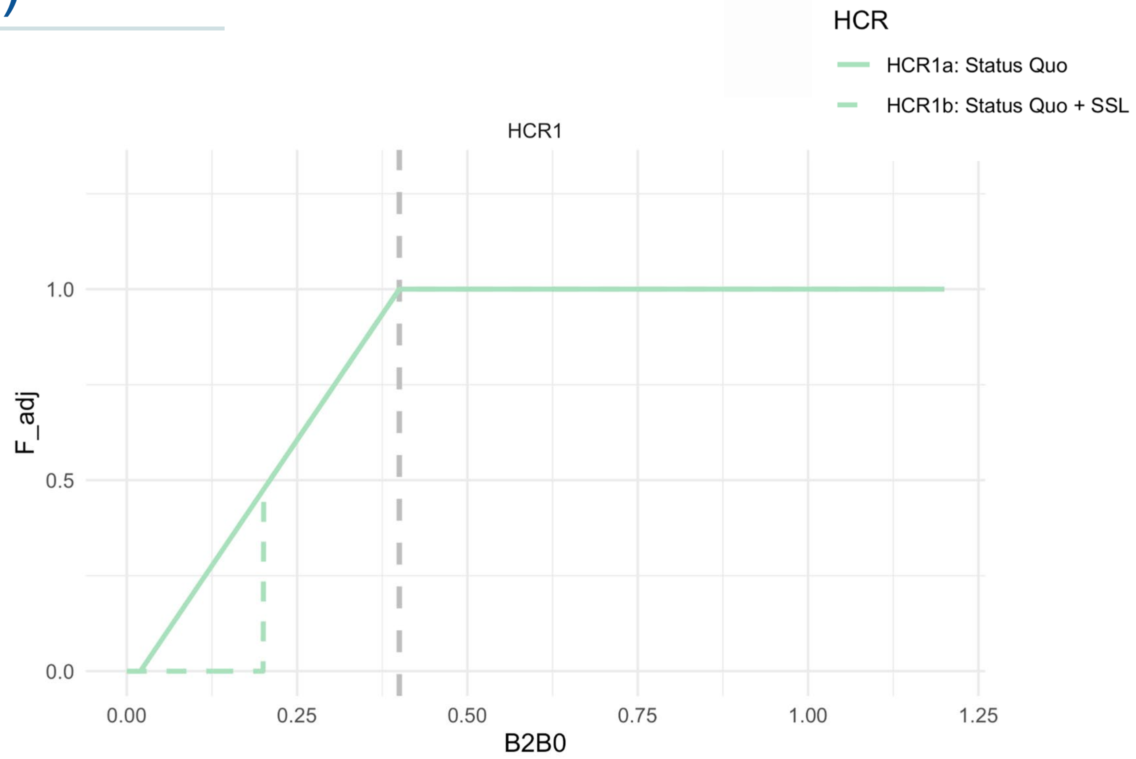
ABC+HCR 9	Forecast informed version of HCR 5
ABC+HCR 10	Maximize productivity/increased reserve (HCR5), linear version (1/ B_target) with offset



HCR 1: Status quo (Tier 3)

Simulation Goal:
This HCR is the baseline sloping harvest control rule used for groundfish in Alaska

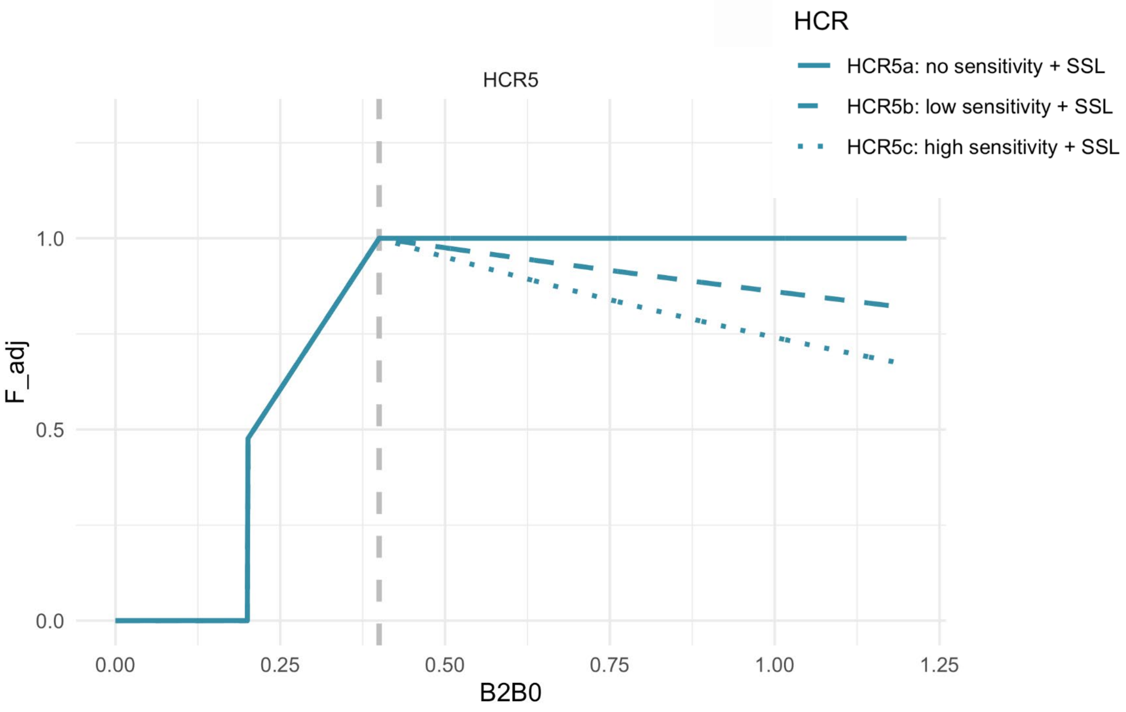
$$F_{ABC_{max}} = \begin{cases} F_{ABC} & \frac{B_y}{B_{target}} > 1 \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} < 1 \\ 0 & \frac{B_y}{B_{target}} < \frac{B_{lim}}{B_{target}} \end{cases}$$



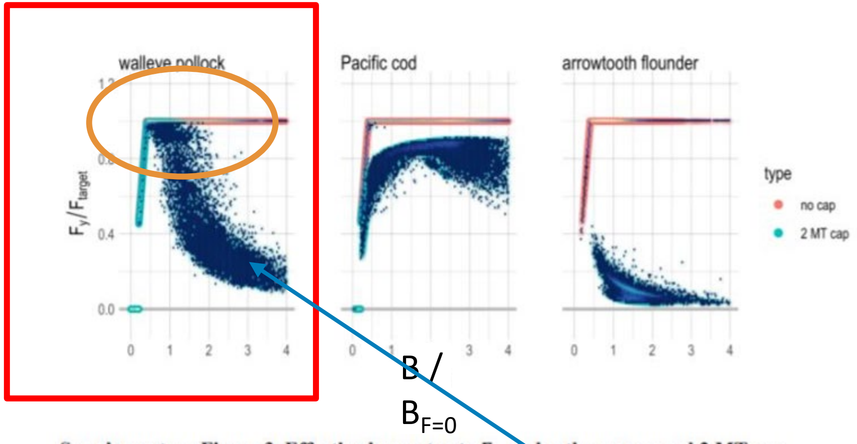
HCR 5 : Maximize productivity/ increased reserve (buffer shocks)

Simulation Goal:
HCR 5 is designed to **maximize ecosystem and spawning biomass productivity** by increasing reserves, creating a buffer against environmental shocks, and enhancing long-term sustainability

$$F_{ABC_{max}} = \begin{cases} F_{ABC}\, e^{(-\gamma(\frac{B_y}{B_{target}}-1))} & \frac{B_y}{B_{target}} > 1 \\ F_{ABC}((\frac{B_y}{B_{target}}-\alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \le \frac{B_y}{B_{target}} < 1 \\ 0 & \frac{B_y}{B_{target}} < \frac{B_{lim}}{B_{target}} \end{cases}$$



Apply effective pollock HCR cap-like effect



Supplementary Figure 3. Effective harvest rate F_y under the no cap and 2 MT cap

Holsman et al. 2020

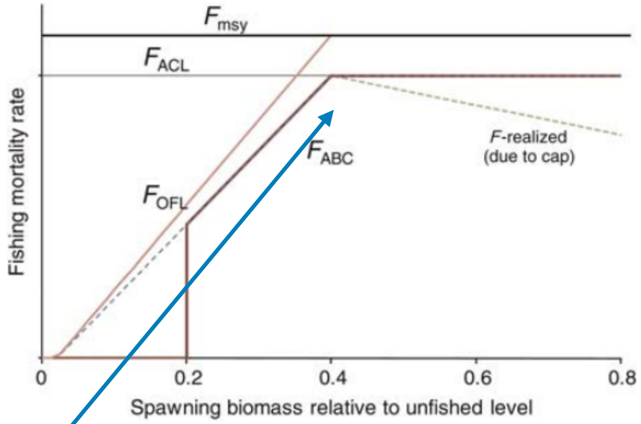


Figure 4. Schematic of harvest control rule currently affecting ABC or annual catch limit (ACL) for Alaska groundfish species like pollock (thick line). Note that this schematic indicates that B_{msy} is 40% of the unfished expected spawning biomass.

Ianelli et al. 2011

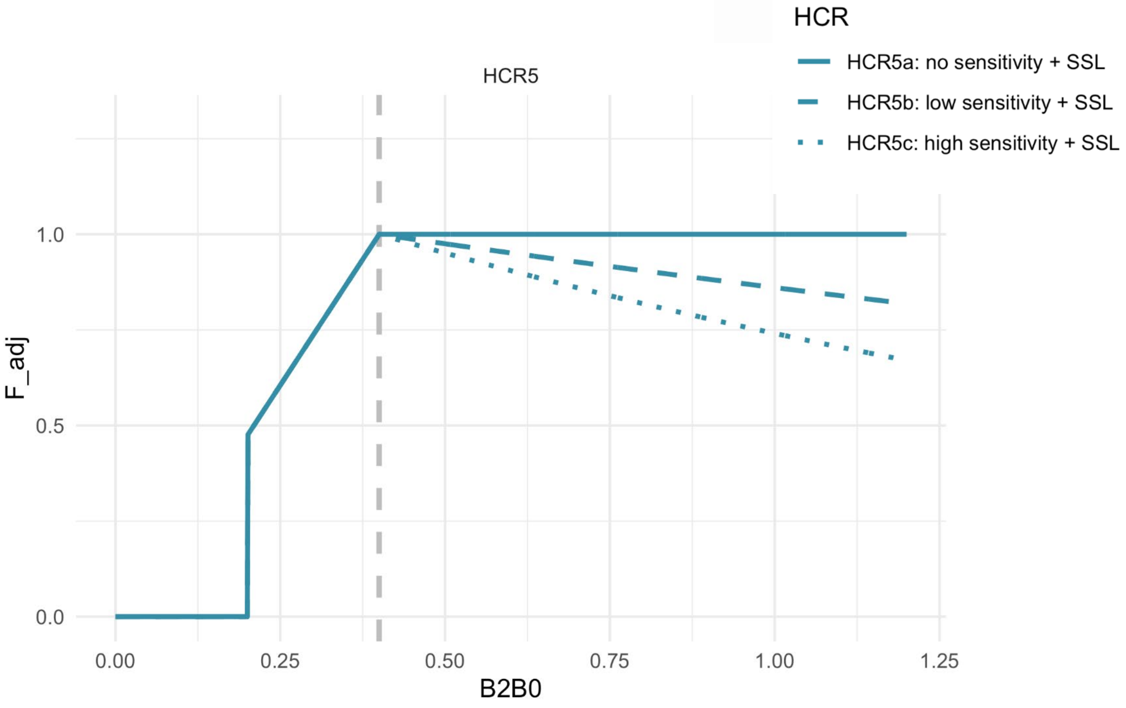
Effect of the 2 mt Cap on pollock

Hollowed et al. (2025) Development of climate informed management scenarios for fisheries in the eastern Bering Sea . ICES Journal of Marine Science, Volume 82, Issue 1, January 2025, fsae034, https://doi.org/10.1093/icesjms/fsae034

HCR 5 : Maximize productivity/ increased reserve (buffer shocks)

Simulation Goal:
HCR 5 is designed to **maximize ecosystem and spawning biomass productivity** by increasing reserves, creating a buffer against environmental shocks, and enhancing long-term sustainability

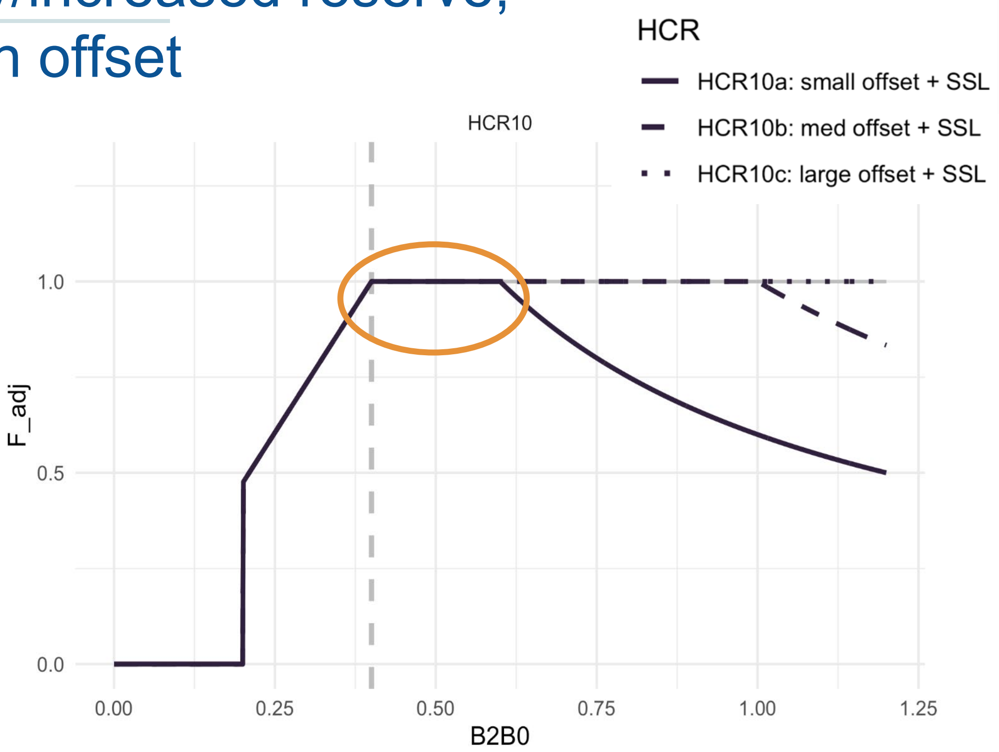
$$F_{ABC_{max}} = \begin{cases} F_{ABC}\, e^{(-\gamma(\frac{B_y}{B_{target}}-1))} & \frac{B_y}{B_{target}} > 1 \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} < 1 \\ 0 & \frac{B_y}{B_{target}} < \frac{B_{lim}}{B_{target}} \end{cases}$$



HCR 10: Maximize productivity/increased reserve; linear version (1/ B_target) with offset

Simulation Goal:
This HCR builds on HCR 5 by applying a proportional reduction in fishing mortality based on biomass levels, further enhancing stock and environmental productivity through strengthening the buffer against environmental shocks.

$$F_{ABC_{max}} = \begin{cases} F_{ABC}/(\frac{B_y}{B_{target}}\frac{1}{(1+\gamma)}) & \frac{B_y}{B_{target}} > (1+\gamma) \\ F_{ABC} & 1 < \frac{B_y}{B_{target}} < (1+\gamma) \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} < 1 \\ 0 & \frac{B_y}{B_{target}} < \frac{B_{lim}}{B_{target}} \end{cases}$$

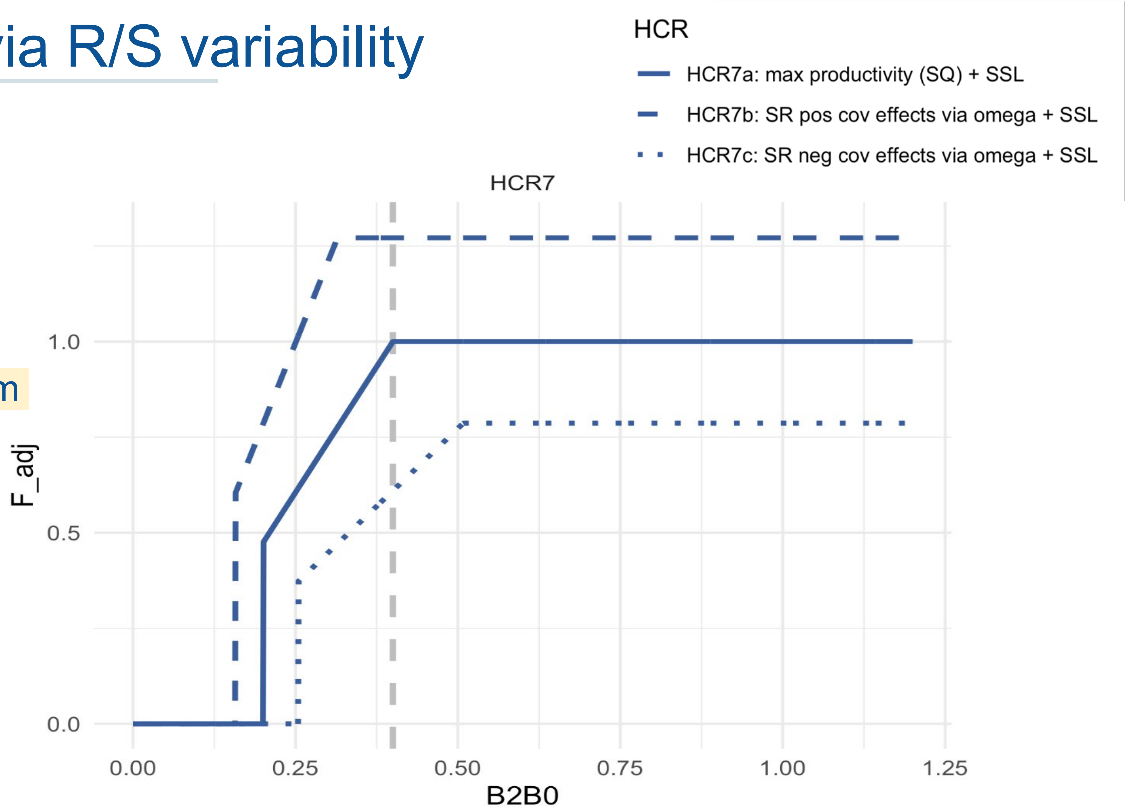


HCR 7: Risk TableBridging via R/S variability covariate adjusted HCR

Simulation Goal:
This HCR provides a way to transition from qualitative risk tables to a more explicit, analytical approach for species whose productivity is known to vary with environmental conditions.

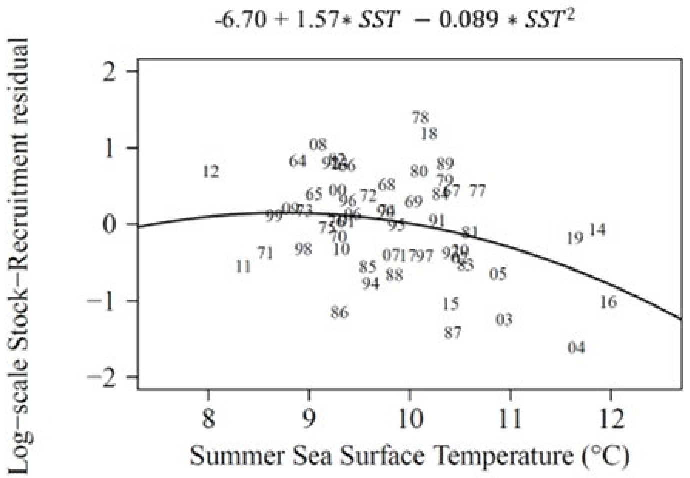
$$F_{ABC_{max}} = \begin{cases} F_{ABC}\ e^{(\omega_1 * x_y)} & \frac{B_y}{\hat{B}_{target}} > 1 \\ F_{ABC}((\frac{B_y}{\hat{B}_{target}} - \alpha)/(1-\alpha))\ e^{(\omega_1 * x_y)} & \frac{B_y}{\hat{B}_{lim}} \leq \frac{B_y}{\hat{B}_{target}} < 1 \\ 0 & \frac{B_y}{\hat{B}_{target}} < \frac{\hat{B}_{lim}}{\hat{B}_{target}} \end{cases}$$

$$\hat{B}_{lim} = B_{lim} e^{(-\omega_3 * x_y)} \qquad \hat{B}_{target} = B_{target} e^{(-\omega_2 * x_y)}$$

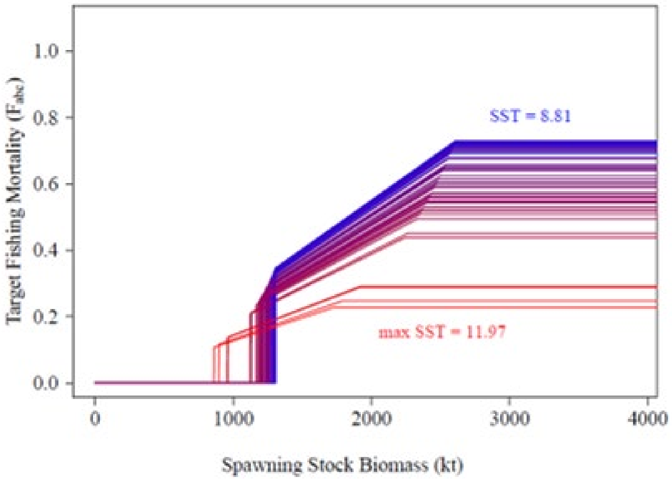


Spencer et al. in prep

Effect of temperature on recruitment



How would the harvest control rule change with temperature?



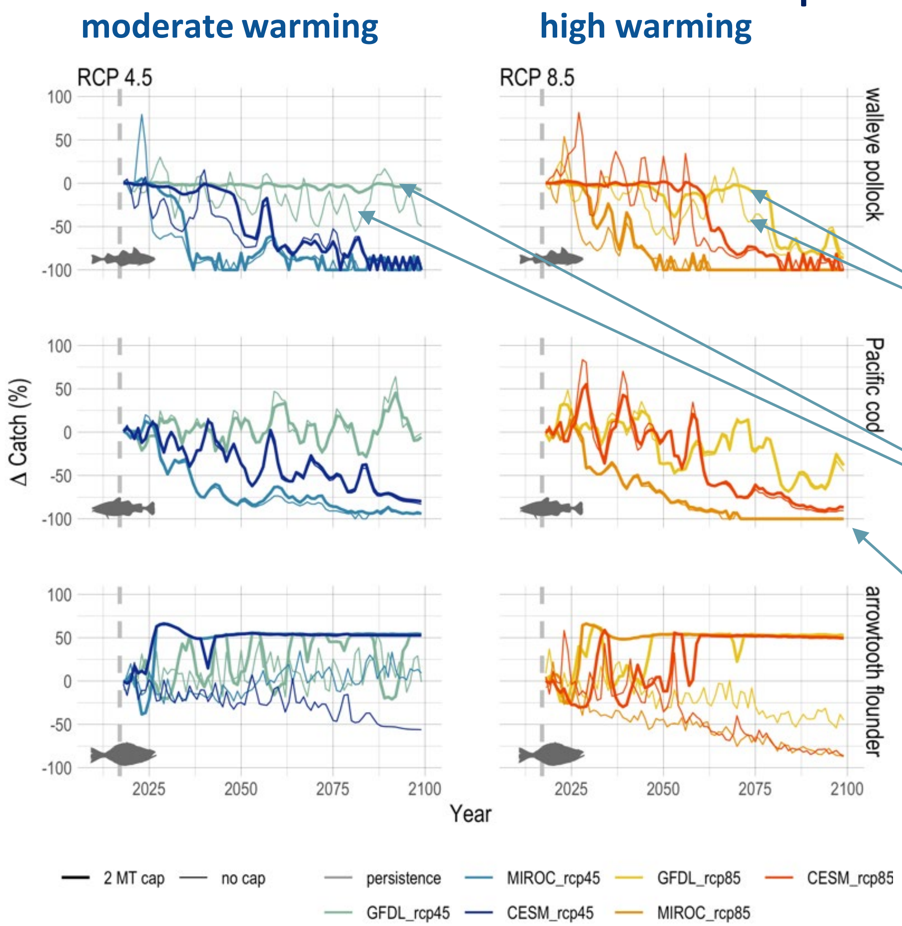
Draft results please do not copy

CAP evaluations also underway

Credit: Kirstin Holsman

CEATTLE: EBFM vs non-EBFM cap

Assumes climate effects on recruitment, growth, & mortality;
Assumes no adaptation of fish or fisheries



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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Assumes climate effects on recruitment, growth, & mortality;
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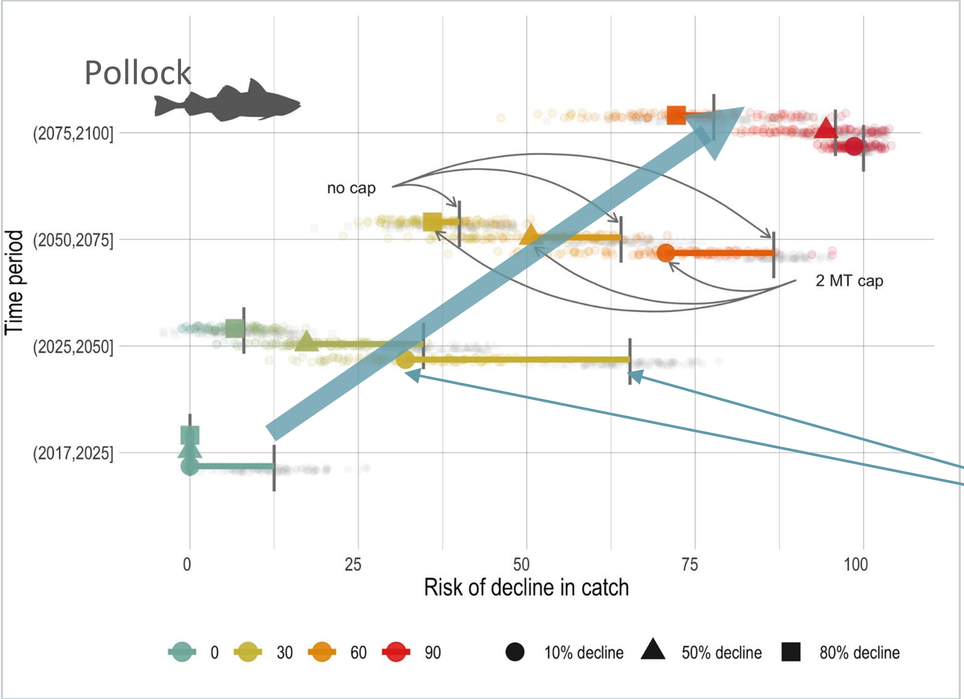


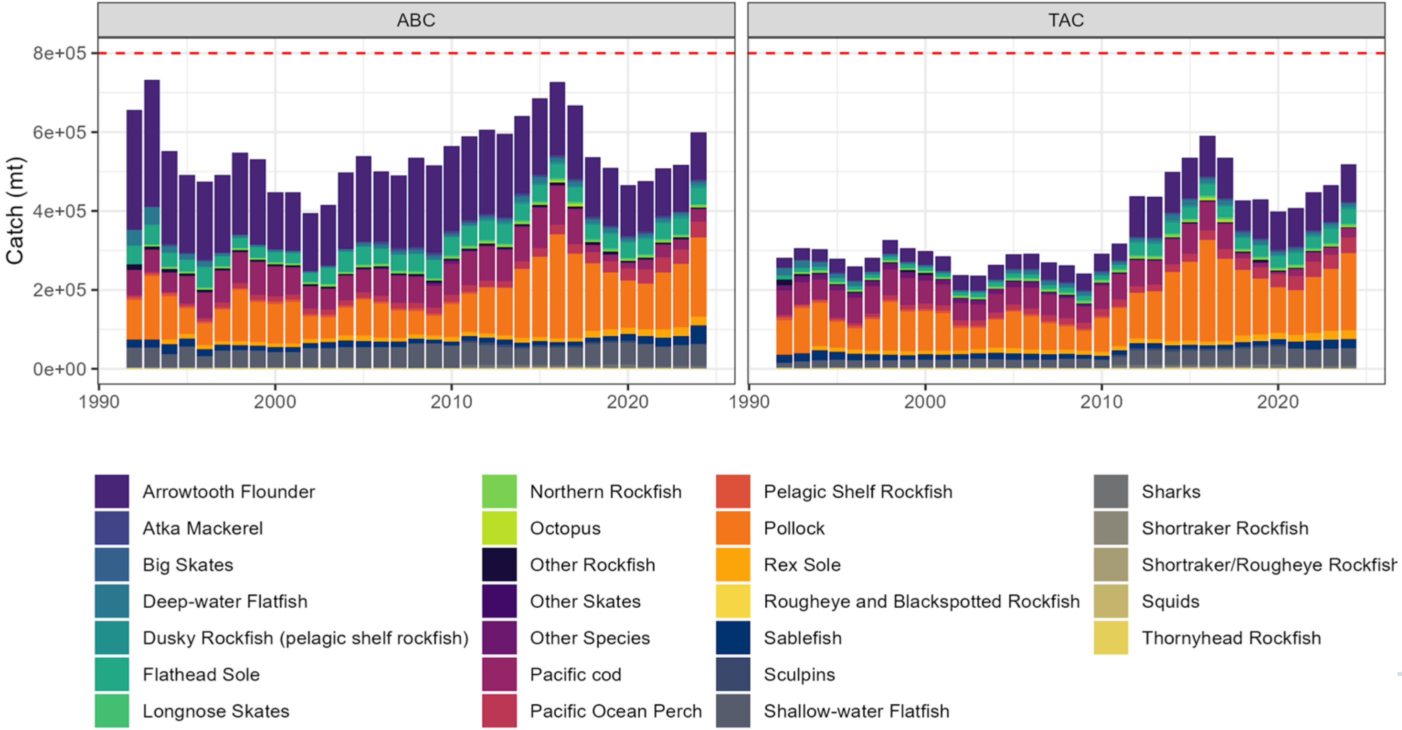
Risk increases over time

Risk is lower for EBFM

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

Alternative ecosystem cap evaluations

- 800,000 mt Optimum Yield cap on GOA groundfish
- Never constrained groundfish harvest specifications (unlike the 2M mt BSAI cap)



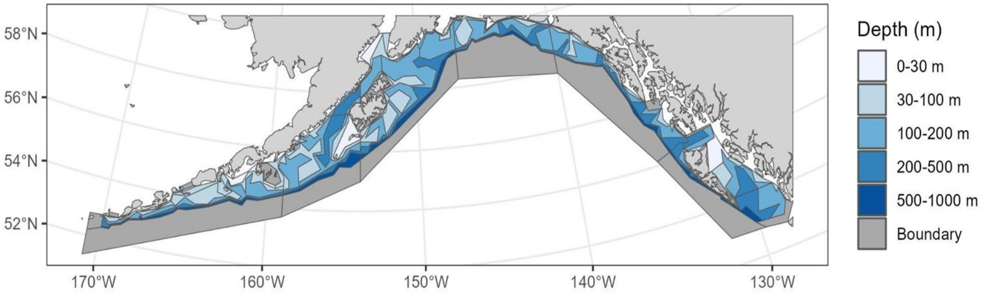
ACLIM
The Alaska Climate Integrated Modeling Project
Eastern Bering Sea
NOAA Alaska Fisheries Science Center

GOA-CLIM
The GOA Climate Integrated Modeling Project
Gulf of Alaska
NOAA Alaska Fisheries Science Center

Alternative ecosystem cap evaluations

Work to date:

- Ecosystem model simulations (**Atlantis**)
- Existing GOA cap unlikely to ever be constraining given predation and under projected climate (https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.70036)



Ongoing work:

- Develop method to rescale harvest specifications under a constraining cap
- Test alternative GOA cap values using Atlantis
- Develop simulation tools in **Rpath / Ecopath with Ecosim**

Performance criteria

- %time below B20
- Number of F = 0, closures
- Diversity of age classes (sensu Ianelli et al.)
- Total Catch
- Total $ Yield
- Stability of Catch over time
- Mean age
- R/S or other product. indices
- Mean trophic level

TABLE 6 | Suite of candidate performance indicators for ACLIM.

Name	Derivation	Purpose
Core species abundance	Mean and variance for time block	Sustainable fishing index
Core species recruitment	Mean and variance for time block	Sustainable fishing index
Core species average size and age at maturity	Mean and variance for time block	Sustainable fishing index
Core species exploitation	Annual time trend F/F_{MSY}	Sustainable fishing index
Core species crab status	Annual time trend reproductive potential vs. target reproductive potential.	Sustainable fishing index
Core species crab catch	Mean and variance for time block	Sustainable fishing index
Centroid of distribution for core species	Annual time trend	Index distribution
Euphausiid biomass	Mean and variance for time block	Ecosystem stability index
Motile epifauna biomass	Mean and variance for time block	Trophic structure index
Benthic forager biomass	Mean and variance for time block	Trophic structure index
Pelagic forager biomass	Mean and variance for time block	Trophic structure index
Apex predator biomass	Mean and variance for time block	Trophic structure index
Species diversity index	Alpha and beta diversity indices	Ecosystem stability index
Mean trophic level of the catch	Mean and variance for time block	Ecosystem Based Fishery Management index
Number of fishery closures by core species	Average for time block	Fishery efficiency index
Core species and fleet CPUE	Annual time trend of CPUE by species and fleet	Fishery catchability index
Fishing effort by fleet	Annual time trend of fishing effort	Fisheries participation and employment
Core species first-wholesale revenue index	Annual time trend	Economic index
Core species percent TAC utilization	Percentage of total allowable catch landed	Management index
Fleet species diversity index	Annual measure of diversity of target species revenues	Measure of fishery portfolio by sector
Fleet revenue variability	Coefficient of variations of fisheries revenue by sector	Financial risk index

Hollowed et al. 2020

Performance criteria

	Study species biomass (t) by age or size	Study species abundance (numbers) by age or size	Study species size (cm) at age	Species distributional overlap (proxy for predation exposure) by size or age	Proxy for recruitment to fishery	Fishing mortality/ FMSY	Spawning biomass/ BMSY	Annual catch (t) by fishing sector (s)	Frequency of fishery closures	1st wholesale value	Species diversity	Forage fish abundance	Mean trophic level of ecosystem
CE-SSM	*	*	*		*	*	*	*	*	*			
CE-MSM	*	*	*		*	*	*	*	*	*			
Spatial CE-SSM	*	*	*	*	*	*	*	*	*	*			
VAST-MICE	*	*	*	*	*	*	*	*	*	*			
IBM-CP	*	*	*	*	*	*	*	*	*	*			
EWE	*	*	*		*	*	*	*	*	*	*	*	*
MIZER	*	*	*		*	*	*	*	*	*	*	*	*
FEAST	*	*	*	*	*	*	*	*	*	*	*	*	*

Workplan goals/needs
could answer questions such as:

- Which stocks are most sensitive?
- Which if any should use an alternative HCRs?
- What are options for alternative HCRs?
- How do the caps x HCR interact?

Plan Teams:
Feedback on what is needed in terms of outcomes and information?


Feedback from Plan Teams

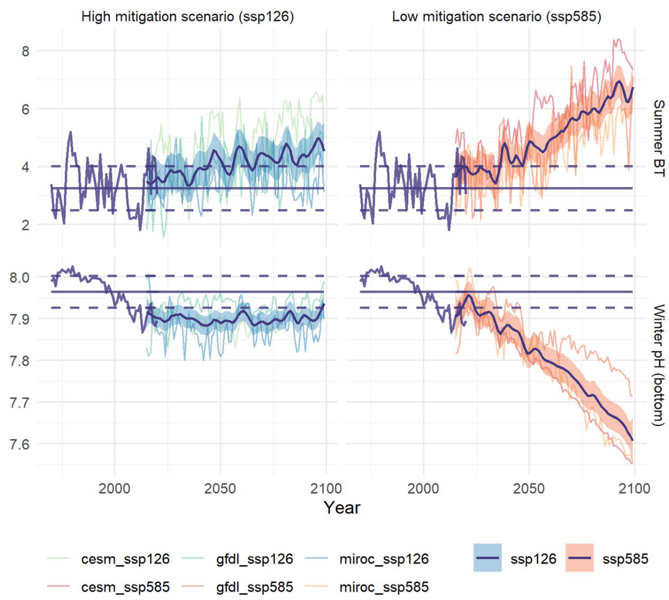
- What HCRs are of interest?
  - SSC/Council focus on 1, 5, 7, 10
- What species should we focus on first (e.g., highest productivity spp?)
  - SSC recommendation for BSAI/GOA P. cod and pollock, AK sablefish, snow crab and BBRKC
- What are some performance criteria to include in our evaluations?
- What to include in a work plan (priorities, capacity, evaluations)

EXTRA SLIDES

Models and projections

Credit: Kirstin Holsman

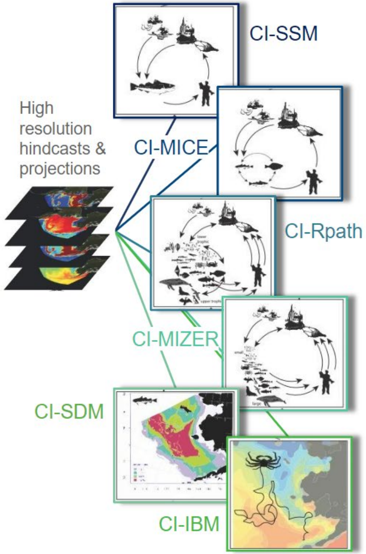
ACLIM Projections

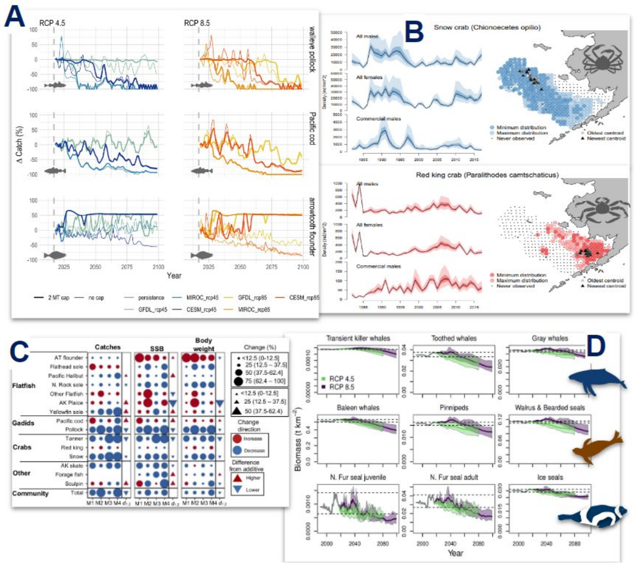


ACLIM phase	GCM or ESM	Years	Carbon mitigation scenario	Scenario name	CMIP Phase	ESM ocean output resolution (deg lat; lon; #layers;time)	Bering10K ROMSNPZ Model	ROMSNPZ output resolution (grid;layers;time)	pH ?	Ref
1	CORE-CFSR	1970-2018	Hindcast	Hindcast	5	2;2;d | 0.5;0.5;40; 5d	H16	10 Km2; 10 ; 1 wk	No	1
1	GFDL-ESM2M	2006-2099	Moderate mitigation	RCP 4.5	5	0.33-1.0; 1.0; 50; Mo	H16	10 Km2; 10 ; 1 wk	No	2
1	GFDL-ESM2M	2006-2099	Low mitigation	RCP8.5	5	0.33-1.0; 1.0; 50; Mo	H16	10 Km2; 10 ; 1 wk	No	2
1	CESM-1	2006-2099	Moderate mitigation	RCP 4.5	5	1.0; 1.0; 60; Mo	H16	10 Km2; 10 ; 1 wk	No	2
1	CESM-1	2006-2080	Low mitigation	RCP8.5	5	1.0; 1.0; 60; Mo	H16	10 Km2; 10 ; 1 wk	No	2
1	MIROC-ESM	2006-2099	Moderate mitigation	RCP 4.5	5	1.7; 1.4; 44; Mo	H16	10 Km2; 10 ; 1 wk	No	2
1	MIROC-ESM	2006-2099	Low mitigation	RCP8.5	5	1.7; 1.4; 44; Mo	H16	10 Km2; 10 ; 1 wk	No	2
2	CORE-CFSR	1970-2021	Hindcast	Hindcast	5	2;2;d | 0.5;0.5;40; 5d	K20P19	10 Km2; 30 ; 1 wk	Yes	3,4
2	GFDL-ESM2M	2006-2099	Moderate mitigation	RCP 4.5	5	0.33-1.0; 1.0; 50; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	5
2	GFDL-ESM2M	2006-2099	Low mitigation	RCP8.5	5	0.33-1.0; 1.0; 50; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	5
2	CESM-1	2006-2099	Moderate mitigation	RCP 4.5	5	1.0; 1.0; 60; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	5
2	CESM-1	2006-2080	Low mitigation	RCP8.5	5	1.0; 1.0; 60; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	5
2	MIROC-ESM	2006-2099	Moderate mitigation	RCP 4.5	5	1.7; 1.4; 44; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	5
2	MIROC-ESM	2006-2099	Low mitigation	RCP8.5	5	1.7; 1.4; 44; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	5
2	GFDL-ESM4	1980-2014	Historical	SSP126	6	0.5; 1.0; 75; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	GFDL-ESM4	2014-2099	High mitigation	SSP126	6	0.5; 1.0; 75; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	GFDL-ESM4	2014-2099	Low mitigation	SSP585	6	0.5; 1.0; 75; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	CESM2	2014-2099	Historical	SSP126	6	1.0; 1.0; 60; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	CESM2	2014-2099	High mitigation	SSP126	6	1.0; 1.0; 60; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	CESM2	2014-2099	Low mitigation	SSP585	6	1.0; 1.0; 60; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	MIROC ES2L	2014-2099	Historical	SSP126	6	1.0; 1.0; 62; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	MIROC ES2L	2014-2099	High mitigation	SSP126	6	1.0; 1.0; 62; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7
2	MIROC ES2L	2014-2099	Low mitigation	SSP585	6	1.0; 1.0; 62; Mo	K20P19	10 Km2; 30 ; 1 wk	Yes	6,7

1. Hermann et al. 2016, 2. Hermann et al. 2019; 3. Kearney et al. 2020; 4. Pilcher et al. 2019; 5. Pilcher et al. 2022; 6. Hermann et al. 2021; 7. Cheng et al. 2021

ACLIM3 Models





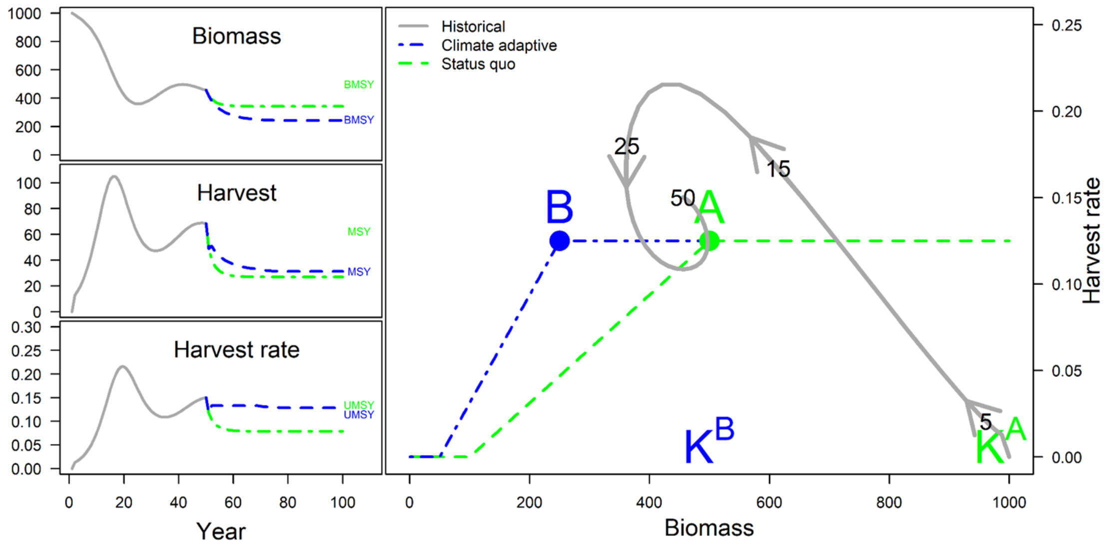
Model type	Model description	Target species	Climate coupling	ROMSNPZ covariates	Refs/ Lead
CI-MICE	Modified single sp, uses spatial distribution to estimate predation mortality	ATF & Pollock	Strata-specific energetics-based predation mortality	BT	Spencer et al 2016, Spencer et al. in prep.
CI-Spatial SSM	Operating model: Spatial single sp; Estimating model: spatial vs aggregate	Snow crab		BT	Szuwalski & Olmos in prep
CI-SR	Climate linked recruitment models	Snow, tanner, and red king crab	covariate effects on CI-ricker recruitment model	AO, sea ice, BT	Szuwalski et al. 2020
CI - MICE	CEATTLE Multi species assessment model/ non-spatial but includes SDMs for predation exposure; annual	ATF, Pollock, P. cod, *optional: halibut, NFS*	Temp. effects on growth, predation (energetics), and multiple covariate effects on CI-ricker recruitment model	Seasonal averages for BT, SST, wind, large Zoop., +...	Holsman et al. 2016, 2020, 2022
CI- IBM	Individual based model of crab larval dispersal and settlement	Snow crab	Nested in ROMSNPZ grid, larval dispersal modeled as a function of drift, temperature, etc.	current , salinity, temp.	Torre, Stockhausen, et al. in revision
CI - SDM	Climate integrated spatial distribution model of at-sea habitat use	Northern fur seals	Climate linked to habitat suitability	BT, Hsbl, MZL, phytoplankton, copepods, bathymetry	McHuron, Hazen, and Sterling
CI-SSM	YFS growth model linked to single species stock assessment (uses climate linked SDMs)	Yellowfin sole	Temp. dependent growth and selectivity?	BT	Spies et al. in prep
CI-SSM	Climate-integrated single-species stock assesment model	Northern rock sole	Climate-integrated recruitment and growth	pH &, BT (recruitment), SST (growth)	Punt et al. 2021
CI-MIZER	Climate integrated size-spectrum foodweb model (MIZER) includes fully resolves the size structure of populations; non-spatial; weekly	7 species, 3 functional groups	Temp. dependent growth & non-predation mortality; lower trophic levels forced by NPZ	BT, SST	Reum et al. 2019, 2020
CI-RPATH	Rpath ecosystem model; This model is the most speciose model, with multiple species and functional groups, several of which are divided further according to life history stage; non-spatial monthly	72 biological groups	Lower trophic levels linked to NPZ output; climate mediated energetics	Phytoplankton production, euphausiid production, benthos, BT, SST	Whitehouse et al. 2021
CI - SSM	Conceptual model of survival Yukon Chinook	Chinook salmon	Marine conditions linked to returns	SST, copepods	Yasumiishi, Farley et al in prep
CI-SDM	Climate integrated spatial distribution model of potential spawning habitat	P. cod	Climate linked to spawning habitat suitability	BT, salinty	Bigman et al. in review
CI-SDM	Climate integrated spatial distribution model for juvenile and adult fish and crab	Pollock, P. cod, ATF, YFS, NRS, snow crab, RKC, P. halibut	Delta GAMs of species distribution models	BT, SST, salinity, pH, O2, ... (multiple covariates)	Goodman et al. in prep; Barnes et al. 2022
CI-spatial catch	Spatial effort and catch model; single sp	Pollock, select A80 species, P. cod	Spatial patterns in effort and catch are related to environmental drivers as well as non-climate drivers (biomass, distance from port, etc).	Cold pool, BT, wind, sea ice	Hayes et al. in prep
ATTACH	Multi-stock allocation model that uses ABC for a given species or set of species to return estimated TAC and Catch under various fishing and management scenarios.	All groundfish stocks in the EBS	Not climate linked	ABC from one or more stocks and various harvest scenarios	Faig et al. 2020

Dynamic B0 issues explained

Credit: Kirstin Holsman

Adapting reference points to reflect changes in productivity

- MSA directs reference points to reflect current and probable future environmental conditions
- Changing reference points for stocks undergoing climate-related productivity shifts can result in counter-intuitive management actions:
  - Declining stocks could be fished harder
  - Flourishing stocks could be fished more conservatively

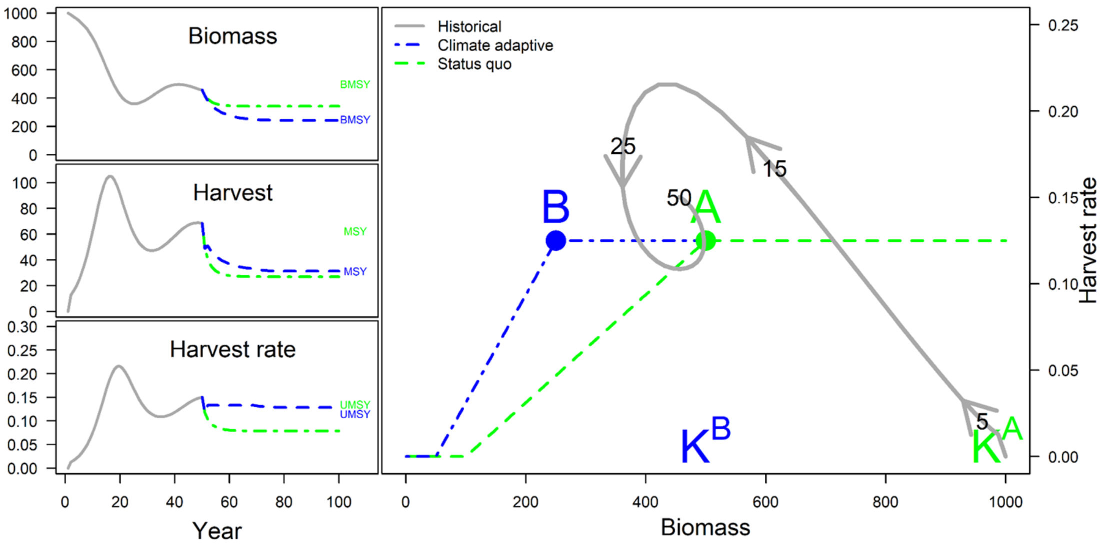


Szuwalski et al. 2023. Unintended consequences of climate-adaptive fisheries management targets. Fish and Fisheries. https://onlinelibrary.wiley.com/doi/10.1111/faf.12737

How might this arise?

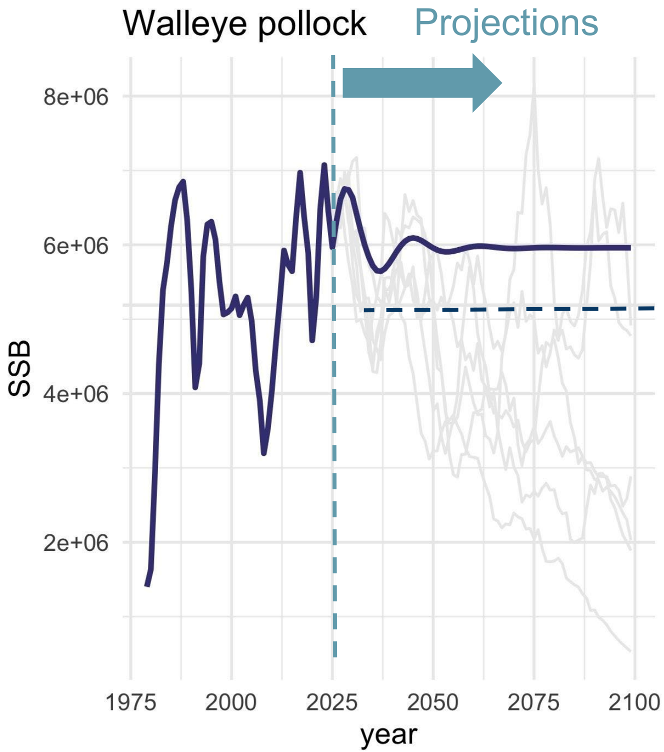
Proceed with caution….

- If using a climate informed target (B0 based on climate trajectory)
- If truncating recruitment time series data to reflect recent lower productivity
- If adopting a long-term higher mortality in recent years as set M
- If re-estimating B0/B40 each year



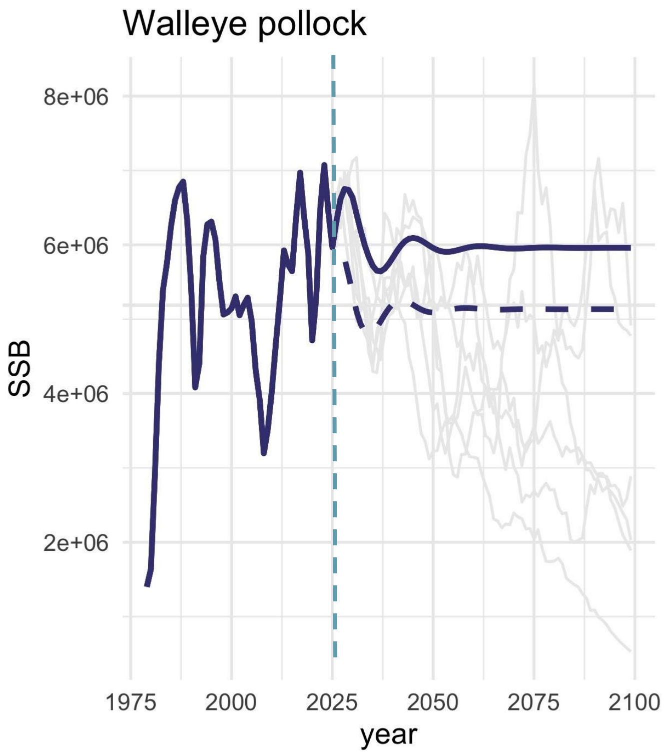
Szuwalski et al. 2023. Unintended consequences of climate-adaptive fisheries management targets. Fish and Fisheries. https://onlinelibrary.wiley.com/doi/10.1111/faf.12737

Dynamic B0 or fixed targets?



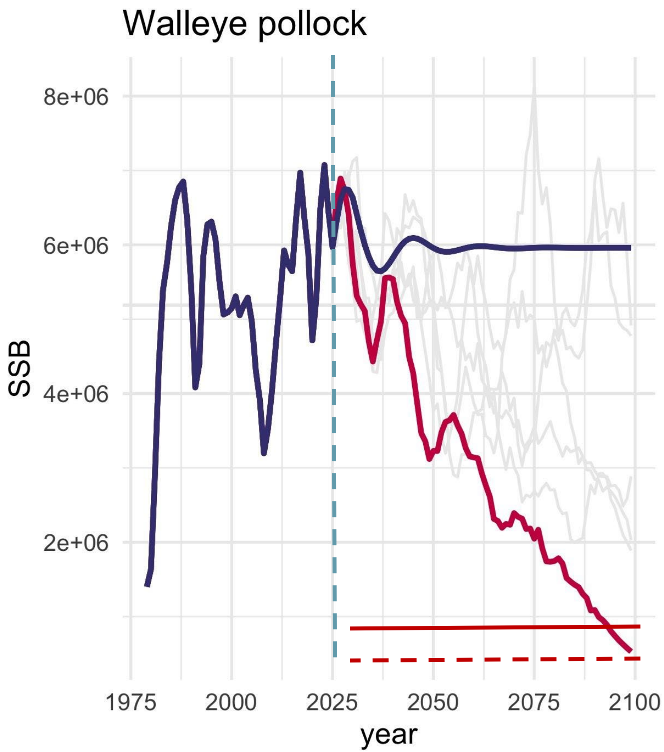
Set Btarget to 40% B0

Dynamic B0 or fixed targets?



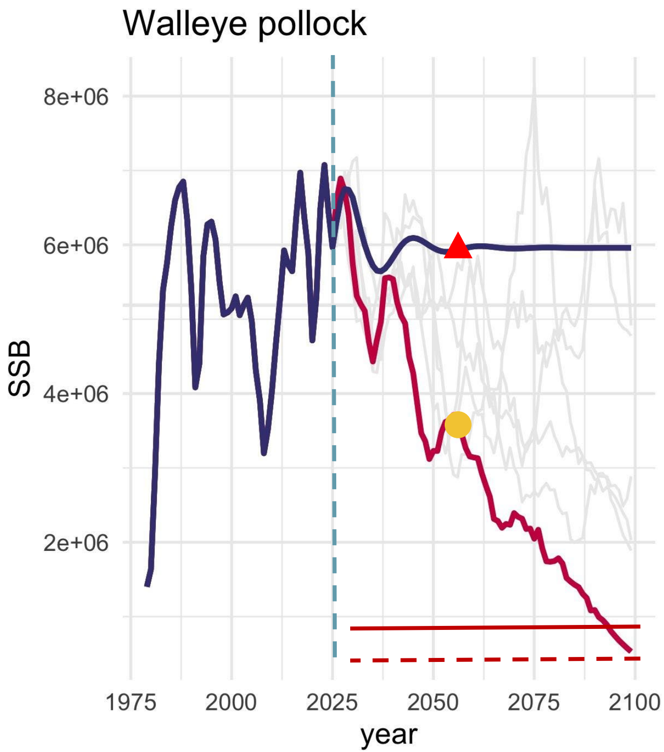
F that results in fished SSB = 40% B0

If using an environmentally-linked B0 (dynamic B0)



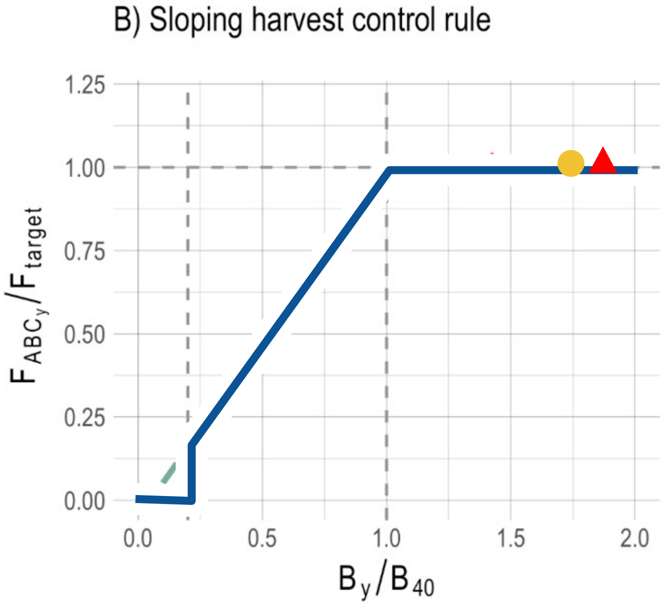
Set Btarget to 40% B0 conditioned on change

If using a environmentally-linked B0 (dynamic B0)



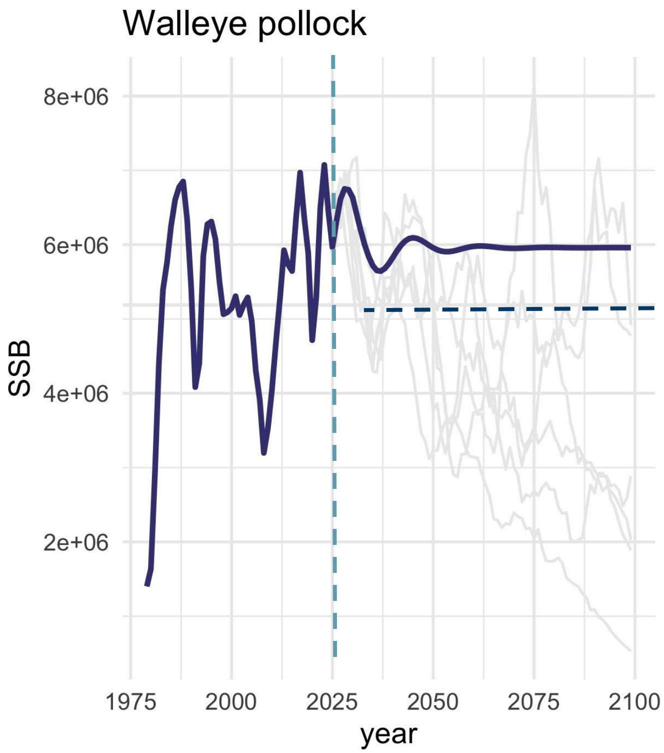
If AKA not declining

If AKA declining

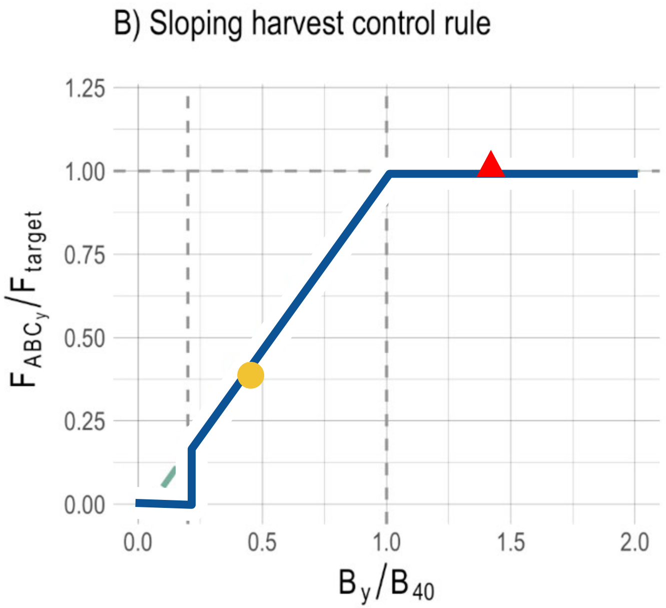


HCR slope is not triggered, even though SSB is rapidly declining

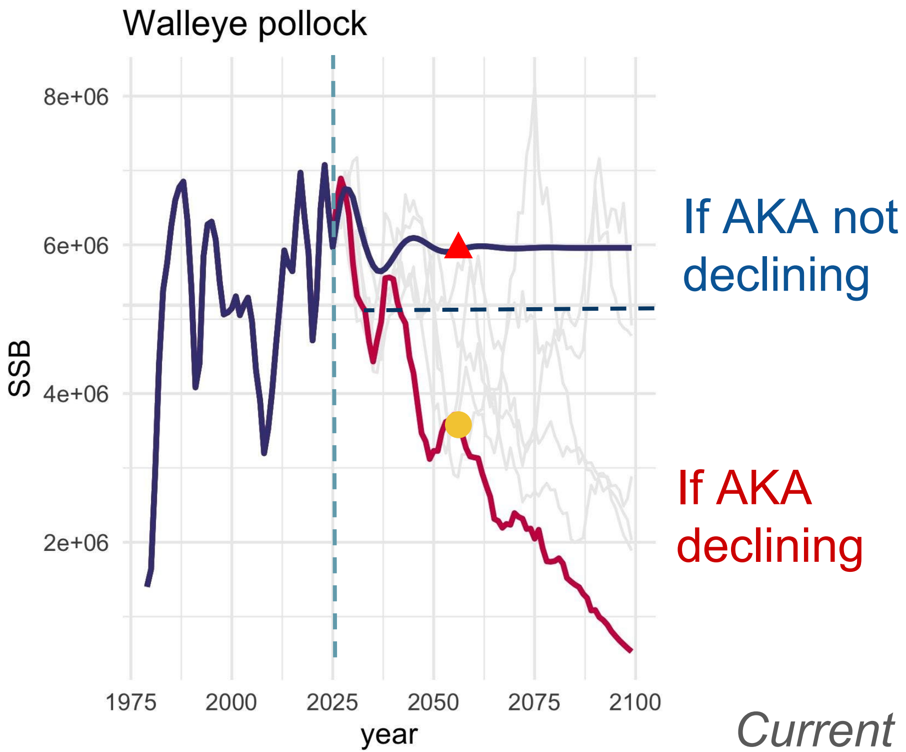
Dynamic B0 or fixed targets?

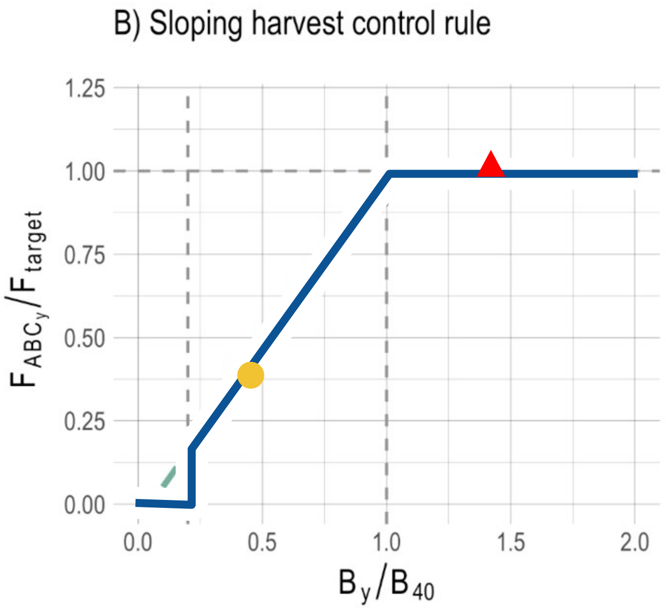


Set Btarget to 40% B0



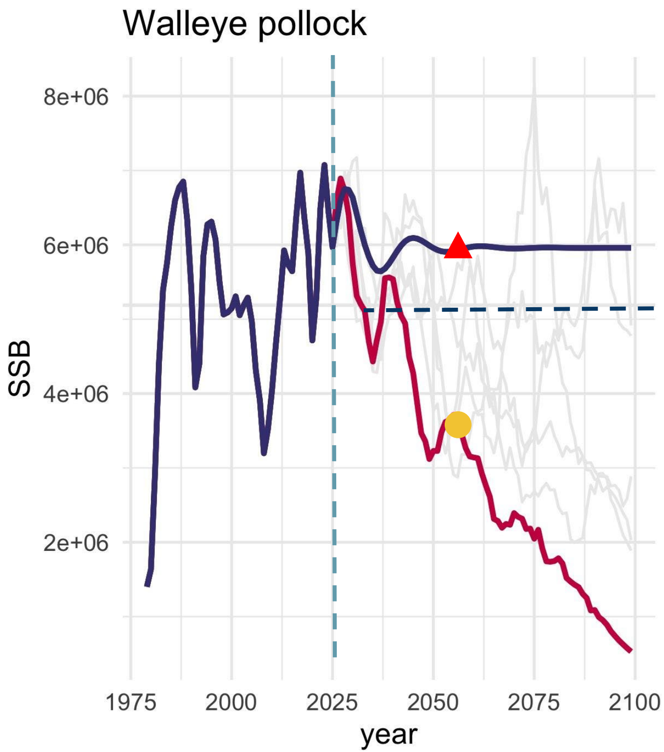
Fixed target (fixed B0)



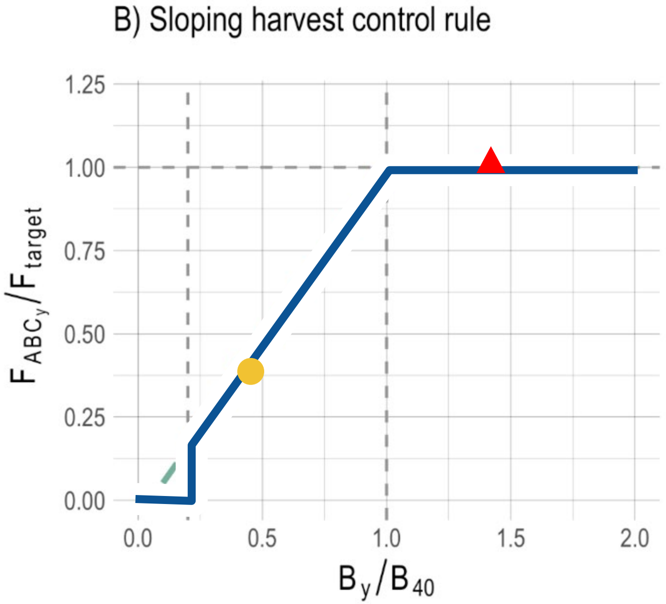


Current status on declining trajectory induces HCR slope trigger

Fixed target (fixed B0)

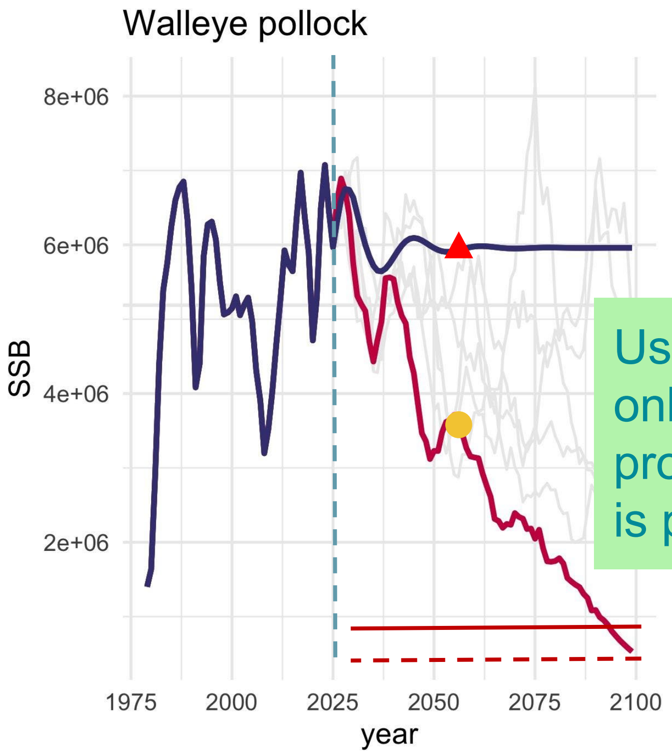


TRUE



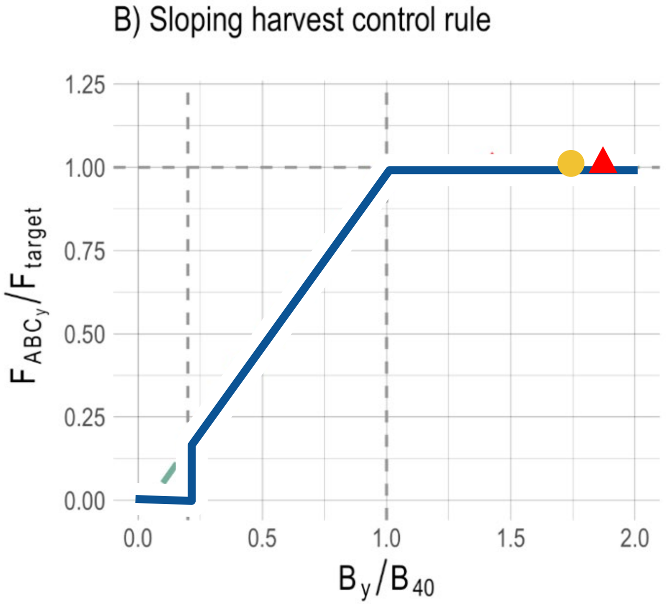
Risk: Lost harvest potential due to climate driven change

If using a environmentally-linked B0 (dynamic B0)



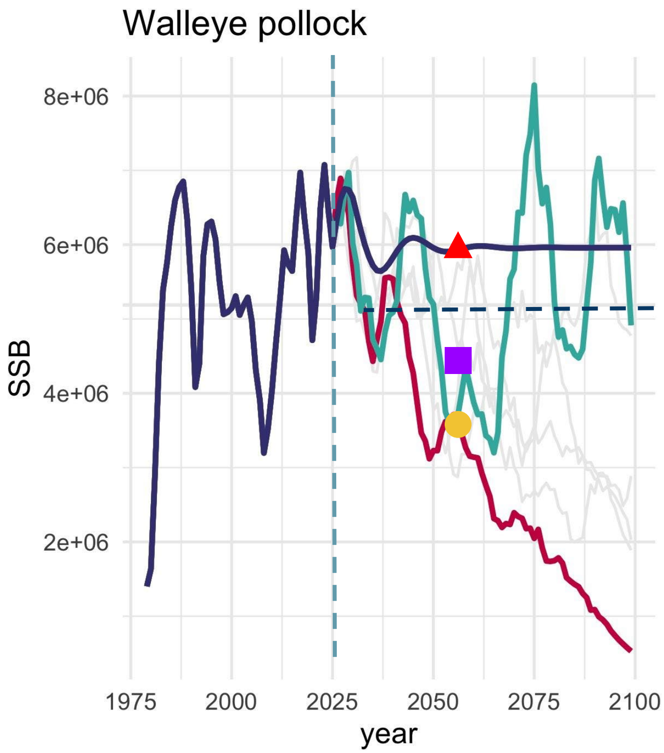
TRUE

Use dynamic B0 only if certain productivity shift is permanent

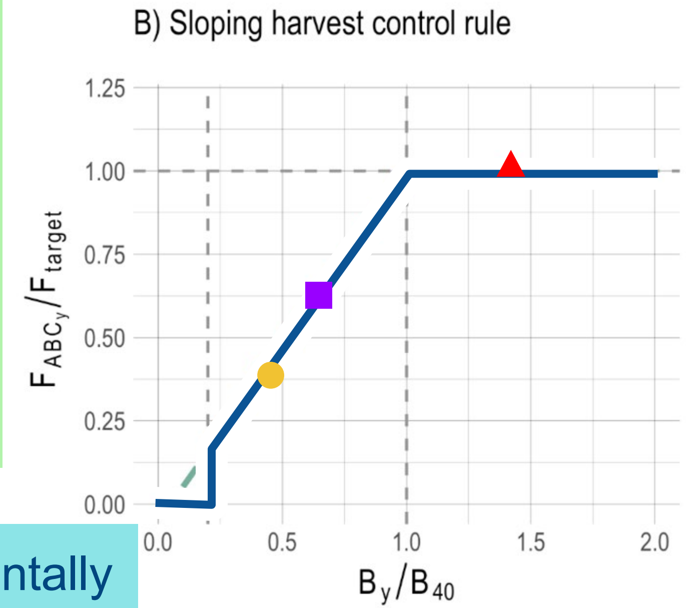


Risk : Overfishing during environmental strain could prevent recovery and lower long-term catch

Fixed target (fixed B0) + Env. enhanced status

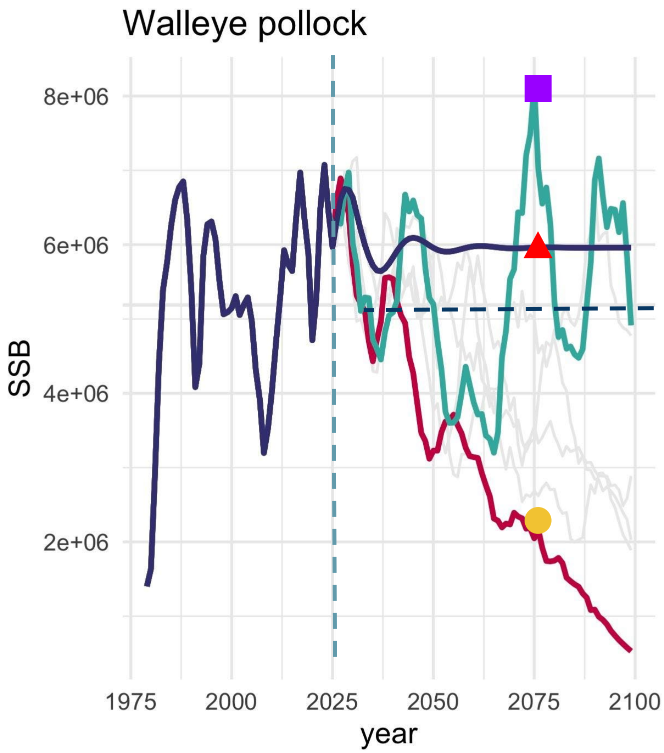


Use fixed B0/B40 if future trajectories include divergent or alternative possibilities

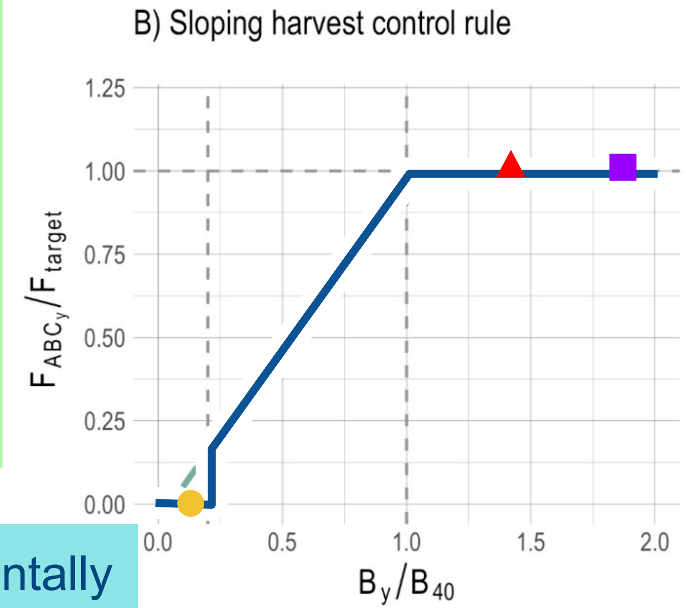


Use environmentally linked status assessments to adjust for variability

Fixed target (fixed B0) + Env. enhanced status

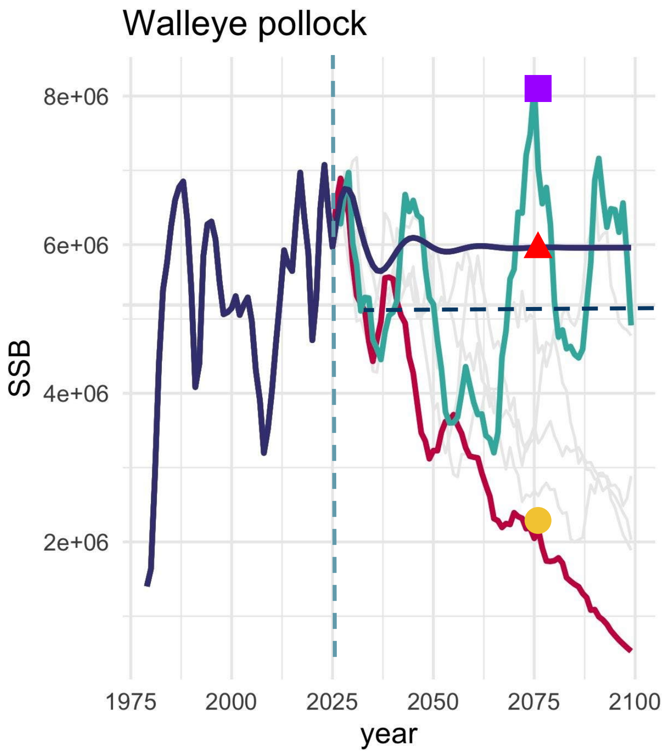


Use fixed B0/B40 if future trajectories include divergent or alternative possibilities



Use environmentally linked status assessments to adjust for variability

Options for “hybrid” approach



(1) Set targets based on fixed productivity potential
   (a) Historical reference period (historical B_0)
   (b) Climate naive models (or historical B_0)

(1) Set status based on dynamic or environmentally informed status
   (a) Use climate or environmentally linked model to estimate current status
   (b) Use base M + additional M_env blocks (sensu Barbeaux et al. and Spies et al. 2024, Holsman et al. 2024)