Alternative HCR evaluations

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Thanks to :

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

Today’s Discussion

- **[10-15 min] Review of ABC/F_ABC (step2), HCR (step3), and TAC modeling (step 4)**
  - ACLIM & GOACLIM modeling:
    - Target setting (ABC/F_ABC)
    - HCR options
    - TAC options (cap or other policy actions that impact TAC specifically)
- **[90 min] Discussion**
  - HCR options for crab?
  - Meaning of “status quo”?
  - Priorities and objectives?
- **Outcome**
  - Draft climate information objectives and process and prioritization for the CPT (will be added to the climate workplan)

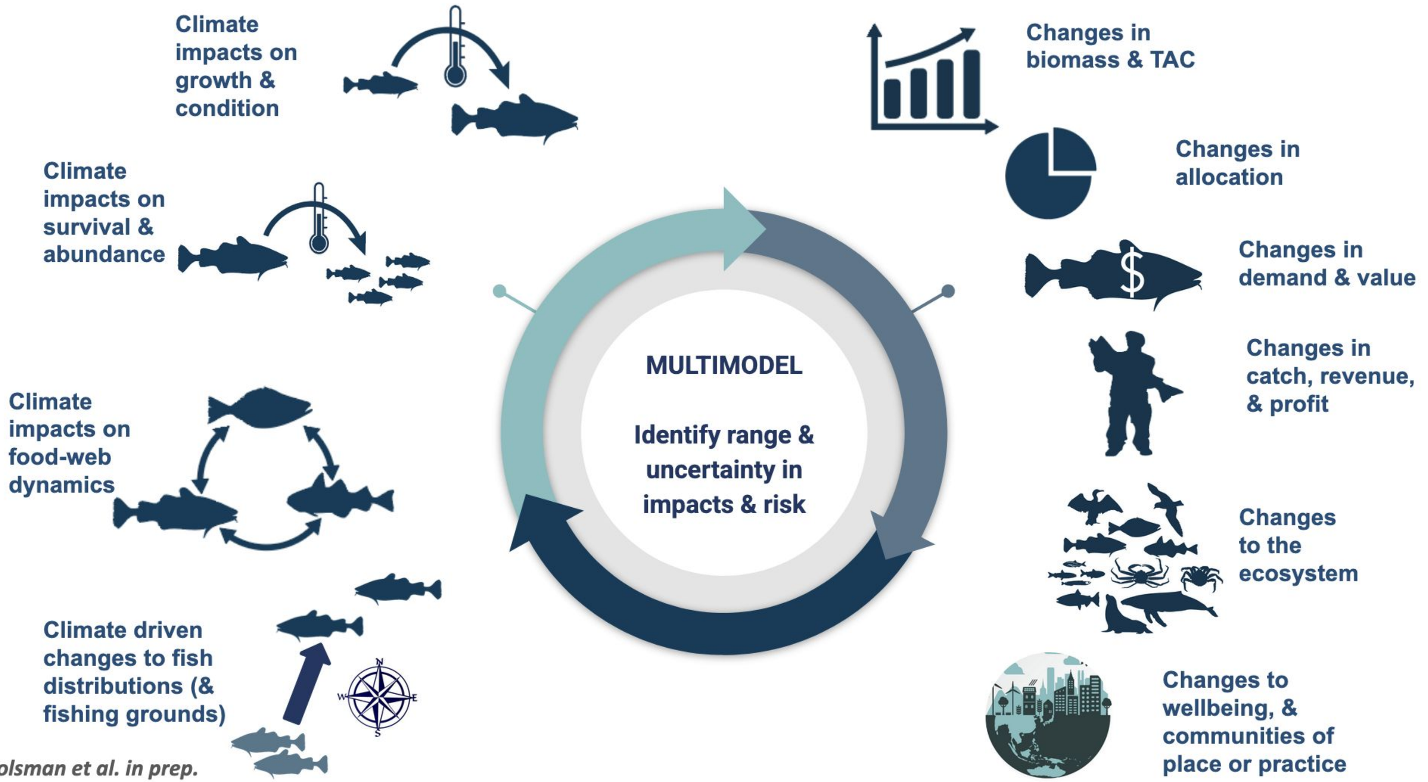
Today's Discussion Topics

Outcome: *Draft climate information objectives and process for the CPT (will be added to the climate workplan)*

1. **HCR options for crab**
   a. What role would an HCR play specifically in crab management?
   b. Can HCR 7 (alpha modifier on $B_{(status)}$) represent the buffer approach currently used for crab?
   c. Could this be implemented as a quantitative buffer based on forecasts of environmental conditions (e.g., marine heatwaves, regime shifts)?
   d. Are crab specific HCRs needed or is the current set enough?

2. **Meaning of "status quo"**
   a. "Status quo" is identified as an ACLIM & GOACLIM goal. What does "status quo" mean for crab management in practice?

3. **Priorities and objectives**
   a. Is this a priority for the CPT?
   b. If so, what are we trying to achieve by incorporating climate information into:
      i. HCRs?
      ii. Potentially ABC and TAC as well?
      iii. Do we need a more meaningful or refined ABC for crab? What if that results in less conservative buffers?



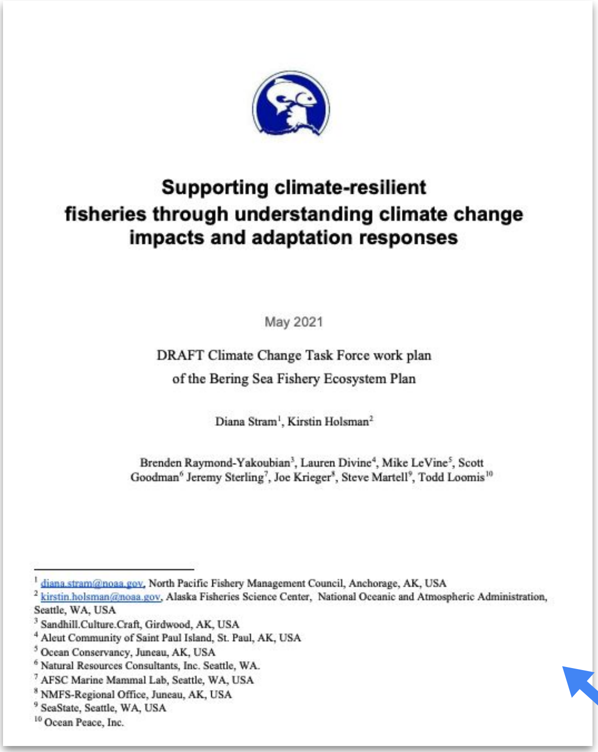
Holsman et al. in prep.

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

Potential climate-linked model evaluations

Provide tools and approaches to support climate informed management decisions



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

May 2021

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

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[8] NMFS-Regional Office, Juneau, AK, USA
[9] SeaState, Seattle, WA, USA
[10] Ocean Peace, Inc.

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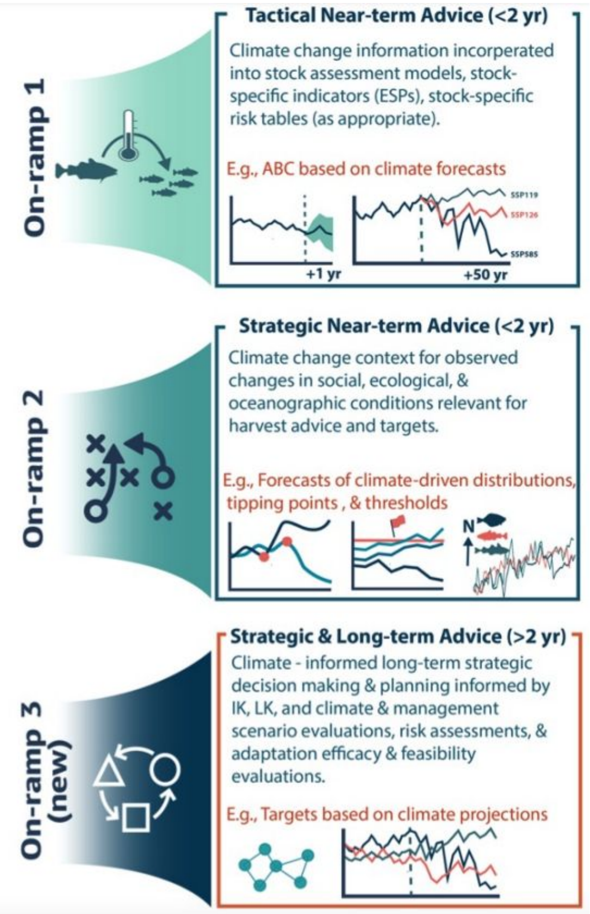
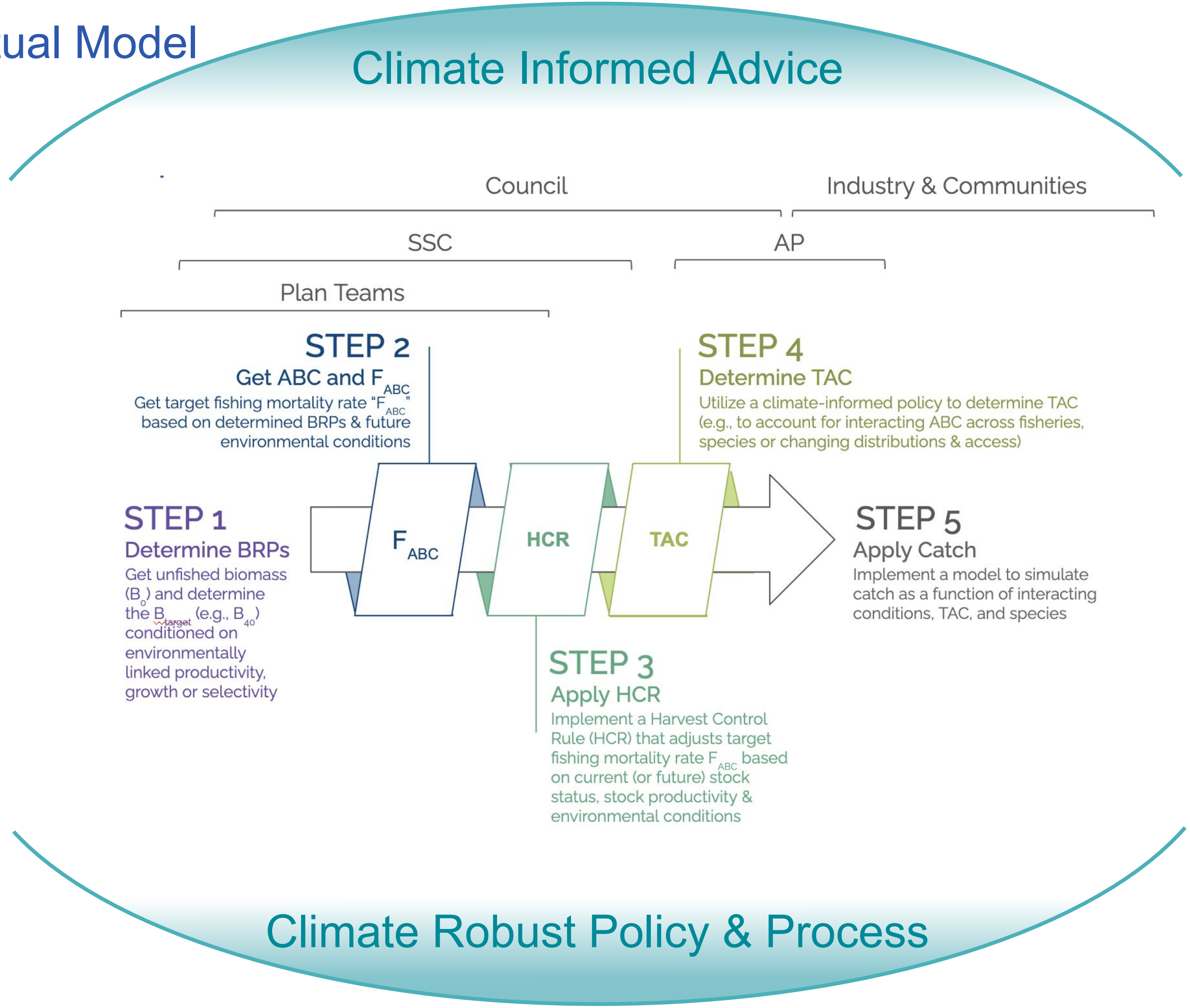
Climate information on ramps for fisheries management



https://www.npfmc.org/about-the-council/plan-teams/bering-sea-fishery-ecosystem-plan-team/#climate-change

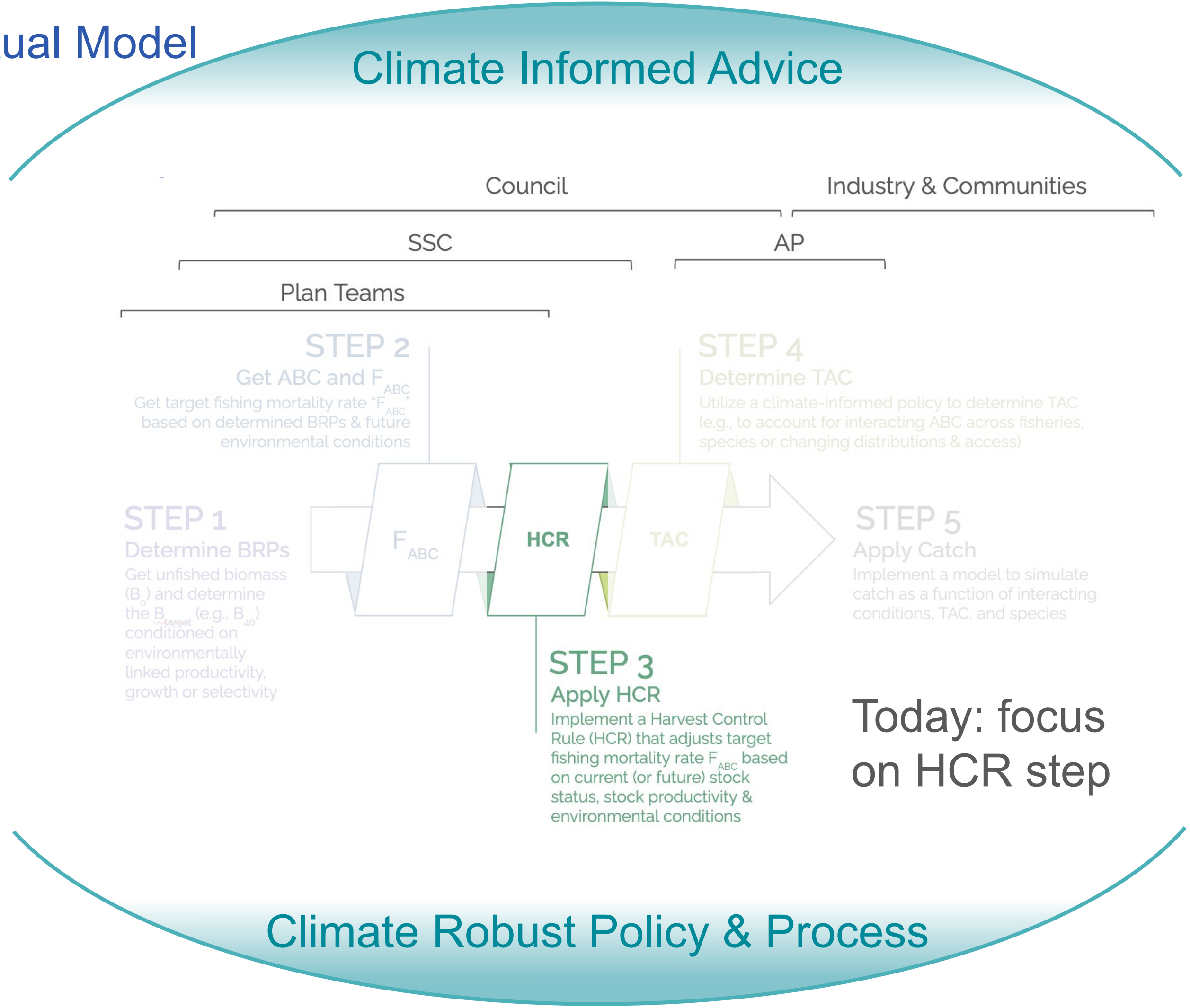
Conceptual Model



Climate workplan will provide the roadmap

Hoslman et al. in prep

Conceptual Model



Climate workplan will provide the roadmap

Today: focus on HCR step

Hoslman et al. in prep

HCR Overview

Credit: Kirstin Holsman

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

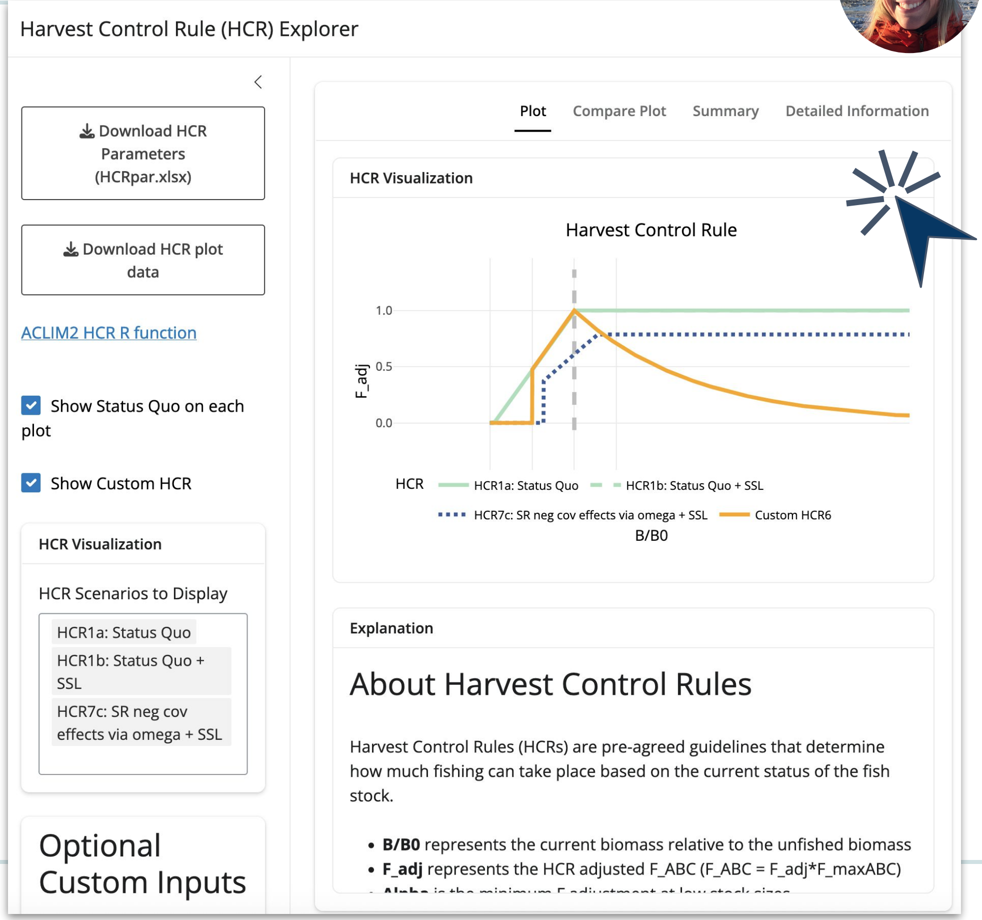
Table 1: Overview of ACLIM and GOACLIM 2025 HCR options. "Stage 2" denotes the HCRs that are not being evaluated as part of the Council's request following the June SSC workshop, but have been or are being evaluated as part of the ACLIM and GOACLIM work.

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/

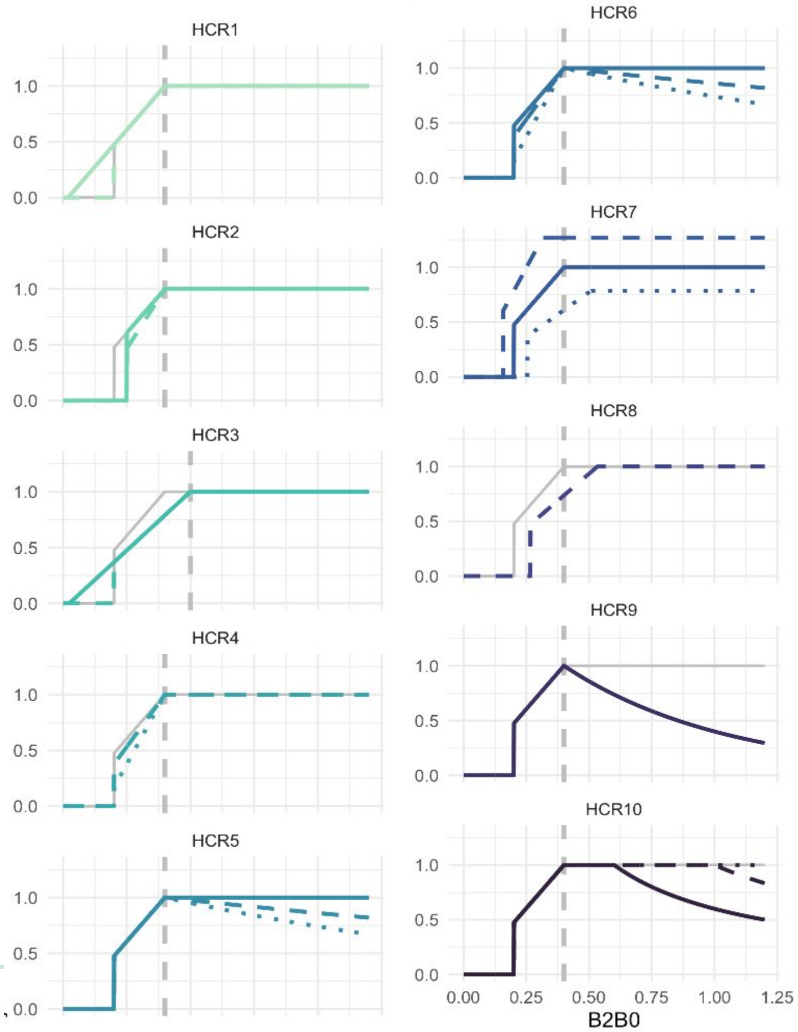
Research question:
Are there alternative HCRs that can perform better than status quo under alternative future scenarios?



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)
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

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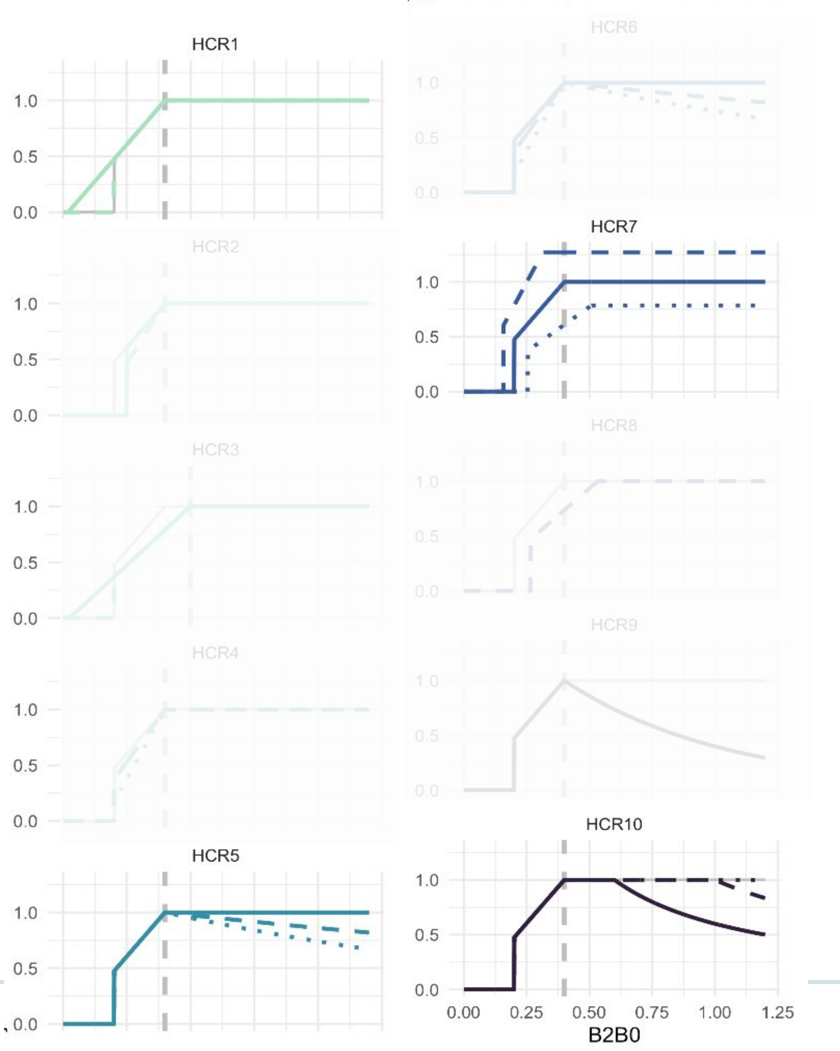
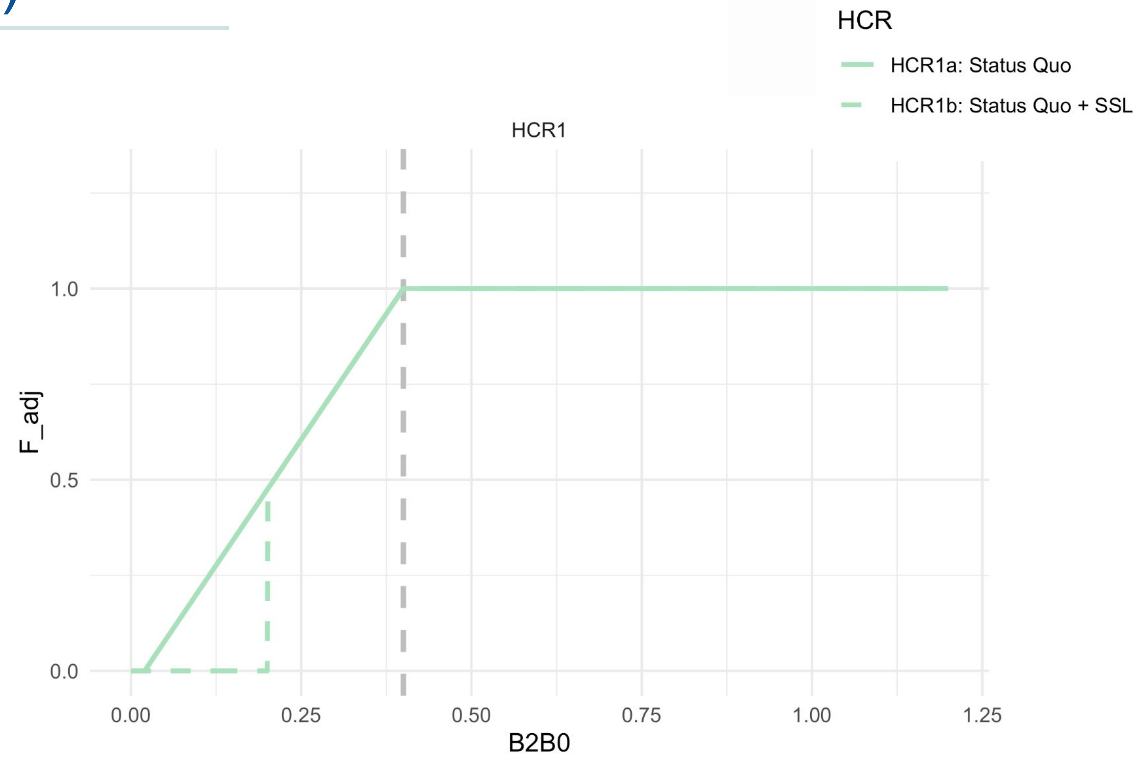


HCR 1: Status quo (Tier 3)

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

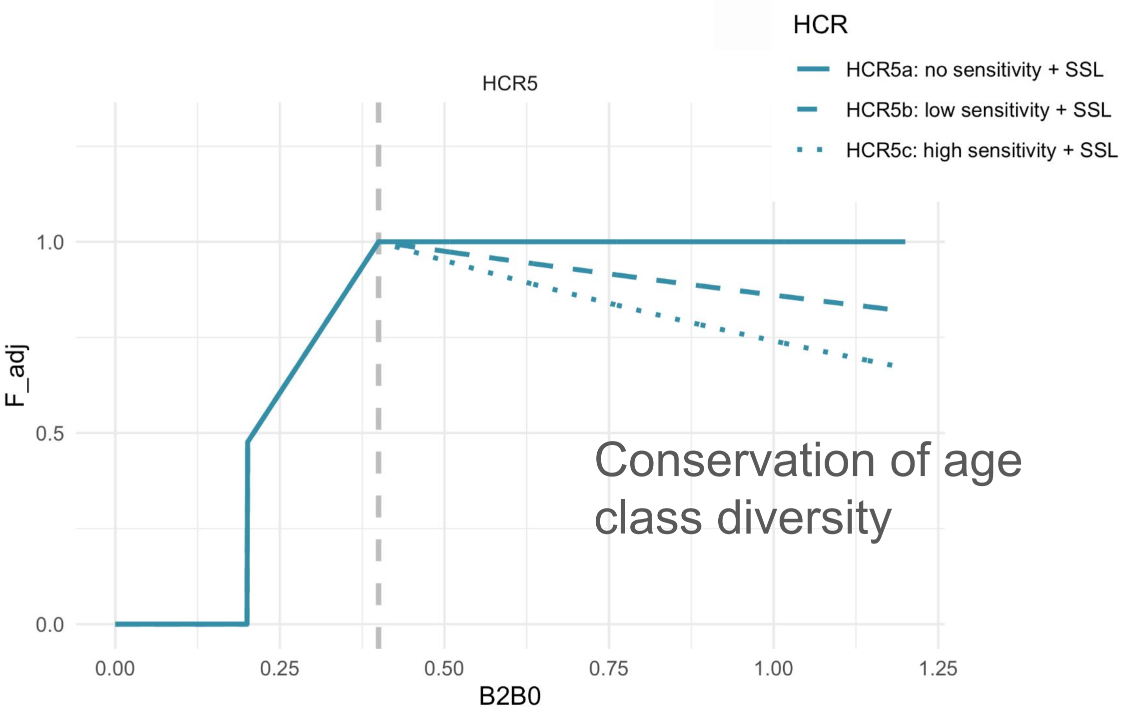
$$F_{ABC_{max}} = \begin{cases} F_{ABC} & \frac{B_y}{B_{target}} > 1 \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} < 1 \\ 0 & \frac{B_y}{B_{target}} < \frac{B_{lim}}{B_{target}} \end{cases}$$



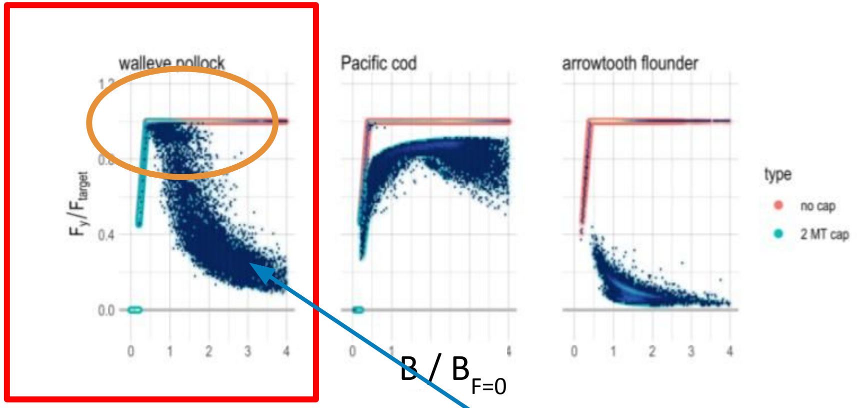
HCR 5 : Maximize productivity/ increased reserve (buffer shocks)

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

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



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

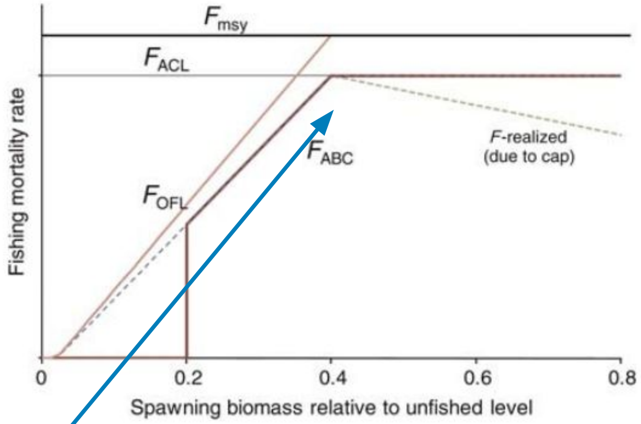


Figure 4. Schematic of harvest control rule currently affecting ABC or annual catch limit (ACL) for Alaska groundfish species like pollock (thick line). Note that this schematic indicates that B_{msy} is 40% of the unfished expected spawning biomass.

Ianelli et al. 2011

Effect of the 2 mt Cap on pollock

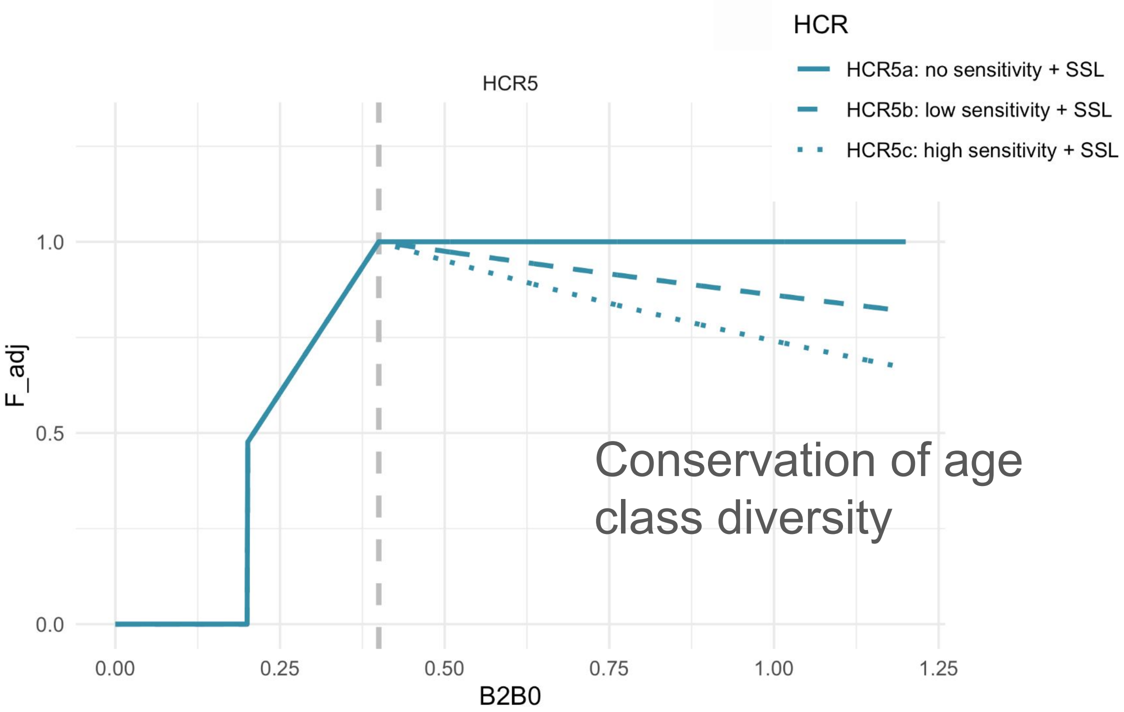
Hollowed et al. (2025) Development of climate informed management scenarios for fisheries in the eastern Bering Sea . ICES Journal of Marine Science, Volume 82, Issue 1, January 2025, fsae034, https://doi.org/10.1093/icesjms/fsae034

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

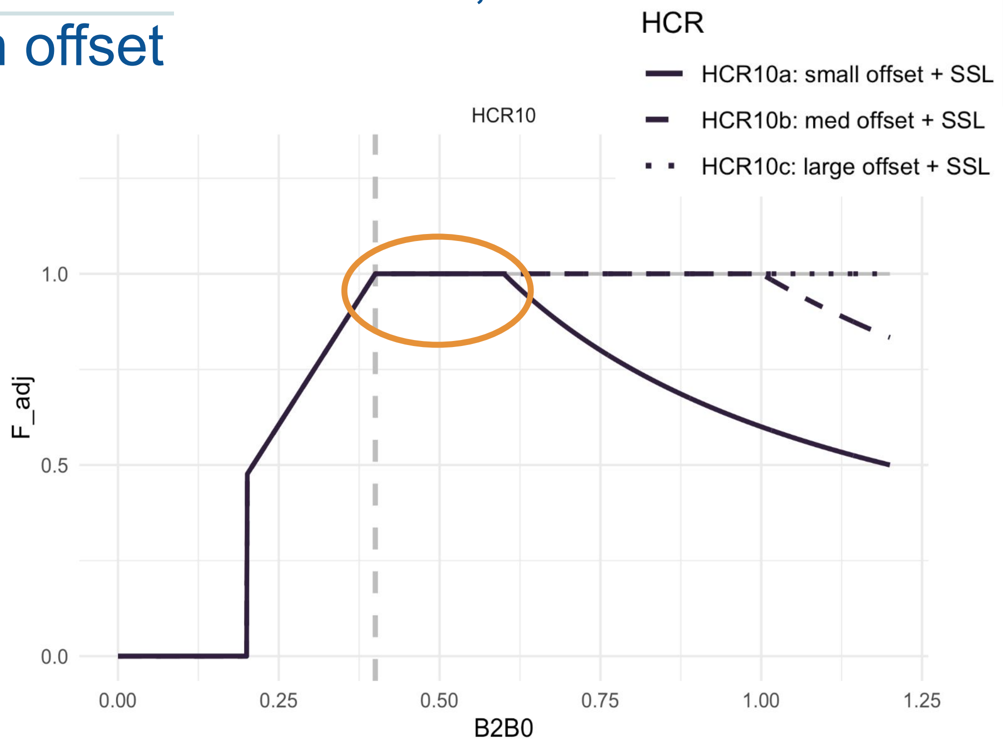
$$F_{ABC_{max}} = \begin{cases} F_{ABC}\, e^{(-\gamma(\frac{B_y}{B_{target}}-1))} & \frac{B_y}{B_{target}} > 1 \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} < 1 \\ 0 & \frac{B_y}{B_{target}} < \frac{B_{lim}}{B_{target}} \end{cases}$$



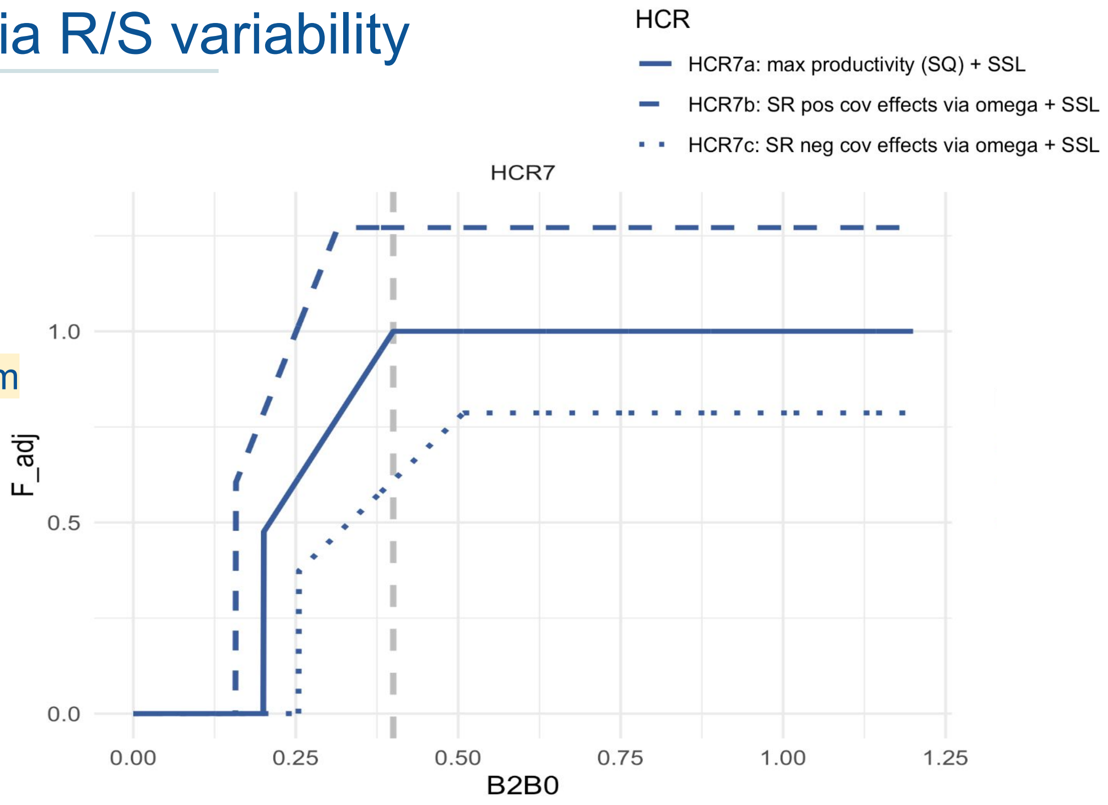
HCR 10: Maximize productivity/increased reserve; linear version (1/ B_target) with offset

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.

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



HCR 7: Risk Table Bridging via R/S variability covariate adjusted HCR



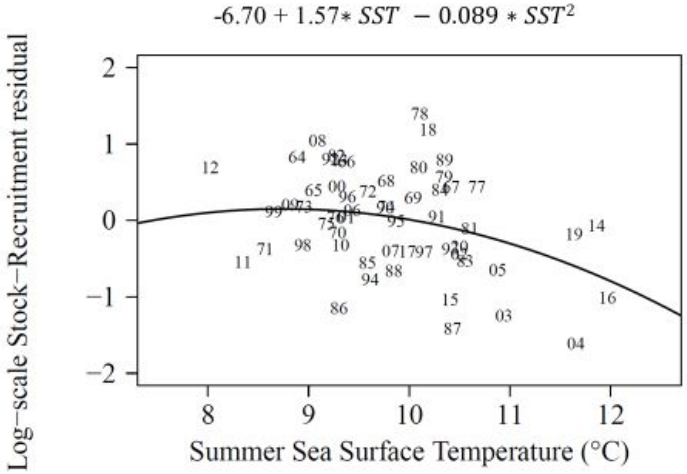
Simulation Goal:
This HCR provides a way to transition from qualitative risk tables to a more explicit, analytical approach for species whose productivity is known to vary with environmental conditions.

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

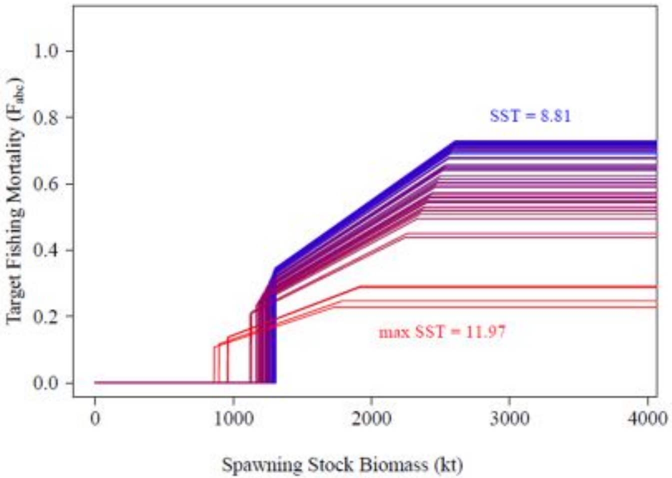
$$\hat{B}_{lim} = B_{lim} e^{(-\omega_3 * \mathrm{x_y})} \qquad \hat{B}_{target} = B_{target} e^{(-\omega_2 * \mathrm{x_y})}$$

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

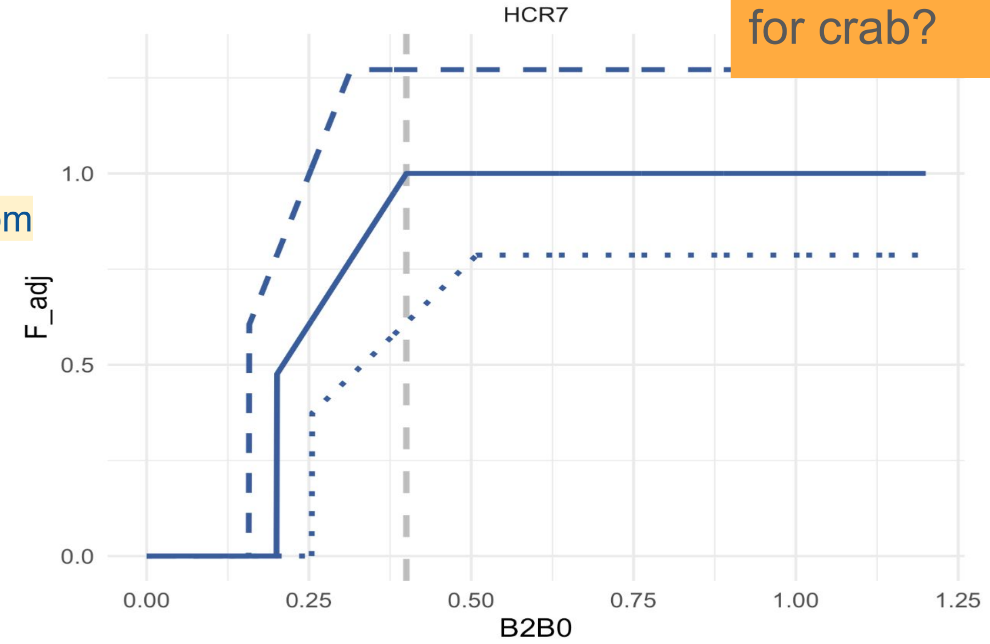
HCR 7: Risk Table Bridging via R/S variability covariate adjusted HCR

Maybe the best starting place for crab?

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.

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

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



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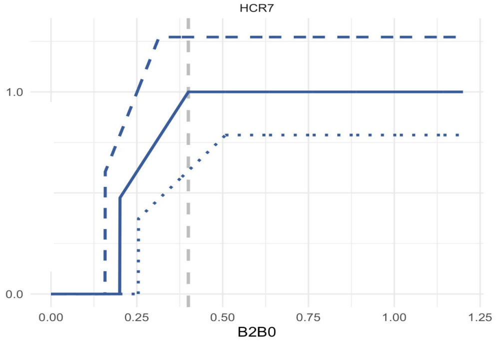


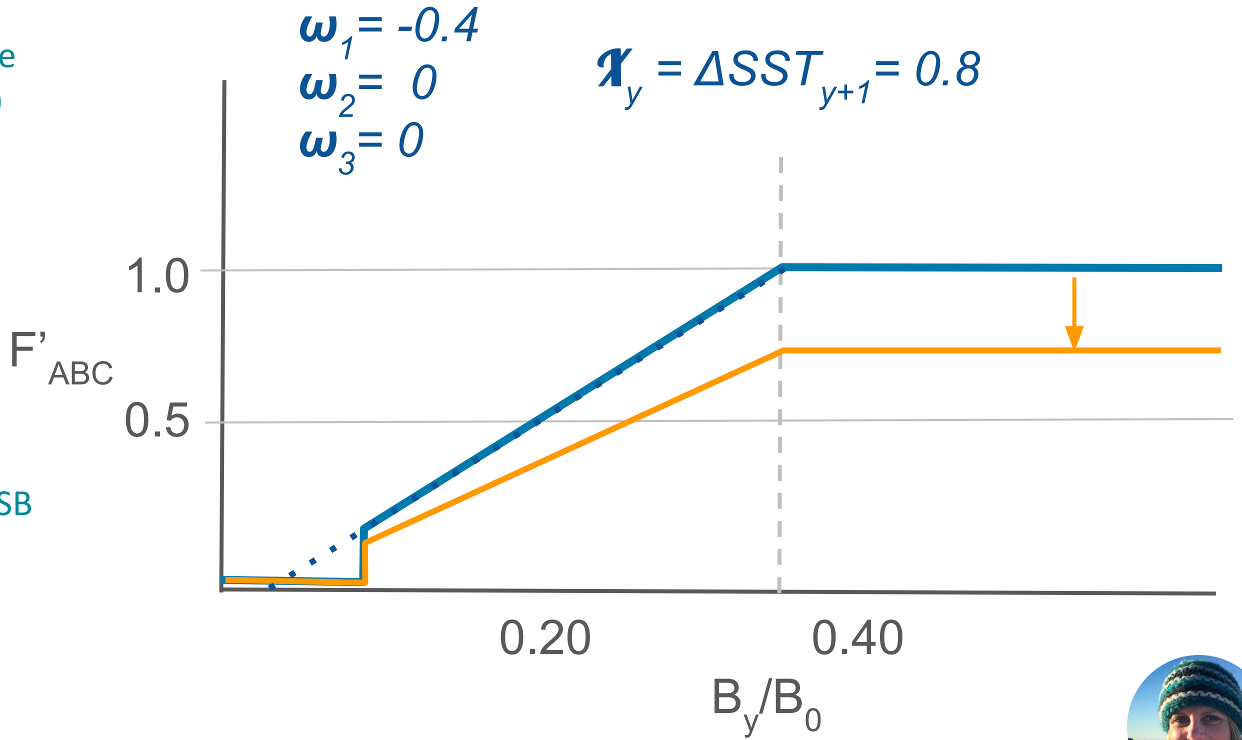
HCR 7: Add climate-linked buffers

Simulation goal: Evaluate if this improves long-term catch (and or stability in C)

Example:
model is climate naive but we know there is a negative effect of MHW on survival (i.e., model based harvest rate $F_{35\%}$ is too high relative to "true" $F_{35\%}$)

CPT Goal:
Capture effect of future MHW on productivity

How:
Adjust F_{ABC} downward to account for the negative impact of future environmental conditions on future SSB and F, assuming that model based harvest rate is too high



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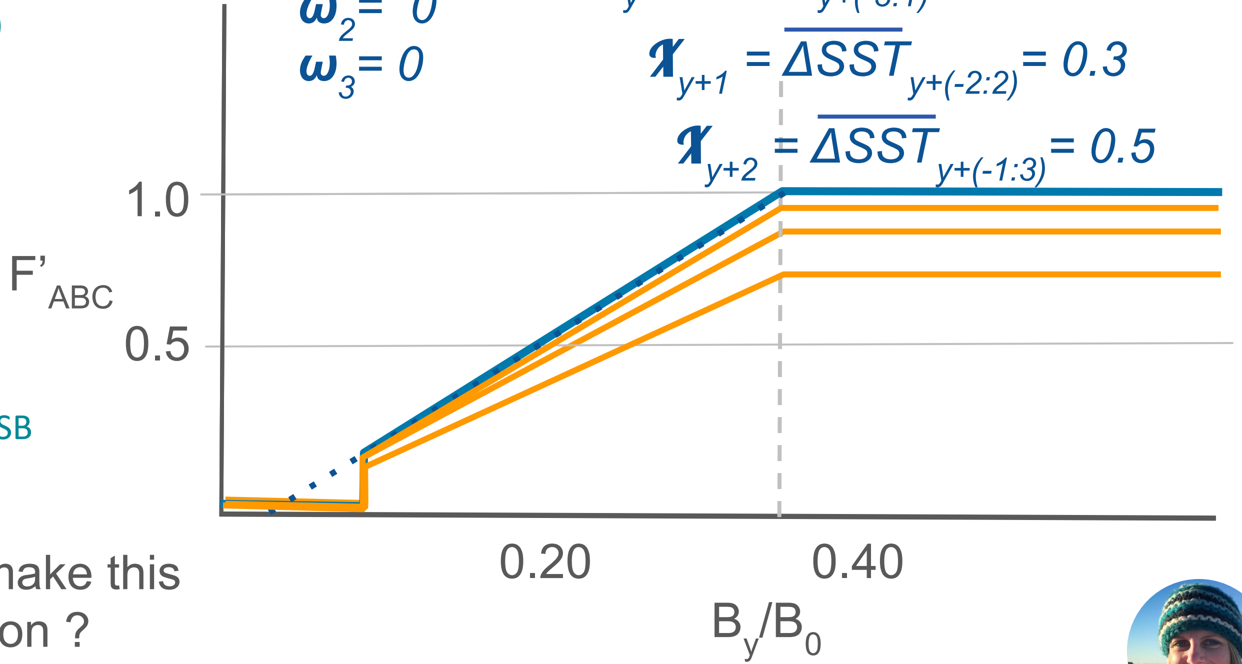
Capture effect of future MHW on productivity

How:
Adjust F_{ABC} downward to account for the negative impact of future environmental conditions on future SSB and F, assuming that model based harvest rate is too high

$\omega_1 = -0.4$
$\omega_2 = 0$
$\omega_3 = 0$

$\chi_y = \overline{\Delta SST}_{y+(-3:1)} = 0.1$
$\chi_{y+1} = \overline{\Delta SST}_{y+(-2:2)} = 0.3$
$\chi_{y+2} = \overline{\Delta SST}_{y+(-1:3)} = 0.5$



Andre: Can we make this a smooth transition ?

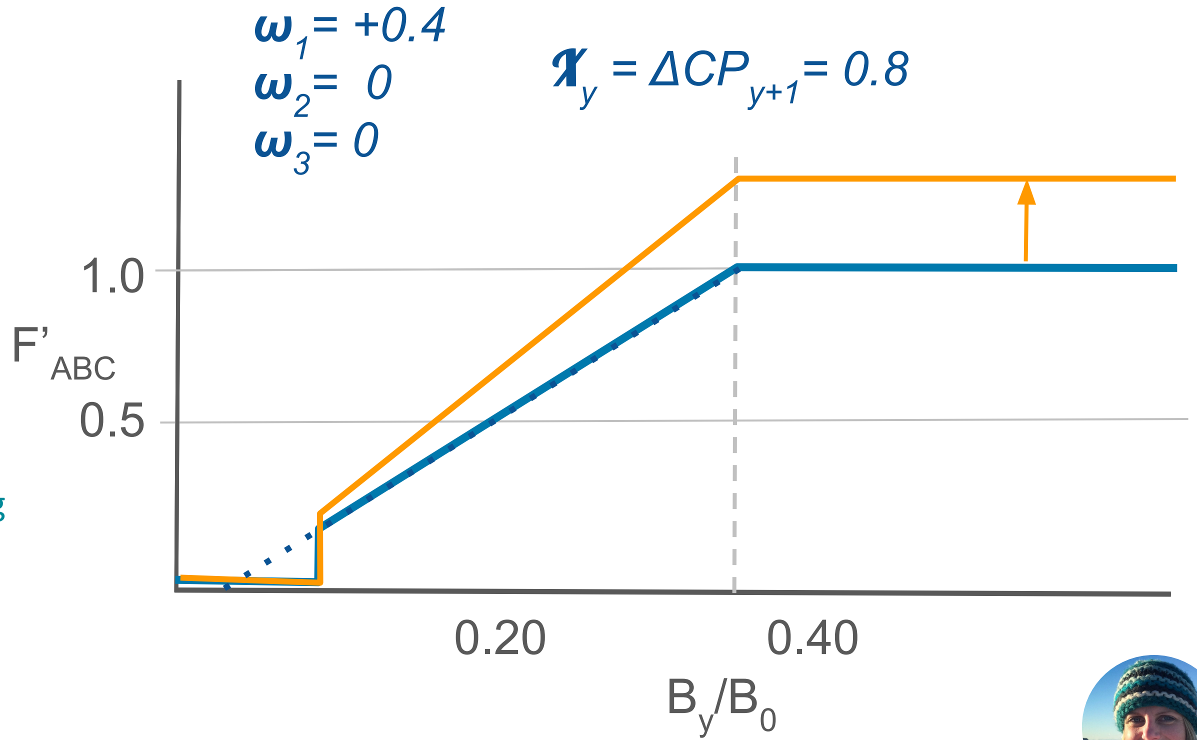
HCR 7: Add climate-linked buffers

Simulation goal: Evaluate if this improves long-term catch (and or stability in C)

Example:
model is climate naive but we know there is a POSITIVE effect of cold pool on survival (i.e., model based harvest rate $F_{35\%}$ is too low relative to "true" $F_{35\%}$)

CPT Goal:
Capture effect of future cold pool on productivity

How:
Adjust F_{ABC} upward to account for the positive impact of future environmental conditions on future SSB and F, assuming that model based harvest rate is too low



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

Maybe the best starting place for crab?

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

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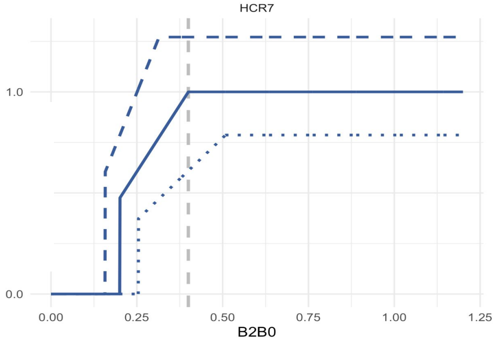


HCR 7: Add climate-linked buffers

Simulation goal: Evaluate if this improves long-term catch (and or stability in C)

Example:

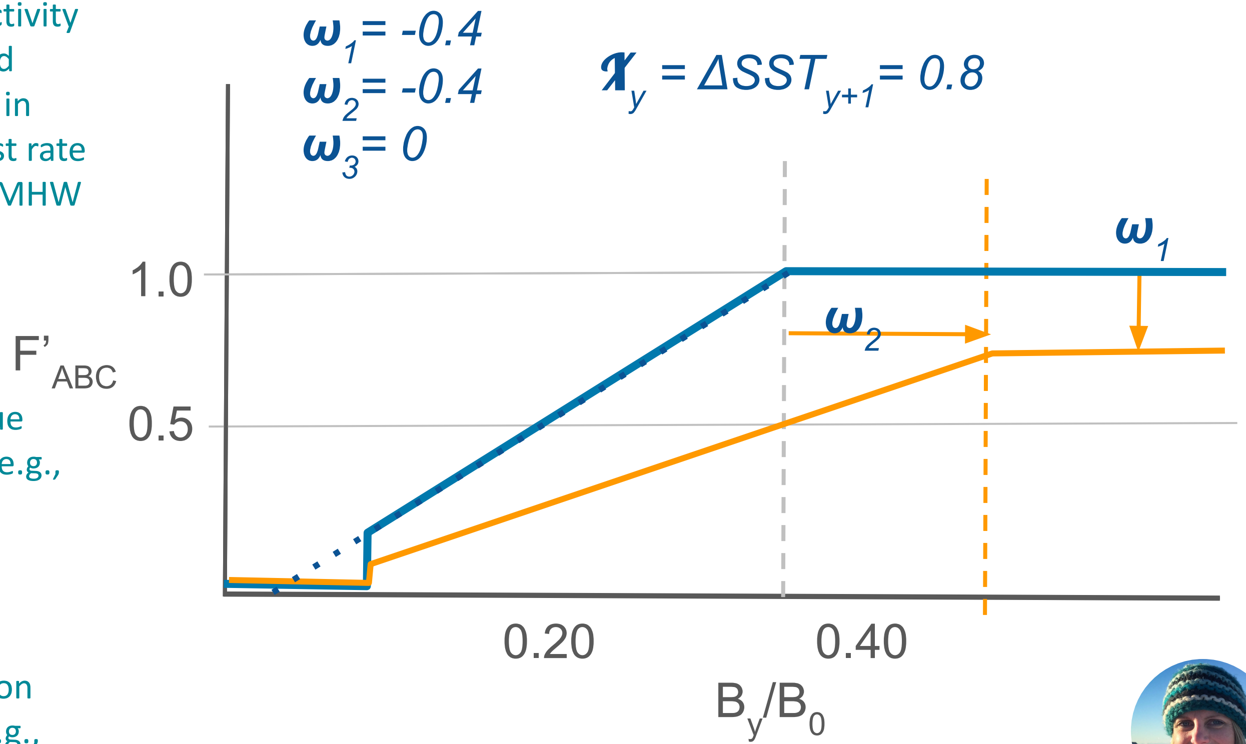
model is climate naive but we know there is a NEGATIVE effect of SST on productivity and we know that more SSB is needed during MHWs to offset early declines in productivity (i.e., model based harvest rate $F_{35\%}$ is too high; est $B_{35\%}$ is too low in MHW relative to "true" B_{MSY})

CPT Goal:

Capture effect of future MHW on productivity and manage closer to true optimal SSB under MHW conditions (e.g., $B_{48\%}$)

How:

Adjust F_{ABC} down to account for the negative impact of future conditions on future SSB and F, shift B_{target} higher (e.g., $B_{48\%}$)



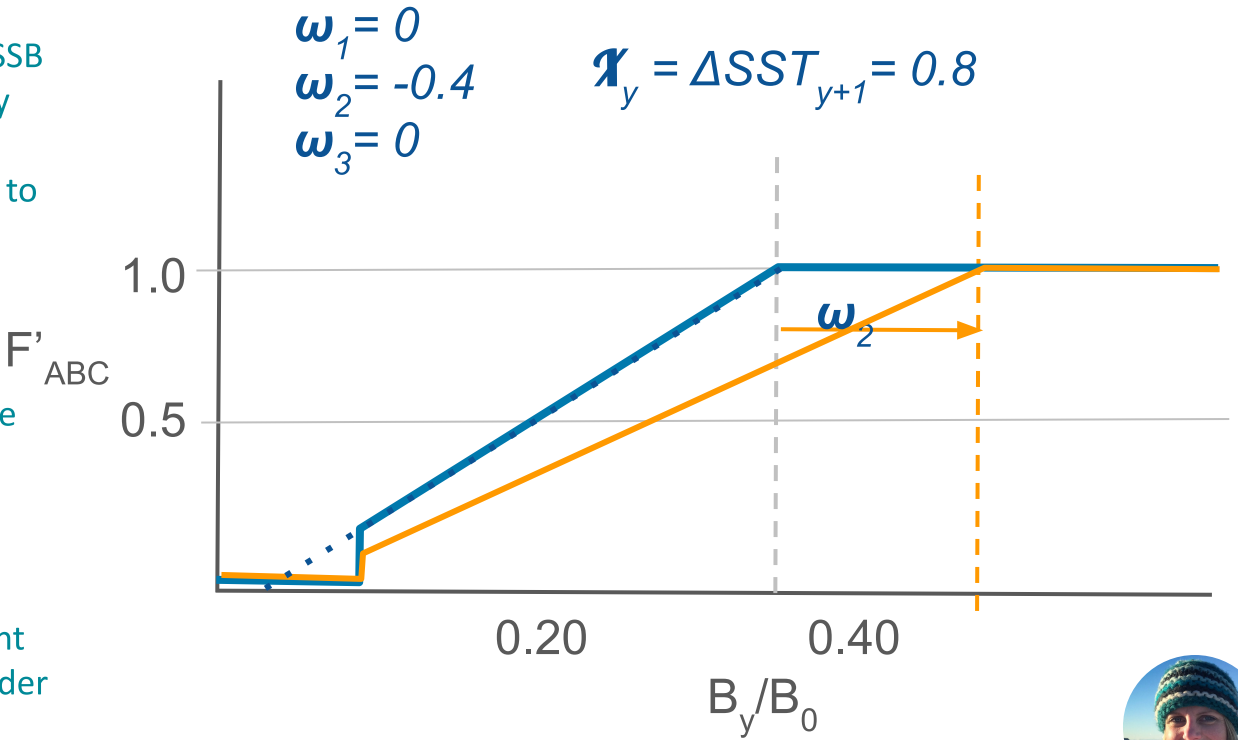
HCR 7: Add climate-linked buffers

Simulation goal: Evaluate if this improves long-term catch (and or stability in C)

Example:
model is climate naive but we know there is a NEGATIVE effect of SST on productivity and we know that more SSB is needed during MHWs to offset early declines in productivity (i.e., model based $B_{35\%}$ is too low in MHW relative to "true" B_{MSY})

CPT Goal:
Capture effect of future MHW on productivity and manage closer to true optimal SSB under MHW conditions (e.g., $B_{48\%}$)

How:
Shift B_{target} higher (e.g., $B_{48\%}$) to account for higher optimal Biomass at MSY under MHW conditions



HCR 7: Add climate-linked buffers

Simulation goal: Evaluate if this improves long-term catch (and or stability in C)

Example:

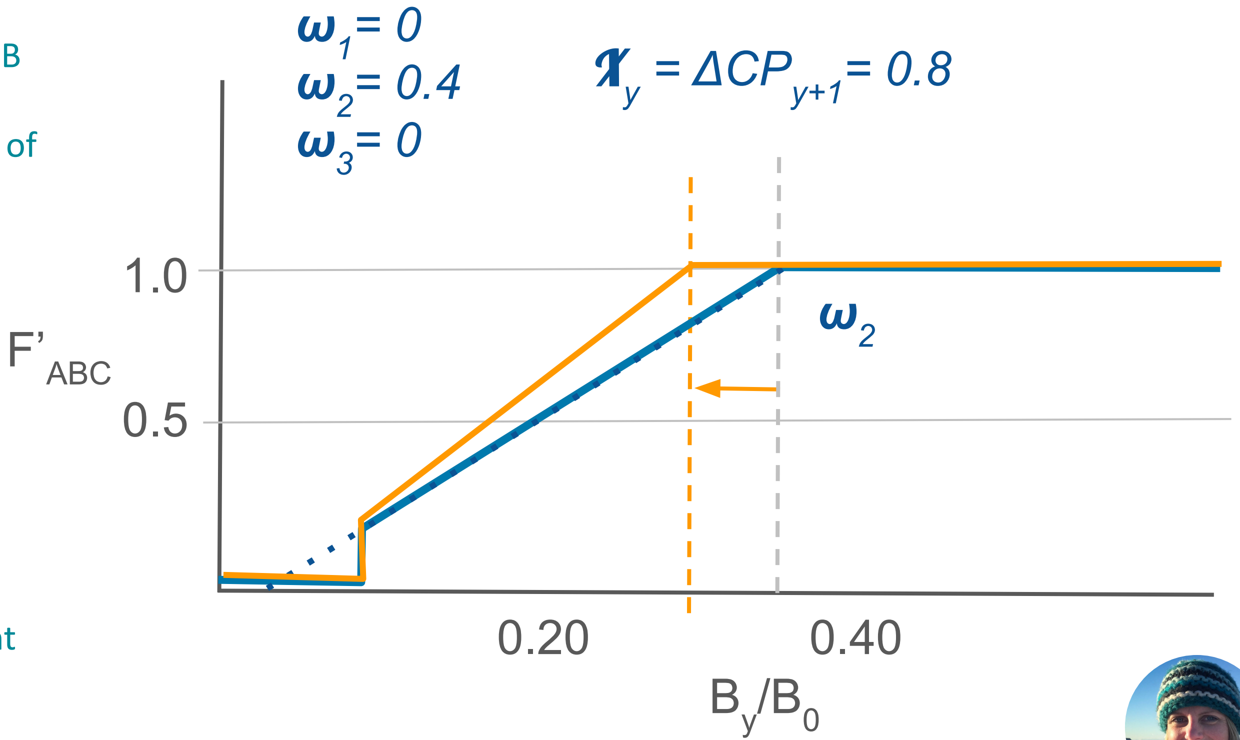
model is climate naive but we know there is a POSITIVE effect of CP on productivity and we know that less SSB is needed during favorable cold conditions to support the same levels of productivity (i.e., model based $B_{35\%}$ is too high in cold conditions relative to "true" B_{MSY})

CPT Goal:

Capture effect of future cold pool on productivity and allow harvest to be closer to MSY (e.g., $B_{25\%}$)

How:

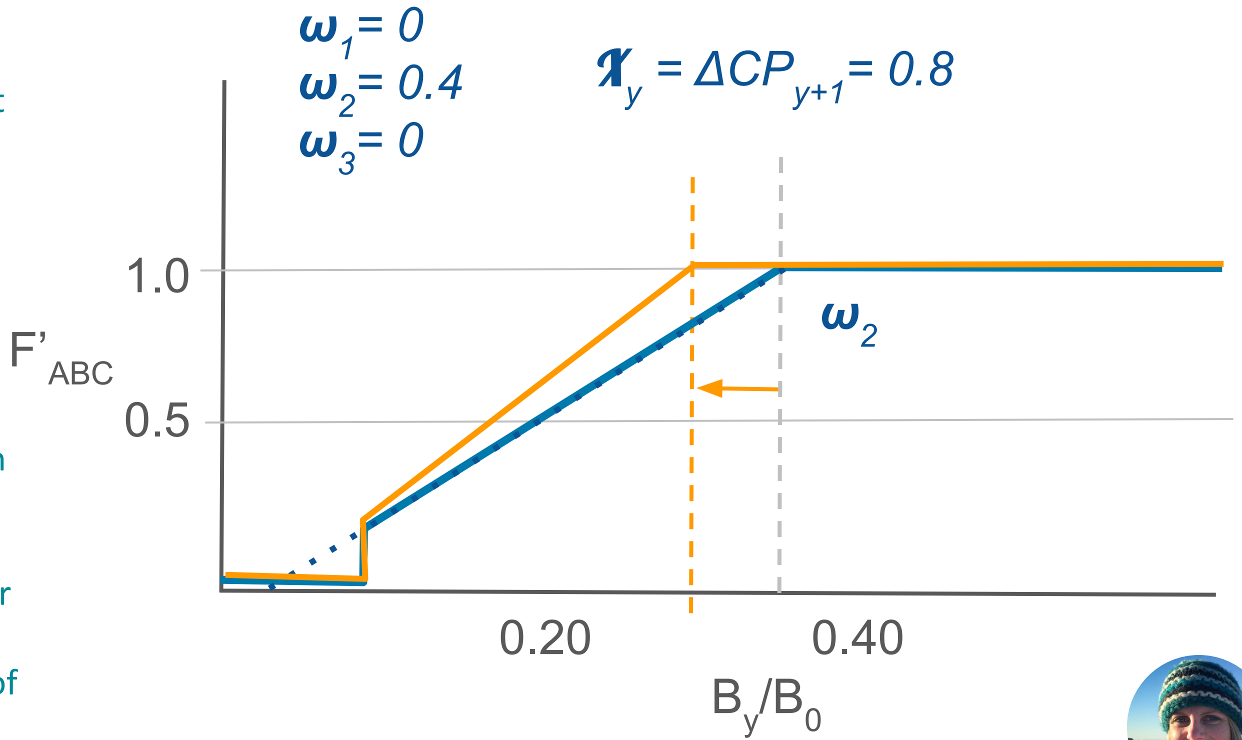
Shift B_{target} lower (e.g., $B_{25\%}$) to account for lower optimal Biomass at MSY under cold productive conditions



HCR 7: Add climate-linked buffers

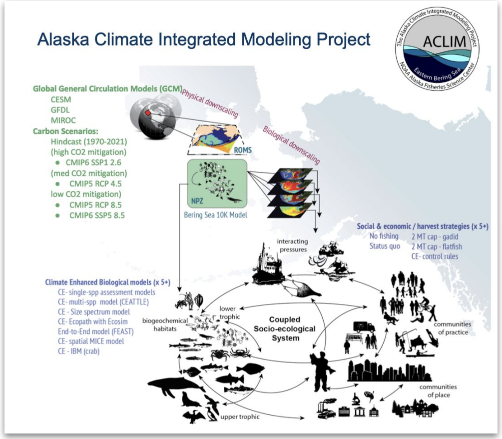
Bottom line:

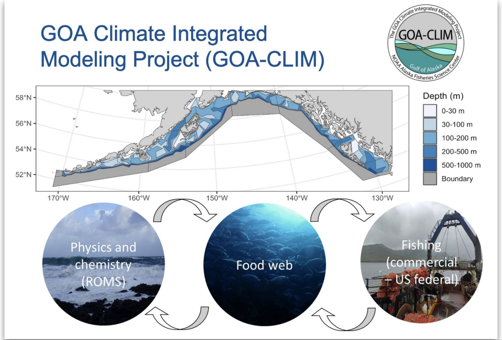
- Replace expert judgement adjustments with quantitative approach to get adjusted F'_{ABC} rather than qualitative or abrupt changes to F.
- Define when to use adjust F and how beforehand
- Test the approach beforehand using simulations to understand skill and to know if the approach will result in desired outcomes
- Optional: Can set adjustments or buffers based on confidence in future indices (e.g., probability of the forecast being true)



Consideration : indices and information increasingly available

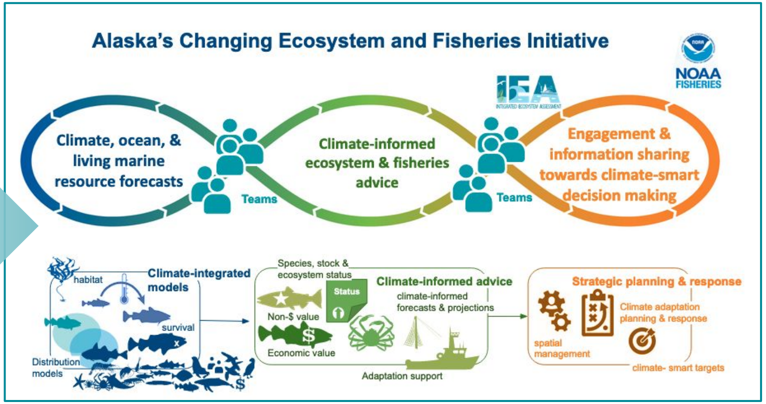
Research & development



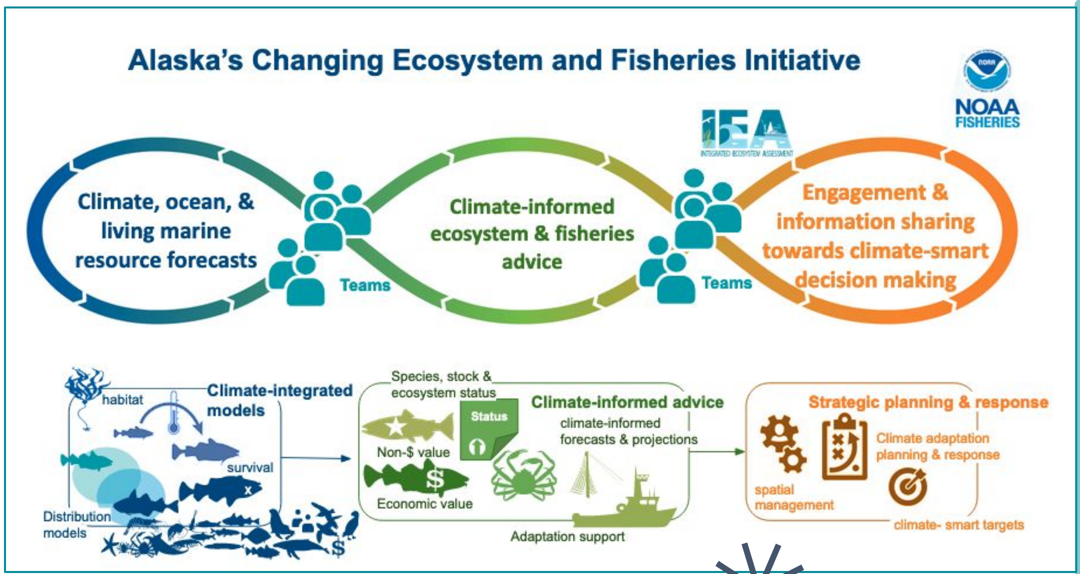


Climate & Ecological (CE) forecasts
CE assessment & foodweb models
CE informed SDMs
CE informed EBM advice
Robust alternative HCRs & CAPs
CE planning support & scenarios

Long-term operational support



Strategic foresight & predictions



Climate change & oceanography

Climate impacts on growth, survival & biomass

Changes to stock distributions (& fishing grounds)

Climate impacts ecosystems & food webs

Climate Informed EBM advice

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

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

CLIM Modeling questions for CPT

- What is the most useful (to you) starting point or status quo simulation for crab?
- Do you agree HCR7 would be useful to evaluate in simulations during 2026?
- What are the key performance criteria?

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

Hollowed et al. 2020

HCR Discussion (90 min)

Credit: Kirstin Holsman

Today's Discussion Topics

Outcome: *Draft climate information objectives and process for the CPT (will be added to the climate workplan)*

1. **HCR options for crab**
    a. What role would an HCR play specifically in crab management?
    b. Can HCR 7 (alpha modifier on B(status)) represent the buffer approach currently used for crab?
    c. Could this be implemented as a quantitative buffer based on forecasts of environmental conditions (e.g., marine heatwaves, regime shifts)?
    d. Are crab specific HCRs needed or is the current set enough?

2. **Meaning of "status quo"**
    a. "Status quo" is identified as an ACLIM & GOACLIM goal. What does "status quo" mean for crab management in practice?

3. **Priorities and objectives**
    a. Is this a priority for the CPT?
    b. If so, what are we trying to achieve by incorporating climate information into:
        i. HCRs?
        ii. Potentially ABC and TAC as well?
        iii. Do we need a more meaningful or refined ABC for crab? What if that results in less conservative buffers?

Considerations on revising harvest control rules to be more climate resilient

- ❑ Identify available flexibility and/or lack thereof in current groundfish and crab tier systems [*paper posted to eAgenda*]
- ❑ Identify recent issues by stock with the application of current system [*periodic discussions by Plan Teams and SSC; April 2025 discussion on risk table application*]
- ❑ Compile existing literature and ACLIM/GOACLIM results to help inform sensitivity of stocks to HCR shapes compared with biological reference points and/or fishing rate modifications
    - ❑ Council would need to weigh in on policy objectives (including risk tolerance) in modification of HCRs or reference levels

EXTRA SLIDES

NPFMC Dec. 2024 Motion

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

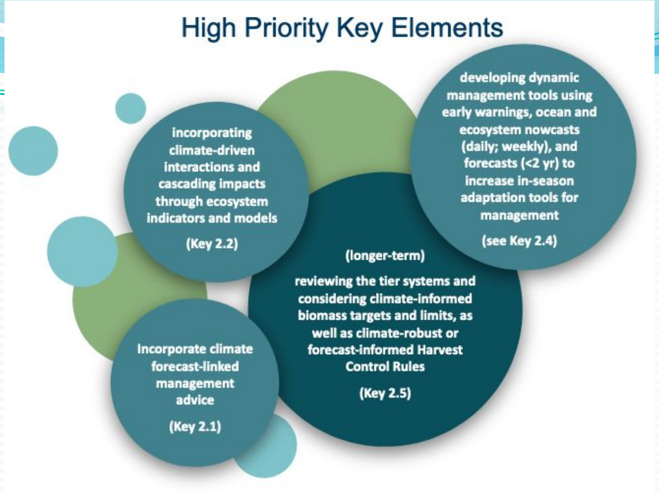
The Council acknowledges the final recommendations of the Climate Change Task Force (CCTF) that was established by the Bering Sea FEP and appreciates the extensive contributions of the Task Force members. The Council establishes a climate resilience workplan as recommended by the CCTF, with efforts guided 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.

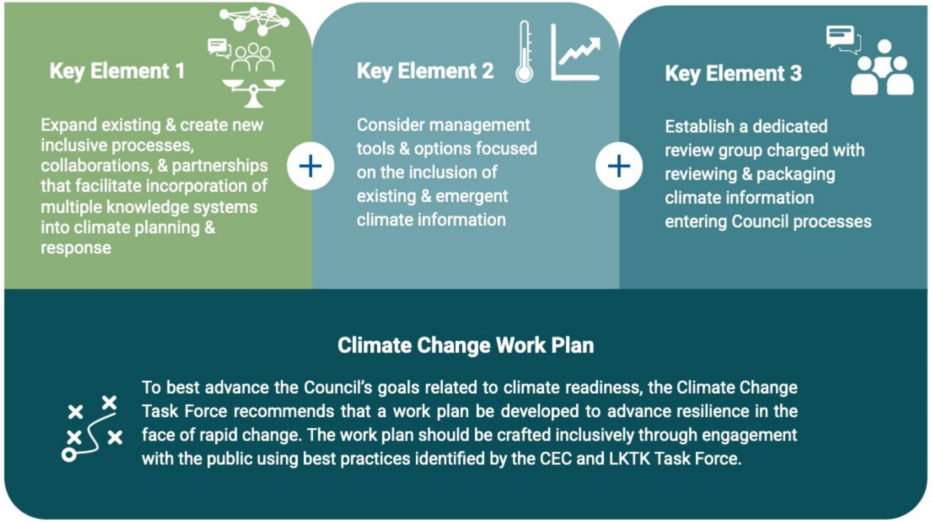
- **Incorporate climate forecast linked management advice (2.1).** Use climate and ecosystem forecasts to improve management advice through assessments and supportive documents:
  a. Incorporate forecasts of climate and ecosystem conditions (+1-2 yrs) in the harvest projections and specifications processes, 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)**





Conceptual Model

Council

Industry & Communities

SSC

AP

Plan Teams

STEP 2

Get ABC and F_{ABC}

Get target fishing mortality rate "F_{ABC}" based on determined BRPs & future environmental conditions

STEP 4

Determine TAC

Utilize a climate-informed policy to determine TAC (e.g., to account for interacting ABC across fisheries, species or changing distributions & access)

STEP 1

Determine BRPs

Get unfished biomass (B_0) and determine the B_{target} (e.g., B_{40}) conditioned on environmentally linked productivity, growth or selectivity

STEP 5

Apply Catch

Implement a model to simulate catch as a function of interacting conditions, TAC, and species

STEP 3

Apply HCR

Implement a Harvest Control Rule (HCR) that adjusts target fishing mortality rate F_{ABC} based on current (or future) stock status, stock productivity & environmental conditions