Alternative HCRs

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Thanks to :

ACLIM and GOA CLIM Teams
CEFI - Alaska
ICES/PICES S-CCME/ SICCME

Outline for today's talk

Credit: Kirstin Holsman

Outline for today's talk

a) Overview of ACLIM & GOACLIM simulations

b) Setting the stage for discussion

   i) B0, B_target; considerations for session 2
   ii) Evaluating HCRs, considerations for session 1
   iii) Cap effects; considerations for session 3

c) SSC Discussion questions / feedback

   i) Simulation evaluation criteria
   ii) First phase HCRs
   iii) First phase focal species

Credit: Kirstin Holsman

a) Overview of ACLIM & GOACLIM simulations

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 3 Team

Supporting productive fisheries & resilient communities through climate-informed Ecosystem Based Management advice

Kirstin Holsman, Sarah Wise, Andre Punt, Albert Hermann, Cheryl Barnes, Cody Szuwalski, Kerim Aydin, Kelly Kearney, Anne Hollowed, Alberto Rovellini, Andrea Havron, Andy Whitehouse, Anna Amalka Sulc, Carey McGilliard, Catherine Moncrieff, Darren Pilcher, Diana Stram, Ed Farley, Elizabeth McHuron, Elizabeth Siddon, Ellen Yasumiishi, Grant Adams, Ingrid Spies, Ivonne Ortiz, James Ianelli, James Thorson, Jean Lee, Jennifer Bigman, Jeremy Sterling, Jodi Pirtle, Jonathan Reum, Kalei Shotwell, Kate Haapala, Kelly Kearney, Lorenzo Ciannelli, Mabel Baldwin-Schaeffer, Maggie Mooney-Seus, Martin Dorn, Maurice Goodman, Meaghan Bryan, Melissa Haltuch, Melissa Parks, Michael Litzow, Mike Dalton, Molly Graham, Patricia Pinto da Silva, Paul Spencer, Sarah Stone, Serena Fitka, Steve Barbeaux, Trond Kristiansen, Wei Cheng, William Stockhausen, Lia Domke, Anne Beaudreau, Justin Hansen, Angela Abolhassani, Matt Callahan, Brett Holycross

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

GOA-CLIM 2 Team

Supporting productive fisheries & resilient communities through climate-informed Ecosystem Based Management advice

Meaghan Bryan, Carey McGilliard, Marysia Szymkowiak, Cheryl Barnes, André Punt, Beth Fulton, Martin Dorn, Isaac Kaplan, Alberto Rovellini, Bridget Ferriss, Bia Dias, Grant Adams, Szymon Surma, Chang Seung, Elizabeth McHuron, Kirstin Holsman, Melissa Haltuch, Albert Hermann, Kerim Aydin, Brian Fadely, Sara Cleaver, Mike Litzow, Kristin Marshall, Robert Suryan, Marjorie Mooney-Seus, Katie Sweeney

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

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

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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]

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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.

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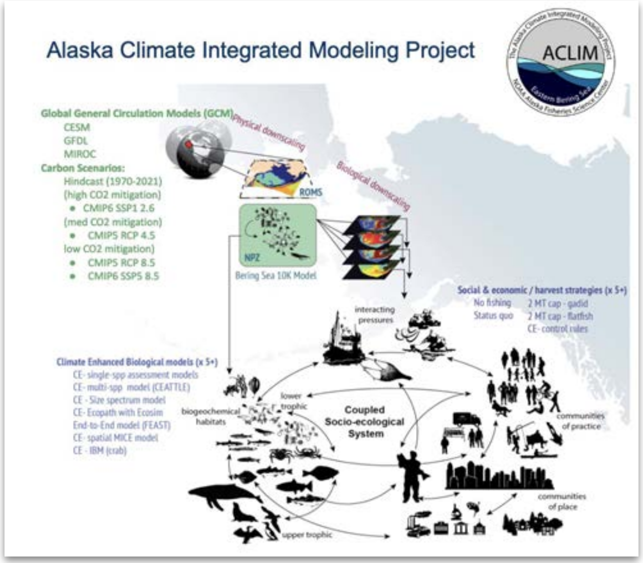
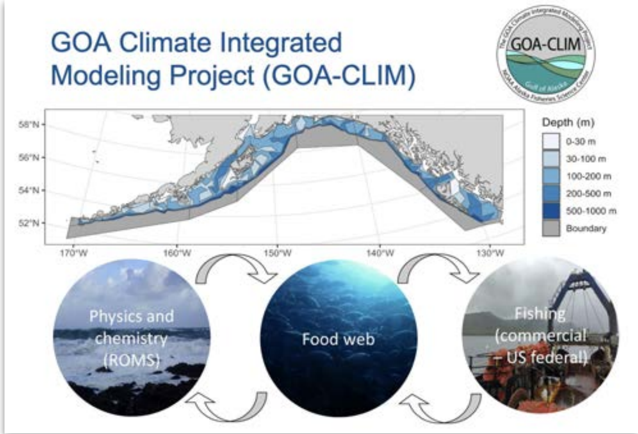
Hollowed et al. 2020





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

What to expect?

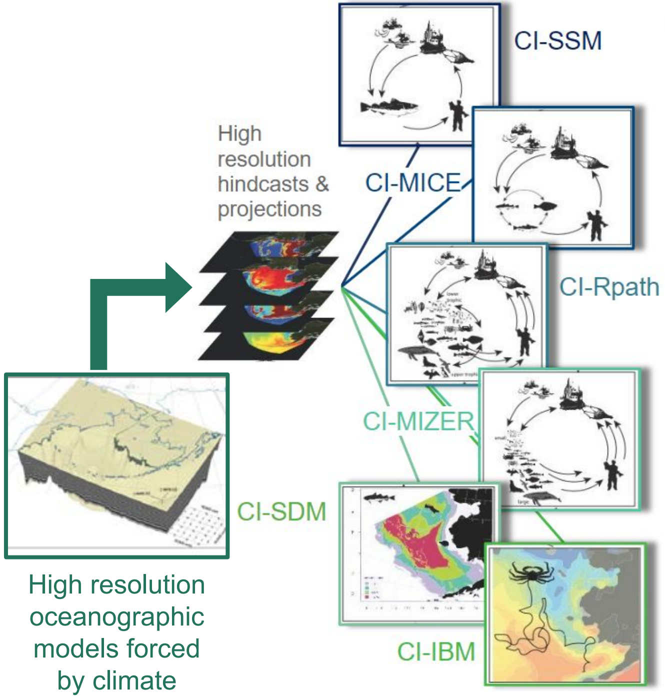
- Project physical and ecological conditions under alternative levels of global carbon mitigation
- Characterize uncertainty

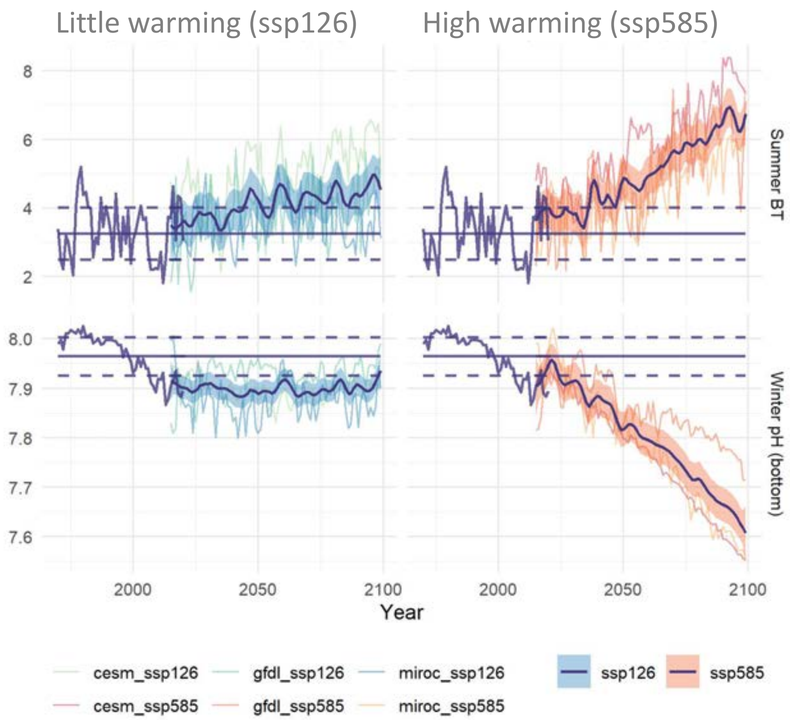
What can be done?

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

Scenarios form the basis for comparative simulations & Management Strategy Evaluations

CLIM Models & Simulations

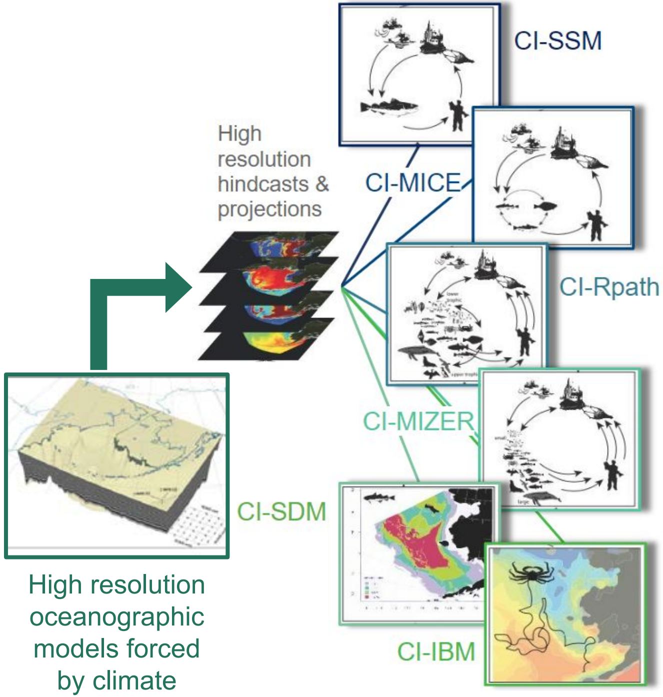




Supporting Publications

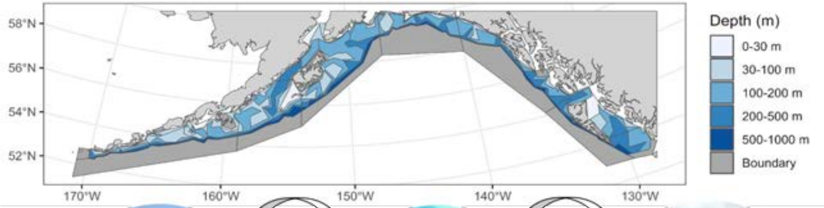
Goodman et al. (2024), Punt et al. (2023), Szuwalski et al. (2023), Olmos et al. (2023), McHuron et al. (2024), Barnes et al. (2022), Thorson et al. (2021), Whitehouse et al. (2021), Kearney et al (2020), Pilcher et al. (2022), Hollowed et al. (2020).

CLIM Models & Simulations



A. Rovellini

GOA-CLIM Atlantis



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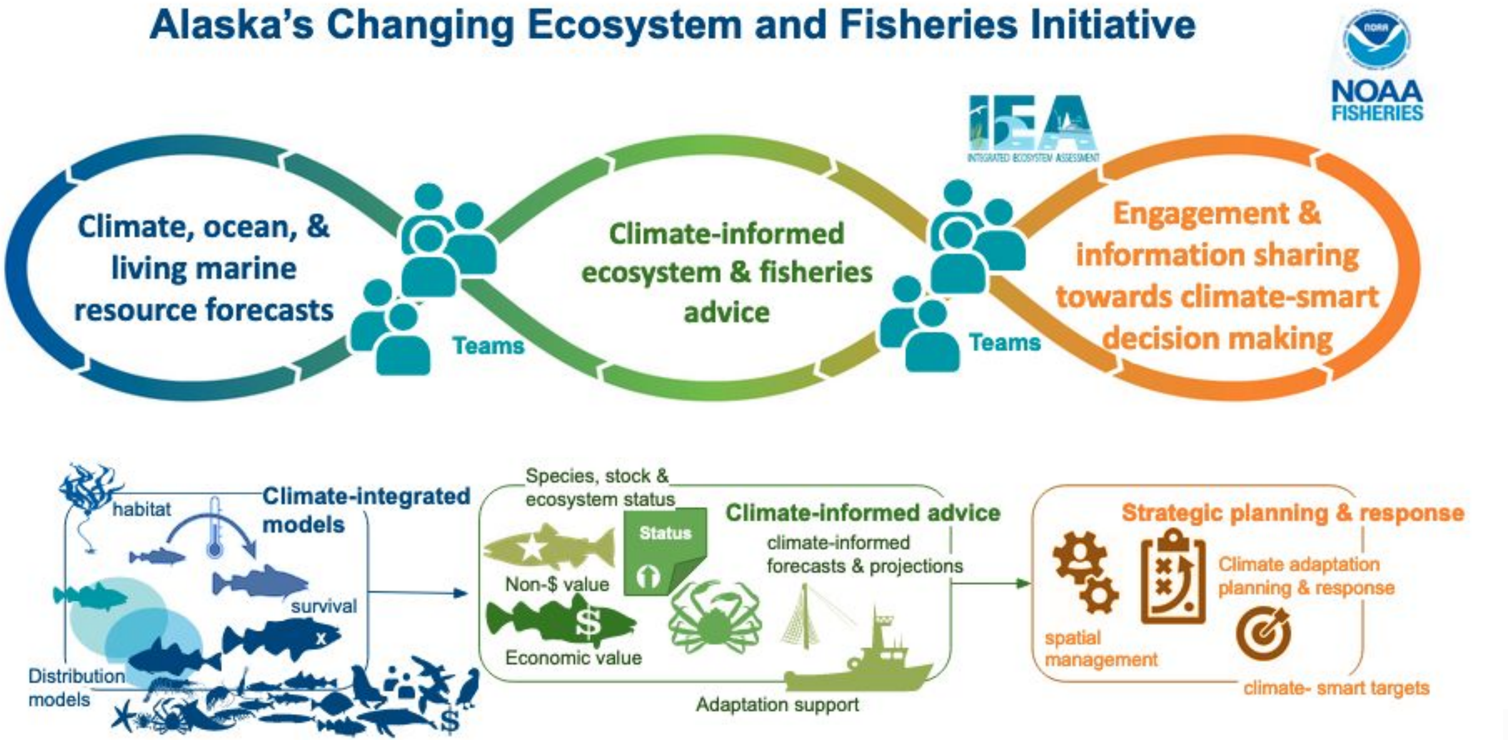
Strategic foresight & predictions

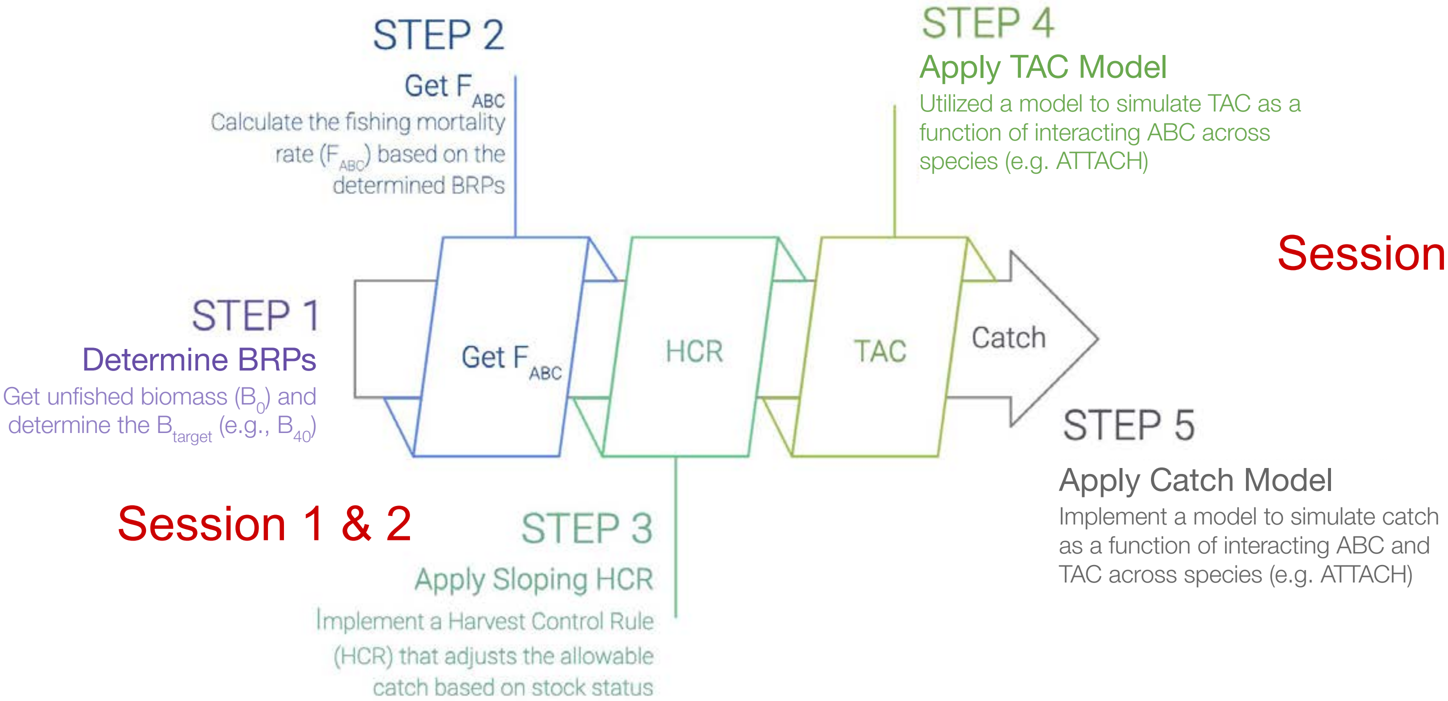


ACLIM

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

b) Setting the stage for HCR discussions

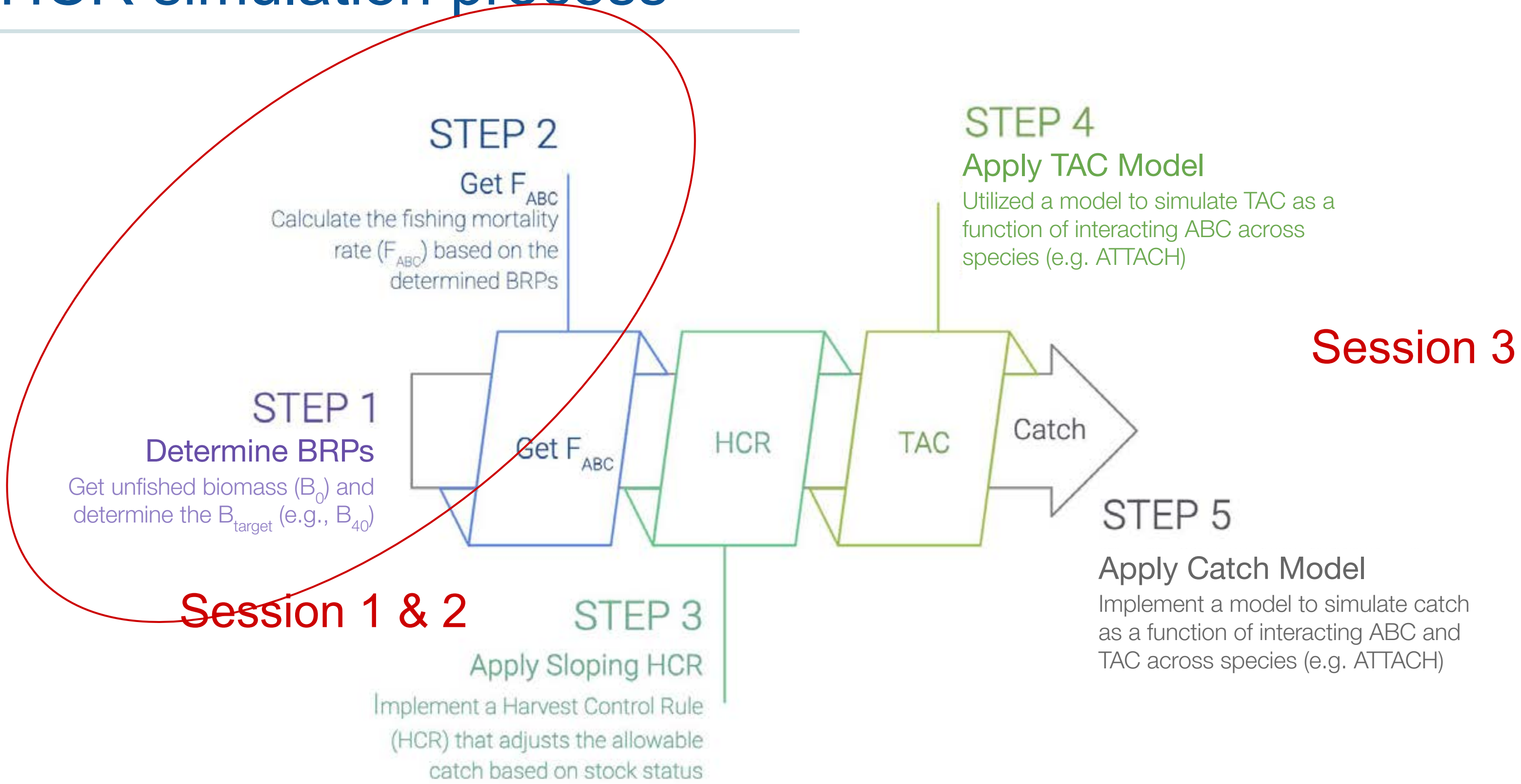
HCR simulation process



Session 3

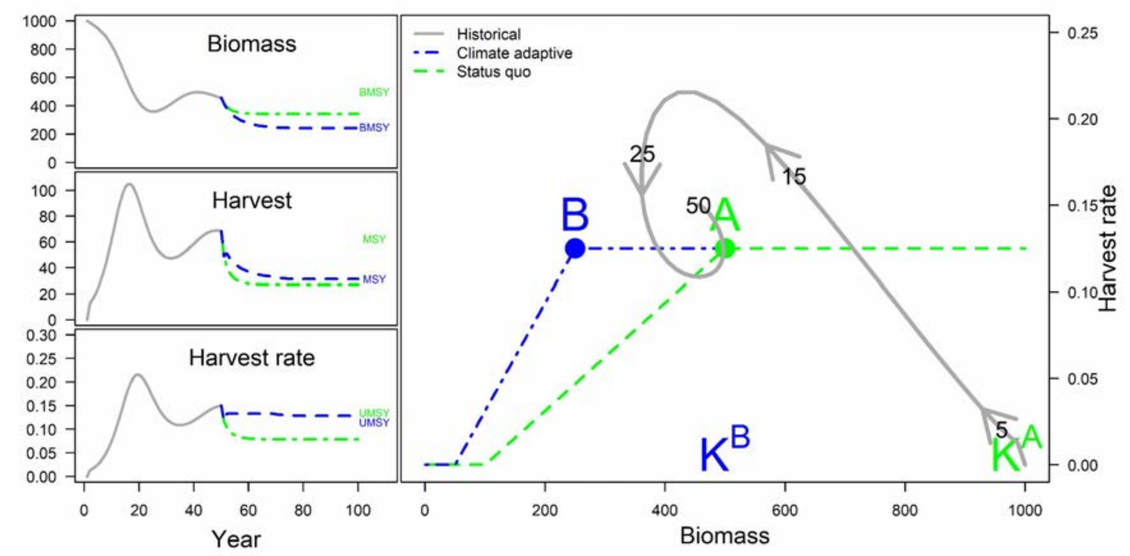
Session 1 & 2

HCR simulation process



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

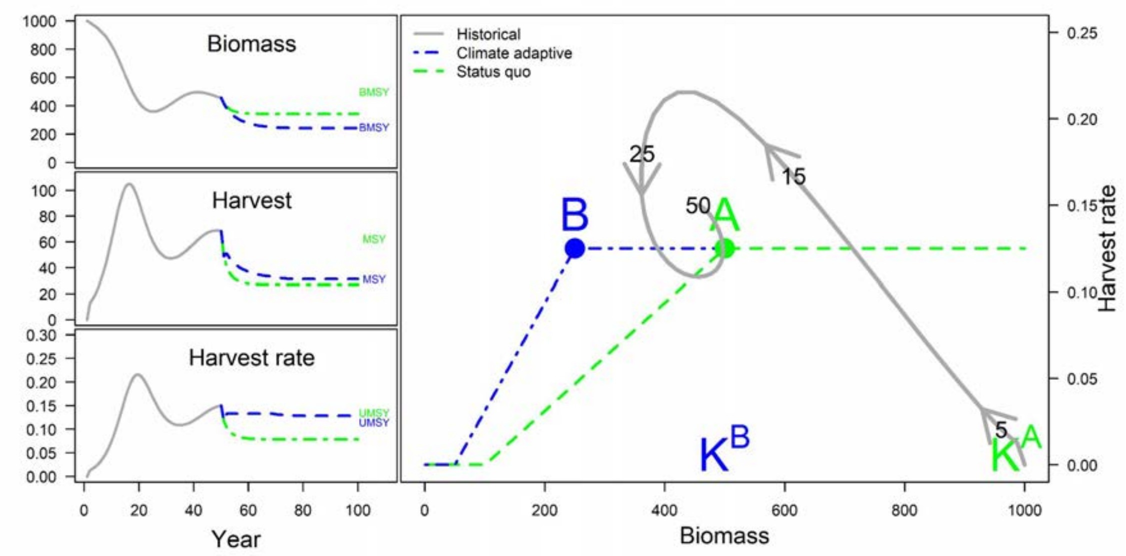


Szuwalski et al. 2023. Unintended consequences of climate-adaptive fisheries management targets. Fish and Fisheries. https://onlinelibrary.wiley.com/doi/10.1111/faf.12737

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



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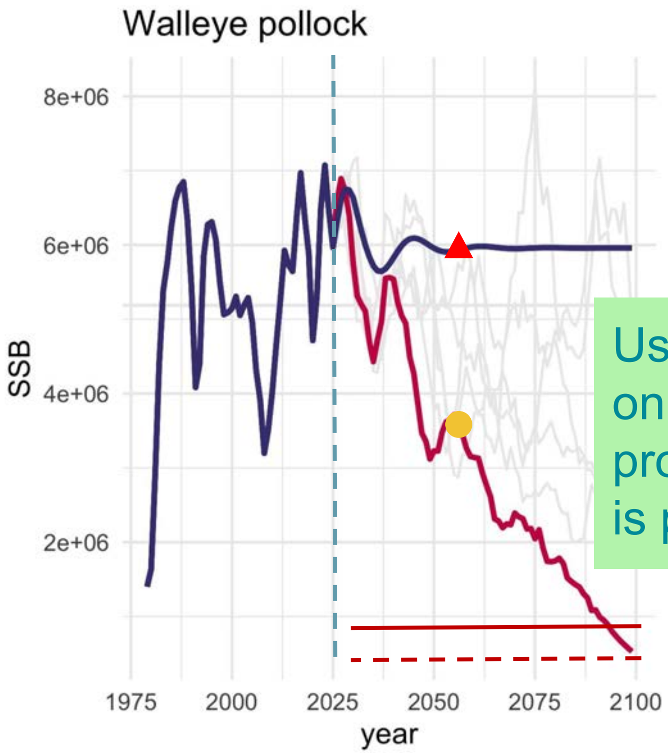
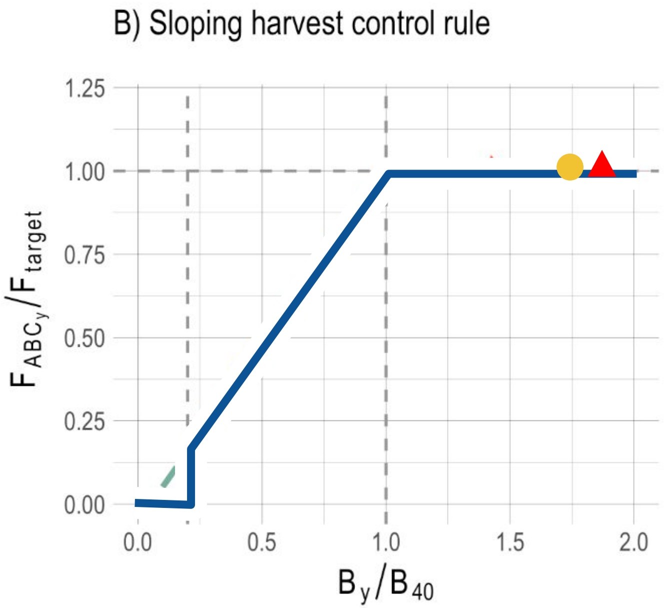
If using a environmentally-linked B0 (dynamic B0)

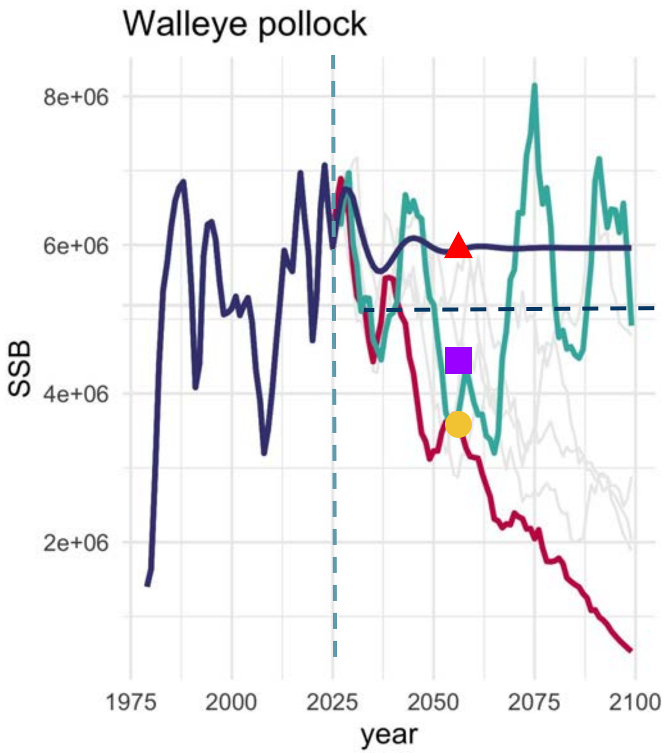


Use dynamic B0 only if certain productivity shift is permanent

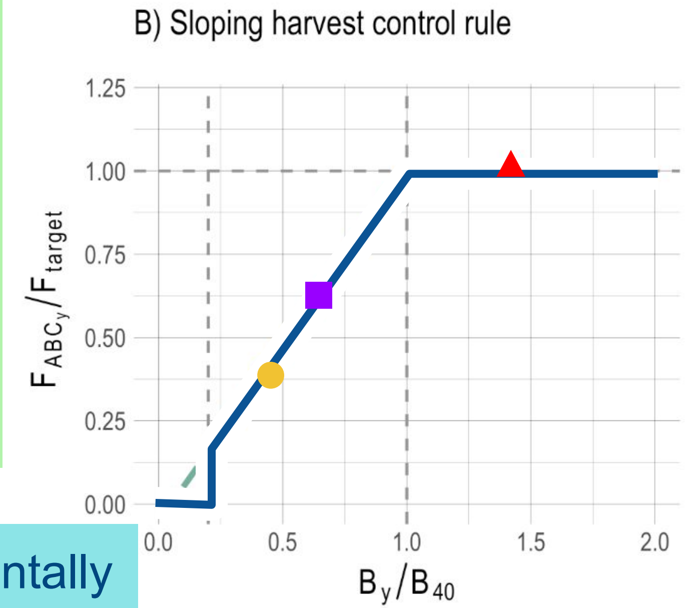


Risk : higher F during environmental strain could prevent recovery and lower long-term catch

Fixed target (fixed B0) + Env. enhanced status

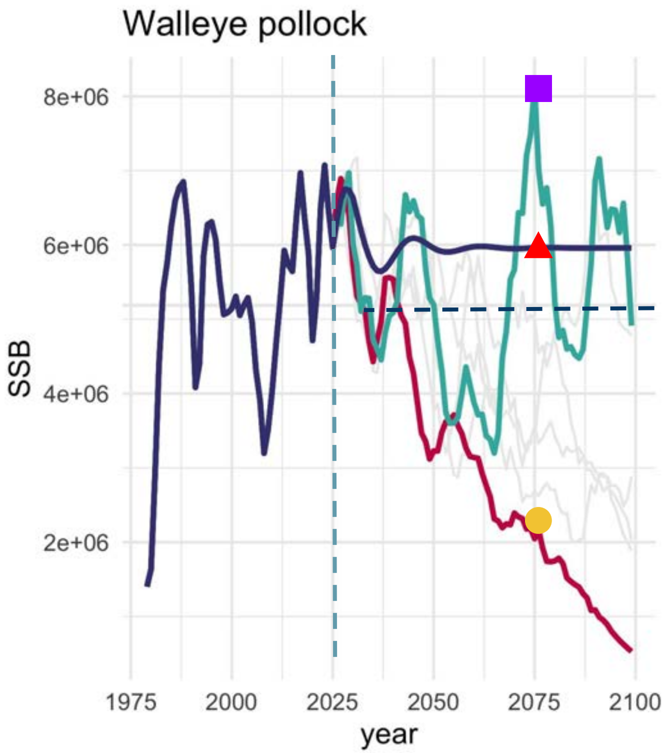


Use fixed B0/B40 if future trajectories include divergent or alternative possibilities



Use environmentally linked status assessments to adjust for variability

Fixed target (fixed B0) + Env. enhanced status



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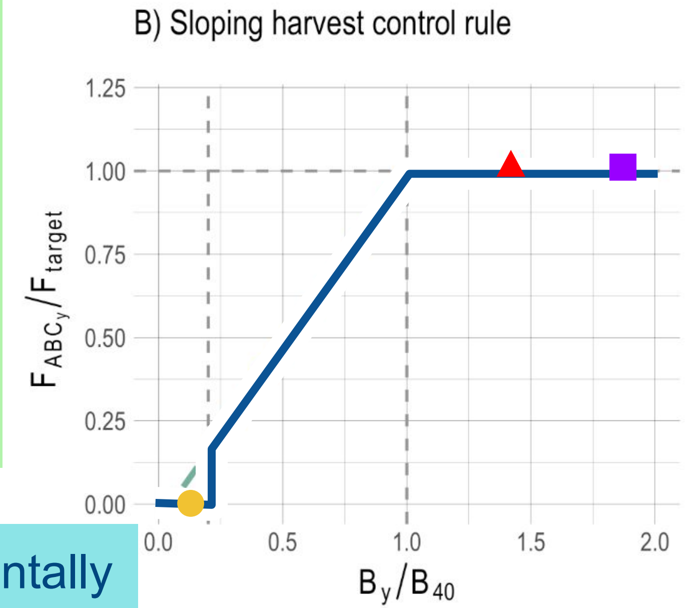
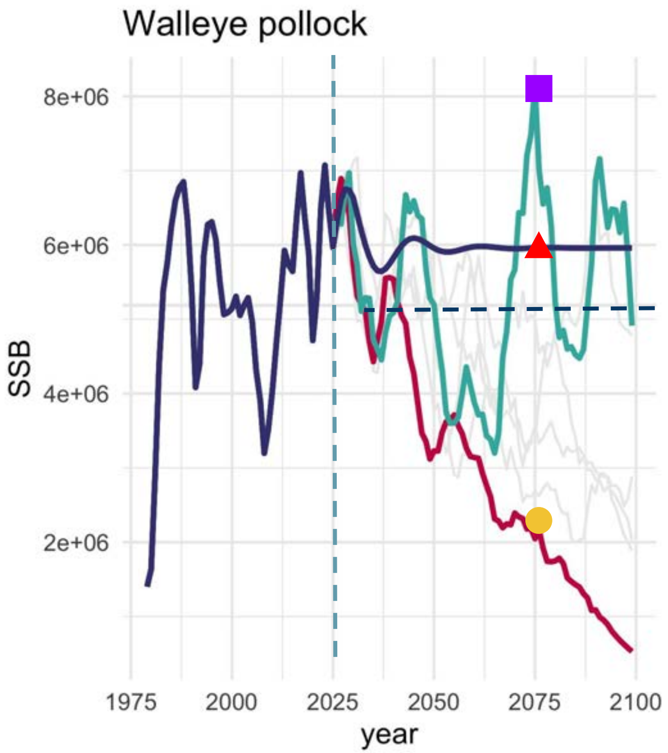


Use environmentally linked status assessments to adjust for variability

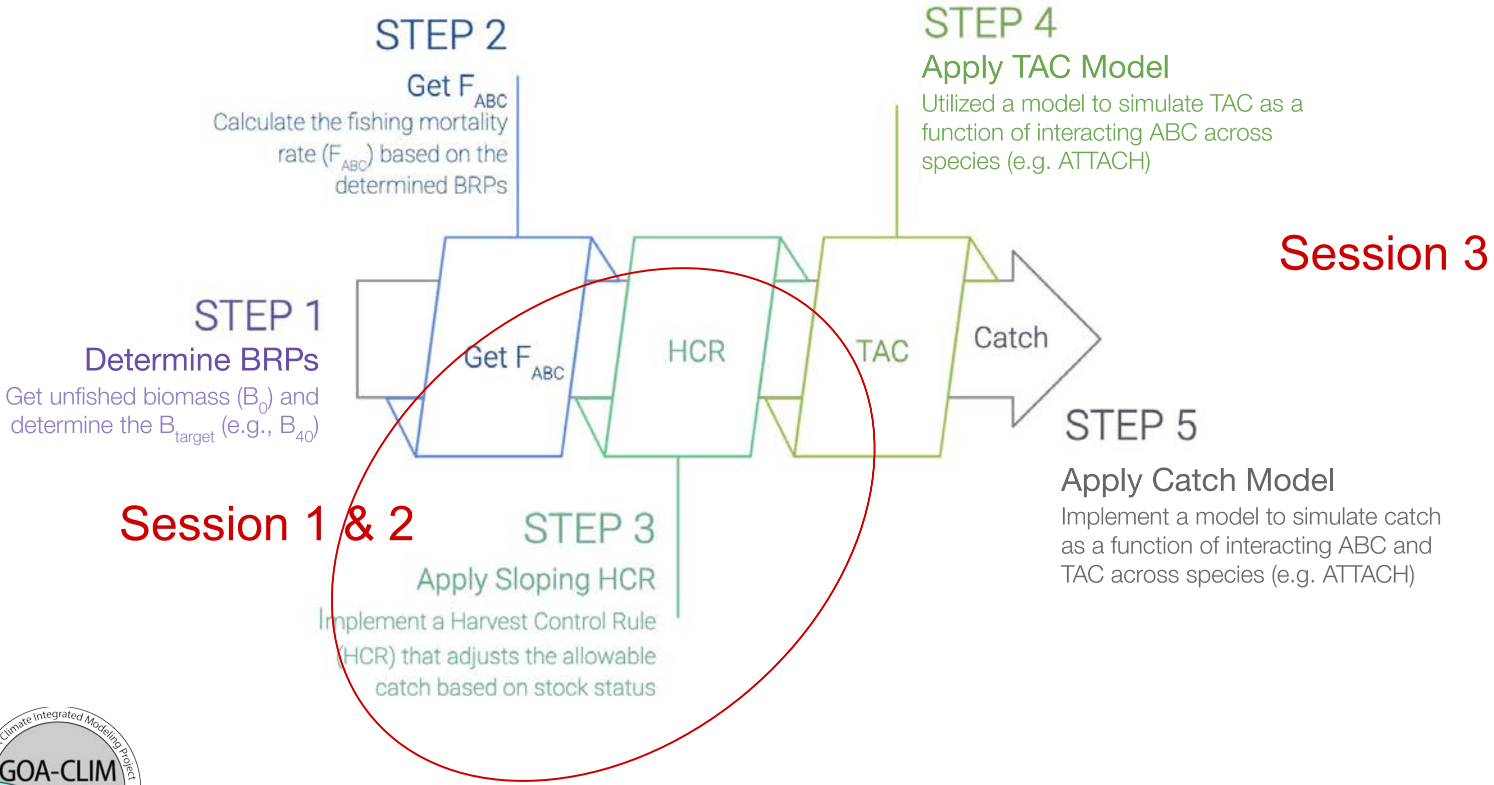
Options for “hybrid” approach



(1) Set targets based on fixed productivity potential
  (a) Historical reference period (historical B_0)
  (b) Persistence (constant environment) model based B_0

(2) Set status based on dynamic or environmentally informed status
  (a) Use 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)

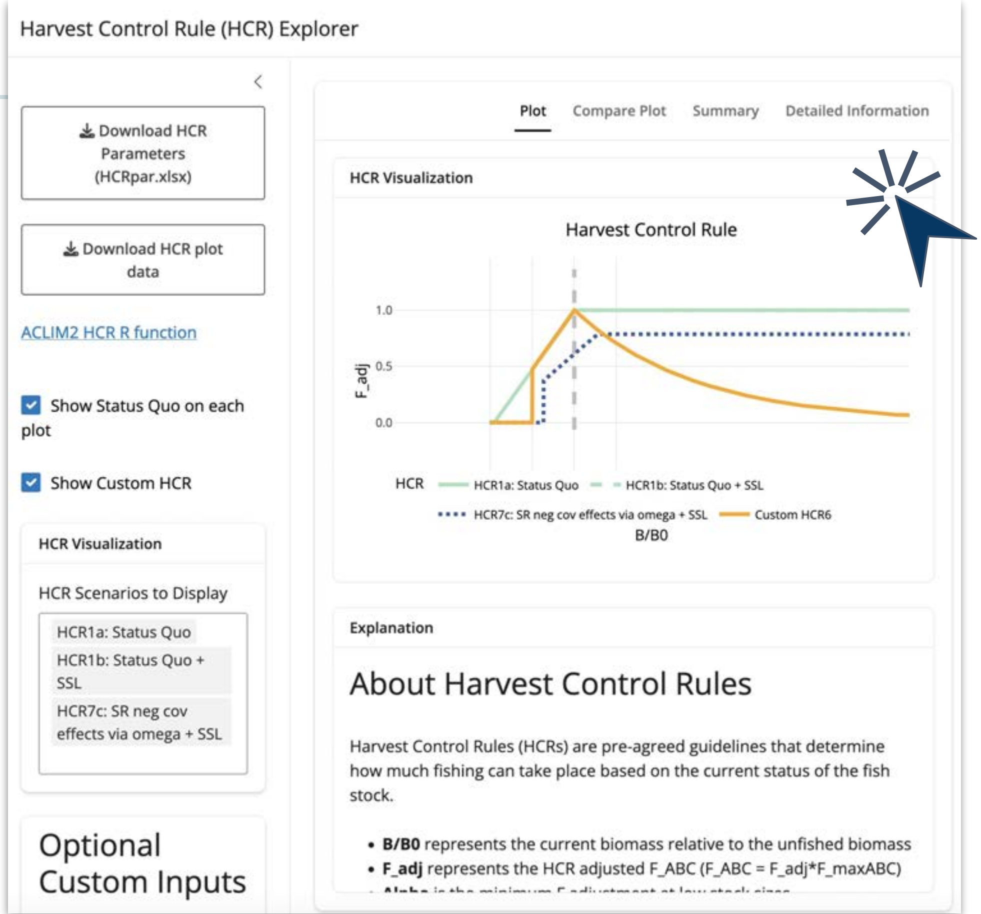
HCR simulation process



Interactive HCR explorer tool

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

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



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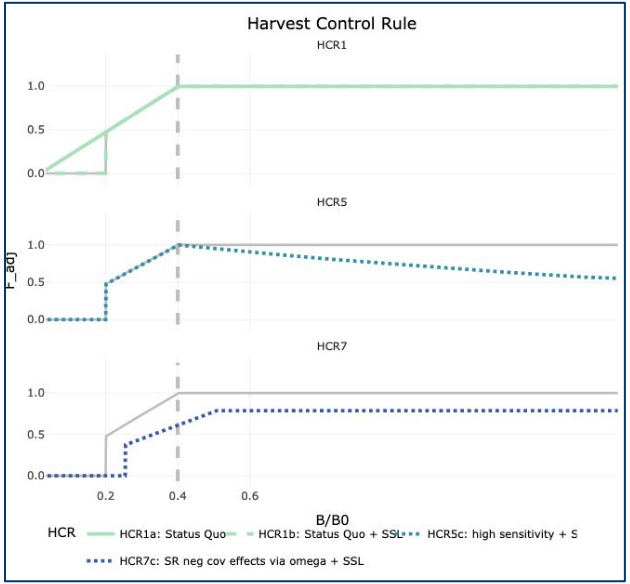

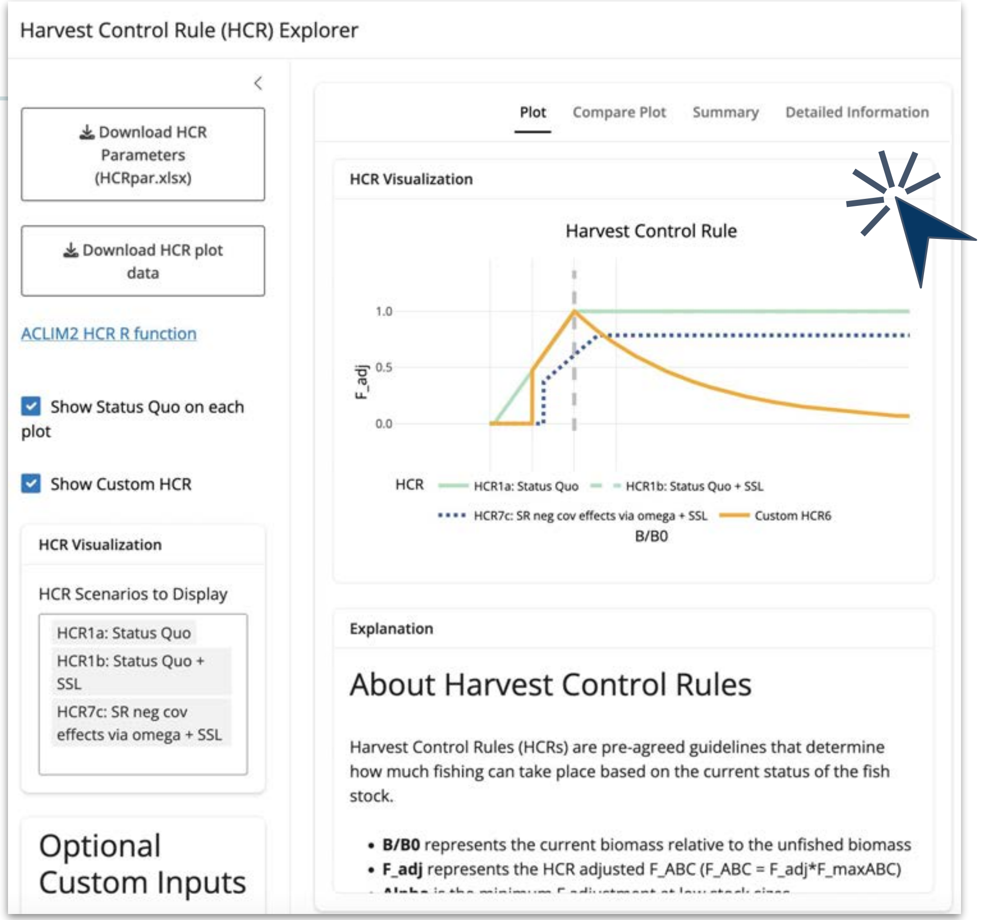

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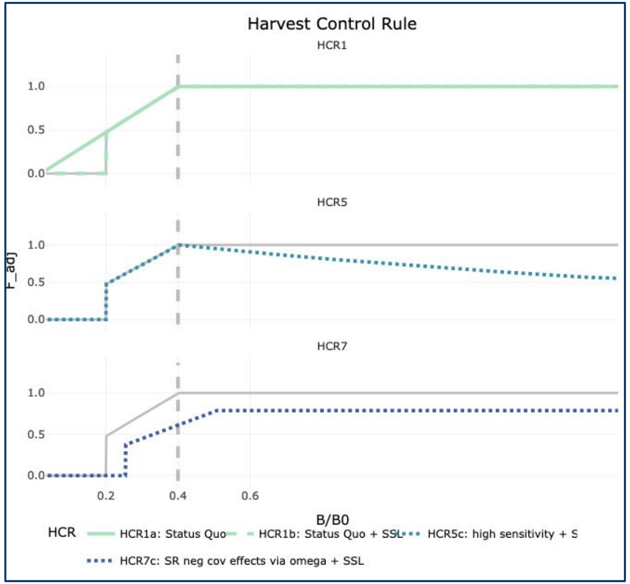

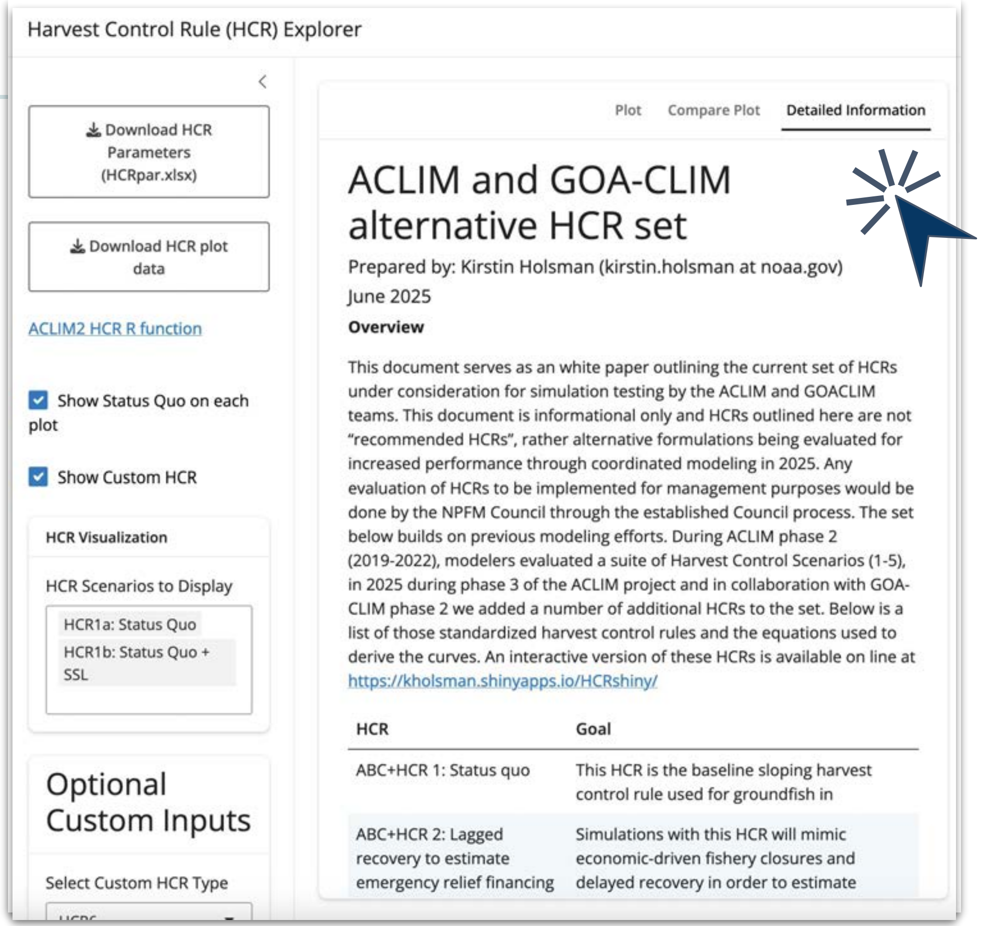

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The GOA Climate Integrated Modeling Project — GOA-CLIM — Gulf of Alaska — NOAA Alaska Fisheries Science Center

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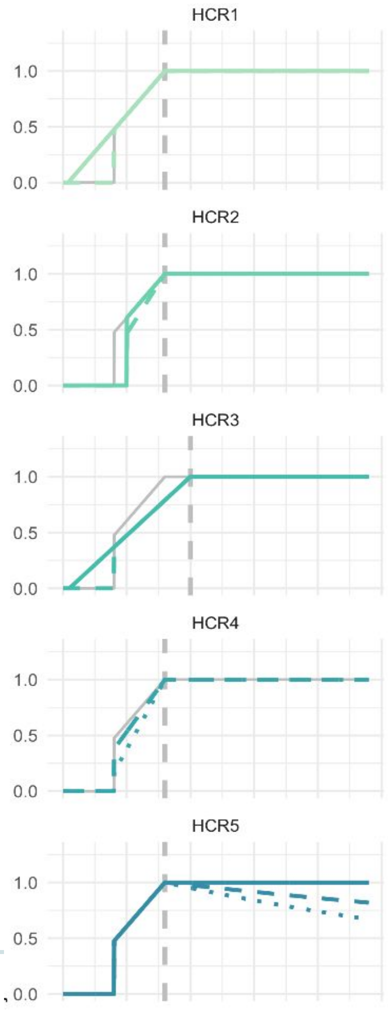
; **accepted:** 21 February 2024
Advance access publication date: 29 March 2024
Stories from the front lines

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



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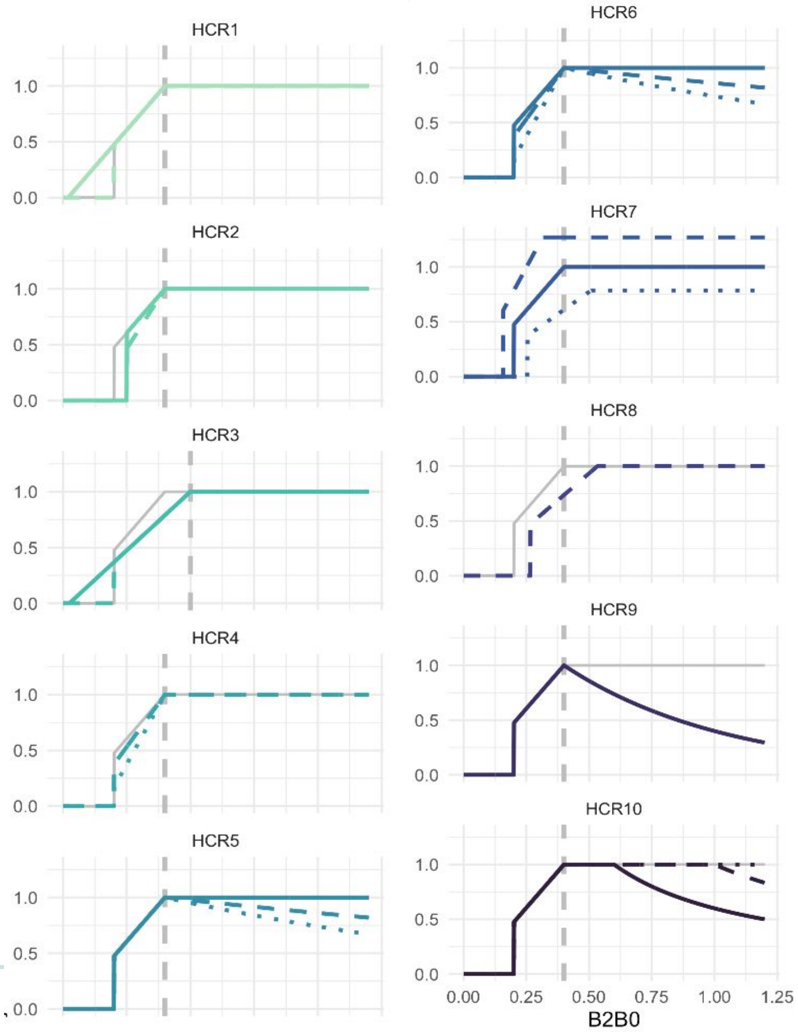
ABC+HCR 5	Maximize productivity/ increased reserve (buffer shocks)
ABC+HCR 6	Combination of MHW (HCR4) + Maximize productivity (HCR5)
ABC+HCR 7	Risk Table Bridging, R/S variability covariate adjusted HCR
ABC+HCR 8	Adjust effective spawning biomass (simulate adjusted B_target)
ABC+HCR 9	Forecast informed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



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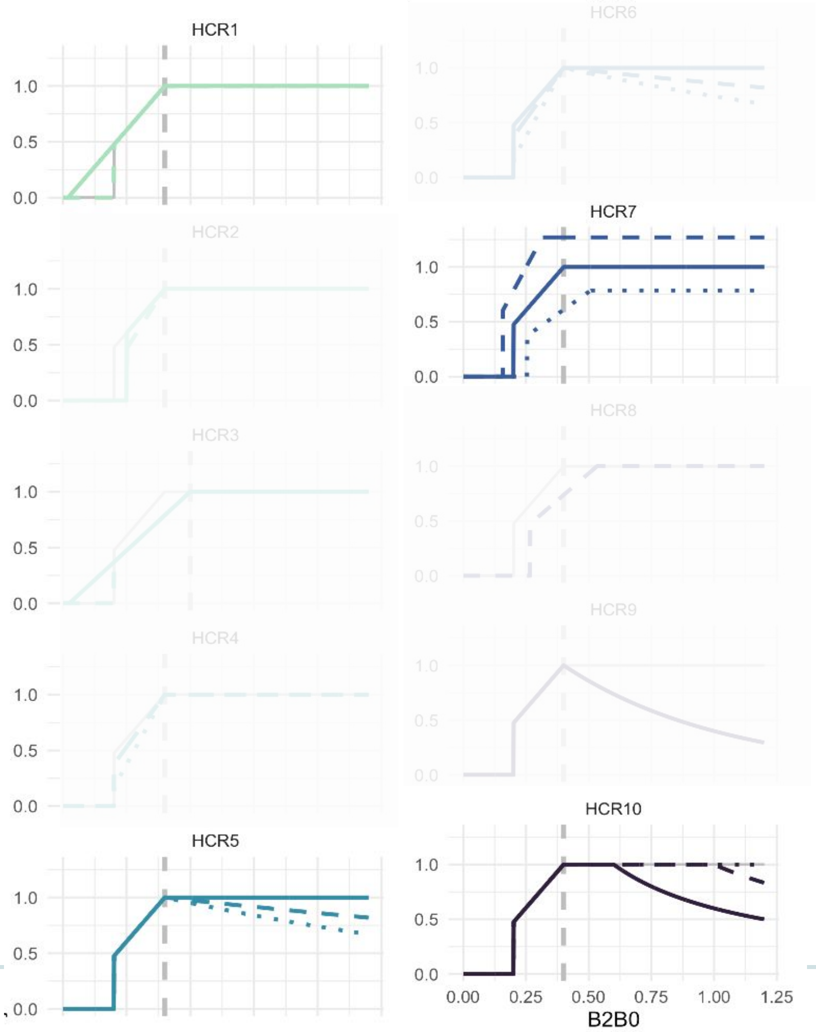
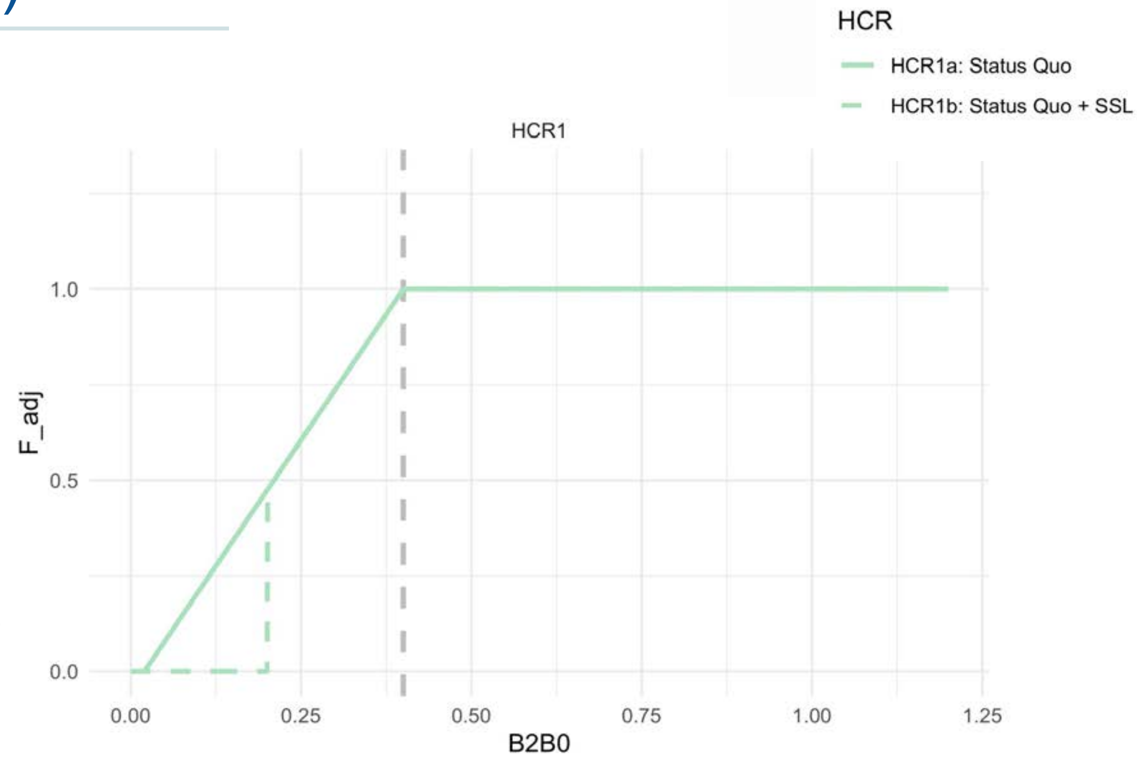


HCR 1: Status quo (Tier 3)

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

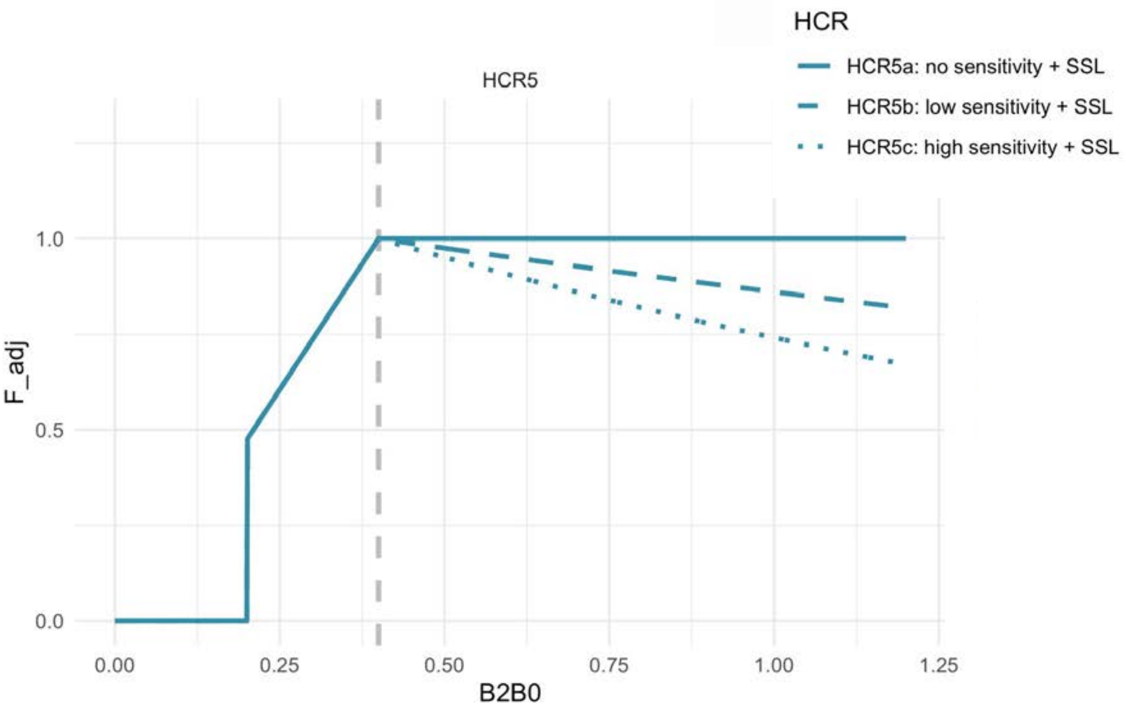
$$F_{ABC_{max}} = \begin{cases} F_{ABC} & \frac{B_y}{B_{target}} > 1 \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} < 1 \\ 0 & \frac{B_y}{B_{target}} < \frac{B_{lim}}{B_{target}} \end{cases}$$



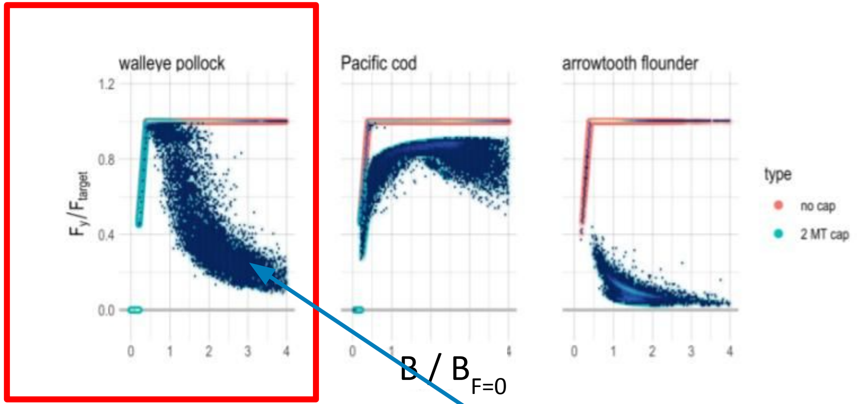
HCR 5 : Maximize productivity/ increased reserve (buffer shocks)

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

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



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

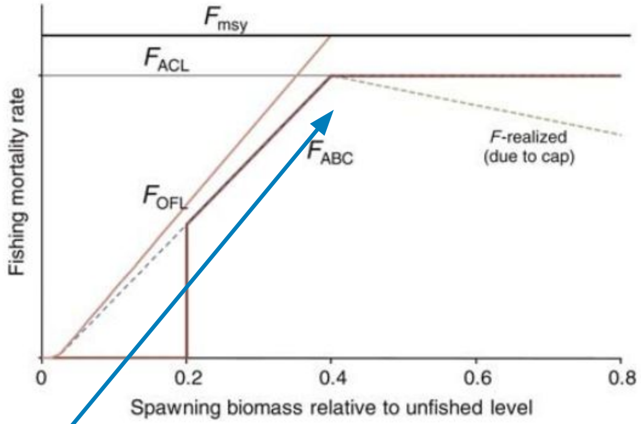


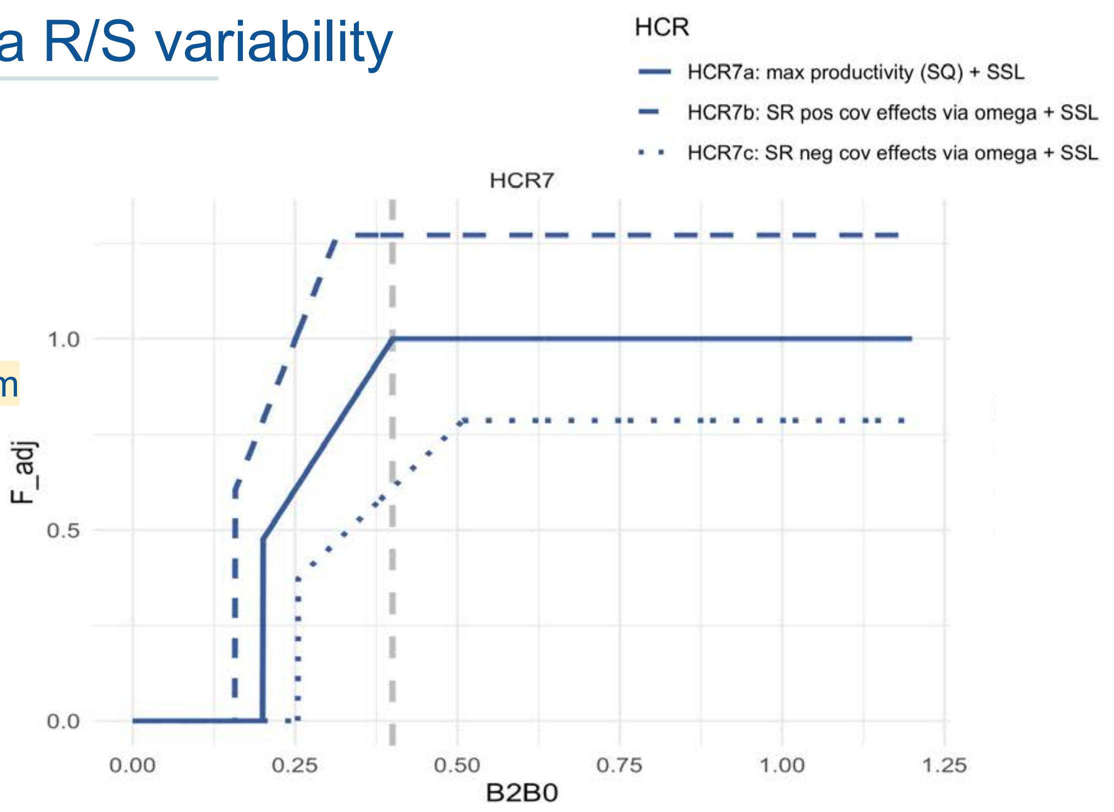
Figure 4. Schematic of harvest control rule currently affecting ABC or annual catch limit (ACL) for Alaska groundfish species like pollock (thick line). Note that this schematic indicates that B_{msy} is 40% of the unfished expected spawning biomass.

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



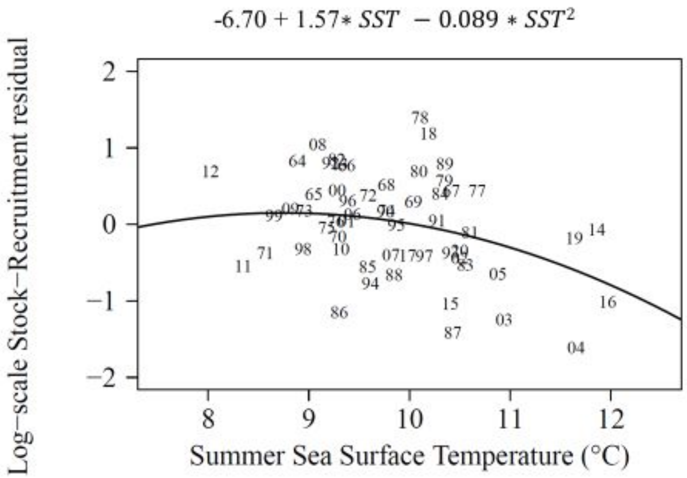
Simulation Goal:
This HCR provides a way to transition from qualitative risk tables to a more explicit, analytical approach for species whose productivity is known to vary with environmental conditions.

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

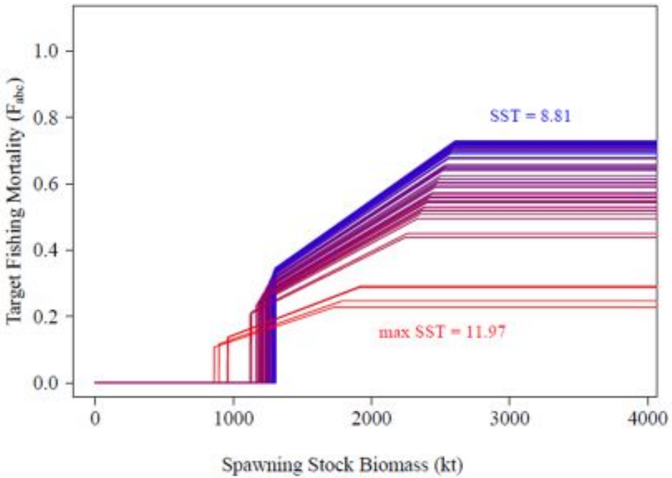
$$\hat{B}_{lim} = B_{lim} e^{(-\omega_3 * x_y)} \qquad \hat{B}_{target} = B_{target} e^{(-\omega_2 * x_y)}$$

Spencer et al. in prep

Effect of temperature on recruitment



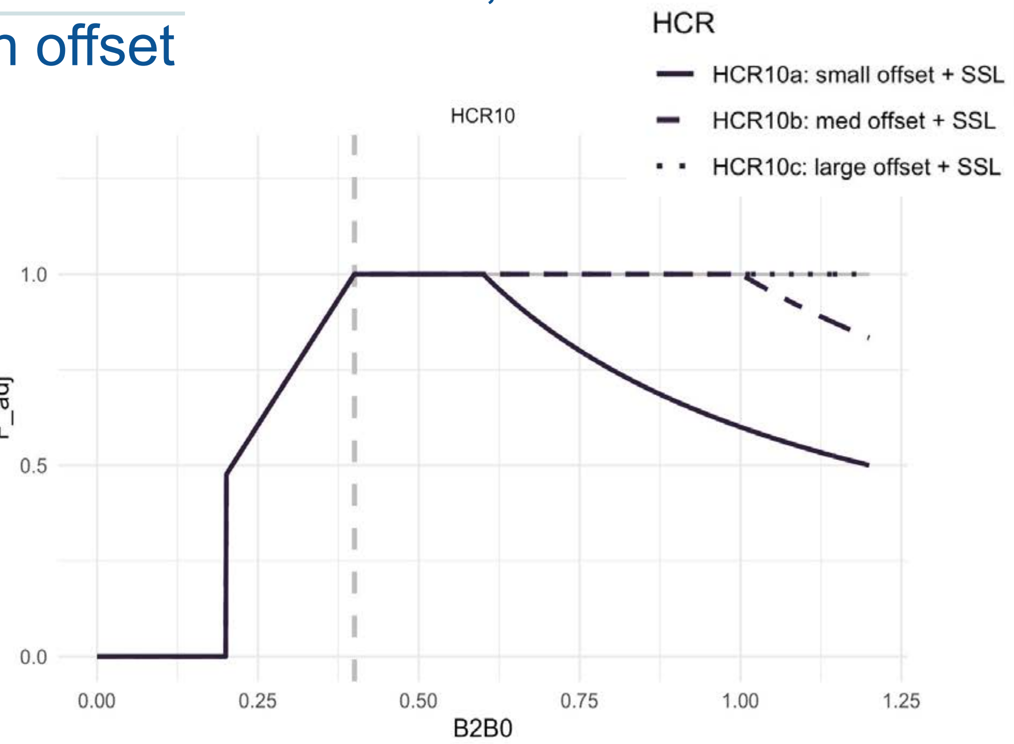
How would the harvest control rule change with temperature?



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.

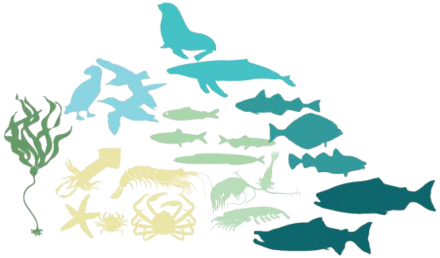
$$F_{ABC_{max}} = \left[\begin{array}{ll} F_{ABC}/(\frac{B_y}{B_{target}}\frac{1}{(1+\gamma)}) & \frac{B_y}{B_{target}} > (1+\gamma) \\ F_{ABC} & 1 < \frac{B_y}{B_{target}} < (1+\gamma) \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) & \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} 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



Rpath() example

P. cod

A. Whitehouse



EBS Food web model

- 76 biological groups
- All 20 federally managed stocks
  + protected species
- ROMSNPZ forces phytoplankton.
  & zooplankton
- BT drives consumption and
  metabolism (energetics)

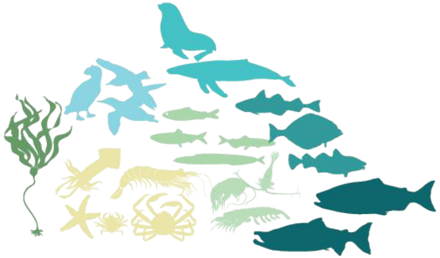
Whitehouse et al. in prep, Whitehouse et al. 2021

Draft Results do not copy

Rpath() example

P. cod

A. Whitehouse



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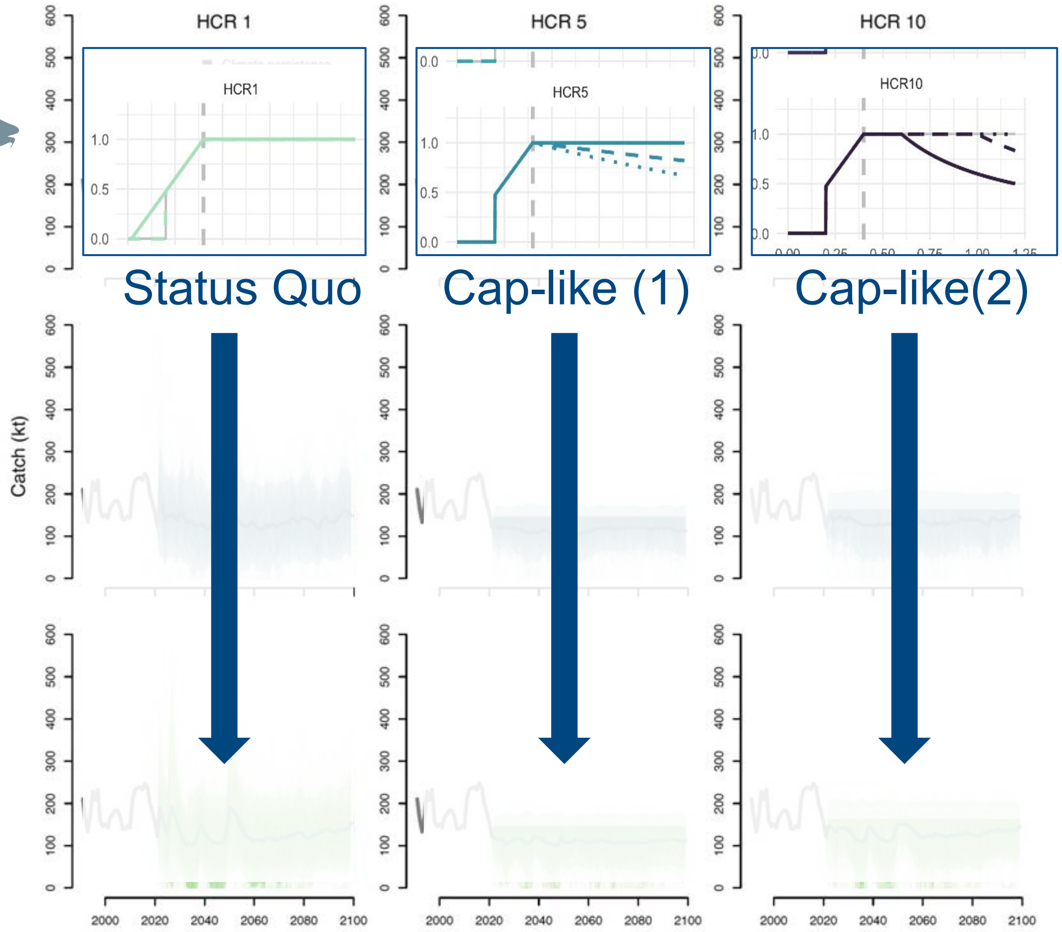

Whitehouse et al. in prep, Whitehouse et al. 2021

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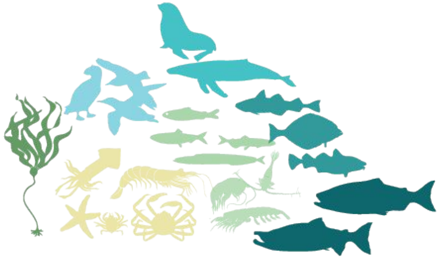

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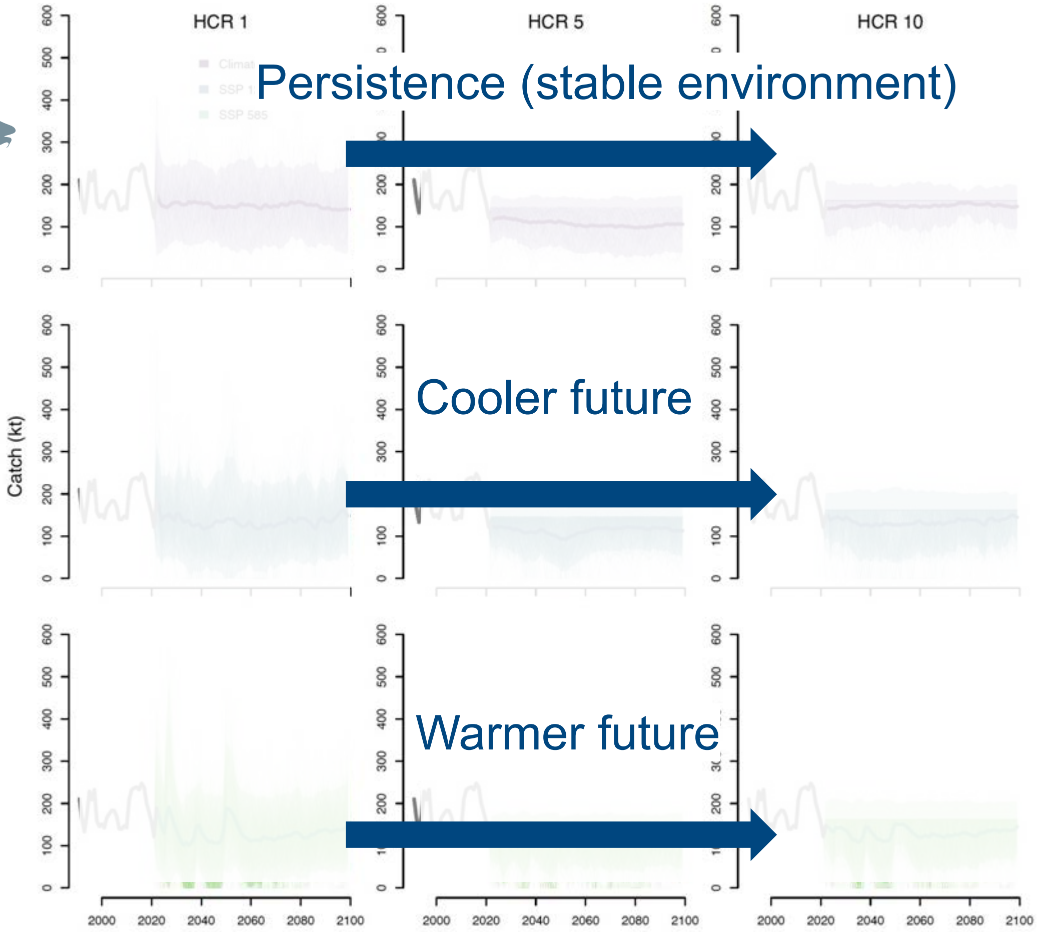


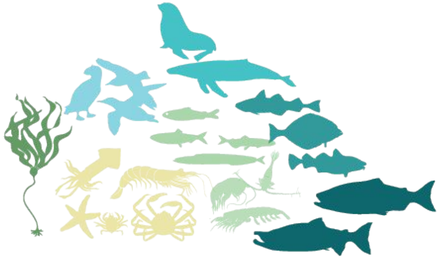
Whitehouse et al. in prep, Whitehouse et al. 2021

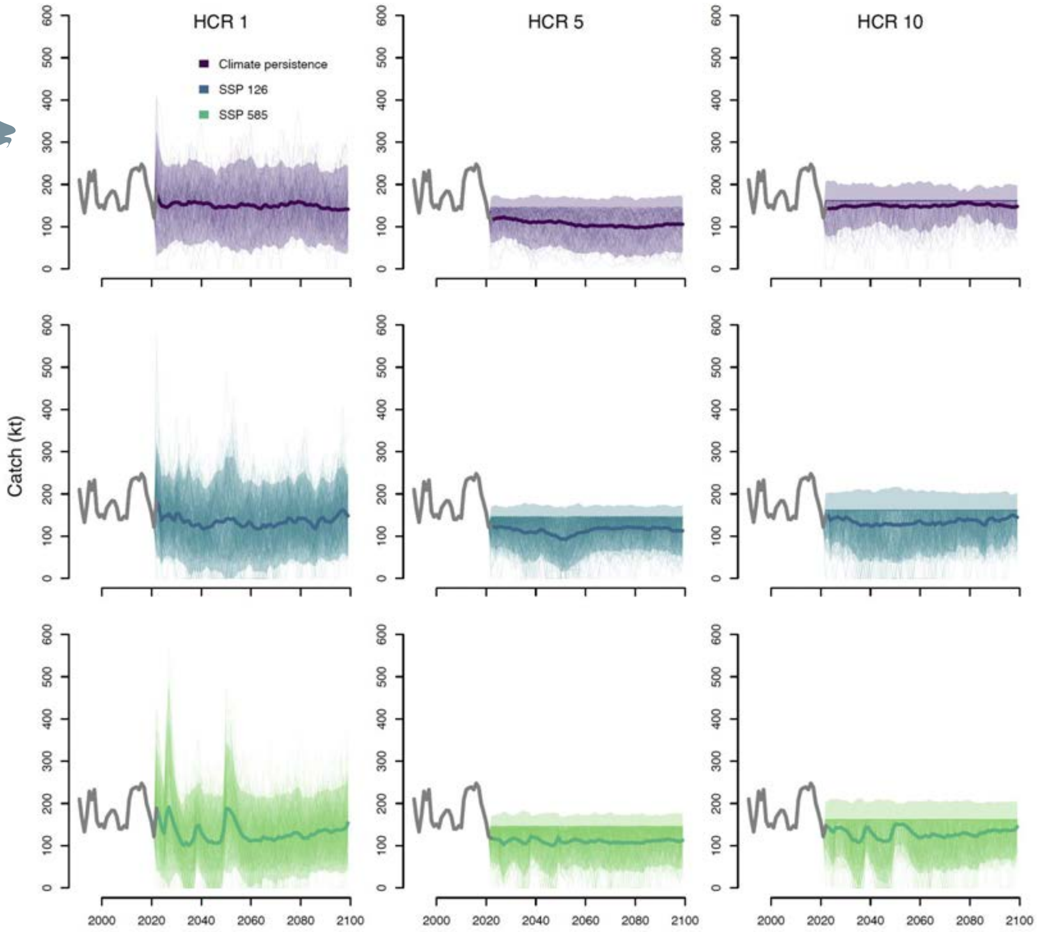
Draft Results do not copy

Rpath() example

P. cod

A. Whitehouse





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Whitehouse et al. in prep, Whitehouse et al. 2021

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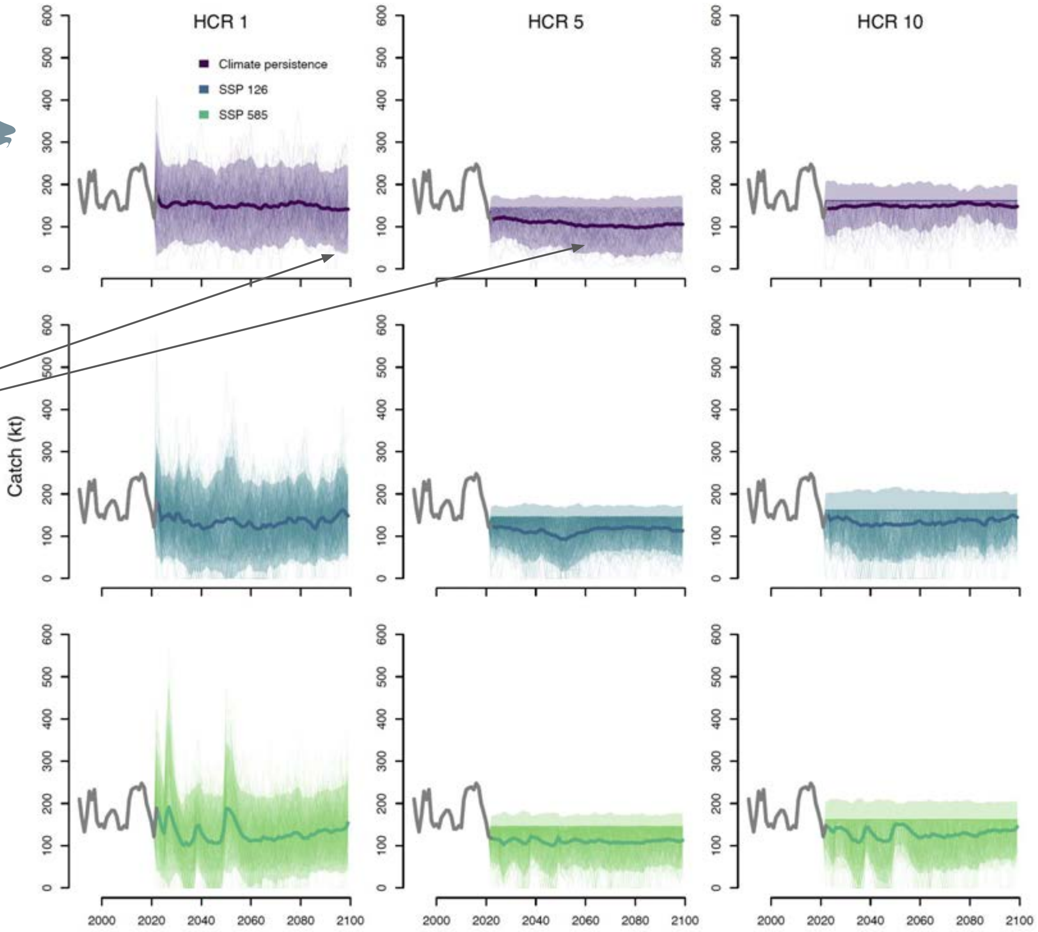


Cap-like HCRs stabilize catch (maybe good for markets?) [plan to add $value]

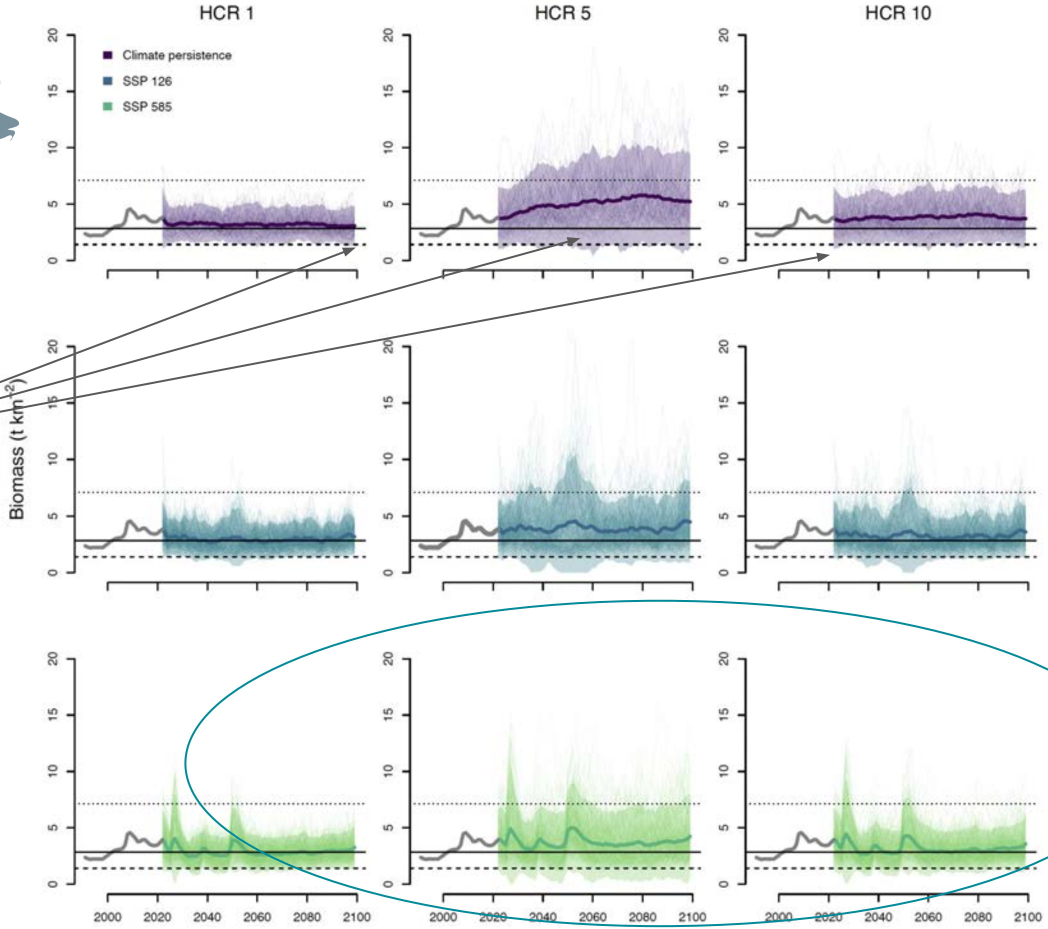
Whitehouse et al. in prep

Draft Results do not copy

Rpath() example

P. cod

A. Whitehouse



Cap-like HCRs
increase SSB over SQ

(through increased
productivity/
reserves?)

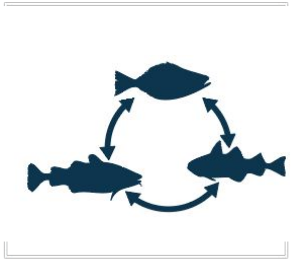
Stable
pop-dynamics
under warmest
scenarios

Whitehouse et al. in prep

Draft Results do not copy

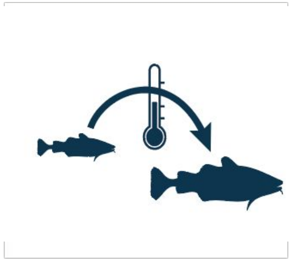
EBS CEATTLE

Mortality



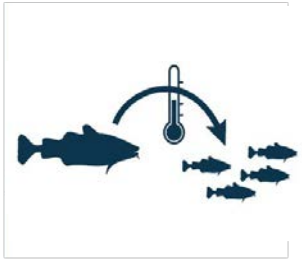
- Empirical diets
- Bioenergetics

Weight @ Age



- Empirical
- VonB with Temp

Rec



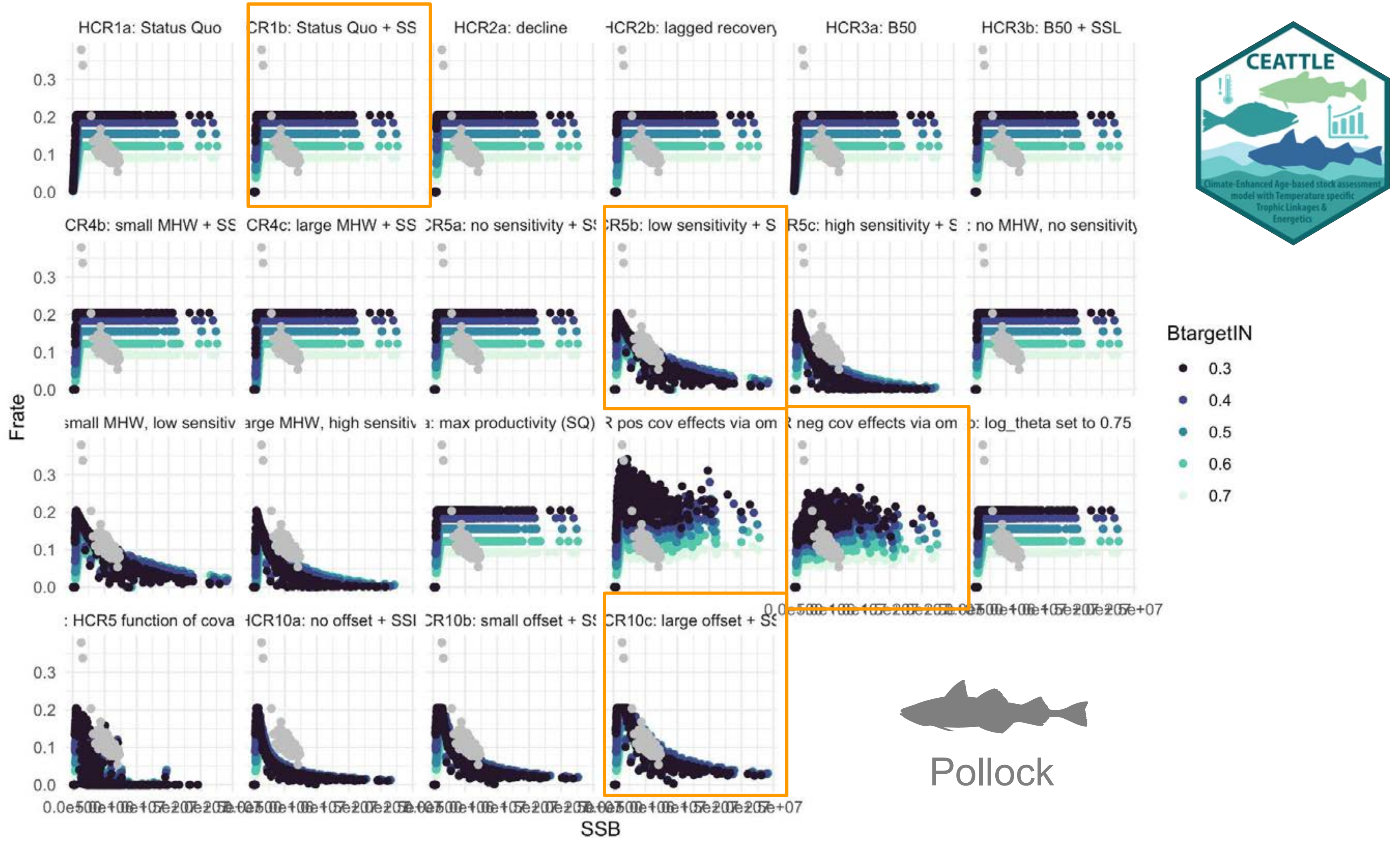
- Climate-S/R
- S/R
- mean R

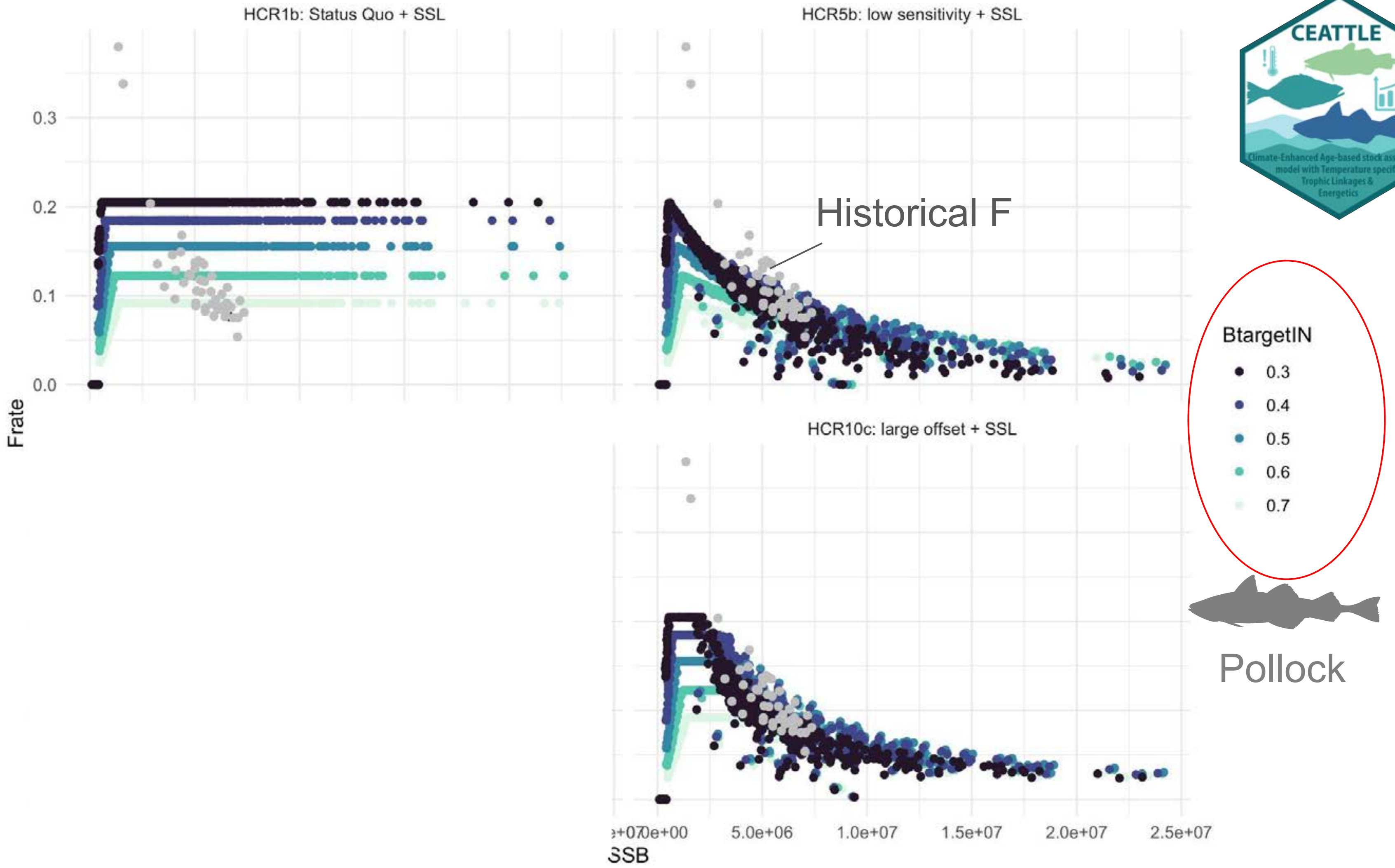
HCRs

- Climate ABC
- MMSY
- MEY
- SPR
- Aggregate MSY

https://www.npfmc.org/wp-content/PDFdocuments/SAFE/2024/EBSmultispp.pdf

Holsman et al. 2016, 2020, 2024


HCR1a: Status Quo
CR1b: Status Quo + SS
HCR2a: decline
HCR2b: lagged recovery
HCR3a: B50
HCR3b: B50 + SSL
CR4b: small MHW + SS
CR4c: large MHW + SS
CR5a: no sensitivity + S
CR5b: low sensitivity + S
R5c: high sensitivity + S
: no MHW, no sensitivity
small MHW, low sensitiv
arge MHW, high sensitiv
a: max productivity (SQ)
R pos cov effects via om
R neg cov effects via om
b: log_theta set to 0.75
: HCR5 function of cova
HCR10a: no offset + SSI
CR10b: small offset + S
CR10c: large offset + S
Frate
SSB
BtargetIN
0.3
0.4
0.5
0.6
0.7
Pollock
CEATTLE
Climate-Enhanced Age-based stock assessment model with Temperature specific Trophic Linkages & Energetics



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Climate-Enhanced Age-based stock assessment model with Temperature specific Trophic Linkages & Energetics

Pollock

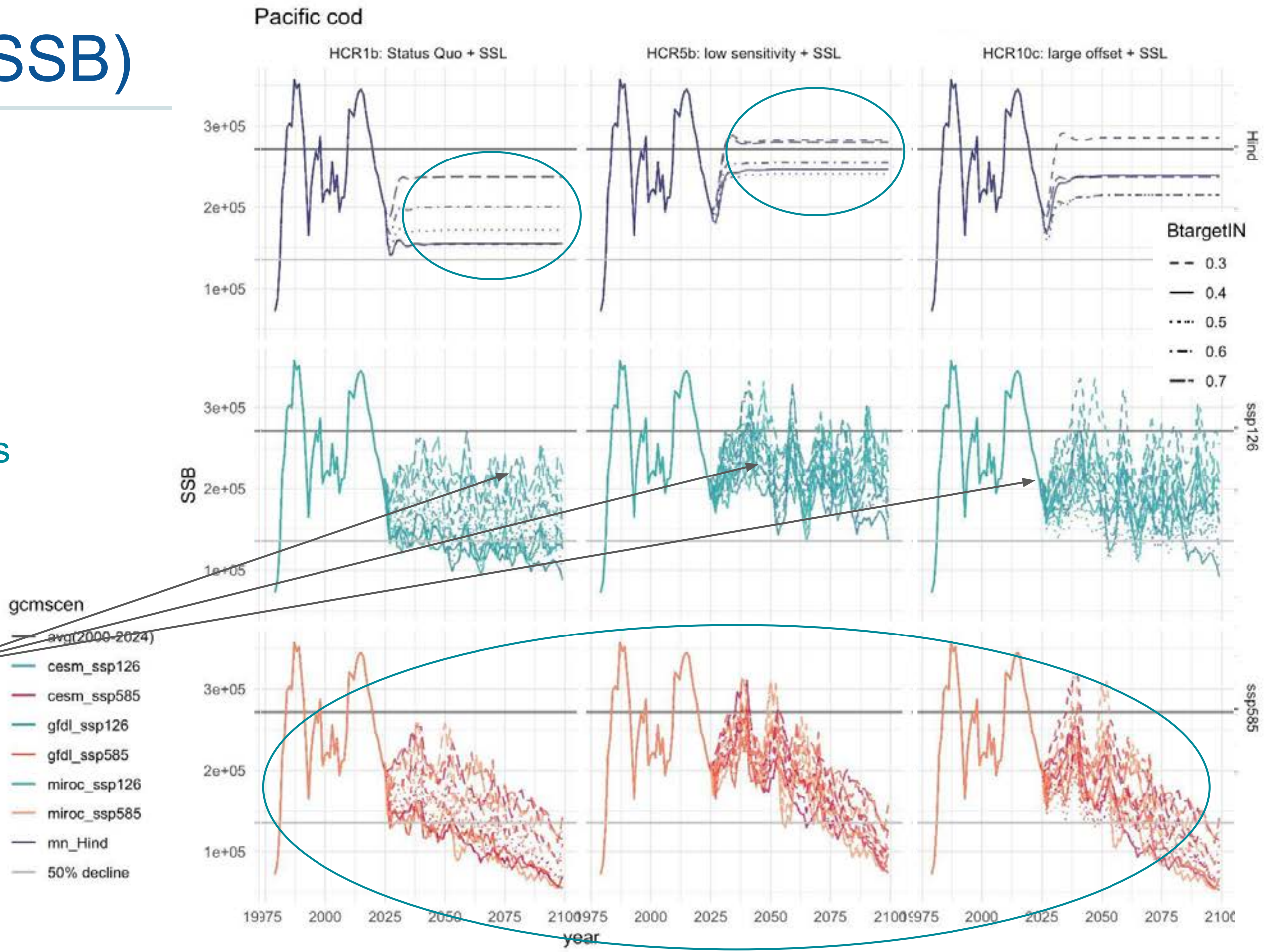
CEATTLE example (SSB)

P. cod

Cap-like HCRs reduce differences across Btarget

Cap-like HCRs increase SSB (through increased productivity/ reserves?)

Environmental dynamics >> HCRs



Holsman et al. in prep

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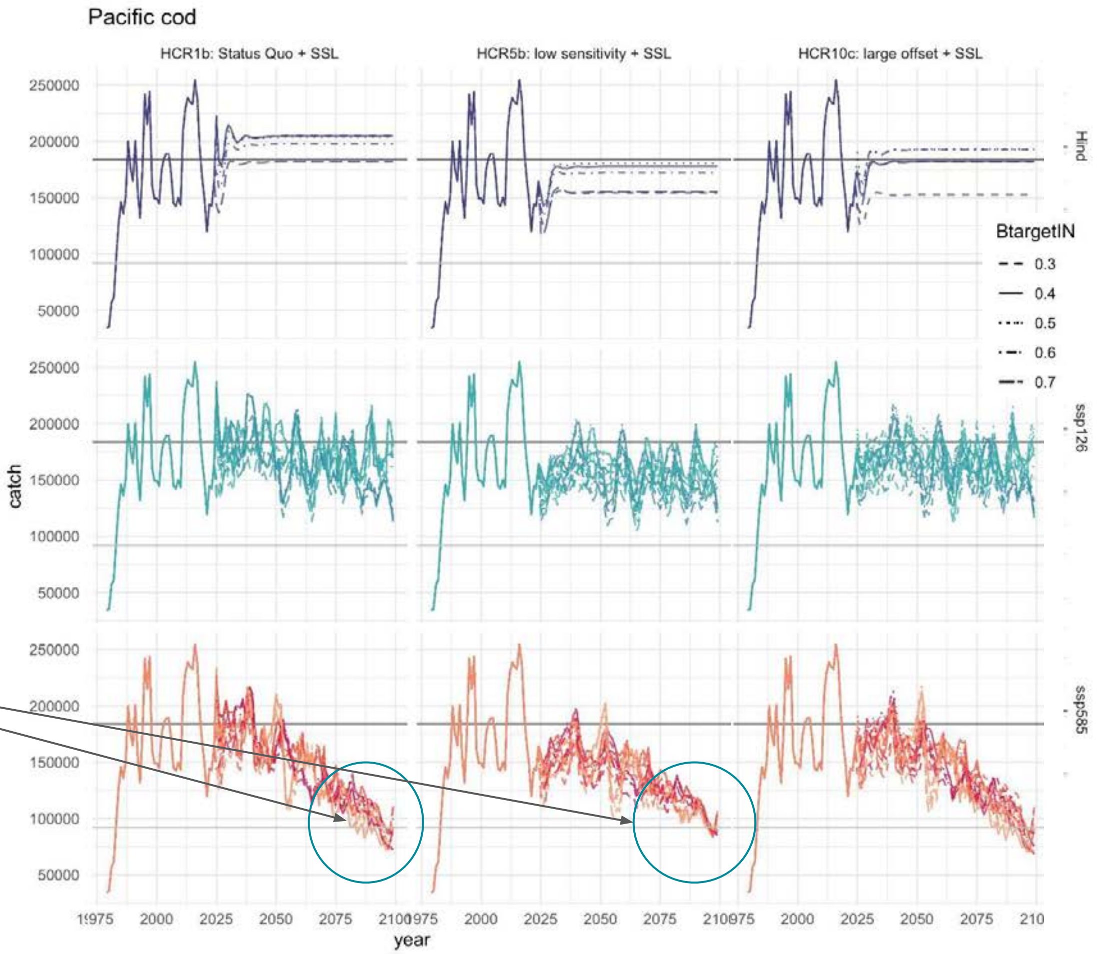
CEATTLE example (Catch = ABC)

P. cod

Catch is relatively similar across runs

slight reduction in # of large declines



Holsman et al. in prep

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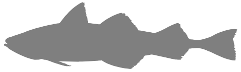
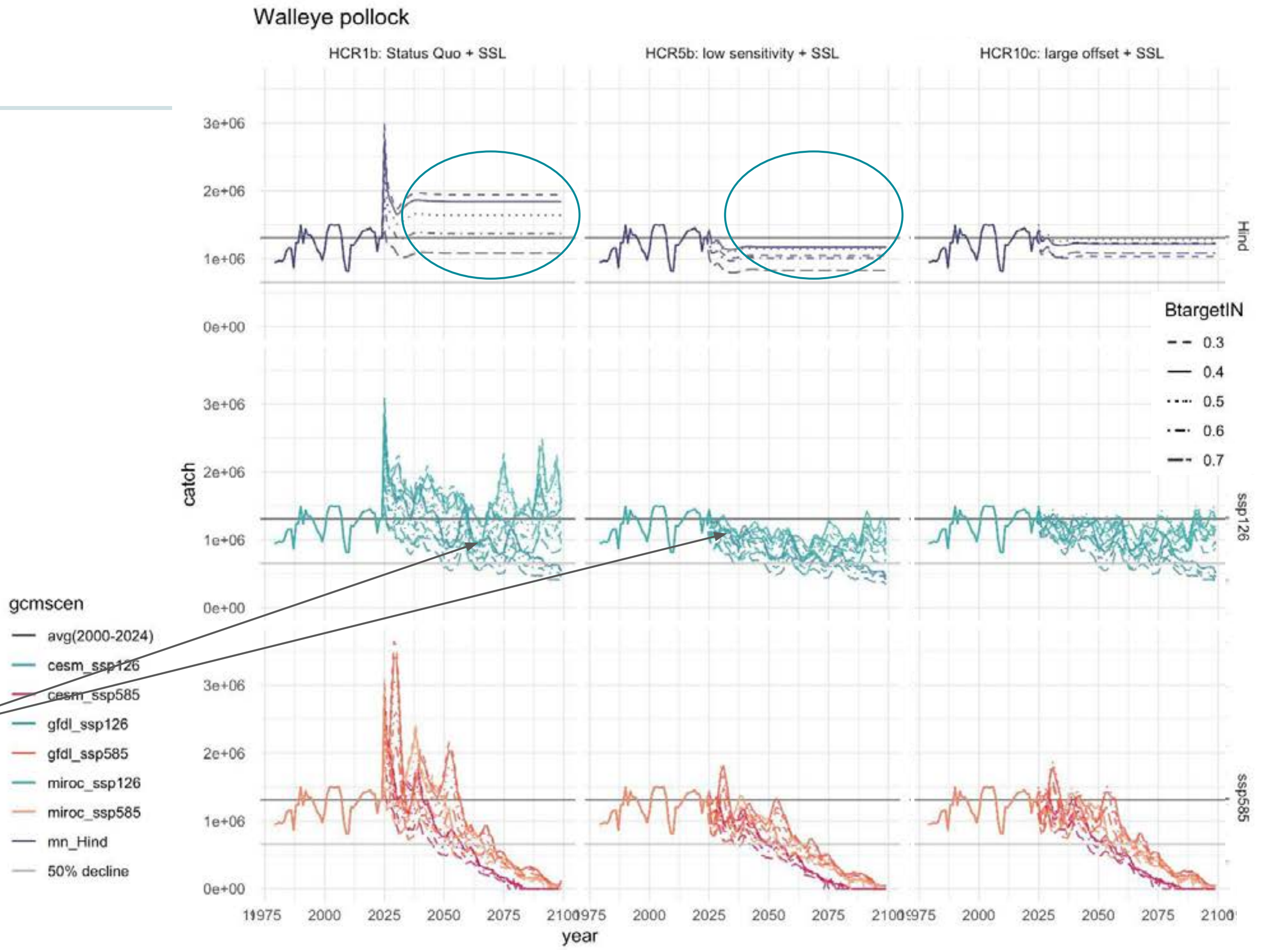
CEATTLE example (Catch = ABC)



Pollock

Cap-like HCRs reduce differences across Btarget

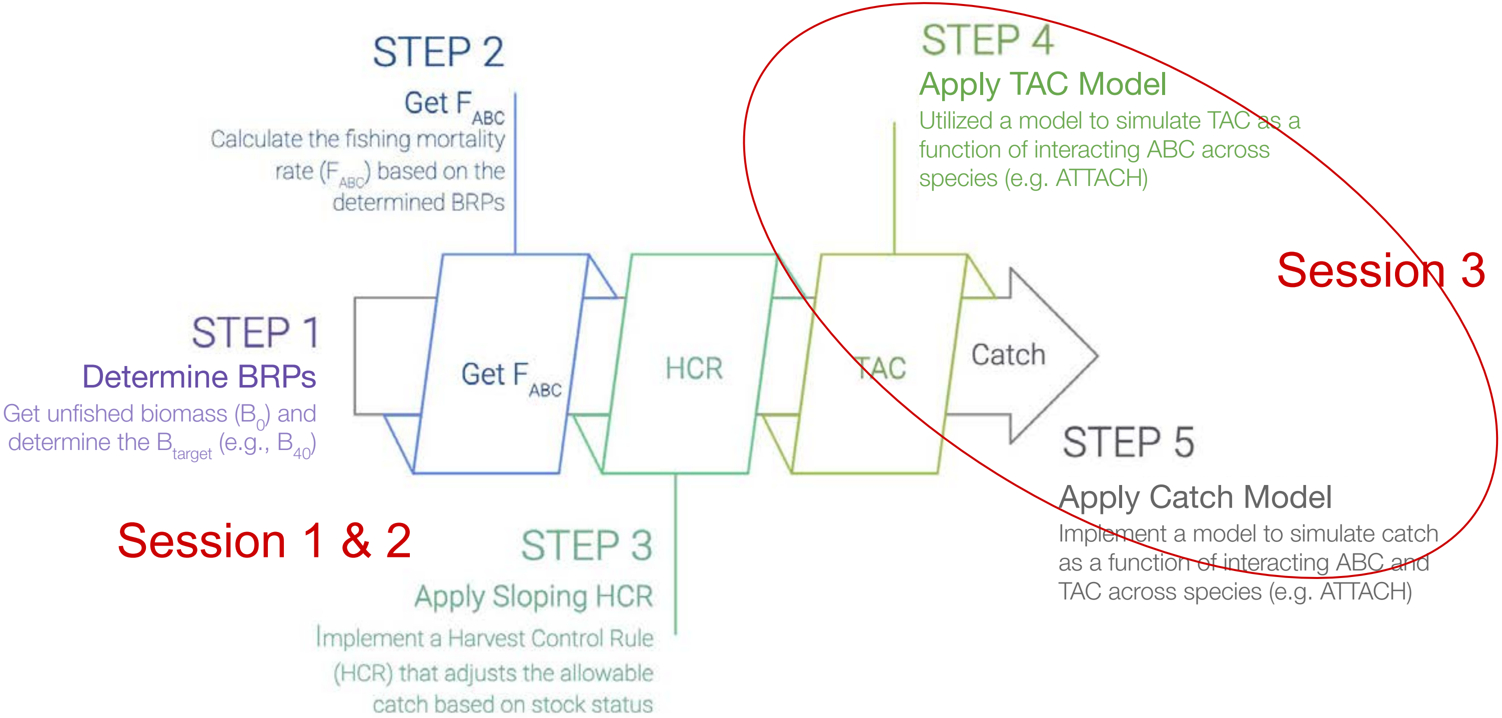
Cap-like HCRs stabilize catch (maybe good for markets?) [plan to add $value]



Holsman et al. in prep

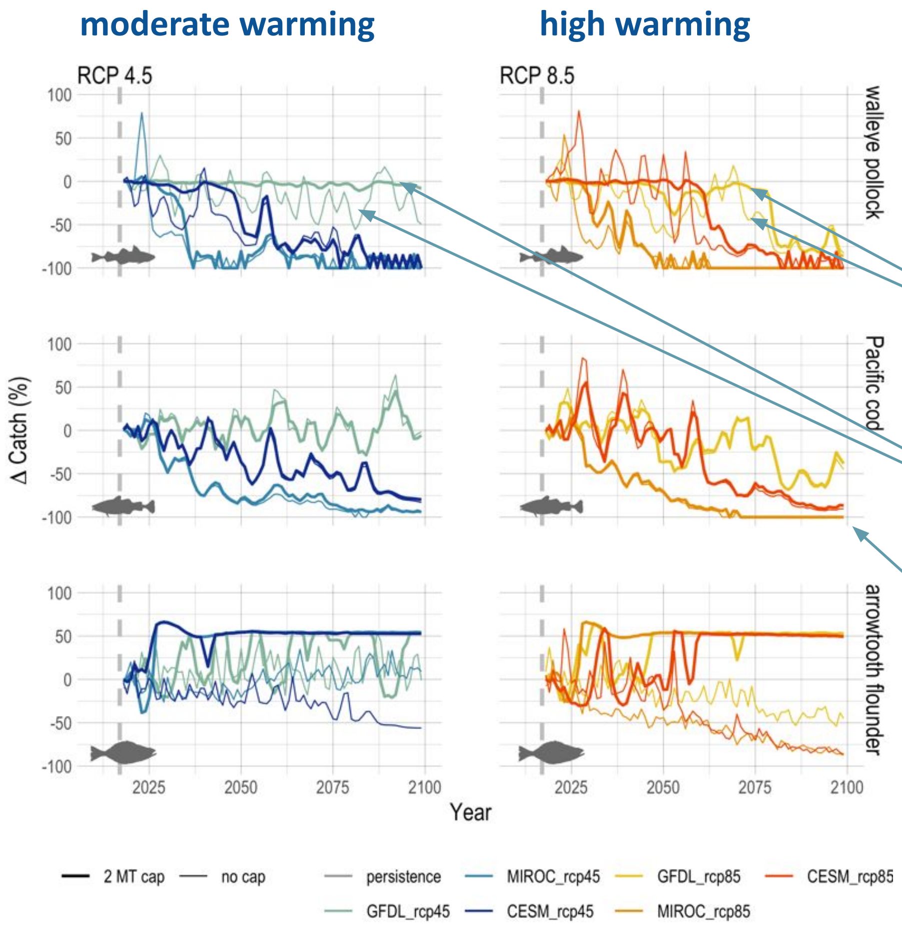
Draft Results do not copy

HCR simulation process



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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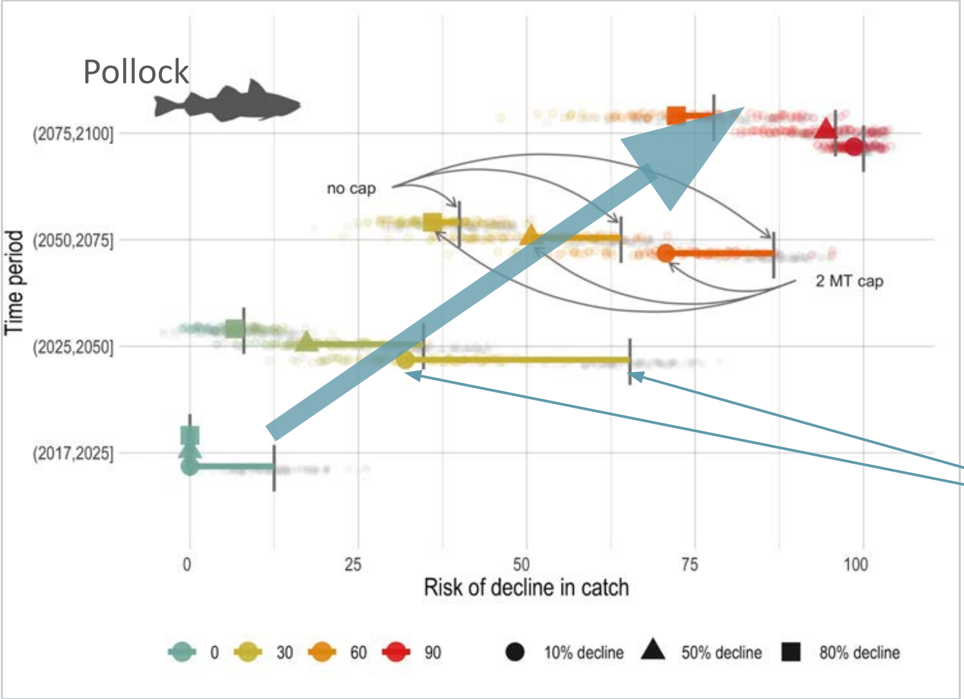


Risk increases over time

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

c) Discussion questions / feedback

- What HCRs are of interest?
- What species should we focus on first (e.g., highest productivity spp?)
- What are some performance criteria to include in our evaluations?

Credit: Kirstin H

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

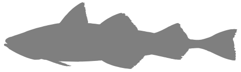
Hollowed et al. Alaska Integrated Climate Modeling

TABLE 6 | Suite of candidate performance indicators for ACLIM.

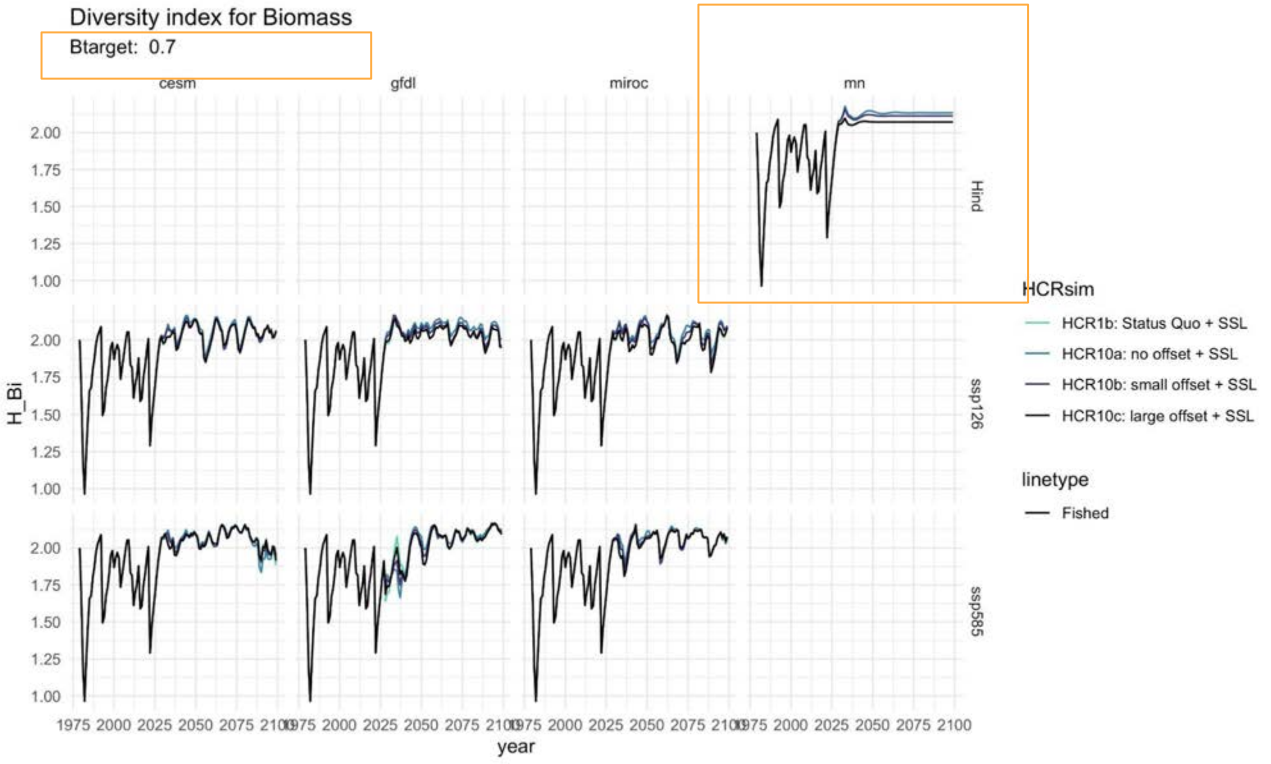
Name	Derivation	Purpose
Core species abundance	Mean and variance for time block	Sustainable fishing index
Core species recruitment	Mean and variance for time block	Sustainable fishing index
Core species average size and age at maturity	Mean and variance for time block	Sustainable fishing index
Core species 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

CEATTLE example



Pollock



Status Quo HCR1 is sensitive to B_target

Diversity Index is lower when B_target is higher

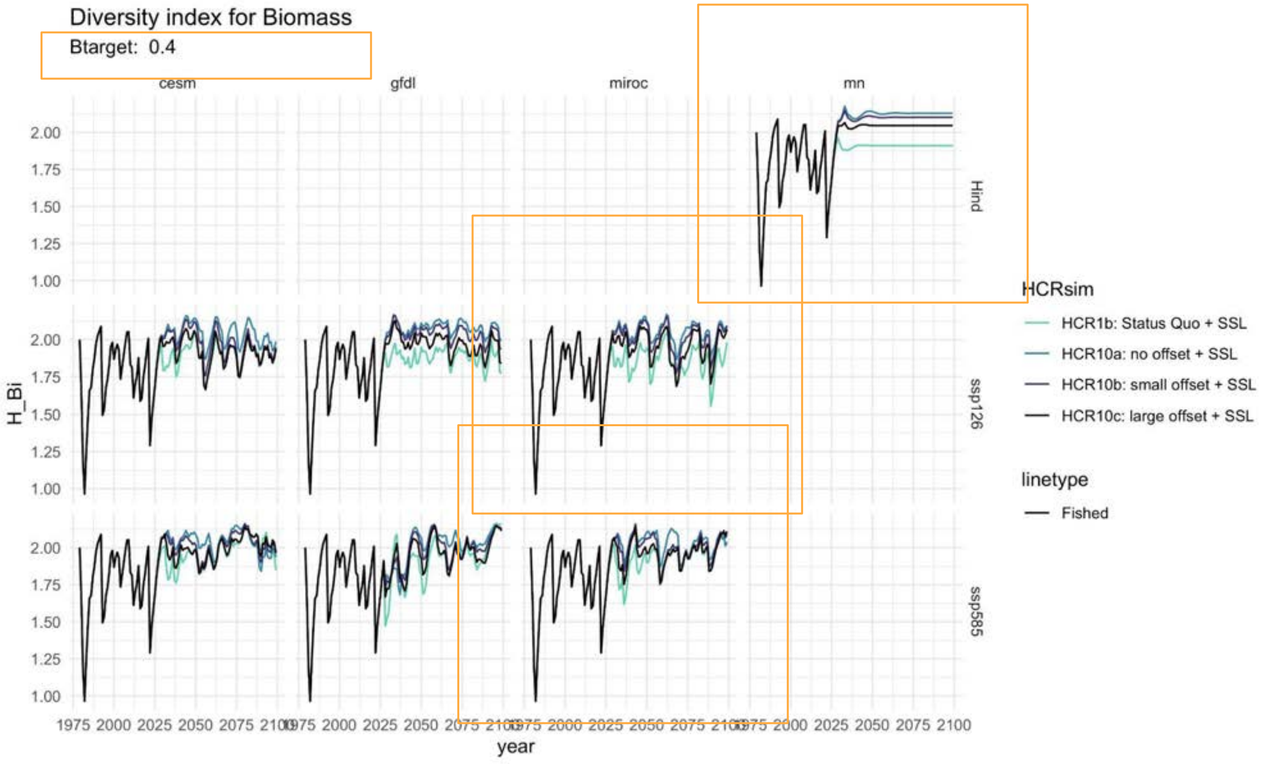
Whitehouse et al. in prep

Draft Results do not copy

CEATTLE example

Pollock

Environmental variability (productivity pulses) reduces that difference for HCR1



Whitehouse et al. in prep

Draft Results do not copy

c) SSC Discussion questions / feedback

- What HCRs are of interest?
- What species should we focus on first (e.g., highest productivity spp?)
- What are some performance criteria to include in our evaluations?

Credit: Kirstin H

Questions?

Thanks!

Credit: Kirstin Holsman

ACLIM Publications (direct & indirect) 1 of 2

(in review) Punt et al. Identifying and reducing climate uncertainty in fisheries management reference points. Fisheries Research

(in review) Stone et al. Socioeconomic risk of coastal Alaskan fishing communities to climate-driven changes in Pacific cod distributions. ICES Journal of Marine Science

(2024) McHuron et al. Current and future habitat suitability of northern fur seals and overlap with the commercial walleye pollock fishery in the eastern Bering Sea. Movement Ecology

(2024) Goodman et al. Climate covariate choice and uncertainty in projecting species range shifts: a case study in the Eastern Bering Sea. Fish and Fisheries. https://onlinelibrary.wiley.com/doi/10.1111/faf.12875

(2024) Hollowed et al. Selecting climate linked decision relevant and adaptation informing community level scenarios for ecosystems through constituent engagement : A case study for the eastern Bering Sea. ICES JMS

(2023) Punt et al. Capturing Uncertainty when Modelling Environmental Drivers of Fish Populations, with an Illustrative Application to Pacific Cod in the Eastern Bering Sea. Fisheries Research

(2023) Bigman, JvS, B J Laurel, K Kearney, A J Hermann, W Cheng, K K Holsman, L A Rogers. Predicting Pacific cod thermal spawning habitat in a changing climate. ICES Journal of Marine Science, fsad096, https://doi.org/10.1093/icesjms/fsad096

(2023) Hermann et al. Applications of biophysical modeling to Pacific high-latitude ecosystems. Oceanography

(2023) Szuwalski, C.S. et al. The collapse of eastern Bering Sea snow crab. Science.

(2023) Olmos, M., et al., Punt, A.E., Szuwalski, C.S. A step towards the integration of spatial dynamics in population dynamics models: Eastern Bering sea snow crab as a case study. Ecological Modelling 485: 110484.

(2023) Szuwalski et al., Unintended consequences of climate-adaptive fisheries management targets. Fish and Fisheries. https://doi.org/10.1111/faf.12737

(2022) Barnes, C.; Essington, T. E.; Pirtle, J; Rooper, C; Laman, E.; Holsman, K.; Aydin, K.; Thorson, J.. Climate-informed models benefit hindcasting but may present challenges when forecasting species-habitat associations. Ecography 2022: e06189 doi:10.1111/ecog.06189

(2022) Pilcher, D.J., J.N. Cross, A. Hermann, K. Kearney, W. Cheng, J.T. Mathis. Dynamically downscaled projections of ocean acidification for the Bering Sea, *Deep-Sea Research II: Topical Studies in Oceanography 198, 105055*

(2022) Hollowed, A. B., A. C. Haynie, A. J. Hermann, K. K. Holsman, A. E. Punt, C. S. Szuwalski. Implications of climate change on the Bering Sea and other cold water systems. Introduction to the special issue of Deep-Sea Research Part II: Topical Studies in Oceanography.

(2022) Punt, A.E., et al., Szuwalski, C.S. 2022. A framework for assessing harvest strategy choice when considering multiple interacting fisheries and a changing environment: The example of eastern Bering Sea crab stocks. Fisheries Research. 252: 106338.

(2022) Szuwalski, C.S.. Estimating time-variation in confounded processes in population dynamics modeling: a case study for snow crab in the eastern Bering Sea. Fisheries Research. 251: 106298.

(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

ACLIM Publications (direct & indirect) 2 of 2

(2021) Cheng, W., Hermann, A. J., Hollowed, A. B., Holsman, K. K., Kearney, K. A., Pilcher, D. J., Stock, C. A., & Aydin, K. Y.. Eastern Bering Sea shelf environmental and lower trophic level responses to climate forcing: Results of dynamical downscaling from CMIP6. Deep-Sea Research Part II: Topical Studies in Oceanography, 193, 104975. https://doi.org/10.1016/j.dsr2.2021.104975

(2021) Punt, A., M G Dalton, W Cheng, A Hermann, K Holsman, T Hurst, J Ianelli, K Kearney, C McGilliard, D Pilcher, M Véron. Evaluating the impact of climate and demographic variation on future prospects for fish stocks: An application for northern rock sole in Alaska. Deep Sea Research Part II: Topical Studies in Oceanography 189–190:104951.

(2021) Whitehouse, G. A., K. Y. Aydin, A. B. Hollowed, K. K. Holsman, W Cheng, A. Faig, A. C. Haynie, A. J. Hermann, K. A. Kearney, A. E. Punt, and T. E. Essington. Bottom-up impacts of forecasted climate change on the eastern Bering Sea food web. Front. Mar. Sci., 03 February 2021 | https://doi.org/10.3389/fmars.2021.624301

(2020) Holsman, K.K., A. Haynie, A. Hollowed, J. Reum, K. Aydin, A. Hermann, W. Cheng, A. Faig, J. Ianelli, K. Kearney, A. Punt. (2020) Ecosystem-based fisheries management forestalls climate-driven collapse. Nature Communications. DOI:10.1038/s41467-020-18300-3

(2021) Thorson, J., M. Arimitsu, L. Barnett, W. Cheng, L. Eisner, A. Haynie, A. Hermann, K. Holsman, D. Kimmel, M. Lomas, J. Richar, E. Siddon. Forecasting community reassembly using climate-linked spatio-temporal ecosystem models. Ecosphere 44: 1–14, doi: 10.1111/ecog.05471

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