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) B_0, B_target; considerations for session 2
    ii)   Cap effects; considerations for session 3
    iii)   Evaluating HCRs, considerations for session 1

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

ACLIM3 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

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

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

ACLIM & GOACLIM Overviews in [eAgenda](#)

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

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

[Hollowed et al. 2020](#)

Alaska Climate Integrated Modeling Project

GOA Climate Integrated Modeling Project (GOA-CLIM)

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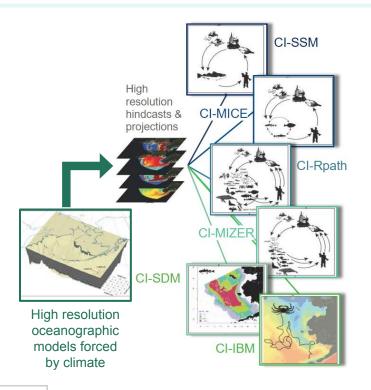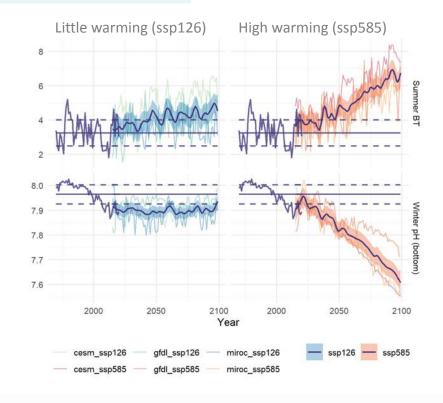
What can be done?
- Evaluate effectiveness of adaptation actions including those supported by fisheries management

Scenarios form the basis for comparative simulations & Management Strategy Evaluations

CLIM Models & Simulations
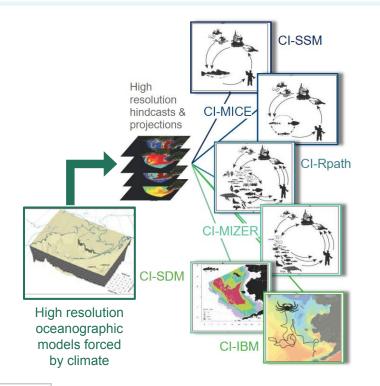
Supporting Publications

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
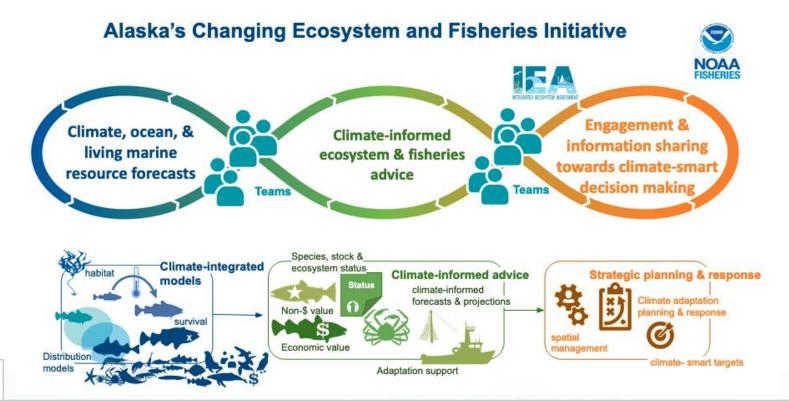
High resolution hindcasts & projections

CI-SSM

CI-MICE

CI-Rpath

CI-MIZER

CI-SDM

CI-IBM

High resolution oceanographic models forced by climate

GOA-CLIM Atlantis

A. Rovellini

Depth (m)
0-30 m
30-100 m
100-200 m
200-500 m
500-1000 m
Boundary

Physics and chemistry (ROMS)

Food web

Fishing (commercial – US federal)

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

Strategic foresight & predictions

Alaska's Changing Ecosystem and Fisheries Initiative

b) Setting the stage for HCR discussions

Credit: Kirstin Holsman

HCR simulation process

STEP 2
Get F$_{ABC}$
Calculate the fishing mortality rate (F$_{ABC}$) based on the determined BRPs

STEP 4
Apply TAC Model
Utilized a model to simulate TAC as a function of interacting ABC across species (e.g. ATTACH)

Session 2

Session 3

STEP 1
Determine BRPs
Get unfished biomass (B$_0$) and determine the B$_{target}$ (e.g., B$_{40}$)

Get F$_{ABC}$ HCR   TAC   Catch

STEP 5
Apply Catch Model
Implement a model to simulate catch as a function of interacting ABC and TAC across species (e.g. ATTACH)

STEP 3
Apply Sloping HCR
Implement a Harvest Control Rule (HCR) that adjusts the allowable catch based on stock status

Session 1

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
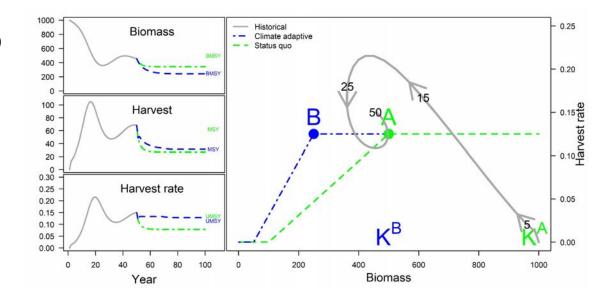
How might this arise?
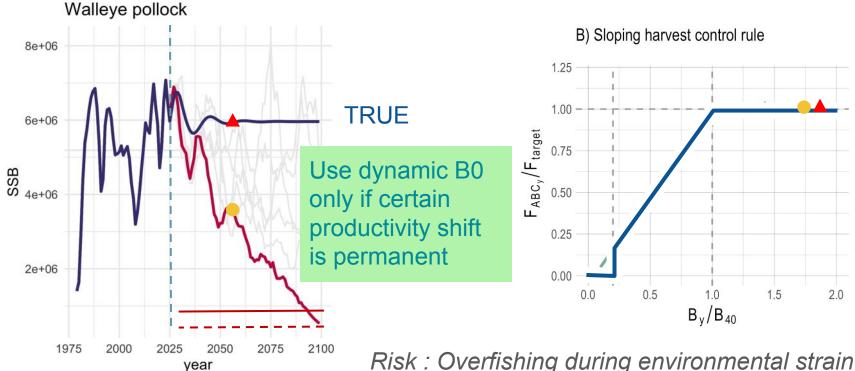
Proceed with caution….
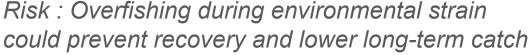
- If using a climate informed target (B0 based on climate trajectory)

- 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
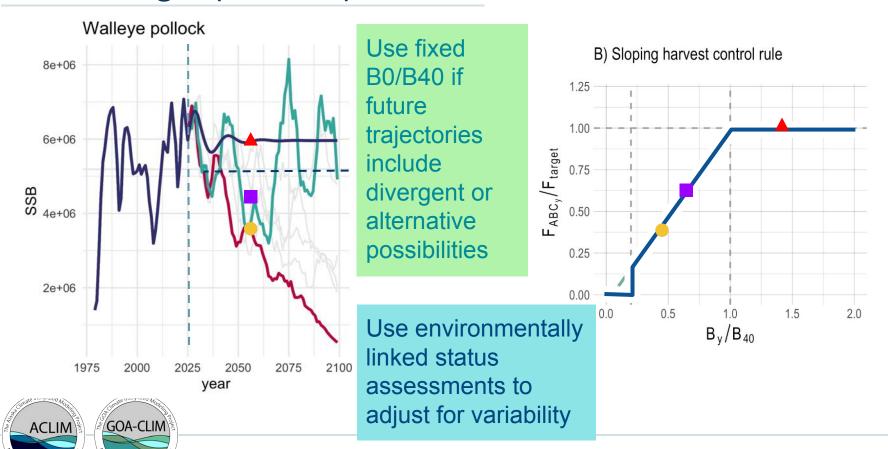
If using a environmentally-linked B0 (dynamic B0)

Walleye pollock

TRUE

Use dynamic B0 only if certain productivity shift is permanent

B) Sloping harvest control rule

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

Fixed target (fixed B0) + Env. enhanced status

Walleye pollock

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

Use environmentally linked status assessments to adjust for variability

B) Sloping harvest control rule

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

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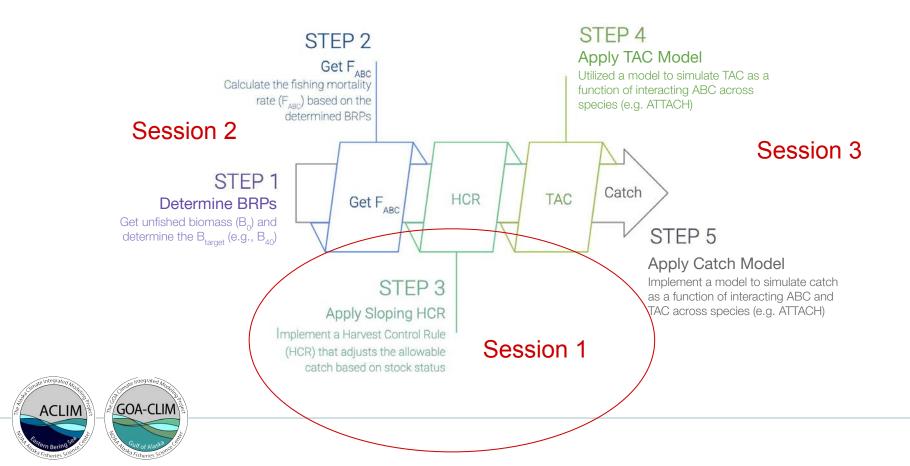
(1) Set targets based on fixed productivity potential
   (a) Historical reference period (historical B_0)
   (b) Persistence (constant environment) model based B_0

(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

STEP 1
Determine BRPs
Get unfished biomass (B_0) and determine the B_{target} (e.g., B_{40})

STEP 2
Get F_{ABC}
Calculate the fishing mortality rate (F_{ABC}) based on the determined BRPs

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Session 1
Session 2
Session 3

Interactive HCR explorer tool

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

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

Interactive HCR explorer tool
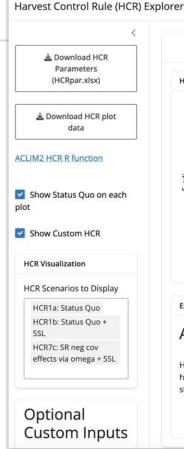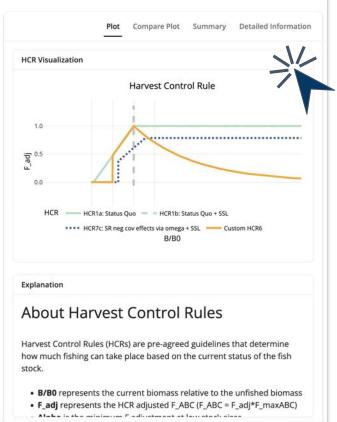
https://kholsman.shinyapps.io/HCRshiny/

Interactive HCR explorer tool

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

HCR Scenarios

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)

ACLIM2

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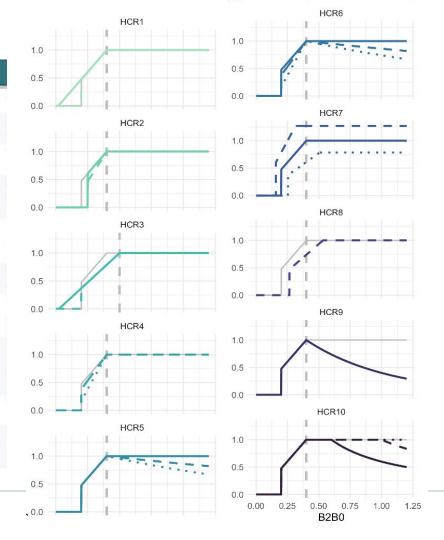
Hollowed et al. (2025) https://doi.org/10.1093/icesjms/fsae034

HCR Scenarios
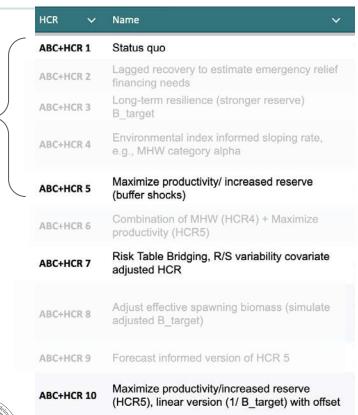
ACLIM2

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

ACLIM2

HCR ⌄	Name ⌄
ABC+HCR 1	Status quo
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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

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

HCR

— HCR1a: Status Quo

-- HCR1b: Status Quo + SSL

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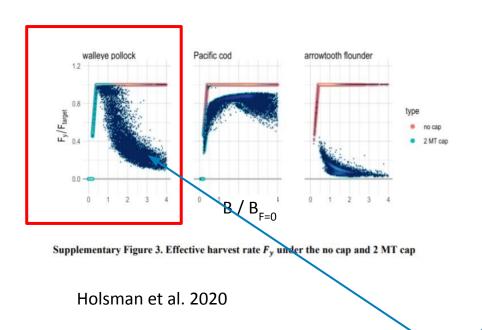
$$F_{ABC_{max}} = \left[\begin{array}{l} F_{ABC} \, e^{(-\gamma(\frac{B_y}{B_{target}}-1))} \\ F_{ABC}((\frac{B_y}{B_{target}} - \alpha)/(1-\alpha)) \\ 0 \end{array} \right. \qquad \begin{array}{l} \frac{B_y}{B_{target}} > 1 \\ \frac{B_{lim}}{B_{target}} \leq \frac{B_y}{B_{target}} < 1 \\ \frac{B_y}{B_{target}}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

HCR5

HCR
— HCR5a: no sensitivity + SSL
– – HCR5b: low sensitivity + SSL
⋯ HCR5c: high sensitivity + SSL

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

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

HCR
- HCR7a: max productivity (SQ) + SSL
- HCR7b: SR pos cov effects via omega + SSL
- HCR7c: SR neg cov effects via omega + SSL
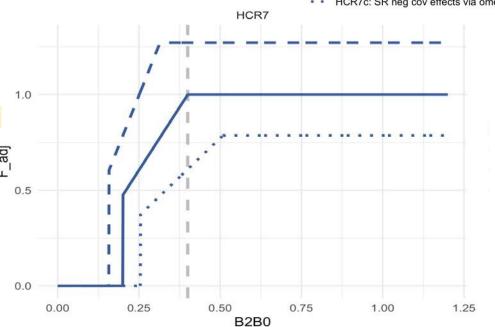
Simulation Goal:
This HCR provides a way to transition from qualitative risk tables to a more explicit, analytical approach for species whose productivity is known to vary with environmental conditions.

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

$$\hat{B}_{lim} = B_{lim}e^{(-\omega_3 * x_y)} \qquad \hat{B}_{target} = B_{target}e^{(-\omega_2 * x_y)}$$
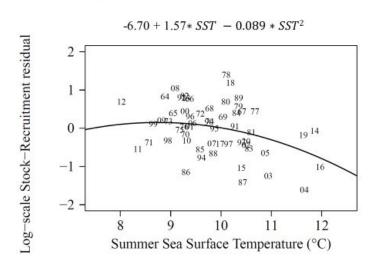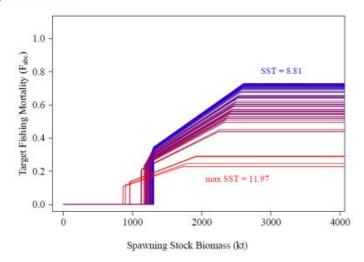
Spencer et al. in prep

Effect of temperature on recruitment

$$-6.70 + 1.57 * SST - 0.089 * SST^2$$

How would the harvest control rule change with temperature?

Draft results please do not copy
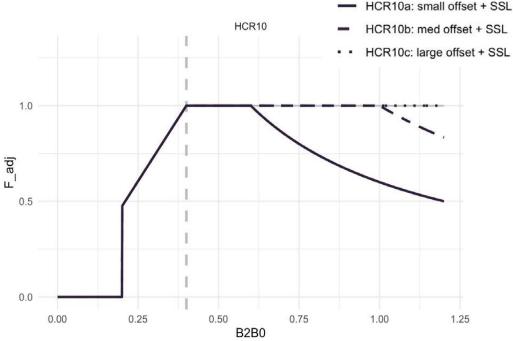
HCR 10: Maximize productivity/increased reserve; linear version (1/ B_target) with offset

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.

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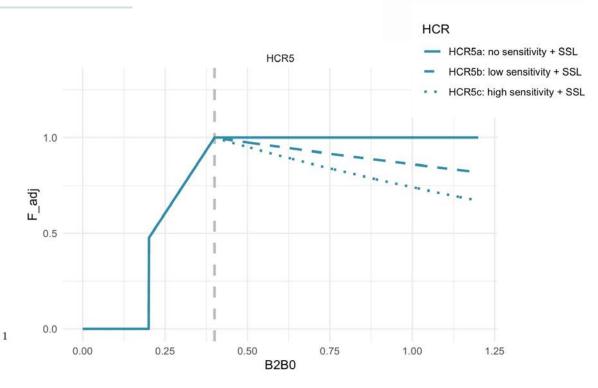

HCR

— HCR10a: small offset + SSL
– – HCR10b: med offset + SSL
· · · HCR10c: large offset + SSL

HCR10

F_adj vs B2B0

Rpath() example

A. Whitehouse

P. cod

EBS Food web model

Rpath() example

A. Whitehouse

P. cod

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

Rpath() example

A. Whitehouse

P. cod

Cap-like HCRs
increase SSB over SQ

(through increased
productivity/
reserves?)

Stable
pop-dynamics under
warmest scenarios

Pollock
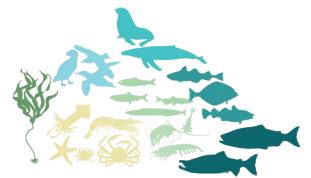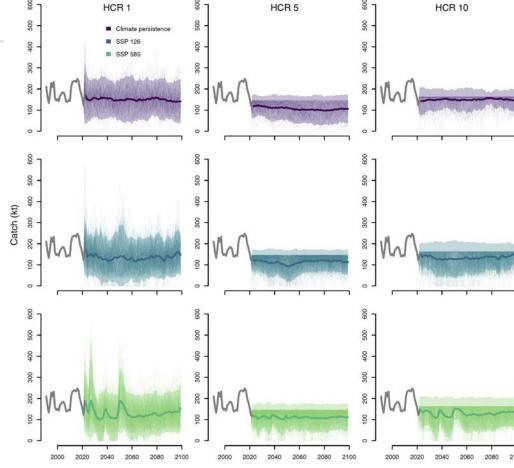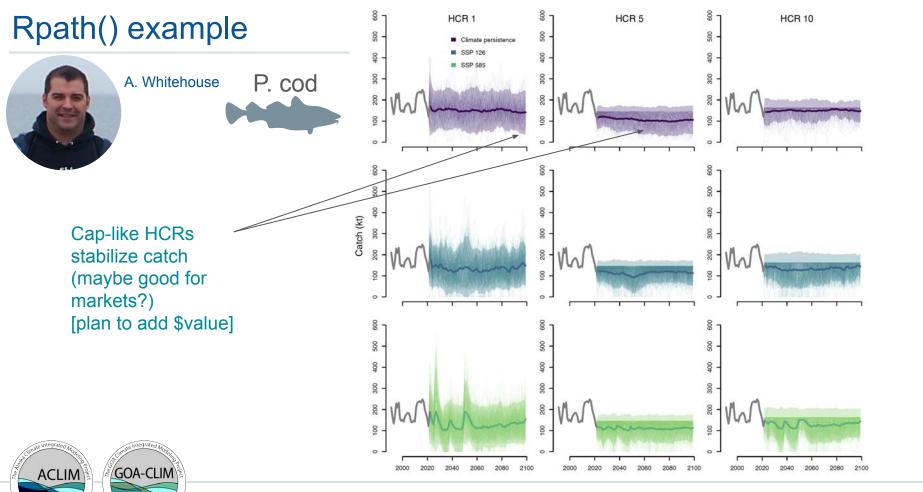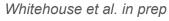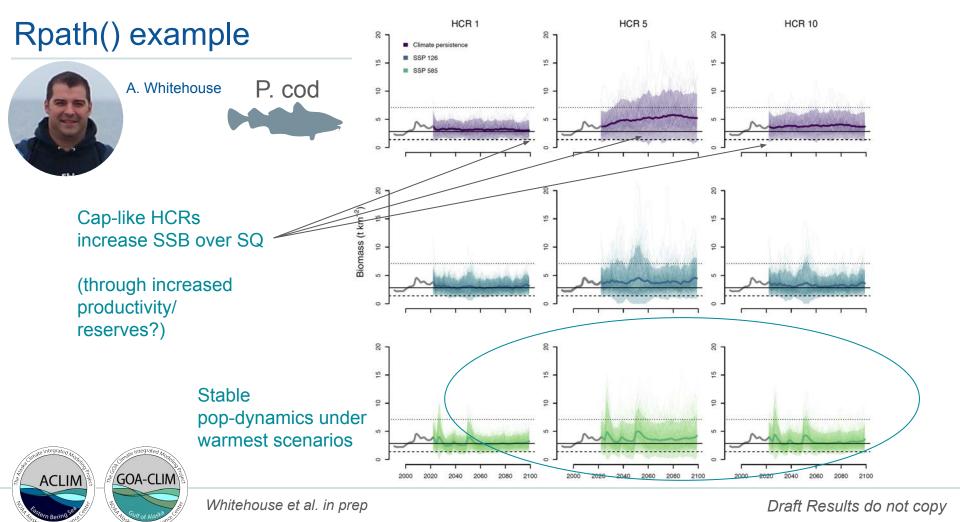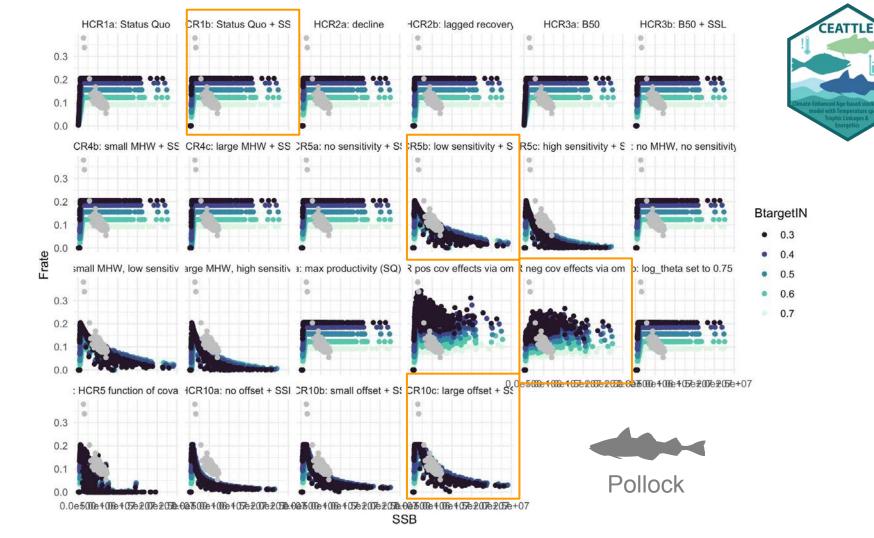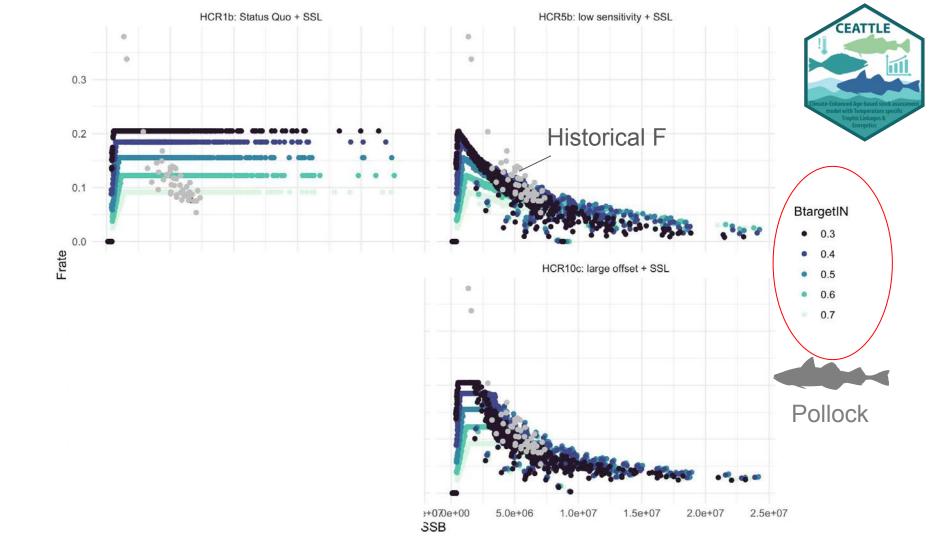
CEATTLE example (SSB)

P. cod
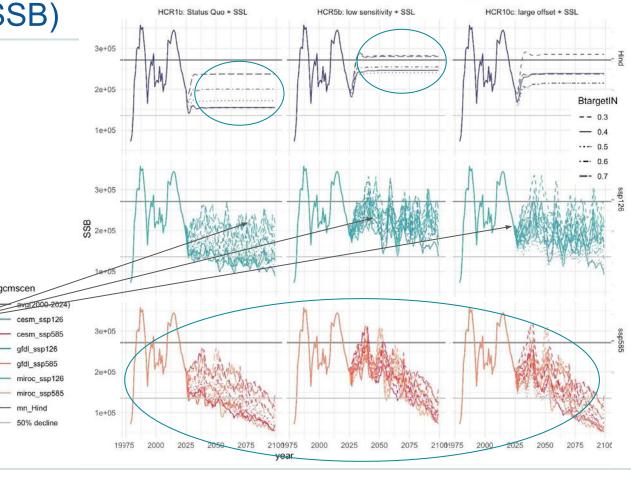
Cap-like HCRs reduce differences across Btarget

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

Environmental dynamics >> HCRs

Holsman et al. in prep

CEATTLE example (Catch

P. cod

Catch is relatively similar across runs

slight reduction in # of large declines

CEATTLE example (Catch

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

STEP 2
Get F_{ABC}
Calculate the fishing mortality rate (F_{ABC}) based on the determined BRPs

Session 2

STEP 1
Determine BRPs
Get unfished biomass (B_0) and determine the B_{target} (e.g., B_{40})

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Utilized a model to simulate TAC as a function of interacting ABC across species (e.g. ATTACH)

Session 3

Get F_{ABC} HCR   TAC   Catch

STEP 5
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STEP 3
Apply Sloping HCR
Implement a Harvest Control Rule (HCR) that adjusts the allowable catch based on stock status

Session 1

CEATTLE: EBFM vs non-EBFM cap

Assumes climate effects on recruitment, growth, & mortality

moderate warming   **high warming**

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

CEATTLE: EBFM vs non-EBFM cap

Assumes climate effects on recruitment, growth, & mortality

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?

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.

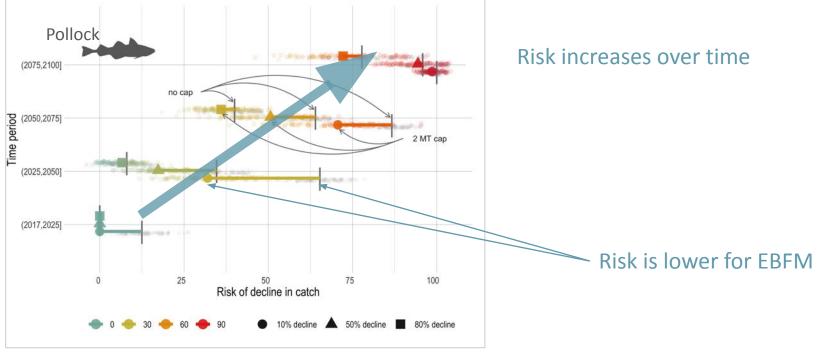| Name	Derivation	Purpose
Core species abundance	Mean and variance for time block	Sustainable fishing index
Core species recruitment	Mean and variance for time block	Sustainable fishing index
Core species average size and age at maturity	Mean and variance for time block	Sustainable fishing index
Core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

CEATTLE example

Pollock
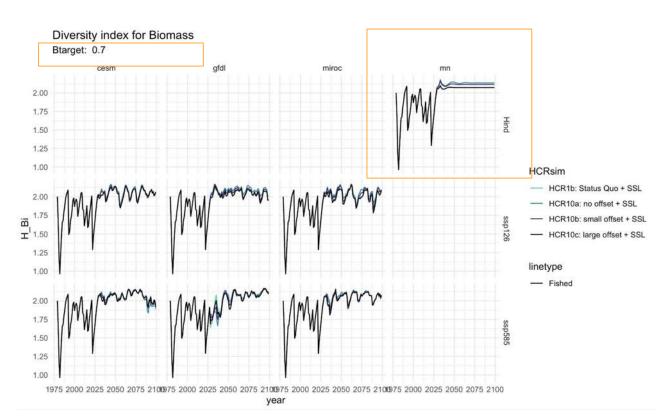
Status Quo HCR1 is sensitive to B_target

Diversity Index is lower when B_target is higher

Diversity index for Biomass
Btarget: 0.7

HCRsim
— HCR1b: Status Quo + SSL
— HCR10a: no offset + SSL
— HCR10b: small offset + SSL
— HCR10c: large offset + SSL

linetype
— Fished
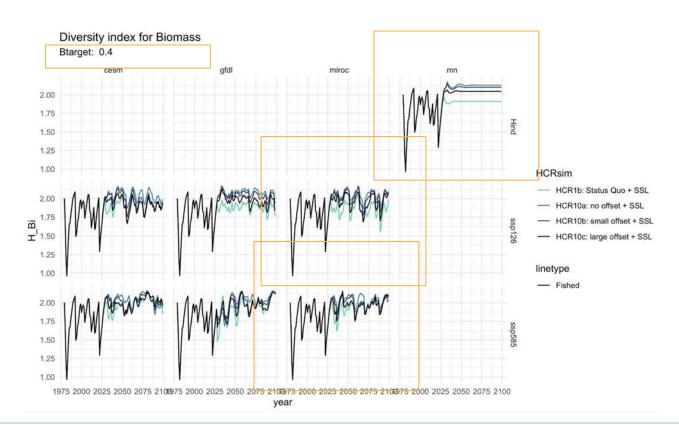
CEATTLE example

Pollock

Environmental variability (productivity pulses) reduces that difference for HCR1

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?

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