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

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Overview

This document serves as an white paper outlining the current set of HCRs under consideration for simulation testing by the ACLIM and GOACLIM teams. This document is informational only and HCRs outlined here are not "recommended HCRs", rather alternative formulations being evaluated for increased performance through coordinated modeling in 2025-2026. Any evaluation of HCRs to be implemented for management purposes would be done by the NPFMC through the established Council process. The HCRs below build on previous modeling efforts. During ACLIM phase 2 (2019-2022), modelers evaluated a suite of Harvest Control Scenarios (1-5; Hollowed et al. 2022), in 2025 during phase 3 of the ACLIM project and in collaboration with GOACLIM phase 2 CLIM modelers added additional HCRs for evaluation. Below is more information on a subset of those standardized harvest control rules and the equations used to derive the curves. This subset of HCRs considered in this document will be referred to as “Stage 1 HCR” throughout (Fig. 1). An interactive version of the full set of HCRs under consideration is available on line at https://kholsman.shinyapps.io/HCRshiny.

Introduction

Background on NPFMC HCRs

The North Pacific Fishery Management Council (NPFMC) has adopted a complex suite of harvest controls that, in aggregate, strive to achieve the goals and objectives of an Ecosystem Approach to Fisheries Management (EAFM). With the adoption of the Aleutian Islands Fisheries Ecosystem Plan (AIFEP) and the Bering Sea Fisheries Ecosystem Plan (BSFEP), the NPFMC is striving to adopt an Ecosystem Based Fisheries Management (EBFM) approach. These management systems include forage fish protections, prohibited species mortality caps, discard prohibitions, habitat protections, marine mammal and seabird provisions, rationalized fisheries, community development quotas, optimal yield system-level caps, and sustainable harvest control rules (HCRs) that encourage rebuilding when the reproductive potential of stocks (e.g., spawning biomass or proxies thereof) falls below target levels. The system limits annual catch levels to to protect non-target groundfish and crab stocks incidentally captured in target fisheries.Collectively these provisions are designed to address National Standard 1 of the Magnuson Stevens Fishery Conservation and Management Act (MSA). Many other regulations address the additional National Standards for successful operation of a rationalized fishing system. These regional management controls are outlined in the Fishery Management Plan for Groundfish of the Bering Sea-Aleutian Islands (BSAIGF FMP), the Fishery Management Plan for the Groundfish Fisheries of the Gulf of Alaska (GOAGF FMP) and the Fishery Management Plan for Bering Sea-Aleutian Islands King and Tanner Crabs (BSAI Crab FMP).

While many of these management provisions have been amended several times, the regulations governing the setting of HCRs outlined in the FMPs have been in place for many years. In 1999, the NPFMC revised their frameworks for setting HCRs for groundfish in the Bering Sea-Aleutian Islands (BSAI FMP Amendment 56) and Gulf of Alaska (GOA FMP Amendment 56). These groundfish HCRs were reviewed by an independent panel in 2002 (Goodman et al., 2002). The NPFMC revised their HCRs for managing Bering Sea- Aleutian Islands crab (BSAI Crab FMP Amendment 24) in 2008. In 2011, the crab HCRs were revised to comply with revisions to the Magnuson Stevens Fishery Conservation and Management Act (in short, the Magnuson Stevens Act, MSA) that required setting Annual Catch Limits (ACLs, BSAI Crab FMP Amendment 38). The HCR frameworks comply with the MSA, National Guidelines for implementation of the MSA (National Standards) and guidelines for use of the Best Scientific Information Available (BSIA).

Considerations for HCRs under changing conditions

At its core, the current HCRs acknowledge that when viewed over long time-frames, most animal populations are governed by logistic population dynamics with associated concepts of maximum sustainable yield (MSY). Based on these concepts, scientists can identify biomass targets, limits, fishing mortality, and biomass reference points for sustainable management. These reference points are set by the NPFMC Scientific and Statistical Committee (SSC) based

on the BSIA regarding the reproductive potential of the stock and the associated fishing mortality target and limit reference points to achieve these biomass reference points.
Due to knowledge gaps and data availability, uncertainty exists for many stocks regarding the relationship between spawning stock size and recruitment. To address this issue, the groundfish and crab HCR frameworks established management tiers based on the BSIA for a given stock. When information is insufficient to reliably define spawner recruit relationships, methods for calculating proxies for biological reference points are provided in the FMP. More recently, analysts have developed methods for estimating biological reference points under multiple axes of uncertainty (Szuwalski and Punt, 2025).

While the frameworks governing the HCRs for groundfish and crab have been static for many years, the calculation of the biological reference points has changed frequently in response to:

- new information on the key vital rates governing population dynamics of the stock
- shifts in BSIA and management tiers
- shifts in spatial distribution of the stock that influence availability and/or catchability
- changes in the selectivity and catchability of the stocks to fishing resulting from gear changes, time-area-gear regulations that influence selectivity, and other factors governing harvest practices of the fleet (including changes in prohibited species mortality caps and discard mortality restrictions).

The NPFMC's HCR framework proved flexible enough to accommodate these changes.

The NPFMC's current system of management has sustained fishing opportunities for many stocks, however, in recent decades shifts in ocean conditions have had profound impacts on some groundfish and crab with associated impacts on the fisheries and communities that depend on them (Bigman et al., 2023; Suryan et al., 2021). These impacts are harbingers of future changes in fish and crab abundance under projected states of nature under future environmental scenarios.

To address observed environmental changes in the Bering Sea-Aleutian Islands and Gulf of Alaska, the Plan Teams and SSC currently review the status of the ecosystem (Ecosystem Status Reports, ESRs) and current knowledge of the responses of stocks to ecosystem change (Ecosystem Socio-economic Profiles, ESPs) to make qualitative adjustments to annual harvest recommendations (ABCs) based on professional judgement using Risk Tables (Dorn and Zador, 2020). While the Risk Table approach is useful for some stocks, the qualitative nature of the application of the risk table approach underutilizes the mechanistic understanding currently available to analysts for key species (e.g., sablefish, pollock, cod, yellowfin sole, northern rock sole, arrowtooth flounder, red king crab, snow crab and Tanner crab).

For key species, the long legacy of monitoring and mechanistic research has enabled scientists to better understand the complex factors governing the productivity and distribution of groundfish and crab and the responses of fisheries to changes in the distribution and abundance of these species (Rogers et al., 2020; Bigman et al., 2023; Thalmann et al. 2024; West et al., 2025). In addition, advancements in understanding the physical and bio-geo-chemical processes governing ocean conditions in the Gulf of Alaska and the Bering

Sea allow hindcasts, forecasts and projections of ocean properties. These coupled high-resolution regional ocean models replicate observed ecosystem phenomena in the region with considerable skill (Hermann et al., 2019, 2020; Pilcher et al., 2022; Cheng et al., 2021; Kearney et al., 2020; Sullaway et al., 2024). When viewed together, these advances in scientific understanding and modeling enable scientists to construct mechanistically informed social and ecological models informed by output from next generation high-resolution regional ocean models to forecast and project future population trends, including fishing effects (Holsman et al., 2020; Punt et al. 2021; Hollowed et al. 2024; Wildermuth et al. 2024; Blamey et al. 2025; Champagnat et al. In Review). These environmentally-coupled socio-ecological models provide powerful platforms for exploring the performance of current and alternative harvest strategies relative to suites of desired outcomes (for example performance measures see Appendix A).

Stage 1 alternative HCRs

The SSC convened a public workshop in June 2025 to review the frameworks for setting HCRs in the Fishery Management Plans given recent observations of environmental change on managed species and the availability of environmentally-coupled socio-ecological models for key species. The overarching goal of the workshop was to develop a scope of work and Terms of Reference for a workgroup (or several coordinated teams) to prepare a discussion paper of proposed HCR adjustments for consideration/recommendations for the Plan Teams/SSC/AP/Council. The workshop discussed and solicited input on adjustments to current Groundfish and Crab fishery management plan (FMP) harvest specification Tier-levels and resulting harvest control rules (HCRs) for determination of the overfishing level (OFL) and acceptable biological catch (ABC).

The June 2025 workshop was designed to address the Council's requests from October and December 2024. The Council's October 2024 motion encouraged researchers to 'Consider to what extent, and whether, to revise groundfish and crab harvest control rules (HCRs) to be more climate-resilient.' In December 2024, the Council identified consideration of Tier-systems, climate-informed biomass targets and climate-robust or forecast-informed harvest control rules as part of their Climate Workplan. The SSC workshop was a starting point to frame how to approach and prioritize HCR adjustment opportunities.

The materials presented during the June 2025 workshop are available on the HCR Workshop website. Briefly, panelists and speakers provided an overview of current harvest control rules (HCRs) for crab and groundfish and introduced 10 alternative approaches (for details see HCR Shiny APP) as well as a suite of potential performance measures that could be considered by the Council. Upon review, CLIM modelers, the SSC and Council found the most promising candidates for future exploration were HCRs 1, 5, 7, and 10. The Council requested that the work-team should present a summary of the objectives for each HCR and draft projections under current and alternative environmental scenarios for suites of groundfish and crab species to the Plan Teams during the fall specifications cycle for comment and recommendations. Plan Team and additional SSC recommendations will be reviewed by the Council. This document is intended to satisfy this request.

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

		values.	
HCR 9	Forecast informed version of HCR 5	This HCR builds on HCR 5 by using environmental forecasts to dynamically adjust reserves, enhancing ecosystem productivity and resilience to environmental shocks.	2

Figure 1. Subset of stage 1 HCRs for evaluation by ACLIM3 and GOACLIM2 during 2025-2026. Slide courtesy of K. Holsman.

Description of stage 1 HCRs (1, 5, 7 and 10)

Below we describe a general overview of the subset of environmentally linked HCRs that are identified for the first stage of ACLIM and GOACLIM coordinated evaluations in 2025/2026. A more detailed description (including the analytical formulation) of each HCR can be found on the HCR Shiny app (Figure 1) under the “detailed information’ tab (see options on landing page in upper right corner).

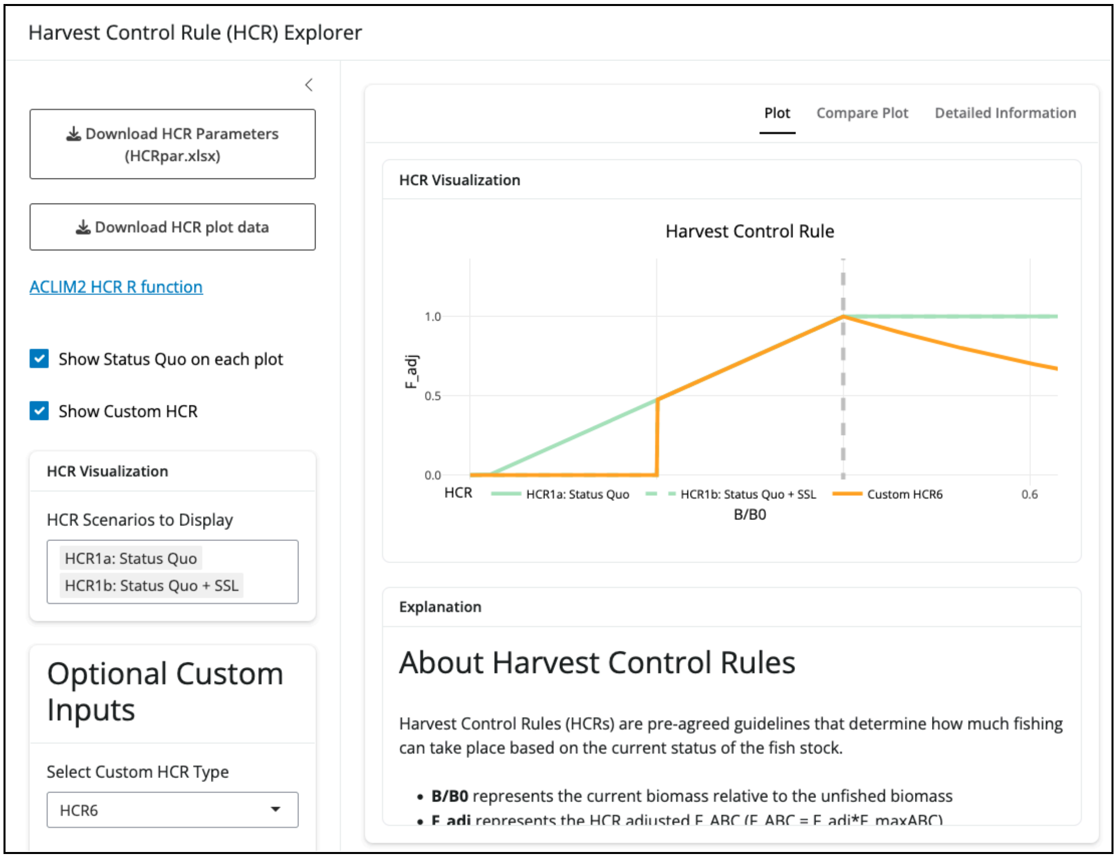


Figure 2. Harvest Control Rule (HCR) Explorer available at https://kholsman.shinyapps.io/HCRshiny/

HCR 1: Status Quo

Simulation goal

This HCR is the baseline (status quo) sloping harvest control rule used for groundfish in Alaska.

Overview HCR 1: Status quo

HCR 1 (Fig. 2 upper left; Fig. 3) is the baseline sloping harvest control rule evaluated in ACLIM phases 1 and 2 (Holsman et al. 2020, Reum et al. 2020, Whitehouse et al. 2020, Punt et al. 2024) and continues to be evaluated during ACLIM3 and GOACLIM2 simulations. It is the Tier 3 HCR currently used by the NPFMC to manage Alaska groundfish stocks, where F_{ABC} is reduced when current biomass falls below target biomass ($B_{40\%}$). There is a cutoff at $B_{20\%}$ for Alaska pollock, Atka mackerel, and Pacific cod where fishing falls to zero to prevent overfishing of these important Steller sea lion prey species. Including the baseline HCR allows us to determine its performance under future EBM, environmental, and climate scenarios.

Details HCR 1: Status quo

This is the basic sloping harvest control rule for groundfish in the EBS (Eq. 1). There is a $B_{20\%}$ cut-off for SSL (Atka, pollock, P. cod). $F_{ABC_{mxc}}$ is the HCR adjusted F rate that corresponds to ABC. The Tier 3 approach is to set the slope of the sloping HCR to $\alpha = 0.05$ and $B_{lim} = 0$ and $B_{target} = B_{40\%}$ or $B_{target} = 0.4$ (i.e., 40% of unfished biomass B_0, as an MSY proxy) for most species except $B_{lim} = 0.2\,B_0$ ($B_{20\%}$) for pollock, Pacific cod and Atka mackerel.

Equation 1. HCR 1: Status quo

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

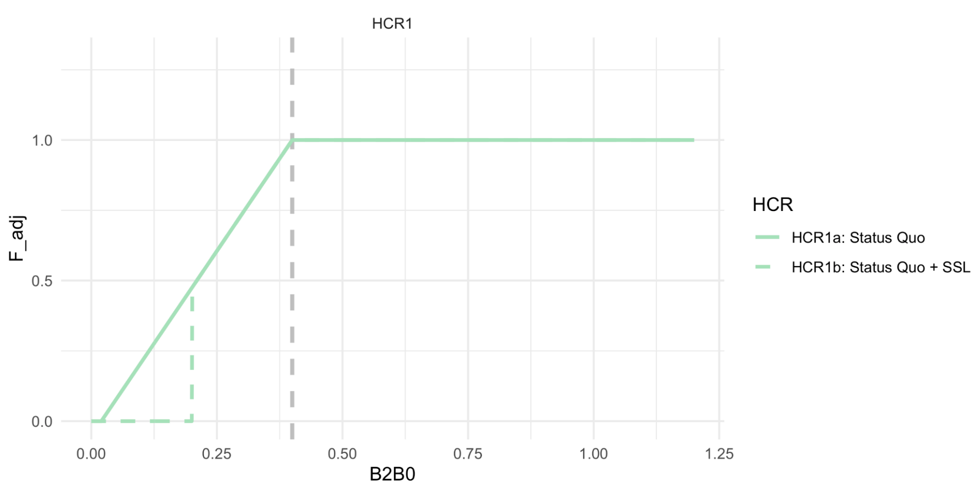


Figure 3. HCR 1: Status quo. This is the Tier 3 Harvest Control Rule, including the cutoff for certain species

HCR 5 & 10: Cap-like benefits / Maximize productivity / increased biomass reserve (buffer environmental shocks)

Simulation goal

HCR 5 is designed to maximize ecosystem and spawning biomass productivity by increasing biomass reserves, creating a buffer against environmental shocks and enhancing long-term sustainability. These HCRs aim to enhance stock robustness to uncertainty in environmental conditions and provide increased potential for higher recruitment levels and growth of fish to larger sizes through preserving higher levels of SSB when the population is abundant.

HCR 10 builds on HCR 5 by applying a proportional reduction in fishing mortality based on biomass levels. It also includes an optional SSB offset, ie. $B_{target+offset}$ (e.g., start slope at $B_{50\%}$).

General overview

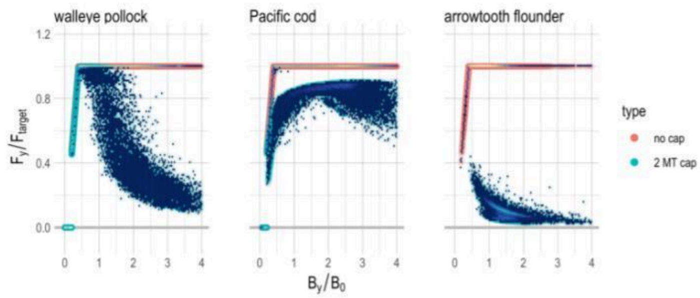
HCR 5 and HCR 10 (Fig. 1 bottom left and bottom right) have the same shape as HCR 1 when SSB <= B_{target}, but allow for a reduction in F_{target} when biomass is above B_{target}. These HCRs are inspired by the effective shape of the realized BSAI pollock harvest rate (F) under current management with the 2 million Ton annual cap on Bering sea groundfish harvest (Holsman et al. 2020, Ianelli et al. 2011). Despite strong environmental effects on stock productivity, BSAI pollock catch was relatively stable through recent marine heatwaves, perhaps due to the combined effect of the HCR and cap on catch above $B_{40\%}$ (i.e., population age structure reserve that helps stabilize ecosystem and stock productivity during unfavorable climate conditions). To test this hypothesis, CLIM modelers aim to test whether using an HCR that follows the shape of the effective pollock F could help impart a similar benefit to other stocks. Again, modelers are testing the hypothesis that by stabilizing catch above some point like B_{target} (left bottom, ski slope shape) or B_{target} with a biomass offset (right; HCR 10; plateau + slope-like shape) the HCR might:

a) increase the age class diversity
b) promote a higher productivity state in the fished biomass
c) promote more larger fish
d) increase ecosystem productivity and therefore fishery productivity

Performance of these HCRs relative to HCR 1 will be evaluated on fishery and management performance metrics described below. Initial results are promising with some indication that HCR 5 and HCR 10 result in an increase of spawning biomass, increased stability in annual catch, more diversity in the spawning biomass age structure, and prevention or forestalling of stock declines/crashes under variable environmental conditions. These are preliminary findings that may change as we expand the suite of models and species being evaluated with HCR 5 and 10. The simulation goals for HCRs 5 and 10 are to better understand the combined influence of the sloping HCR and the ecosystem cap in total catches, as well as evaluating whether buffering fishing mortality by maintaining larger stock sizes has additional benefits to the population against environmental shocks.

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

HCR 5 recreates the realized pollock cap effect on F_{target} when a stock is over B_{target} , which may maximize long-term ecosystem and stock productivity. The steepness of the cap effect could be varied based on vulnerability analyses (e.g., Spencer (2019); Hare (2016)) (or approximated via MSE), with species that are known to be more sensitive to environmental variability, such as Pacific cod (Barbeaux et al. 2022), needing more reserve in the “bank”. Pollock is an example of HCR 5 in practice (via effects of the 2MT cap + sloping HCR; Holsman (2020)).



Supplementary Figure 3. Effective harvest rate F_y under the no cap and 2 MT cap scenarios. Ratio of effective F_y to F_{target} as a function of the ratio of biomass to unfished biomass reference points (B_y/B_0) for each pollock (left), Pacific cod (middle), and arrowtooth flounder (right). Scenarios without the cap (orange; follow the ABC harvest control rule exactly) and scenarios with the 2 MT cap (scatter, teal).

Figure 4. Effective F given cap effects on pollock, Pacific cod, and arrowtooth flounder in the EBS. Figure from Holsman et al. 2020.

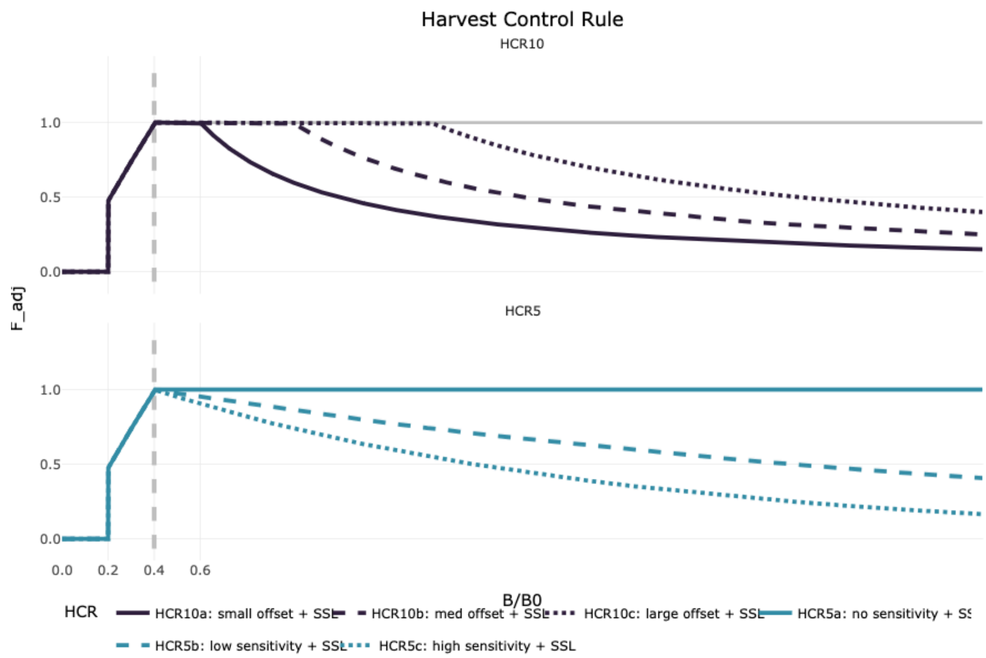


Figure 5. Cap-like HCRs 10 (top) and 5 (bottom). Below or at B_{target} this HCR is the same as the Status Quo (HCR1) Tier 3 Harvest Control Rule, including the cutoff for certain species at low SSB. Above B_{target} catch is stabilized (F is reduced) with (HCR10) or without (HCR5) biomass offsets.

Details: HCR 5

As in HCR 1 with the 20% cutoff for SSL (Eq. 1), set the target to 40% of B_0 ($\alpha = 0.05$, $B_{lim} = B_{20\%}$, $B_{target} = B_{40\%}$). After $B_{40\%}$ have a slowly sloping F proportional to climate sensitivity to mimic realized F rates of pollock under the 2 MT cap. This approach is designed to maximize ecosystem productivity and build a reserve biomass for environmental or climate shocks (sensu Holsman (2020)). In this (Eq. 2) the climate sensitivity buffer γ is a value > 0 that controls the F decay rate (increase in reserve biomass) above B_{target}, i.e., $B_{40\%}$:

Equation 2: HCR 5

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

where, $0 \leq \gamma \leq 1$.

Example: Set the biological reference points as in HCR 1, i.e., 40% of B_0, ($\alpha = 0.05$, $B_{lim} = B_{20\%}$, $B_{target} = B_{40\%}$). Above B_{target} apply the gamma / 2MT cap effects. Shown in Fig. 6, for low sensitivity stocks set γ = 0.1, for highly sensitive stocks set γ = 0.2. We're testing whether this would result in more stable biomass levels and catches through environmental shocks.

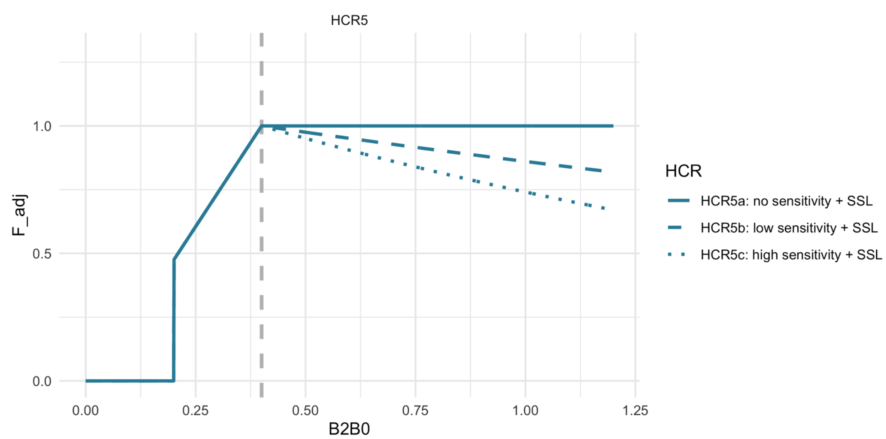


Figure 6: HCR 5: climate sensitivity reserve (buffer shocks). Below or at B_{target} this HCR is the same as the Status Quo (HCR1) Tier 3 Harvest Control Rule, including the cutoff for certain species at low SSB. Above B_{target} catch is stabilized (F is reduced).

Details: HCR 10

As in HCR 5 (Eq.2), HCR 10 aims to recreate the benefits of the cap effect on pollock via implementing and HCR that follows the effective F rates above B_{target}. The steepness of that cap effect here is inverse to SSB, with an optional B_{target} offset (γ, i.e. the point at which F reduction starts), more sensitive species might need a lower gamma (γ) to drive a larger age class reserve resulting in increased abundance of large spawners and benefits to recruitment and stock productivity sooner. BSAI Pollock are an example of the HCR 10 in practice (via effects of the 2MT cap + sloping HCR).

Equation 3: HCR 10

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

where, $0 \leq \gamma \leq 1$.

Example: As in HCR1 (Eq. 1), set the target to 40% of B_0, ($\alpha = 0.05$, $B_{lim} = B_{20\%}$ for amendment 80 species, $B_{target} = B_{40\%}$). Shown in Fig. 7, "small offset" where γ = 0.5, "medium offset" γ = 1.5, and "large offset" where γ = 3. We're testing whether this would result in more stable biomass levels and catches through upcoming environmental shocks.

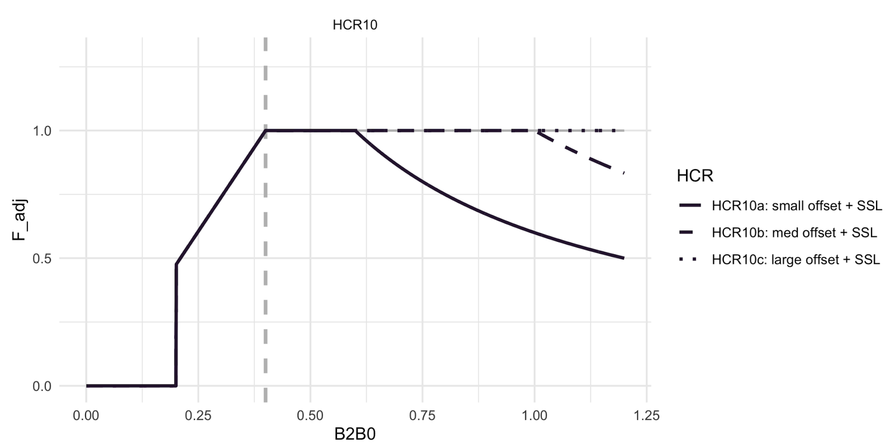


Figure 7: HCR 10: gamma offset on inverse SSB decay rate.

HCR 7: Risk Table Bridging: 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.

HCR 7 is a dynamic HCR that allows for adjustments in the F_{target} and B_{target} with changes in population productivity and is based on recent work of Dr. Paul Spencer on Tier 1 HCRs where he found that the realized F varied with sea surface temperature (SST) in the EBS. We borrowed from that to adjust either F or B_{target} or a combination of both as a function of an index of annual bottom temperature. The goal of this HCR is to evaluate a HCR that allows for a transition from qualitative risk tables to a quantitative approach for species with known productivity variation due to environmental conditions. Currently, HCR 7 is parameterized such that productivity varies with an environmental covariate (Eq. 4). Future work will modify HCR 7 to be informed by retrospective analyses of stock-recruitment relationships.

HCR 7 is of particular interest to CLIM modelers. Preliminary evaluations reveal good performance; catch looks similar to Status quo (HCR 1) but SSB is higher with fewer catch or SSB crashes under high environmental variability (Holsman et al. in prep).

Details HCR 7

The HCR reference points for HCR 7 are adjusted based on variability in spawner-recruitment relationships using a covariate X_y (e.g., SST) such that:

Equation 4: HCR 7

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

such that F_{ABC} is adjusted by covariate x_y according the parameter ω_1 and B_{target} and B_{lim} are adjusted based on the parameters ω_2 and ω_3 such that:

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

and

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

and $\omega_1, \omega_2\ and\ \omega_3 \ge 0.$

For the ACLIM HCR 7 simulations ω_1 and ω_2 will eventually be fit using retrospective analyses of spawner-recruitment relationships across scaled (z-scored) SST (x_y) on EBS pollock by Spencer et al. in prep.

Example: Set the target to 40% of B_0 ($\alpha = 0.05$, $B_{lim} = B_{20\%}$, $B_{target} = B_{40\%}$). In the example below (x_y) = 2.4 and for case 7a all ω values were set to 0.0, in case 7b $\omega_1 = \omega_2 = \omega_3$ = 0.1, and in case 7c ω_1 = -0.1, ω_2 = -0.1, ω_3 = -0.1.

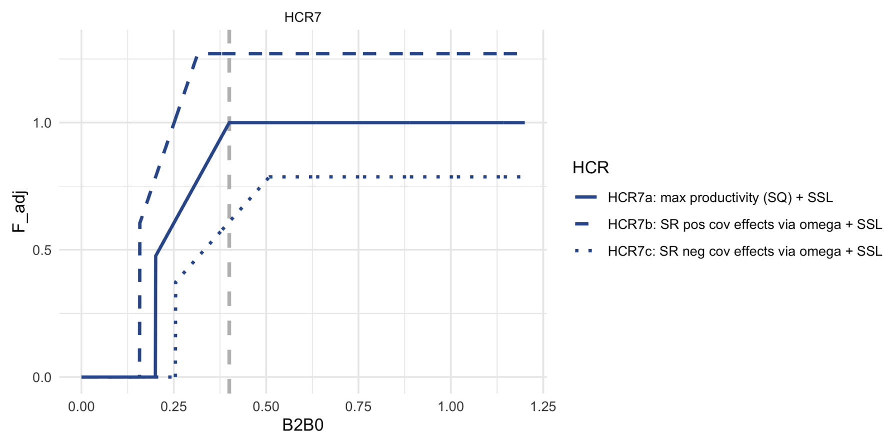


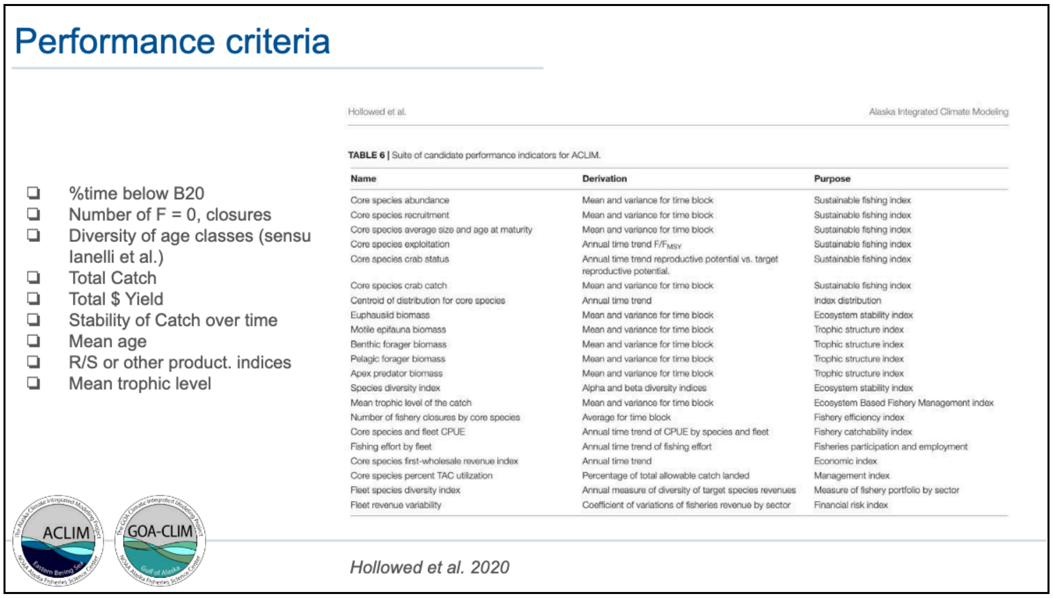
Figure 8. HCR 7:Recruit per spawner biomass variability adjusted HCR.

Alternative ecosystem cap evaluations

As part of GOACLIM we investigated the effectiveness of the 800,000 mt Optimum Yield (OY) cap on annual groundfish catches in the Gulf of Alaska (GOA). Using the Atlantis end-to-end ecosystem model that simulates species interactions and ecosystem processes, we found that projected total GOA groundfish catches does not approach the current OY cap across a range of fishing scenarios and projected environmental conditions (Rovellini et al. 2025). Notably, underexploitation of arrowtooth flounder led to increased predation pressure on pollock and other groundfish, resulting in foregone catches and demonstrating how species interactions can influence total yield even when caps are not binding. These findings suggest that the current 800,000 mt cap is unlikely to constrain future GOA groundfish catches under predator-prey dynamics and projected environmental conditions. Building on this work, we are now developing new functionalities within Atlantis to simulate the implementation of alternative OY cap values, including a mechanistic method to preferentially rescale fishing mortality across stocks under constraining caps. We are currently conducting simulations that use these new functionalities, together with the status-quo HCR, to apply a range of OY caps to the GOA groundfish fisheries under various simulated environmental conditions. The purpose of this work is to evaluate ecosystem and fishery responses to alternative OY cap values, and to alternative fishing rescaling schemes when the cap is constraining. In parallel, OY estimation and simulation tools are being developed in the Rpath/Ecopath with Ecosim (EwE) food web modeling framework for both the GOA and the Bering Sea.

Performance metrics

The ACLIM and GOACLIM teams are in the process of developing a full set of performance metrics for simulation evaluations. We welcome feedback on additional performance metrics that may be of interest.



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

Figure 9: Potential performance metrics for HCR simulation evaluation.

Appendix A: ACLIM and GOACLIM model overview

More information can be found about ACLIM and GOACLIM in the following places:

- ACLIM website: https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project
- GOACLIM website:https://www.fisheries.noaa.gov/alaska/ecosystems/gulf-alaska-climate-integrated-modeling-project
- ACLIM overview (Hollowed et al. 2020): https://www.fisheries.noaa.gov/alaska/ecosystems/gulf-alaska-climate-integrated-modeling-project
- GOACLIM overview for the SSC (2025):https://meetings.npfmc.org/CommentReview/DownloadFile?p=9db617a9-0b9a-4ab9-af00-de13f2fd91ce.pdf&fileName=GOA%20Climate%20Integrated%20Modeling.pdf

These resources provide an overview of the multimodel interdisciplinary approach to the Alaska and Gulf of Alaska Integrated Modeling projects as well as more detailed information about each of the modeling platforms available for HCR and CAP evaluations. The table below further summarizes the core models that can be utilized for HCR evaluations (although this table is not exhaustive, as multiple additional models are being developed and used within the CLIMs for additional purposes).

Table 2: Overview of CLIM models presently available for HCR and CAP evaluations in Stage 1 evaluations.

Model Name	EBS	GOA	Bottom-up dynamics included	Top- down dynamics included	Social/ Econ Included	Model type	Examples
ROMS-NPZ	X	X	X			Oceanographic and lower trophic (nutrient to zooplankton)	Hermann et al. 2016, 2019, 2021; Cheng et al. 2021; Kearney et al. 2020, Pilcher et al. 2019;
CE-Single spp models	X	X				Climate enhanced single species stock assessment models	Ianelli et al. 20XX; Spencer et al. 2019;
CEATTLE	X	X	[optional in rec; growth]	X	X (with ATTACH)	Multispecies stock assessment model	Holsman et al. 2016, 2020; Adams et al. 2022
Atlantis		X	X	X		End-to-end ecosystem model	Rovellini et al. (2024, 2025)
Rpath/EwE	X	X	X	X		Production to Biomass based end-to-end food-web model	Whitehouse et al. 2020;
MIZER	X (in progress)	X	X	X		Size-spectrum based food-web model	Reum et al. 2019b,c, 2020
SDMs	X	X (in progress)	X			Species distribution models	Goodman et al. 2024; Bigman et al. 2023; Kristiansen et al. in prep
ATTACH	X			X		Social-economic model of TAC and Catch	Faig et al. 2019
Conceptual models /	X	X	X	X	X	Semi-quantitative or qualitative	Reum et al. 2019a; Wise et al.

QNMs						network models	in prep
Food and nutrition security	X (in progress)					Social	Wise et al. in prep

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Appendix A. Suite of candidate performance indicators for ACLIM (from Hollowed et al. 2022).

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/FMSY	Sustainable fishing index
Core species stock status	Annual time trend reproductive potential vs. target reproductive potential	Sustainable fishing index
Core species 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