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AD HOC WORKING GROUP TO STRENGTHEN THE DIALOGUE AMONG SCIENTISTS, MANAGERS AND OTHER STAKEHOLDERS ON MANAGEMENT STRATEGY EVALUATION (WORKING GROUP ON MSE)

1st Informal MEETING

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PRELIMINARY RESULTS OF THE MANAGEMENT STRATEGY EVALUATION FOR BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN

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1. INTRODUCTION

An open-source R package (*IATTCMSE*) has been developed to conduct management strategy evaluation (MSE) for tropical tunas in the eastern Pacific Ocean (EPO) and is publicly available at https://github.com/HaikunXu/IATTCMSE. The package has been rigorously tested for bigeye tuna in the EPO using the suite of reference models included in the 2024 benchmark stock assessment (SAC-15-02). This report presents preliminary results intended to support discussion at the second MSE workshop.

Since the previous meeting of the MSE working group (MSEWG) in December 2025, additional analyses and simulations have been conducted to address comments provided during that meeting. These comments fall into three broad categories: performance indicators, harvest control rules (HCRs), and MSE specifications. In response to comments on performance indicators, the MSE code was updated to generate maximum sustainable yield (MSY)–related quantities, enabling calculation of the probability that spawning biomass exceeds $50\% S_{MSY}$ and the probability that the stock remains in the green quadrant of the Kobe plot ($S > S_{MSY}$ and $F < F_{MSY}$). Projected longline catch and catch-per-unit-effort (CPUE) is compared with historical levels. Projected total longline catch was also compared with the current total longline quota specified in Resolution C-21-04. The explicit inclusion of a limit reference point ($50\% S_{MSY}$) in the HCR was also explored, and its effects on MSE performance were evaluated. With respect to MSE specifications, implementation error was incorporated into the management module to assess its influence on simulation outcomes.

In addition to addressing the comments from the previous meeting, the staff evaluated the performance of the eight candidate HCRs identified for prioritization in the previous meeting to facilitate finalization of the set of HCRs to be tested for bigeye tuna in the EPO.

2. MSE FRAMEWORK

2.1. Operating models

The operating models (OMs) used in the MSE consist of the 36 reference models included in the 2024 risk analysis (ensemble of stock assessment models). For the purposes of the MSE, these models were updated in 2025 by incorporating one additional year of data to better reflect current stock status and fishery conditions. The reference models address three major sources of uncertainty within a hierarchical framework: (1) uncertainty in the misfit to the length-composition data for the longline fishery under the assumption of asymptotic selectivity, (2) uncertainty in the rate of effort creep in the longline fishery, and (3) uncertainty in the steepness of the stock–recruitment relationship

Level 1 hypothesis: Four models structures are used to address the misfit to the longline composition data under the assumption of asymptotic selectivity (hypotheses names in parentheses): (1) ignoring the issue (Fix); (2) estimating the growth curve with a prior on L_{inf} (Gro); (3) estimating dome-shape selectivity curve for the longline fishery that is assumed to have asymptotic selectivity (Sel); and (4) estimating a scaler for the natural mortality vector (Mrt). Each model structure is equally weighted.

Level 2 hypothesis: Three annual rates of increase in longline catchability (0%, 1%, and 2%) are considered to represent uncertainty in effort creep. Because bigeye tuna is the primary target species of the Japanese longline fleet in the EPO, catchability is expected to increase over time as fishing skill and technology improve. Based on recommendations from the review panel (RVMTT-01-RPT), a 1% annual increase was suggested, with 0% and 2% included to bracket this uncertainty. Each annual rate is equally weighted.

Level 3 hypothesis: Three steepness values (1.0, 0.9, and 0.8) are included to address the uncertainty in the shape of the stock-recruitment relationship. The three steepness values are weighted based on expert judgement from the risk analysis for the last benchmark assessment (SAC-11 INF-F).

2.2. Estimation models

The Estimation model (EM) used in the MSE is the ASPM_Rdevs+ version of the base reference model (Fix-1-1), selected to ensure rapid convergence. ASPM_Rdevs+ refers to the age-structured production model that includes recruitment deviations and is fitted to the abundance index as well as length composition data for the abundance index (assuming dome-shape selectivity) and for one longline fishery (assuming asymptotic selectivity).

Estimates of fishing mortality and dynamic spawning biomass ratio (dSBR) from the EM are bias-adjusted using terminal-year values from the OM ensemble. Specifically, scaling factors of 0.833 and 1.163 are applied to fishing mortality and dSBR, respectively, when implementing the HCR. These factors are calculated as the ratio of the weighted terminal estimates across all OMs to the terminal estimate from the EM. This tuning approach adjusts EM estimates to be consistent with the OM ensemble.

3. RESULTS

3.1. Performance indicators

Several additional performance indicators were calculated in response to MSEWG feedback. Under the staff HCR, the probability that spawning biomass exceeds $50\%S_{MSY}$—a candidate limit reference point intended to have a very low probability of being breached—is 100% (Figure 1). The probability that the stock remains in the green quadrant of the Kobe plot ($S > S_{MSY}$ and $F < F_{MSY}$) is 92% (Figure 2). Projected Japanese longline CPUE is approximately twice the historical average observed during 2017–2019 (Figure 3).

3.2. Longline catch quota

Under the staff HCR, the mean total longline catch is projected to be close to the current total longline quota specified in Resolution C-21-04 (Figure 4). Annual quotas for China, Japan, Korea, Chinese Taipei, and the United States are 2,507 t, 32,372 t, 11,947 t, 7,555 t, and 750 t, respectively, summing to approximately 55,000 t. Given interannual variability in recruitment and catch, there is a high probability that total longline catch could exceed the current quota in some of future years if longline effort changes at a rate similar to purse-seine effort.

3.3. Limit reference point

To evaluate the effect of explicitly incorporating a limit reference point into the HCR, a value of $50\%S_{MSY}$ was added to one candidate HCR (Figure 5). Across the 36 OMs, the mean ratio of $50\%S_{MSY}$ to unfished spawning biomass (S_0) is close to 0.1. Accordingly, the modified HCR specifies zero fishing mortality when dSBR < 0.1, a linear decrease in fishing mortality to zero when dSBR is between 0.3 and 0.1, and fishing mortality equal to the target when dSBR exceeds 0.3. Incorporating the limit reference point steepens the HCR slope between dSBR values of 0.1 and 0.3, resulting in more conservative management actions (Figure 5).

3.4. Implementation error

In the EPO, the purse-seine fishery is managed through effort controls that are assumed to be linearly related to the number of days the fishery is open. However, factors such as fleet capacity, the bigeye individual vessel threshold, abundances of skipjack and yellowfin tuna, the number of active fish aggregating devices (FADs), can cause fishing mortality for bigeye tuna to deviate from this theoretical linear relationship. To account for such deviations, implementation error was incorporated into the MSE simulations, modeled as a lognormally distributed error with no bias and a standard deviation of 0.1.

Including implementation error has a noticeable effect on MSE outcomes. It produces a more optimistic mean dSBR trajectory in most years, likely due to asymmetric effects of fishing mortality deviations (Figure 6), and generates more extreme dSBR trajectories that may influence safety-related performance indicators, such as the probability of breaching limit reference points.

3.5. Cap for closure changes

All candidate HCRs proposed by the MSEWG include a 10-day cap on changes in closure duration between consecutive management cycles. In addition, these HCRs specify that the cap is removed when the stock is below the control point to allow for rapid response to depletion. The performance of three HCRs incorporating this stock-status-dependent cap was evaluated (Table 1).

For the first HCR, the stock remains consistently above the control point so the 10-day cap is applied throughout the seven management cycles. The second HCR is slightly more conservative, resulting in occasional stock levels below the control point and temporary removal of the cap. It leads to some large closures of exceeding 100 days (Figure 7). The third HCR is the most conservative among the three candidates and since the estimated current dSBR (approximately 0.25) is below the control point (0.3), the cap is removed in the first cycle, increasing closure duration from 72 days to more than 130 days (Figure 7). Although the stock subsequently rebuilds above the control point, the closure remains excessively conservative because reductions are limited to 10 days per cycle, preventing rapid convergence to the target level. Overall, complete removal of the cap when the stock is below the control point results in management instability for HCR2 and inflexibility for HCR3.

An alternative asymmetric cap of 10 days when the stock is above the control point and 20 days when it is below was also tested. This approach allows faster responses to depletion while preserving stability. For HCR2, the asymmetric cap produces minimal changes in dSBR but improves stability in closure duration (Figure 8). For HCR3, it enables the stock to reach the target level within two cycles, substantially outperforming the no-cap-below-control-point scenario (Figure 8).

3.6. Comparison of eight candidate HCRs

The eight candidate HCRs identified for prioritization in the previous meeting (Figure 9) were compared using a very limited number of iterations (72 per HCR) for illustrative purposes. All HCRs assume that the implementation error is lognormally distributed with no bias and a standard deviation of 0.1, and that the 10/20-day asymmetric cap is applied when the stock is above/below the control point, respectively.

A range of performance indicators were calculated for each HCR (Table 2). All HCRs result in a 100% probability that the stock remains above the two hard limit reference points (0.077%S_0 and 50%S_{MSY}), and a near-100% probability (>97.4%) of remaining above the soft limit reference point (20%dSBR). The probability of remaining in the green quadrant of the Kobe plot exceeds 94.2% for all HCRs. The staff HCR (F30–S20) is the most aggressive, yielding the shortest average closure duration (41 days; Figure 11) and the highest average total catch (104,281 t; Figure 12). In contrast, the most conservative HCR (F40–S40) produces the longest average closure (87 days) and the lowest average catch (97,285 t). Across all HCRs, interannual variability in total catch is approximately 8%, and the mean change in closure duration between cycles is about 10 days.

4. DISCUSSION

Longline catch quota

Simulation results indicate that longline CPUE for bigeye tuna is expected to reach approximately twice the historical average observed during 2017–2019. Given that bigeye tuna is the primary target species of the tropical EPO longline fishery, increases in fishing effort in response to higher abundance and profitability are plausible. Even without increases in effort, simulations suggest a substantial probability that future longline catch could, at least in a portion of future years, exceed the quota specified in Resolution C-21-04. This issue requires further discussion by the MSEWG when developing the harvest strategy.

Limit reference point

Preliminary results for the eight candidate HCRs indicate a zero probability of breaching the two hard limit reference points proposed by the MSEWG (0.077SBR and 50%S_{MSY}). If an asymmetric cap on closure changes is used to enable rapid responses to depletion before reaching limit reference points, explicit inclusion of a limit reference point in the HCR may be unnecessary. Moreover, incorporating a limit reference point increases the number of HCR parameters (e.g., the limit reference point and its associated fishing mortality), further complicating negotiations surrounding the harvest strategy for bigeye tuna in the EPO.

Implementation error

Results demonstrate that implementation error has asymmetric effects on dSBR and can produce more extreme trajectories. Because fishing mortality is influenced by factors beyond formal management measures (i.e., fishery closure), including implementation error enhances the realism and robustness of MSE outcomes. A remaining question for further discussion is the appropriate magnitude of implementation error. There is no quantitative estimate of that for EPO purse-seine fisheries at this stage.

Cap for closure changes

Simulations show that fully removing the cap on closure changes when the stock is below the control point can lead to undesirable outcomes, including excessively large closures and overly conservative management after stock rebuilding. In contrast, an asymmetric cap of 10 days above and 20 days below the control point balances responsiveness and stability. Under this approach, faster responses to depletion are possible, and once the stock has been rebuilt, management measures can return to the previous level within at most two management cycles.

Candidate harvest control rules

The eight candidate HCRs evaluated span a wide range of harvest strategies, with target points between 0.3 and 0.4 and control points between 0.2 and 0.4. These HCRs differ notably in average closure duration (41–87 days) and average annual total catch (97,285–104,281 t). However, differences among HCRs in the variability of annual total catch is relatively small, likely because the same asymmetric cap on management changes (10 days above and 20 days below the control point) is applied across all candidates. Exploration of a broader contrast in catch variability would require alternative cap scenarios for fishery closures.

TABLES

TABLE 1. Harvest control rules tested for the cap for closure change.
TABLA 1. Reglas de control de extracción probadas con respecto al límite de cambios en la veda.

Component	HCR1	HCR2	HCR3
F_{max}	$F_{30\%}$	$F_{40\%}$	$F_{30\%}$
$S_{control}$	$S_{20\%}$	$S_{30\%}$	$S_{30\%}$
Max change in closure ($S > S_{control}$)	10 days	10 days	10 days

TABLE 2. Performance indicators for each harvest control rule summarized across all iterations, simulation years, and operating models. From left to right: HCR specifications, average annual total catch (mt), average annual variability in annual total catch (%), probability of spawning biomass ratio > 0.077 (%), probability of dynamic spawning biomass ratio > 0.2 (%), probability of dynamic spawning biomass > 50% dynamic spawning biomass at the level of maximum sustainable yield (%), probability of being in the green quadrant of the Kobe plot (%), and average closure (day).

TABLA 2. Indicadores de desempeño para cada regla de control de extracción resumidos en todas las iteraciones, años de simulación y modelos operativos. De izquierda a derecha: especificaciones de la RCE, captura total anual promedio (t), variabilidad anual promedio de la captura total anual (%), probabilidad de cociente de biomasa reproductora > 0.077 (%), probabilidad de cociente de biomasa reproductora dinámica > 0.2 (%), probabilidad de biomasa reproductora dinámica > 50% biomasa reproductora dinámica al nivel del rendimiento máximo sostenible (%), probabilidad de estar en el cuadrante verde de la gráfica de Kobe (%), y veda promedio (día).

HCR	Catch	AAV in catch	Prob SBR > 0.077	Prob dSBR > 0.2	Prob S > 50%SMSY	Prob Kobe in green	Closure
F30-S20	104281	7.9	100	97.4	100	94.2	41
F30-S30	103829	7.9	100	97.8	100	94.7	45
F35-S20	102677	8.0	100	98.4	100	95.5	52
F35-S25	102587	8.0	100	98.4	100	95.5	53
F35-S30	99609	7.9	100	98.8	100	96.8	74
F40-S20	99410	8.0	100	98.8	100	96.7	74
F40-S30	97940	8.0	100	99.1	100	97.4	84
F40-S40	97285	8.1	100	99.2	100	97.4	87

FIGURES

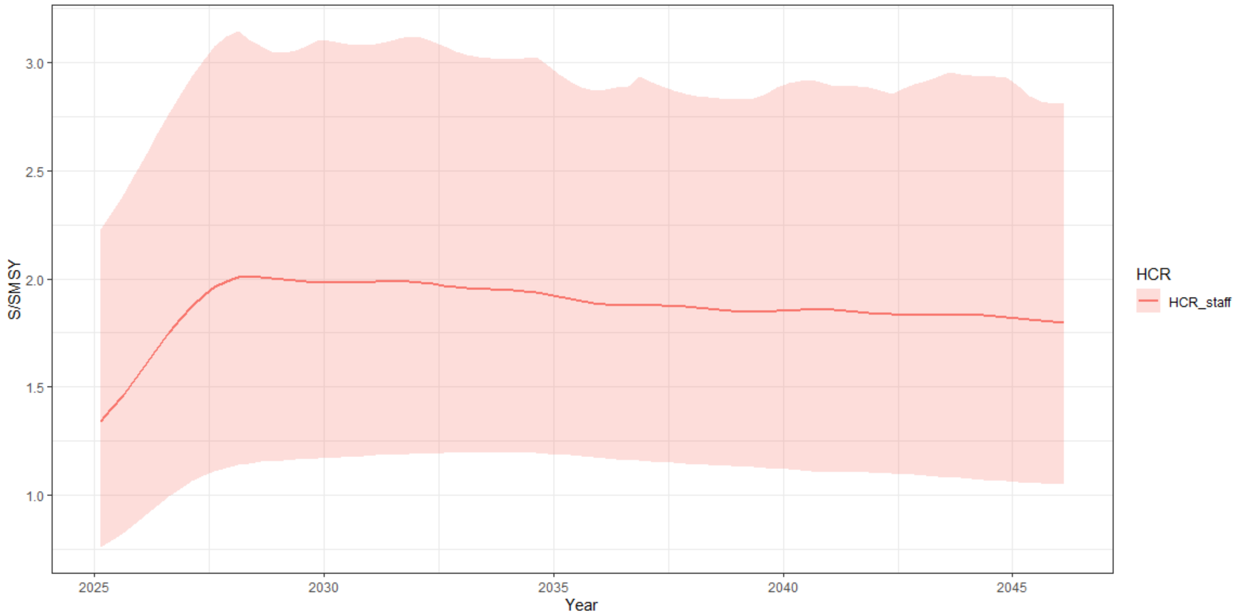

FIGURE 1. The ratio of spawning biomass to the spawning biomass at the maximum sustainable yield for bigeye in the eastern Pacific Ocean. The red line and ribbon represent the mean value and the 80% confidence interval, respectively.

FIGURA 1. La razón entre la biomasa reproductora y la biomasa reproductora en el rendimiento máximo sostenible para el patudo en el Océano Pacífico oriental. La línea roja y la cinta representan el valor promedio y el intervalo de confianza del 80%, respectivamente.

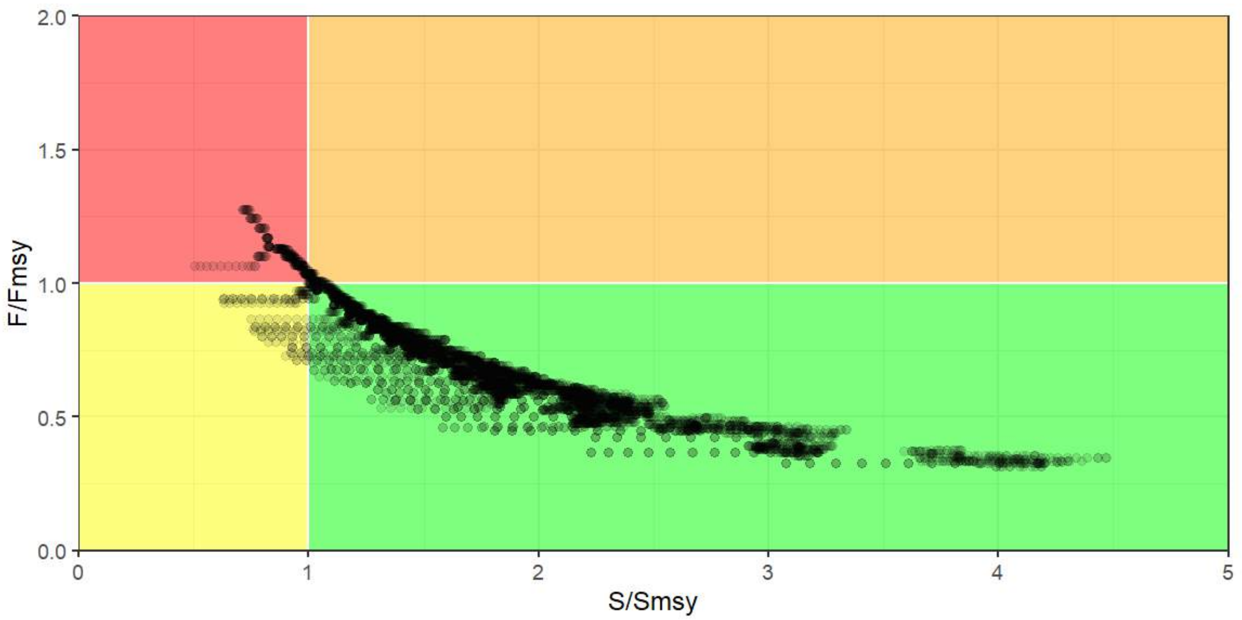

FIGURE 2. The Kobe plot for bigeye simulated under the staff's harvest control rule in the MSE.
FIGURA 2. La gráfica de Kobe para el patudo simulado bajo la regla de control de extracción del personal en la EEO.

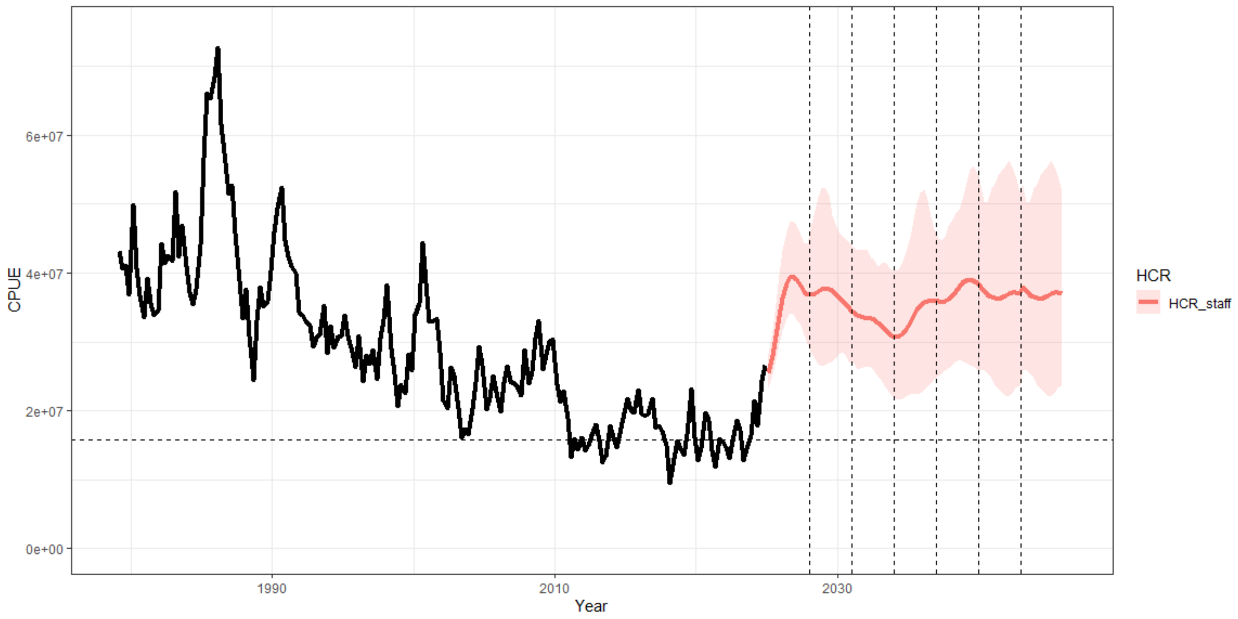

FIGURE 3. The historical (black line) and projected (red line and ribbon) Japanese longline CPUE for bigeye in the eastern Pacific Ocean. The horizontal dashed line represents the average value for 2017-2019 and the six vertical dashed lines mark the boundary of the seven management cycles.

FIGURA 3. La CPUE palangrera japonesa histórica (línea negra) y proyectada (línea roja y cinta) de patudo en el Océano Pacífico oriental. La línea horizontal discontinua representa el valor promedio para 2017-2019 y las seis líneas verticales discontinuas marcan el límite de los siete ciclos de ordenación.

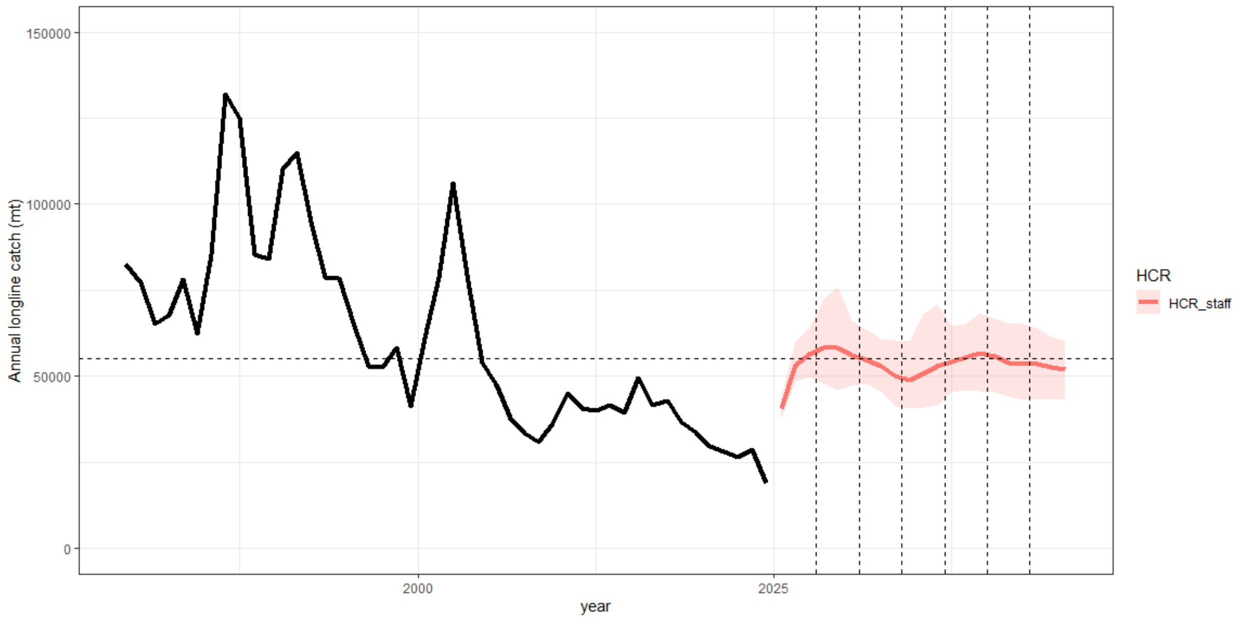

FIGURE 4. The historical (black line) and projected (red line and ribbon) annual longline catch for bigeye in the eastern Pacific Ocean. The horizontal dashed line represents the total longline catch quota specified in C-21-04 and the six vertical dashed lines mark the boundary of the seven management cycles.

FIGURA 4. Captura palangrera anual histórica (línea negra) y proyectada (línea roja y cinta) de patudo en el Océano Pacífico oriental. La línea horizontal discontinua representa la cuota total de captura de palangre especificada en la res. C-21-04 y las seis líneas verticales discontinuas marcan el límite de los siete ciclos de ordenación.

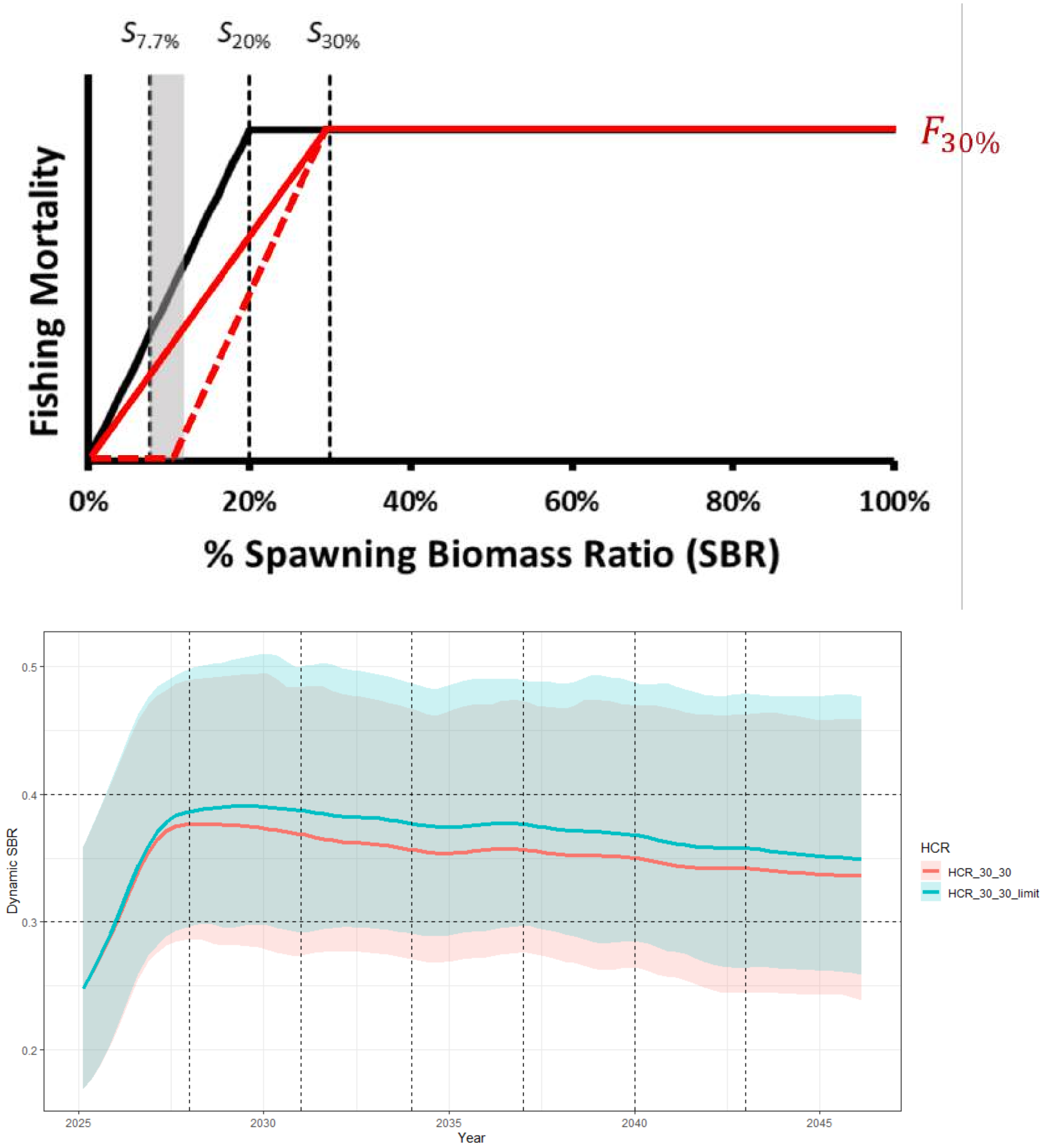

FIGURE 5. Comparison of simulated dynamic spawning biomass ratio under two similar harvest control rules (red solid line vs red dashed line in the top panel), only one of which includes a limit reference point of $0.5S_{MSY}/S_0$ (i.e., 0.1).

FIGURA 5. Comparación del cociente de biomasa reproductora dinámica simulado bajo dos reglas de control de extracción similares (línea continua roja vs línea discontinua roja en el panel superior), solo una de las cuales incluye un punto de referencia límite de $0.5S_{RMS}/S_0$ (es decir, 0.1).

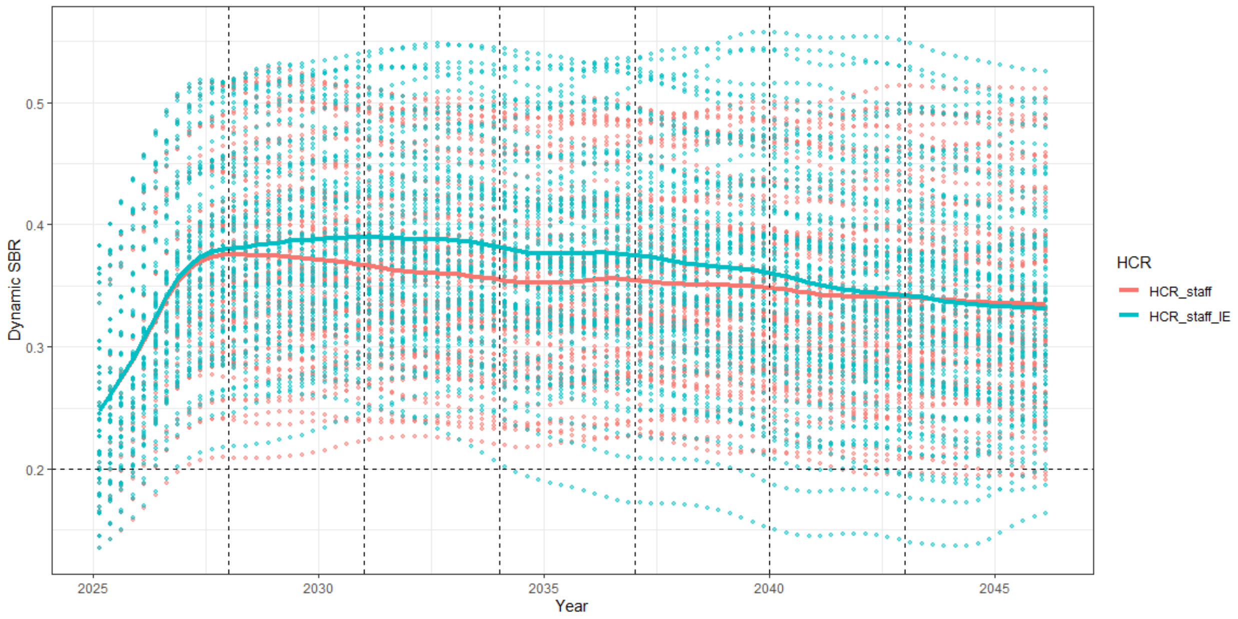

FIGURE 6. Dynamic spawning biomass ratio for bigeye in the eastern Pacific Ocean simulated under identical harvest control rule and recruitment deviations with (blue) and without (red) implementation error. Doted lines represent individual iterations and solid lines represent the average across all iterations.

FIGURA 6. Cociente de biomasa reproductora dinámica para el patudo en el Océano Pacífico oriental simulado bajo reglas de control de extracción idénticas y desviaciones de reclutamiento con (azul) y sin (rojo) error de implementación. Las líneas punteadas representan iteraciones individuales y las líneas continuas representan el promedio de todas las iteraciones.

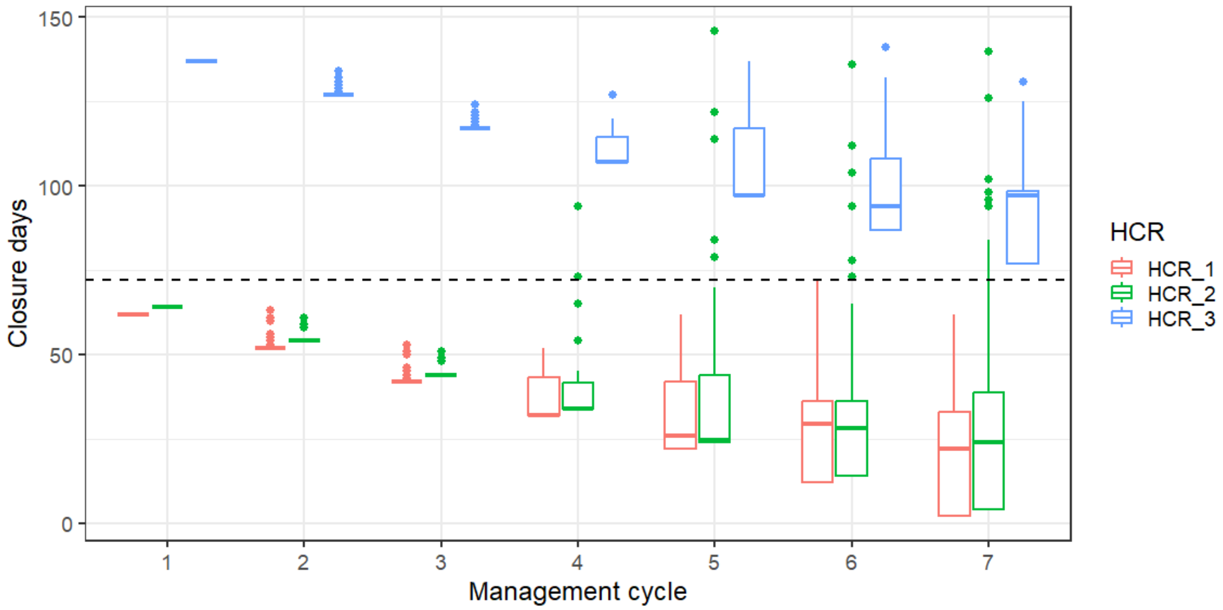

FIGURE 7. Boxplot for the number of closure days predicted for the seven management cycles under the three harvest control rules listed in Table 1.
FIGURA 7. Diagrama de caja del número de días de veda previstos para los siete ciclos de ordenación bajo las tres reglas de control de extracción que figuran en la Tabla 1.

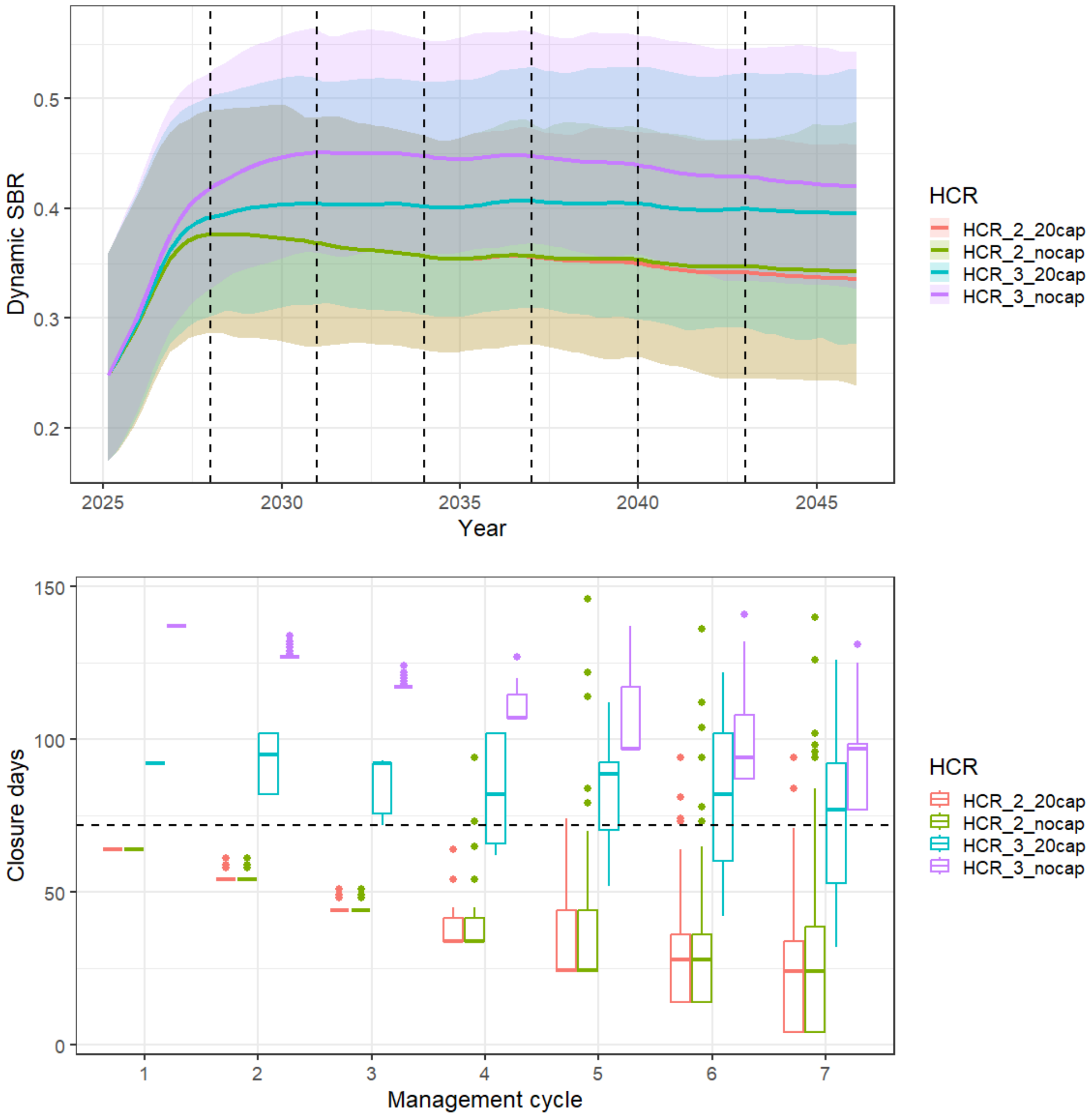

FIGURE 8. Comparison of dynamic spawning biomass ratio (top) and closure days (bottom) simulated for the second and third harvest control rules in table 1 under either a 20-day cap or no cap for the stock below the control point.

FIGURA 8. Comparación del cociente de biomasa reproductora dinámica (arriba) y los días de veda (abajo) simulados para la segunda y tercera regla de control de extracción de la Tabla 1 con un límite de 20 días o sin límite para la población por debajo del punto de control.

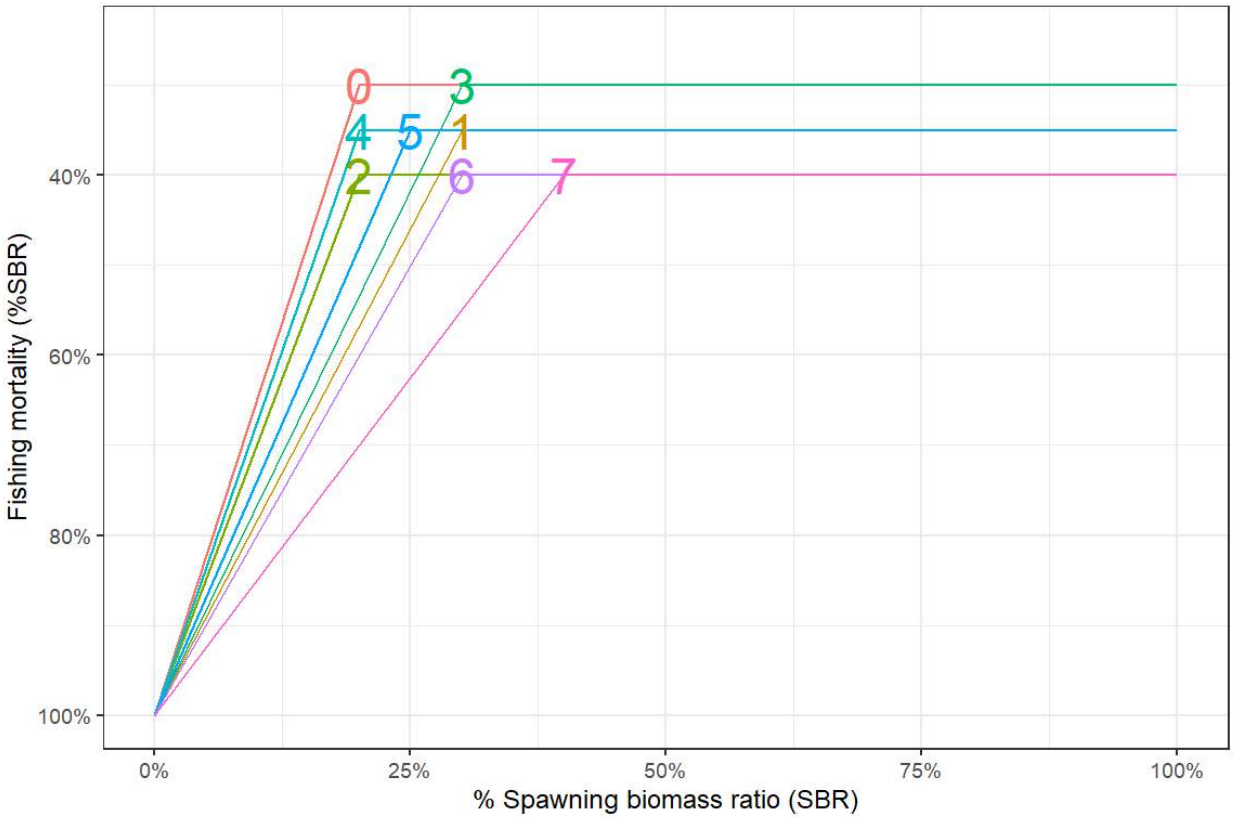

FIGURE 9. The eight candidate harvest control rules identified for prioritization in the previous MSEWG meeting.

FIGURA 9. Las ocho reglas de control de extracción candidatas identificadas como prioritarias en la reunión anterior del GTEEO.

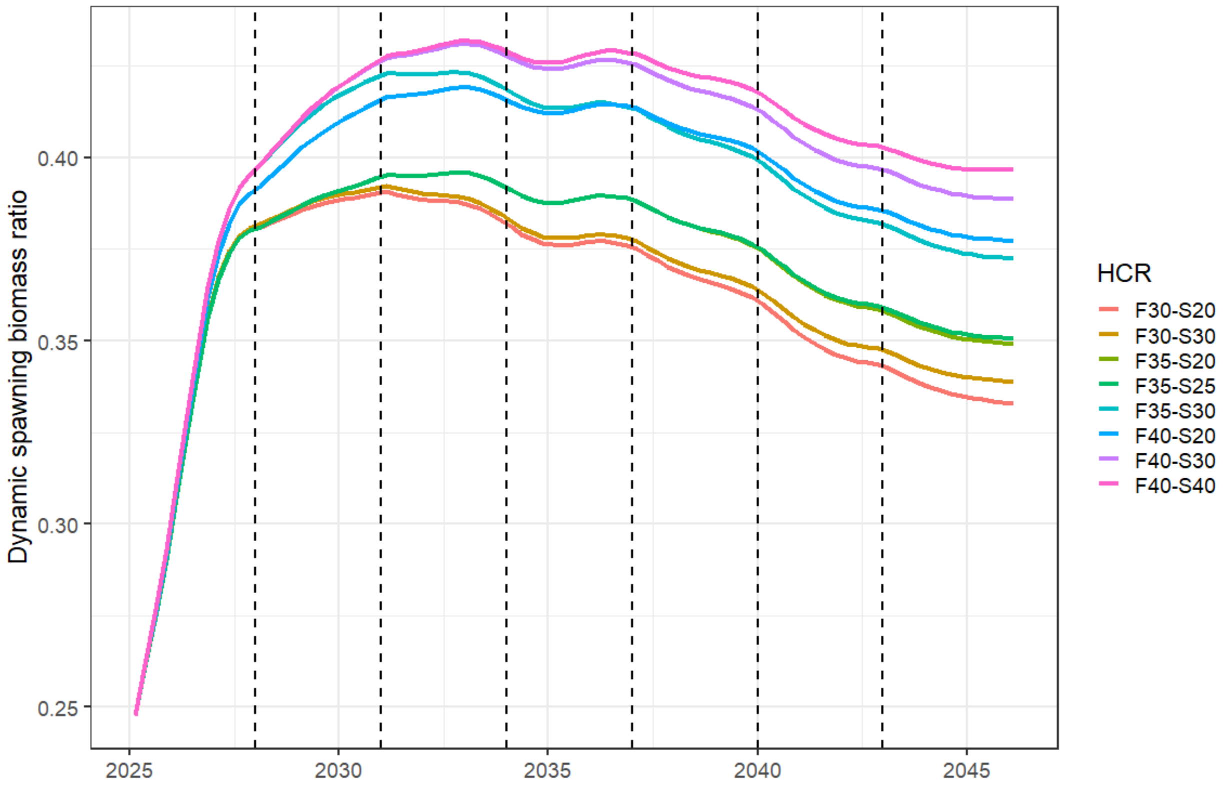

FIGURE 10. Average dynamic spawning biomass ratio simulated for bigeye under each candidate harvest control rule.

FIGURA 10. Promedio del cociente de biomasa reproductora dinámica simulado para el patudo bajo cada regla de control de extracción candidata.

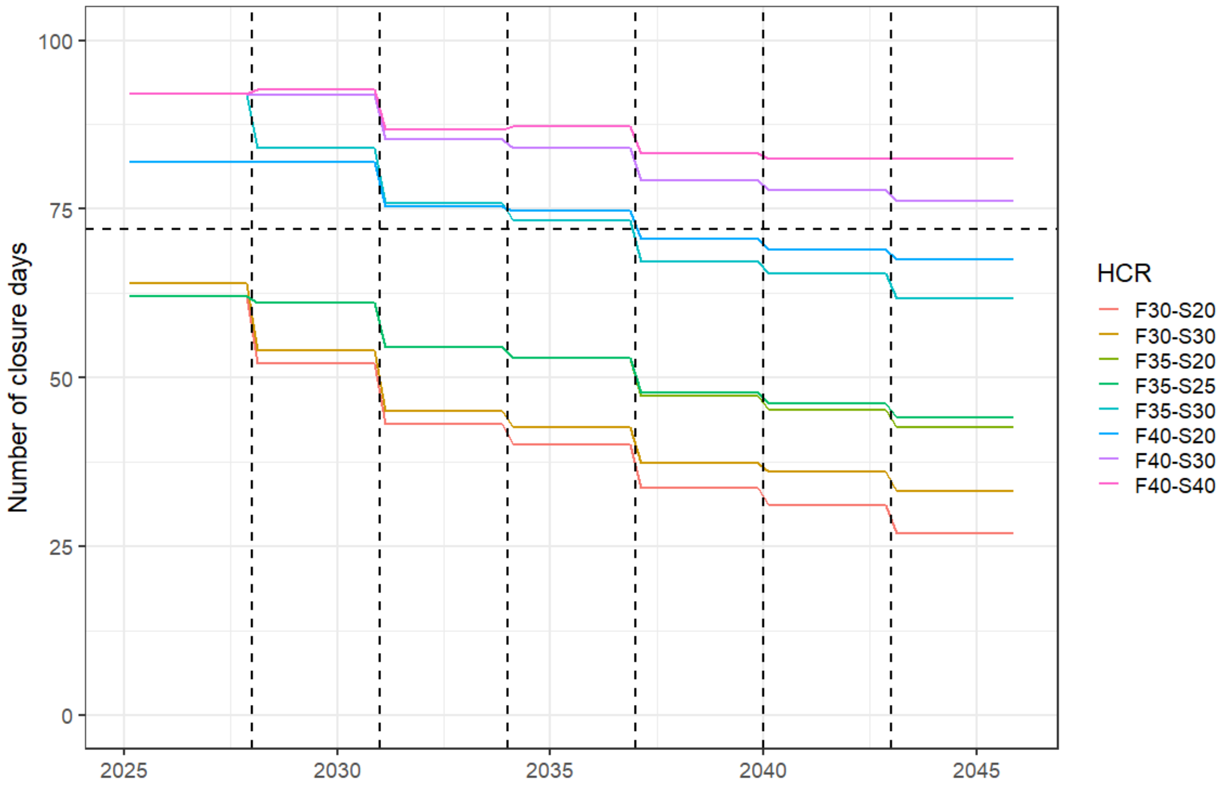

FIGURE 11. Average number of closure days simulated for bigeye under each candidate harvest control rule.

FIGURA 11. Número promedio de días de veda simulados para el patudo bajo cada regla de control de extracción candidata.

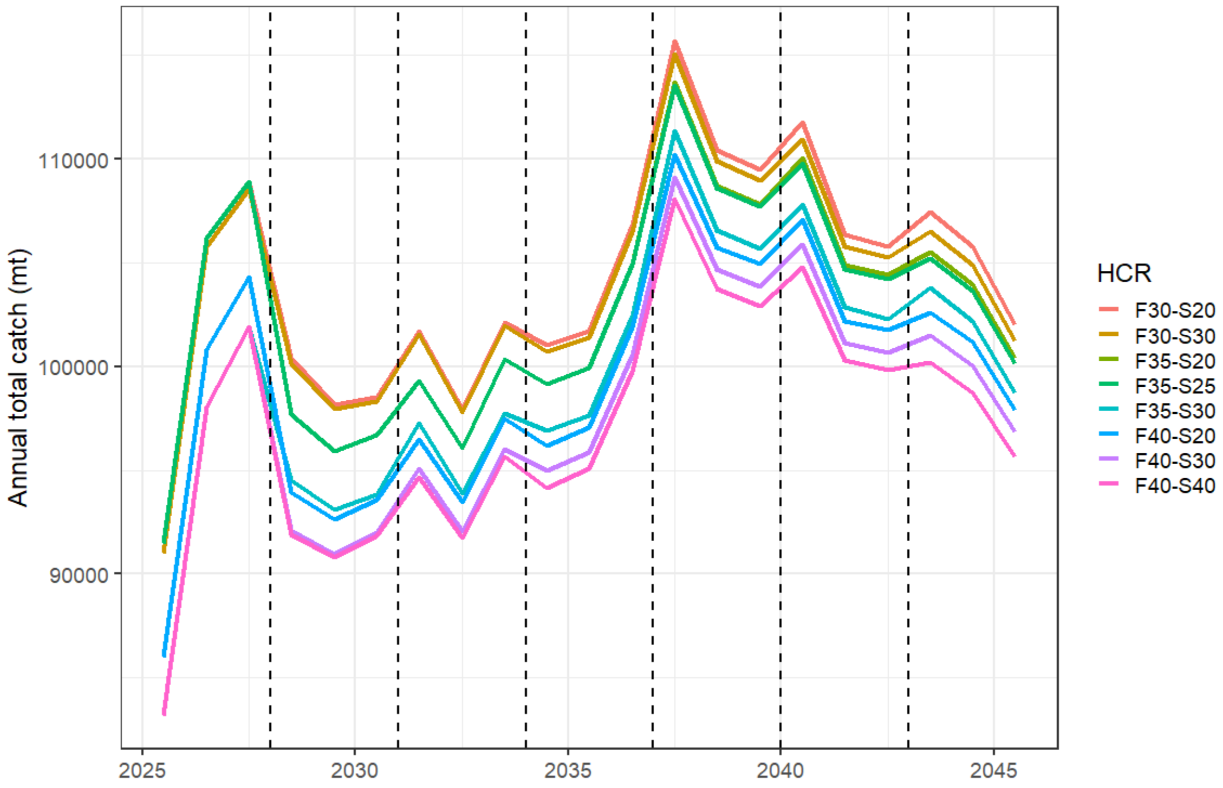

FIGURE 12. Average annual total catch (mt) simulated for bigeye under each candidate harvest control rule.

FIGURA 12. Captura total anual promedio (t) simulada para el patudo bajo cada regla de control de extracción candidata.