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RISK ASSESSMENT OF SKIPJACK TUNA IN THE EASTERN PACIFIC OCEAN

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Contents

SUMMARY

1. In 2024, a benchmark stock assessment for skipjack tuna in the eastern Pacific Ocean (EPO) was performed using an integrated statistical age-structured catch-at-length model in Stock Synthesis.
2. A conservative proxy target for the spawning biomass ratio (SBR) was set at 0.3, with the corresponding fishing mortality ($F_{\text{MSY proxy}}$) established as the management reference point. The limit reference point was defined as an SBR of 0.077.
3. A reference model was constructed using the most plausible assumptions, supplemented by sensitivity analyses to evaluate the robustness of results against variations in model assumptions and data sets.
4. Sensitivity analyses encompassed seventeen models varying in five key parameters: growth, selectivity, tagging absolute biomass, indices of abundance, and steepness of the stock-recruitment relationship.
5. A risk assessment conducted herein incorporates both the reference and seventeen sensitivity models to provide management advice, treating all models with equal weight.
6. The risk analysis reveals unimodal probability distributions for key management metrics, indicating:
    a. A 4% probability that the spawning biomass at the start of 2024 was below 30% of the unexploited level, according to the dynamic SBR ($\text{dSBR}_{\text{MSY proxy}}$).
    b. Zero probability that average fishing mortality during 2021-2023 exceeded the level associated with the target biomass ($F_{\text{MSY proxy}}$).

c. Less than 1% probability that the spawning biomass at the start of 2024 was below the limit reference point (S_{limit}).

1. INTRODUCTION

This report presents the results of a risk assessment of skipjack tuna (SKJ; *Katsuwonus pelamis*) in the eastern Pacific Ocean (EPO), based on the benchmark assessment conducted in 2024 (SAC-15-04).

1.1. Background

The 2024 benchmark assessment for skipjack covered the period from 2006 to 2023, using an integrated statistical age-structured catch-at-length model in Stock Synthesis (Methot and Wetzel 2013; version 3.30.22.beta). This marked a significant update from the initial interim assessment conducted in 2022, reflecting substantial advancements in the assessment methodologies. Of great relevance to the assessment was the incorporation of biomass indices—both relative and absolute—derived from a spatiotemporal approach applied to extensive tagging data from the Regional Tuna Tagging Program in the EPO (RTTP-EPO 2019-2020, Project E.4.a; SAC-16 INF-G).

A reference model was developed based on the most plausible assumptions, alongside a series of sensitivity analyses to explore the effects of changes in model assumptions. The reference model assumptions included:

a) Unavailability of large fish to the purse-seine fishery, reflecting dome-shaped selectivity.

b) Modeling of longline fishery selectivity using a cubic spline, with constant selectivity beyond 80 cm.

c) Constant natural mortality post 65 cm in length.

d) Asymptotic length set at 83 cm.

e) Age at 37 cm set at 2 quarters.

f) The coefficient of variation (CV) of length-at-age described by a linear function of length, with 0.09 for age zero and 0.06 for age 20 quarters.

g) Recruitment independence from stock size (steepness h = 1), estimated quarterly.

h) Quarterly recruitment variability modeled around the average, defined by a lognormal distribution with a standard deviation of 0.6, applying a single iteration of bias correction as per Methot and Taylor (2011) implemented in r4ss.

i) The echosounder buoy-based index of relative abundance and tagging-based absolute biomass selected by the purse-seine floating object (OBJ) "survey"; other indices (catch-per-set on OBJ and unassociated (NOA) fisheries and tagging-based index of relative biomass) were not used.

j) Utilization of the most precise tagging-based absolute biomass estimate (quarter 2 of 2020, CV = 0.3) in the assessment.

k) The length compositions constructed for the purse-seine NOA fishery were not fit in the analysis; those constructed for the purse-seine OBJ index were used for both the echosounder buoy index and tagging-based absolute biomass.

Sensitivity analyses evaluated the impact of varying assumptions on growth, selectivity, tagging data, indices of abundance, and steepness to ascertain the robustness of the stock status estimates (Table 1). These are used in the risk analysis presented here.

1.2. Summary of stock status

In 2024 benchmark assessment, the stock status of skipjack tuna was evaluated using established interim proxy reference points as outlined in Resolution C-23-06, which amended the earlier Resolution C-16-02. The spawning biomass ratio (SBR) was set at 0.3, representing 30% of the unfished spawning biomass, with a limit reference point defined at an SBR of 0.077. These reference points were employed alongside methods such as lognormal bias correction for recruitment and a dynamic SBR approach to enhance the precision of recruitment estimates and address variability effectively.

The reference model indicated that the spawning biomass is currently above the 30% target of the unfished biomass under both static and dynamic SBR frameworks (Table 1). Only one sensitivity model that excluded the echosounder buoy index (model #16) suggested that the stock might be below the proxy target under the static SBR definition, although no scenarios estimated the stock being below the limit reference point (Table 1; Figure 1).

Analysis of fishing mortality revealed that current levels were below those associated with the biomass target established for the reference model, which was also consistent across all sensitivity analyses (Table 1). Comparisons against the *status quo*, defined by average fishing mortality rates from 2017 to 2019, indicated that exploitation rates in 2022 and 2023 were below these historical levels (Table 1). Only the most pessimistic model, which excluded the echosounder buoy index, suggested slight exceedance of the *status quo* exploitation rates in these years (Table 1).

2. RISK ASSESSMENT

The staff's risk analysis approach, developed in 2020 (SAC-11-08) to explicitly evaluate the probability of breaching the reference points defined in the IATTC's harvest control rule for tropical tunas (C-16-02), was applied to the results of the 2024 skipjack benchmark assessment.

2.1. Joint probability and cumulative distributions for management quantities

Based on the estimates of management metrics related to the target reference points ($F_{\text{current}}/F_{\text{MSY proxy}}$ and $S_{\text{current}}/\text{d}S_{\text{MSY proxy}}$) and their associated CVs from the eighteen models (one reference and seventeen sensitivity models), the joint probability and cumulative probability distributions were computed for these metrics, treating all models with equal weight.

The joint distributions for both $F_{\text{current}}/F_{\text{MSY proxy}}$ and $S_{\text{current}}/\text{d}S_{\text{MSY proxy}}$ are unimodal (Figure 2). There is zero probability that F_{current} exceeds the $F_{\text{MSY proxy}}$ and a 3.73% probability that S_{current} falls below $\text{d}S_{\text{MSY proxy}}$. Among the six model groups, the sensitivity model for steepness (model #18) is more pessimistic, showing higher $F_{\text{current}}/F_{\text{MSY proxy}}$ and lower $S_{\text{current}}/\text{d}S_{\text{MSY proxy}}$ compared to other models (Figure 3). For this model, there is zero probability that F_{current} exceeds the $F_{\text{MSY proxy}}$ and a 3.02% probability that S_{current} falls below $\text{d}S_{\text{MSY proxy}}$.

Joint probability and cumulative probability distributions are also derived for $S_{\text{current}}/S_{\text{limit}}$. This distribution is also unimodal (Figure 2), indicating a 0.85% probability that S_{current} falls below the limit reference point.

Historical trends of $F/F_{\text{MSY proxy}}$, $S/\text{d}S_{\text{MSY proxy}}$ and S/S_{limit} are consistent across the six model groups (Figure 4). All models estimate that $F/F_{\text{MSY proxy}}$ remains below 1 throughout the time series, peaking in 2017; $S/\text{d}S_{\text{MSY proxy}}$ is above 1 after 2006; and S/S_{limit} remains above 1 for the entire period. The equally weighted average across all eighteen models follows the same trend.

REFERENCES

Bi, R., Maunder, M.N., Xu, H., Minte-Vera, C.V., Valero, J.L., and Aires-da-Silva, A. 2024. Stock assessment of skipjack tuna in the eastern Pacific Ocean: 2024 benchmark assessment. Inter-Amer.Trop. Tuna Comm., 15th Scient. Adv. Com. Meeting: SAC-15-04.

Methot, R.D., and Wetzel, C.R. 2013. Stock synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research **142**: 86-99.

TABLE 1. Estimates of spawning biomass (S), spawning biomass ratio (SBR) and dynamic spawning biomass ratio (dSBR) at the beginning of 2024, average recruitment over the model time period (except the 4th quarter of 2023) as a ratio of the estimated virgin recruitment for all of the models, average exploitation rate in 2022 as a ratio of the *status quo*, average exploitation rate in 2023 as a ratio of the *status quo*, and current fishing mortality (the average F over the most recent three years, 2021-2023) as a ratio of the fishing mortality corresponding to $B_{\text{MSY proxy}} = 0.3B_0$. R_{ave}/R_0 is a check to make sure the SBR based on B_0 is not biased due to the bias correction for recruitment residuals (this will affect the plots of SBR that are plotted with confidence intervals). The dSBR is adjusted by the ratio R_{ave}/R_0. The red highlighting and text indicate where SBR or dSBR are below the proxy target reference point (0.3) and when the *status quo* fishing mortality (average of 2017-2019) has been exceeded.

TABLA 1. Estimaciones de biomasa reproductora (S), cociente de biomasa reproductora (SBR), cociente de biomasa reproductora dinámica (dSBR), reclutamiento promedio a lo largo del periodo del modelo (excepto el cuarto trimestre de 2023) como razón del reclutamiento virgen estimado para todos los modelos, tasa promedio de explotación en 2022 como razón del *statu quo*, tasa promedio de explotación en 2023 como razón del *statu quo*, y mortalidad por pesca actual como razón de la mortalidad por pesca correspondiente a $B_{\text{objetivo}} = 0.3B_0$. R_{prom}/R_0 es una comprobación para asegurarse de que el SBR basado en B_0 no esté sesgado debido a la corrección del sesgo por los residuales de reclutamiento (esto afectará a las gráficas de SBR que se trazan con intervalos de confianza). El dSBR se ajusta por la razón R_{prom}/R_0. Las celdas y el texto en rojo indican los casos en que el SBR o dSBR están por debajo del punto de referencia objetivo sustituto (0.3) y cuando se ha rebasado la mortalidad por pesca del *statu quo* (promedio de 2017-2019).

Group	ID	Model	S_{cur}	SBR$_{cur}$	dSBR$_{cur}$	R_{av}/R_0	F_{2022}/F_{sq}	F_{2023}/F_{sq}	$F_{cur}/FB_{\text{MSY proxy}}$
Reference	1	Reference model	17809	0.43	0.47	0.95	0.85	0.85	0.42
Growth	2	Estimating L_{inf}	17873	0.43	0.48	0.95	0.85	0.85	0.42
	3	L_{inf} = 78 cm	16769	0.42	0.46	0.95	0.85	0.85	0.45
	4	L_{inf} = 88 cm	18181	0.43	0.48	0.96	0.85	0.84	0.41
	5	Estimating L_{cv}	14055	0.41	0.43	1.01	0.82	0.82	0.46
	6	L_{cv} = 0.03	18926	0.43	0.49	0.94	0.86	0.85	0.41
	7	L_{cv} = 0.09	16612	0.42	0.46	0.97	0.84	0.84	0.44
	8	Estimating growth shape parameter	17814	0.43	0.48	0.95	0.85	0.85	0.42
Selectivity	9	Constant longline selectivity after 78 cm	17873	0.43	0.48	0.95	0.85	0.85	0.42
	10	Constant longline selectivity after 83 cm	17818	0.43	0.48	0.95	0.85	0.85	0.42
	11	Constant longline selectivity after 88 cm	17826	0.43	0.48	0.95	0.85	0.85	0.42
	12	F9 asymptotic selectivity, fixed longline selectivity and no fit for longline size composition	17263	0.42	0.47	0.96	0.85	0.85	0.44
Tagging-absolute	13	Using the most precise tagging-based absolute index and upweight by ten times	13357	0.37	0.41	0.95	0.90	0.87	0.54
	14	Using four tagging-based absolute indices with low CVs and weight by one	20018	0.46	0.50	0.96	0.83	0.83	0.38
Indices	15	No tagging-based absolute index	21849	0.47	0.53	0.96	0.83	0.83	0.36
	16	No echosounder buoy index	8543	0.22	0.31	0.96	1.00	1.07	0.55
	17	Including longline survey index and size composition	24444	0.50	0.56	0.95	0.80	0.85	0.30
Steepness	18	Steepness = 0.75	18420	0.39	0.43	0.92	0.85	0.84	0.53

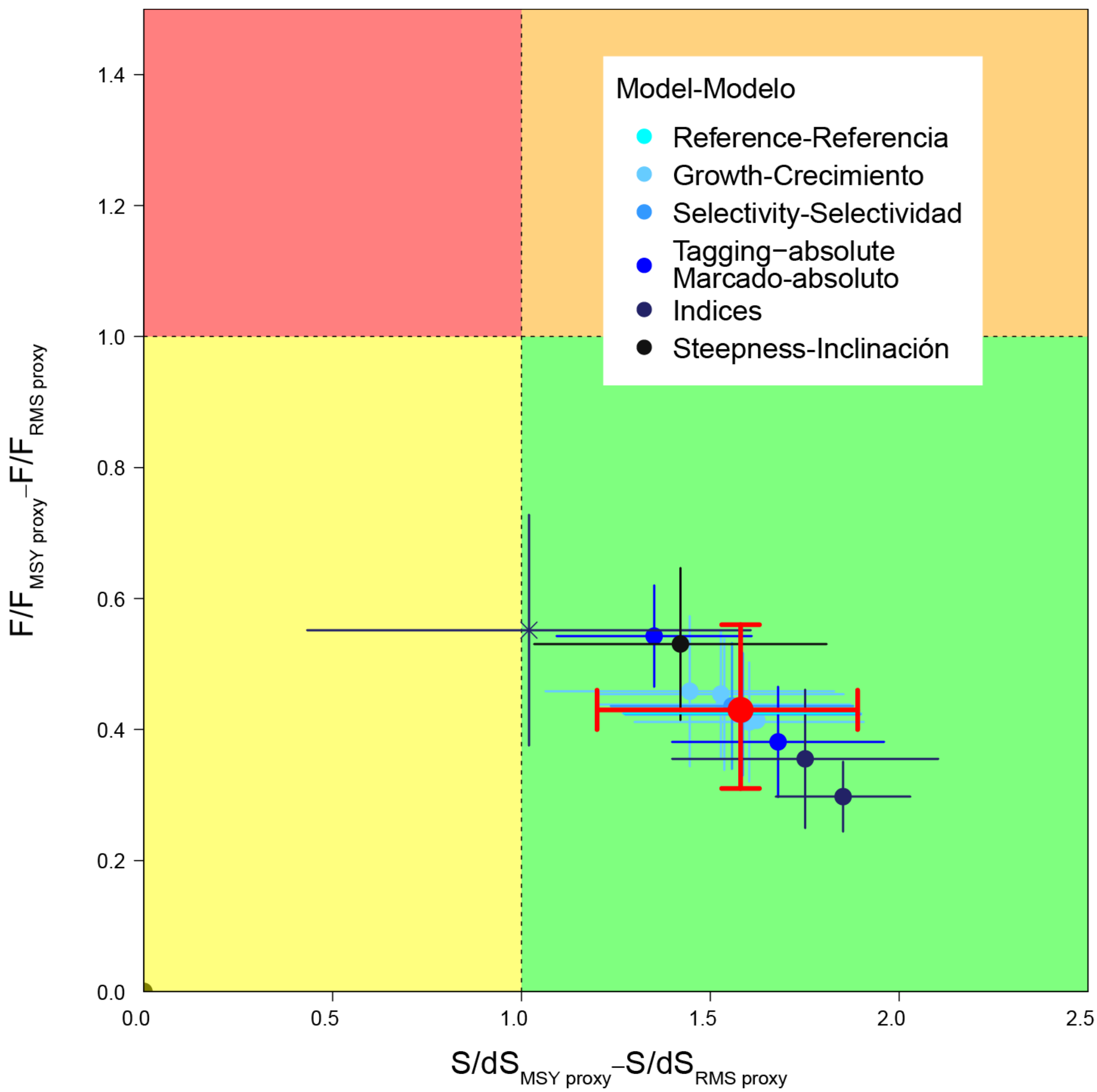

FIGURE 1. Kobe plot showing the most recent stock status estimates from all the models. The x-axis is S_{currnt}/0.3*dynamic S_0. Each dot is based on the average *F* over the most recent three years, 2021-2023, and the error bars represent the 80% confidence intervals of model estimates. The red dot and error bars represent weighted values across all eighteen models. The deep indigo cross and error bars represent the estimates from the model in which the ECHO index was removed.

FIGURA 1. Gráfica de Kobe que muestra las estimaciones más recientes de la condición de la población de todos los modelos. El eje *'x'* es S_{actual}/0.3* S_0dinámica. Cada punto se basa en la *F* promedio de los tres años más recientes, 2021-2023, y las barras de error representan los intervalos de confianza del 80% de las estimaciones del modelo. El punto rojo y las barras de error representan las estimaciones del modelo de referencia.

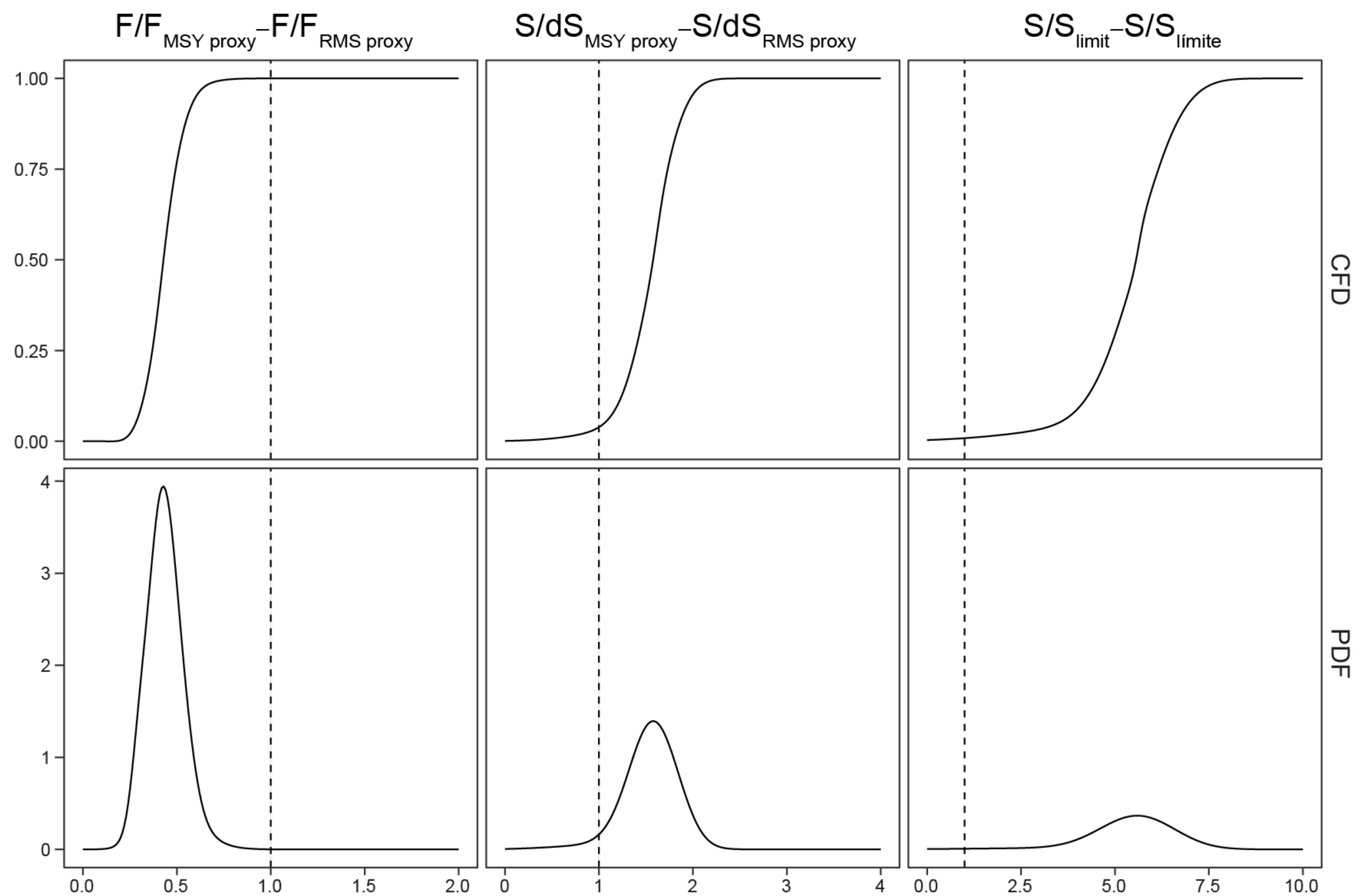

FIGURE 2. The joint probability and cumulative distributions for spawning biomass (*S*) in the first quarter of 2024 and fishing mortality (*F*) in 2021-2023 relative to their reference points ($F_{\text{MSY proxy}}$, $dS_{\text{MSY proxy}}$, S_{limit}).

FIGURA 2. Las distribuciones acumuladas y de probabilidad conjunta para la biomasa reproductora (*S*) en el primer trimestre de 2024 y la mortalidad por pesca (*F*) en 2021-2023 con respecto a sus puntos de referencia ($F_{\text{RMS sust.}}$, $dS_{\text{RMS sust.}}$, $S_{\text{límite}}$).

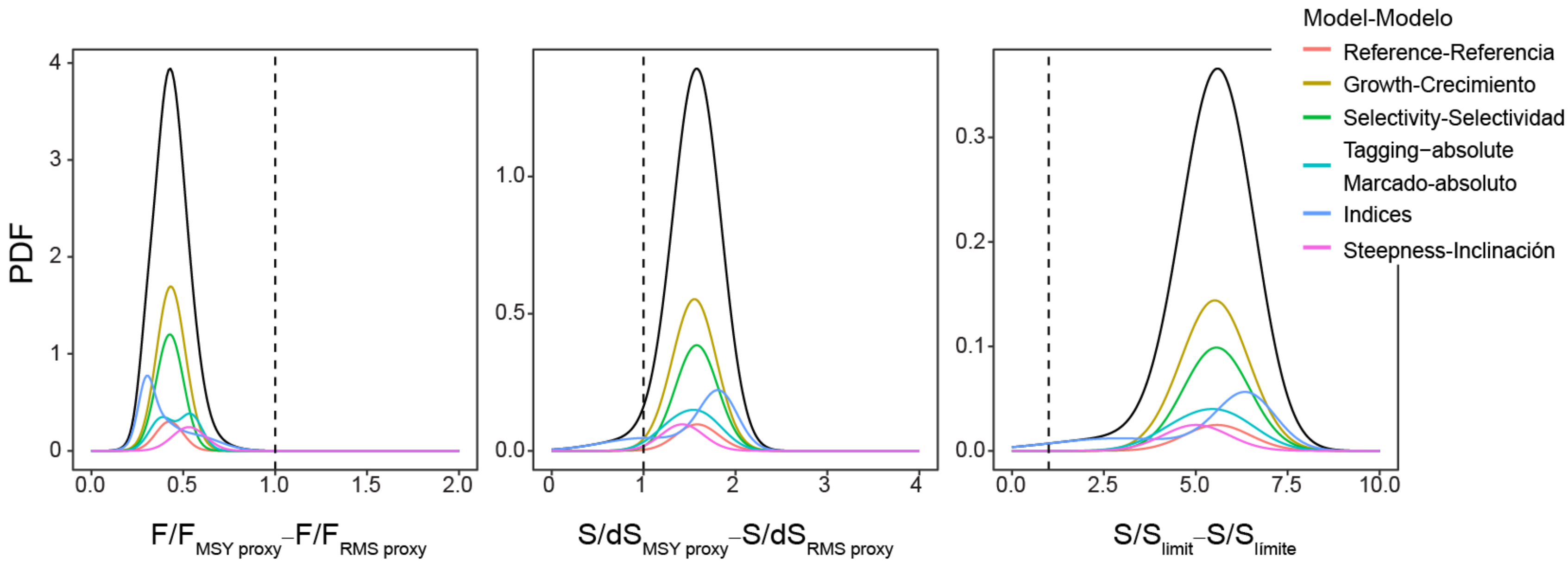

FIGURE 3. The joint probability distributions for $F_{\text{current}}/F_{\text{MSY proxy}}$, $S_{\text{current}}/dS_{\text{MSY proxy}}$ and $S_{\text{current}}/S_{\text{limit}}$ broken down into different model groups. The black lines represent weighted values across all eighteen models.

FIGURA 3. Las distribuciones de probabilidad conjunta para $F_{\text{actual}}/F_{\text{RMS sust.}}$, $S_{\text{actual}}/dS_{\text{RMS sust.}}$ y $S_{\text{actual}}/S_{\text{límite}}$, desglosadas en diferentes grupos de modelos. Las líneas negras representan los valores ponderados de los dieciocho modelos.

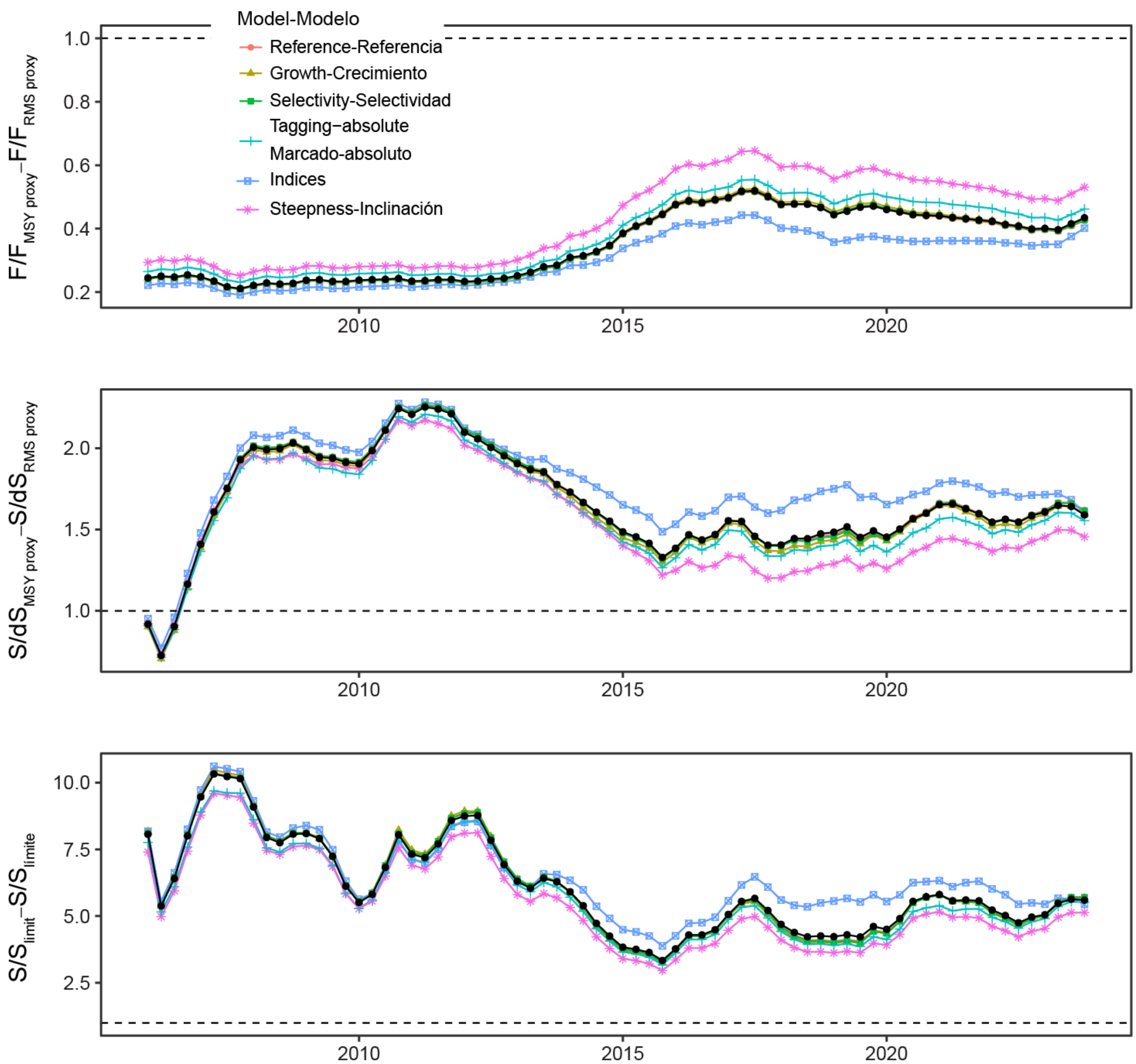

FIGURE 4. Time series of estimated spawning biomass (*S*) and fishing mortality (*F*) relative to their reference points ($F_{\text{MSY proxy}}$, $dS_{\text{MSY proxy}}$, S_{limit}) for the six model groups considered. All models are weighted equally. Each dot for *F* is based on the average *F* over three years. The black lines represent weighted values across all eighteen models.

FIGURA 4. Series de tiempo de la biomasa reproductora (*S*) y la mortalidad por pesca (*F*) estimadas con respecto a sus puntos de referencia ($F_{\text{RMS sust.}}$, $dS_{\text{RMS sust.}}$, $S_{\text{límite}}$) para los seis grupos de modelos considerados. Todos los modelos tienen la misma ponderación. Cada punto para *F* se basa en el promedio de *F* durante tres años. Las líneas negras representan los valores ponderados de los 18 modelos.