INTER-AMERICAN TROPICAL TUNA COMMISSION

SCIENTIFIC ADVISORY COMMITTEE

SEVENTH MEETING

La Jolla, California (USA)

09-13 May 2016

DOCUMENT SAC-07-06a(ii)

EXPLORATORY MANAGEMENT STRATEGY EVALUATION (MSE) OF DORADO (*CORYPHAENA HIPPURUS*) IN THE SOUTHEASTERN PACIFIC OCEAN

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EXECUTIVE SUMMARY

In this study we develop an exploratory management strategy evaluation (MSE) for dorado (*Coryphaena hippurus*) in the southern Eastern Pacific Ocean (EPO). MSE is a framework used to evaluate management procedures. A management procedure is a set of pre-agreed decision rules that specify what data are to be collected and how the data are to be used to set catches, or determine input controls such as allowable fishing effort or fishing seasons. The evaluation of alternative management procedures is typically done by comparing performance statistics reflecting management objectives and the interests of managers, resource users, and scientists. We conditioned the operating model to all available data used in the current exploratory assessment for dorado, which spans the 2007-2014 period, using the stock assessment modeling platform Stock Synthesis,. We projected population and fisheries dynamics for 2015-2019 under alternative harvest strategies and scenarios, including alternative monthly closures and openings, minimum size limits for the dorado in the catch, and discard mortality rates. The alternative harvest strategies were also evaluated retrospectively. Yield per recruit (YPR) analyses were conducted to describe expected YPR and spawning biomass ratio (SBR) as a function of age of entry to the fishery and annual fishing mortality. We present tradeoffs between SBR and yield for strategies based on alternative openings and closings of the fishing season, as well as minimum size limits with different assumptions regarding mortality rates of discarded undersized fish. We found that alternative season closings and openings have similar general effects on SBR and total yield. However, later season openings increase SBR without marked reductions in expected yield, while earlier closings increase SBR, but at the expense of reduced catch. YPR analyses show that the age of entry that will produce the maximum YPR is around 10 months, based on the annual fishing mortalities estimated by the assessment. That would mean that openings around October-November would be consistent with YPR considerations. The age of entry consistent with maximum YPR would be higher at fishing mortalities higher than those estimated by the assessment. SBR is expected to increase with minimum size limits, while yield is expected to increase under no or moderate discard mortality and to decrease at greater discard mortality rates. Under an assumed moderate discard mortality, increased minimum size limits are expected to result in increased SBR, but at the expense of reduced yield.

This exploratory study is not intended in any way as a final MSE to be used for the management of dorado; it is rather the first step in a process of evaluating the utility of MSE for dorado, and is intended to further collaboration between all interested parties in order to continue developing this framework for dorado and, if found useful and appropriate, consider its utility for determining the potential outcome of alternative decisions.

1. INTRODUCTION

There are various approaches to the provision of scientific advice for fisheries management. One approach is assessment-based, and relies on a regular (usually annual) cycle of evaluation of the status of stocks, the determination of “best” estimates of biomass, and the calculation of quotas based on a predetermined target harvest rate. Target harvest rates can be calculated in different ways, depending on specific management goals; for example, maximizing yield (MSY based), minimizing risk to the stock, and coping with fluctuating populations. The early historical emphasis on maximum sustainable yield (MSY) and optimal target rates has seen a transition into a framework of harvest control rules that includes target and limit reference points, and associated target harvest rates (Mace and Sissenwine 2002). This change has been motivated by a transition towards a precautionary approach to fisheries management (FAO 1996), and by the realization of the uncertainty associated with assessment model errors, uncertainty around reference points, and implementation errors, and their combined impact on the ability to manage fisheries successfully. An alternative, often complementary approach, takes into account a greater spectrum of relevant uncertainties using “feedback control policies” (Mace and Sissenwine 2002).

These have been referred to as a "fisheries control system" (Hilborn 1979), "revised management procedure" (IWC 1994), "system for evaluating management strategies" (ICES 1994), "management procedures simulation" (ICCAT 2000), "management procedure approach" (Butterworth 2007), and "management strategy evaluation", or MSE (Smith 1994, Smith *et al.* 1996, Polacheck *et al.* 1999, De Oliveira *et al.* 2008, Butterworth *et al.* 2010), but they have similar a meaning: a framework for evaluating management procedures. A management procedure (Butterworth *et al.* 1997) is a set of pre-agreed decision rules that specify what data are to be collected and how they are to be used to set a total allowable catch (TAC) or determine input controls such as allowable fishing effort. The evaluation of alternative management procedures is typically done by comparing performance statistics reflecting management objectives and the interests of managers, resource users, and scientists (Butterworth and Punt 1999; Parma 2002). Rather than focusing on optimality and best estimates (as in the assessment-based approach), the overall objectives of MSE are to evaluate management alternatives under different biological scenarios, and determine those that are robust to the associated uncertainty and provide reasonable outcomes. The IATTC staff has conducted research-oriented exploratory MSE work for Pacific bluefin tuna (Maunder 2014) and bigeye tuna (Maunder *et al.* 2015).

Dorado (*Coryphaena hippurus*) is one of the most important species caught by Latin American artisanal fisheries in the eastern Pacific Ocean (EPO). In Peru, for example, it is estimated that catches in recent years average about 50 thousand metric tons (t), most of which is consumed internally. In Ecuador, dorado accounts for over 65% of the estimated landings of the artisanal fishery for large pelagics and 35-40% of pelagic fish exports. Dorado is also caught, both as a target and bycatch species, in other fisheries throughout the Pacific coastal States of Latin America. It is therefore important that the stock status of dorado is monitored and alternative management strategies evaluated, in order to provide a basis for guiding sustainable fisheries management of the species in the EPO.

The fisheries for dorado in Peru and Ecuador are managed using a combination of minimum size limits and seasonal closures. Specifically, the minimum legal size is 70 cm in fork length (with a 10% tolerance) in Peru and 80 cm in total length and Ecuador, and the dates of opening and closing the fishery are 30 September and 1 May in Peru (since 2014), and 7 October and 1 July in Ecuador (since 2011) (IATTC 2015). These regulations are intended to improve yields, and to ensure that sufficient spawning biomass is left to perpetuate the population, particularly when stock assessments are uncertain and the form of the stock-recruitment relationship is unknown.

At the request of some EPO coastal Members, the IATTC staff initiated collaborative work on dorado stock assessment methodologies (Aires-da-Silva *et al.* 2014). A large and diverse amount of fishery and biological data for dorado available from IATTC member countries was identified at the first IATTC Technical Meeting on Dorado, held in Manta, Ecuador, in October 2014 (IATTC 2014). In addition, the collaborative efforts between members of the IATTC Stock Assessment Program and Ecuadorian scientists produced a research paper describing the Ecuadorian artisanal fisheries in great detail, with emphasis on dorado and tuna-billfish-sharks (Martinez-Ortiz *et al.* 2015). More recently, a second IATTC Technical Meeting on Dorado was held in Lima, Peru, in October 2015, with the main objectives of discussing the assumptions about stock structure of dorado and indicators for monitoring the status of the species in the EPO. One important outcome of this second meeting was a preliminary assessment model for dorado, using Stock Synthesis (SS) (Methot and Wetzel 2013). The fishery and biological data used in that model were updated with the best available data from Peru and Ecuador, the two countries with the main fisheries; the resulting improved model was used to conduct a full stock assessment of dorado (Aires-da-Silva *et al.* 2016).

In this study we develop an exploratory MSE for dorado in the EPO. This is not intended in any way as a final MSE to be used in the management of dorado; it is rather the first step in a process of evaluating the utility of MSE for dorado, and is intended to further collaboration between all interested parties in order to continue developing this framework for dorado and, if found useful and appropriate, consider its utility for determining the potential outcome of alternative decisions.

2. METHODS

Reference points (RPs), harvest control rules (HCRs), and management strategy evaluations (MSE) are becoming important tools for fisheries management. Their use is being widely promoted for the management of a variety of stocks, from data-poor to data-rich. An MSE can provide a formal framework for evaluating the performance of a current harvest strategy with different types and levels of uncertainty. It can also be used to evaluate different management procedures that could be considered as alternatives to the current management approach. Decisions regarding the selection and evaluation of alternative strategies are informed by testing alternative candidates against a series of performance indicators that reflect management goals. One of most important components of the MSE process is the construction of simulation models, called operating models, that describe potential past and future scenarios for the dynamics of the stock and the fishery and include key uncertainties. Other components of the MSE approach are a conditioning module, a projection module, and an evaluation module, as illustrated in Figure 1 and described below.

2.1. Operating models

The goal of the operating models is to describe population and fishery dynamics under alternative hypotheses and model formulations to capture the real (statistical and structural) uncertainty. The Stock Synthesis stock assessment model (Aires-da-Silva *et al.* 2016) developed after the second meeting on dorado was used as the basis for the operating model for testing the alternative harvest strategies.

2.2. Conditioning

The goal of the conditioning component is to condition the operating models on available historic data in order to make them consistent with the historic dynamics of the stock. It is important to note that conditioning operating models is not the same as conducting a full stock assessment. The focus of the conditioning component is not to arrive at the best assessment of the stock, but to ensure that the operating models are consistent with the historical data. This is an important distinction, since operating models often include processes for which the data necessary for fitting are not available. For example, operating models may focus on potential climate impacts on individual growth, or sea-surface temperature effects on CPUE. Even if the data necessary for providing a definitive description and fit to the process are not available, we still want to have operating models that incorporate such an effect in a way that is consistent with historic data on the dynamics of the stock. In other MSE projects underway in the fisheries community, the conditioning of operating models has been done using different approaches, including recent stock assessments, all available data, and expert opinion. The choice of type of conditioning depends on the hypothesis and focus of the operating model and the data on which the model will be conditioned. In this study we conditioned the operating model on all the available data used in the current exploratory assessment of dorado in Stock Synthesis (Aires-da-Silva *et al.* 2016), which spans the 2007-2014 period.

2.3. Projections

The goal of the projection component is to re-create all the steps involved in the annual management cycle (Figure 1). This includes how catches are removed from the conditioned operating models (as described in previous sections), what data to collect, how to use the data to determine stock status and trends, how to estimate the following year's catches, and any other relevant management actions. For evaluation purposes, this process is not only repeated over several years during a pre-specified projection time, but it is also repeated many times to incorporate different types of uncertainty in the process. We used a modelling approach based on work done previously by Maunder (2014) and Maunder *et al.* (2015) for MSE research on Pacific bluefin and bigeye tunas. The procedure uses samples from the posterior distribution of a Bayesian application of Stock Synthesis using Markov Chain Monte Carlo (MCMC) simulation methods to represent possible states of nature, allowing for uncertainty in parameters of the operating model. R code was developed to communicate between the Stock Synthesis-based operating model and the harvest strategy that was being evaluated. The projection period was 2015-2019, and 300 MCMC posterior samples were used for each scenario.

2.4. Harvest strategies

Projections were conducted under alternative harvest strategies and scenarios, including various dates and durations of the fishery closures, size limits for the dorado in the catch, and discard mortality rates.

2.4.1. Season closures based on alternative closing and openings

The 12 scenarios in the table below and illustrated in Figure 2, based on alternative months of opening and closing of the fishery and resulting closures of different durations, were used in this study. They apply to the Peru and Ecuador fisheries only; the fishing mortality associated with bycatch removals from purse-seine fisheries is not affected by the closures. No minimum size limits are considered; however, the selectivities estimated in the assessment for the historical period correspond to the time when size limits were first being implemented, so the estimated selectivities reflect in part their implementation. All monthly fishing mortalities are set at the average monthly estimates from the stock assessment during 2007-2014 except *NoFishing*, where the mortalities are set at zero.

	Name	Opening	Closing	No fishing (closure)
1.	*Base*	-	-	-
2.	*NoFishing*:	-	-	-
3.	*January*	-	January	January-April
4.	*February*	-	February	February-April
5.	*March*	-	March	March-April
6.	*April*	-	April	April
7.	*July*	August	-	July
8.	*August*	September	-	July-August
9.	*September*	October	-	July-September
10.	*October*	November	-	July-October
11.	*November*	December	-	July-November
12.	*December*	January	-	July-December

2.4.2. Size limits and discard mortality

In this section we describe how we further incorporate the effect of size limits by implementing retention curves and discard mortality. The retention curves corresponding to each size limit were computed in Stock Synthesis from the selectivities estimated in the assessment (Figure 4). We assume that all dorado below the size limit are discarded. The values of discard mortality are chosen for illustrative purposes only, and ranged from 0 (no discard mortality) to 0.5 (50% of the discarded dorado below the minimum size limit die).

Projections were conducted with the following combinations of minimum size limits, in cm of fork length, and discard mortalities. In all cases the monthly fishing mortalities were set at the average monthly estimates from the stock assessment during 2007-2014.

	Size limit (cm)	Discard mortality
1.	70	0.0
2.	80	0.0
3.	90	0.0
4.	100	0.0
5.	80	0.1
6.	80	0.3
7.	80	0.5

2.5. Retrospective model runs under alternative scenarios

A retrospective analysis was conducted to determine the potential impact of minimum size limits and seasonal closures. For illustrative purposes we chose the size limits and seasonal closures that showed potential benefits to the stock based on yield-per-recruit analyses. The retrospective analysis was carried out using the Stock Synthesis model, which makes the analysis consistent with the stock assessment assumptions. To implement the retrospective analysis, the Stock Synthesis model was first re-run using the fishing mortalities as parameters, and checked to ensure that the results were the same as when using the hybrid approach (an efficient method of solving the catch equation in Stock Synthesis; see Methot and Wetzel 2013) to implement fishing mortality. Using the fishing mortalities as parameters allowed the fishing mortality rates to be fixed for the retrospective analysis, and to be changed to implement the size limit through a knife-edge retention curve; similarly, the seasonal closures can be manipulated by changing the fishing mortality to zero for the closed months. We investigated a size limit of 90 cm with a 30% mortality rate for the discarded dorado, chosen arbitrarily for illustrative purposes only. We investigated delaying the opening of the season by closing the fishery during July-January.

2.6. Evaluation

The evaluation component summarizes the results of simulations based on performance indicators for alternative management strategies. Performance indicators reflect management goals, and are instrumental in the evaluation and comparison of alternative strategies. Common indicators include measures of yield, conservation risk, and stability; additional specific indicators could be identified by consulting stakeholders involved in the process. For this study we used total catch during the projected years (2015-2019) and the spawning biomass ratio (SBR; the ratio of the spawning biomass at that time to that of the unfished stock) for the last year in the projection (2019).

2.7. Yield per recruit (YPR) and spawning biomass ratio (SBR)

A simple YPR analysis was conducted to describe expected YPR and SBR as a function of age of entry to the fishery and annual fishing mortality. We used the population (*e.g*. growth, natural mortality, maturity) and fishery (*e.g*. selectivity) parameters used by Aires-da-Silva *et al.* (2016) in the dorado stock assessment.

3. RESULTS

3.1. Season closures based on alternative closing and openings

The results of the analyses presented in this report are preliminary. Under the *Base* scenario, which represents the implied strategy applied during the assessment period (2007-2014), used for conditioning the operating model, the projected spawning biomass (2015-2019) and SBR stay at levels comparable to those estimated before the projection period (Figure 5). Under the *NoFishing* scenario, the stock is projected to increase rapidly, to close to its unfished biomass (SBR of 0.95) by the end of the projection period (Figure 5). However, the projections are highly uncertain, due to uncertainty in the parameters used to condition the model and in the projected recruitment levels. There is less uncertainty in the projected SBRs than in the projected spawning biomasses (Figure 5). Closures during January-April result in intermediate trajectories between the *NoFishing* and *Base* scenarios (Figure 5).

Alternative fishery closures have similar general effects on the SBR and total yield in 2019, the last year of the projection (Figure 6). However, opening the fishery later than in the *Base* scenario increases the projected terminal SBR without marked reductions in expected yield compared to the *Base* scenario (Figure 6, right panel), while earlier closures increase SBR but at the expense of reduced expected catch (Figure 6, left panel).

3.2. Size limits and discard mortality

A minimum size limit of 80 cm fork length with discard mortalities between 0 (no discard mortality) and 0.5 (50% discard mortality) resulted in higher SBRs than in the *Base* scenario (Figure 7, left panel). Yield is expected to increase slightly with a size limit of 80 cm; however, it is expected to decrease with discard mortalities at 30% or above (Figure 7, left panel). Assuming 30% mortality of discarded fish, increasing the size limit from 70 cm to 100 cm is expected to increase the SBR relative to the *Base* scenario, but at the expense of yield (Figure 7, right panel).

3.3. Retrospective model runs under alternative scenarios

Closures have a much greater impact than size limits on both catches and biomass, reducing the former and increasing the latter (Figure 9). A closure eliminates catch in the months it is in effect, but then results in larger catches in the months that are open to the fishery. Over the entire assessment period, the loss in catch is 34% for the closure and 16% for the size limits, but by the final year of the analysis the loss in catch due to the closure is only 11%, about the same as for the size limits (12%). Note that the biomass associated with closures starts off at the same level as in the *Base* scenario, but the biomass associated with minimum size limits starts at a higher level, because they are implemented in the initial conditions, but the closure is not. This is a consequence of the setup for Stock Synthesis, and further investigation is needed.

3.4. Yield per recruit (YPR) and spawning biomass ratio (SBR)

The yield curve is very flat at high fishing mortalities (F), and therefore the YPR keeps increasing with increasing F (Figure 9). On the other hand, maximum YPR is achieved with an age of recruitment to the fishery of around 10 or 11 months with the annual *Fs* (median F = 0.8, range 0.5-0.9) estimated by the stock assessment model (Aires-da-Silva *et al.* 2016).

4. DISCUSSION

This work should be considered a first exploratory evaluation of alternative strategies for dorado in the EPO. Although the results are informative regarding the expected effect of alternative strategies on metrics of interest, more work is needed to be able to more adequately compare additional alternative strategies relative to additional metrics of interest, and under a wider range of model uncertainties. We have shown tradeoffs between SBR and yield for strategies based on different months of opening and closing the fishery and on different minimum size limits with various assumed discard mortality rates for dorado below the legal size limit. The preliminary results suggest that, without a size limit, opening the fishery later than in the *Base* scenario would increase the SBR but have little effect on yield, unless the fishery opened later than November, in which case yield decreases. Alternative opening dates have an effect on the age at which dorado enter the fishery: YPR analyses show that, with the annual fishing mortalities estimated by the assessment, the age of entry that would maximize the YPR is around 10 months. Our model assumes that dorado are recruited in December and January, at age 0, which means that opening the fishery around October-November would be consistent with YPR considerations. The age of entry consistent with maximum YPR would be higher with fishing mortalities higher than those estimated by the assessment.

The SBR is expected to increase with minimum size limits, while yield is expected to increase with no or moderate discard mortality and decrease with higher discard mortalities. Assuming moderate discard mortality, increasing the minimum size limit would increase the SBR, but at the expense of reduced yield. This is because the pattern and level of fishing mortalities are fixed at those of the stock assessment, which assumes no minimum size limit; in other words, with a minimum size limit, fishing mortality would have to be higher than is estimated by the stock assessment in order for catches to be comparable to those seen in the recent history.

5. FUTURE DIRECTIONS

The following topics should be a priority in future research into MSE for dorado:

1. Additional candidates should be identified for the different components of management strategies (*e.g.* data, assessment method, harvest control rule, reference points) and the performance measures for evaluating those strategies (*e.g*. SBR, total catch, average catch, size of dorado in the catch).
2. Additional harvest strategy options should be explored. Candidates include CPUE thresholds (either in absolute units, or relative to, for instance, CPUE at the start of the season) that would trigger management action. These strategies could use a reference CPUE that triggers a reduction in effort, and a limit CPUE that closes the fishery. Dynamic seasonal strategies could be based on timing of recruitment, expected growth, and time of the year when the recruited cohort is expected to maximize YPR. Other alternatives resulting from discussions between project participants could be evaluated.
3. Reference points, whether target, threshold, or limit, have not been implemented in the fisheries for dorado in the EPO. MSY-based reference points seem problematic given how flat the relationship between fishing mortality and yield is. Another alternative is reference points based on SBR. Once reference points are decided, MSE is a valuable tool for evaluating alternative harvest strategies and their expected performance relative to the chosen reference points.
4. Alternative dynamics should be incorporated in the operating model. Given the uncertainty in the magnitude of availability or recruitment, as seen in the interannual differences in the CPUE at the start of each fishing season, alternative operating models should be used that describe various different levels of these processes. A relationship between sea-surface temperature and the CPUE of dorado has been proposed; operating models and/or management procedures incorporating this process could be used in the MSE. The current operating model represents the parameter uncertainty from the stock assessment. Additional uncertainty in parameters that are fixed in the assessment model (*e.g*. natural mortality, the stock-recruitment relationship, and growth) should also be considered.

ACKNOWLEDGEMENTS

Many IATTC and member country staff provided data and participated in discussions that made possible the dorado assessment, which served as the first step in this exploratory MSE. The authors thank the participants at the 2nd Technical Meeting on Dorado in 2015 for the discussion and input on candidate alternative strategies. World Wildlife Fund (WWF) partially funded Juan Valero to conduct this work.

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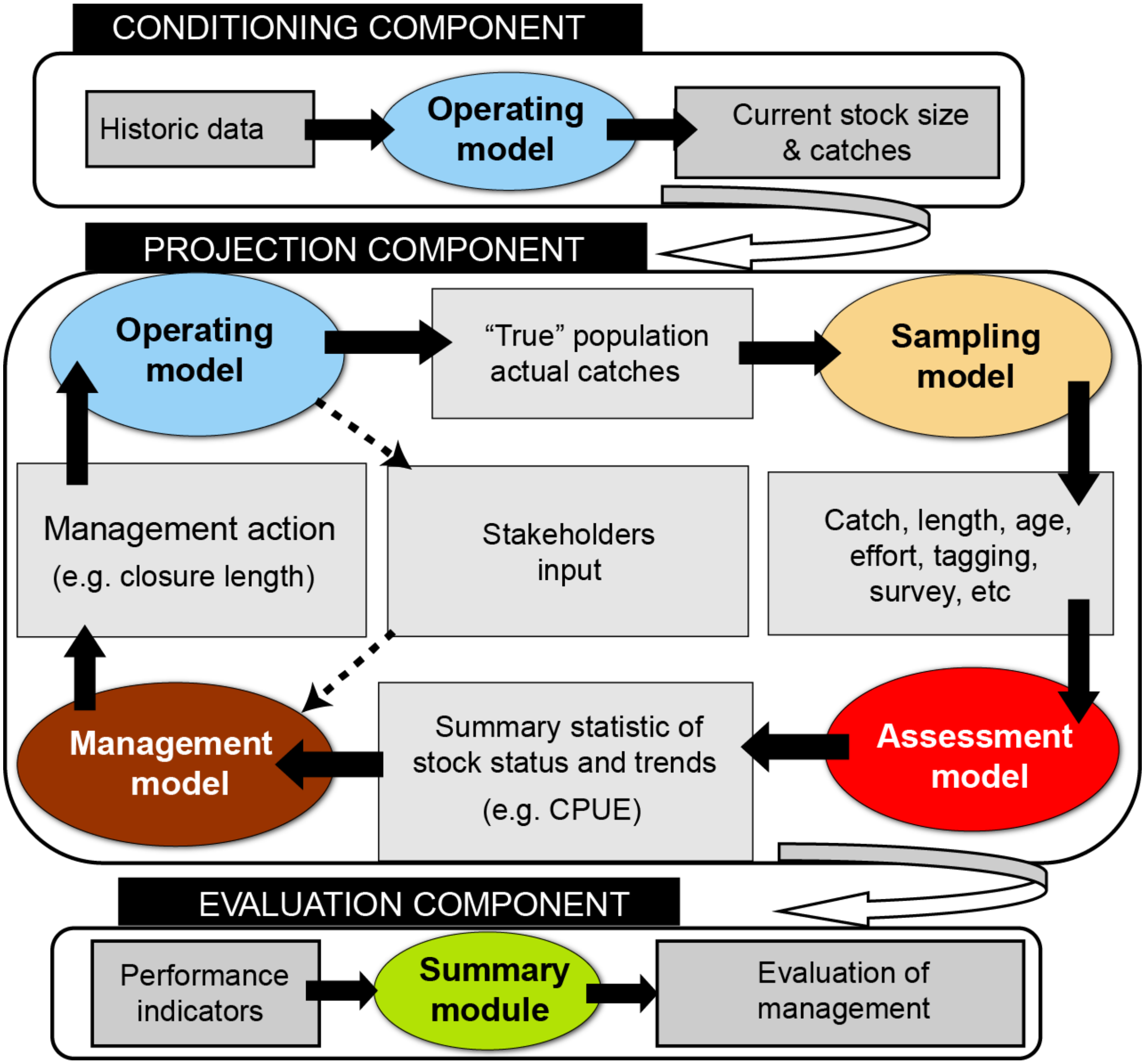


FIGURE 1. Schematic of the main components of a Management Strategy Evaluation (MSE).
FIGURA 1. Diagrama esquemático de los componentes principales de una Evaluación de Esquemas de Ordenación (EEO).

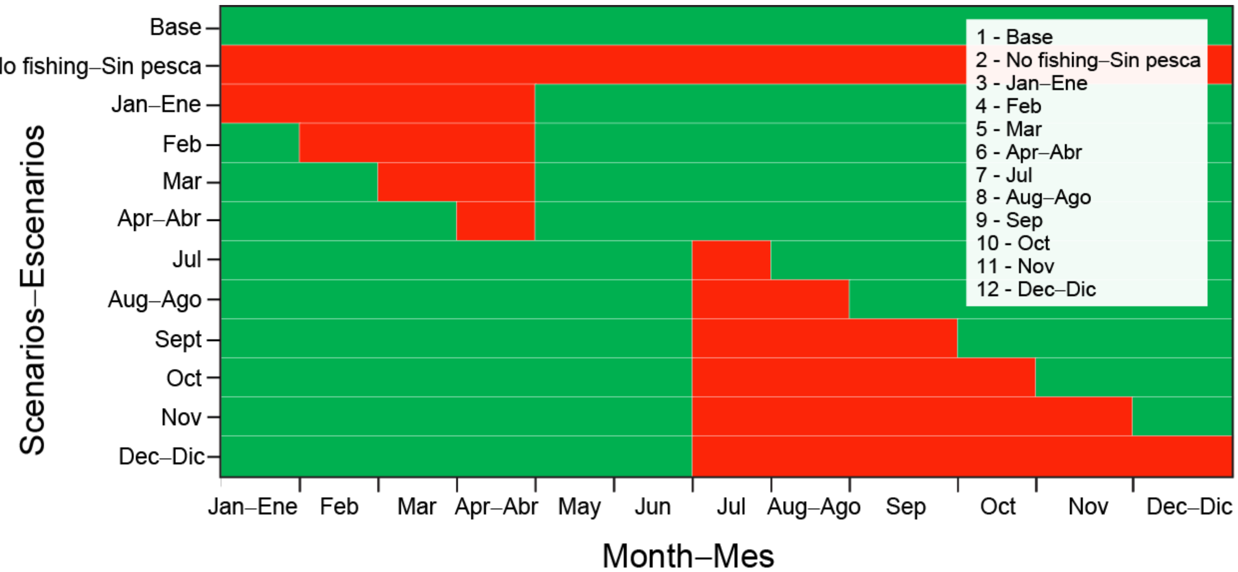


FIGURE 2. Scenarios based on alternative openings and closures of the fisheries; see text, Section 2.4. Red: closed to fishing; green: open to fishing.

FIGURA 2. Escenarios basados en fechas alternativas de apertura y cierre de las pesquerías; ver texto, sección 2.4. Rojo: cerrado a la pesca; verde: abierto a la pesca.

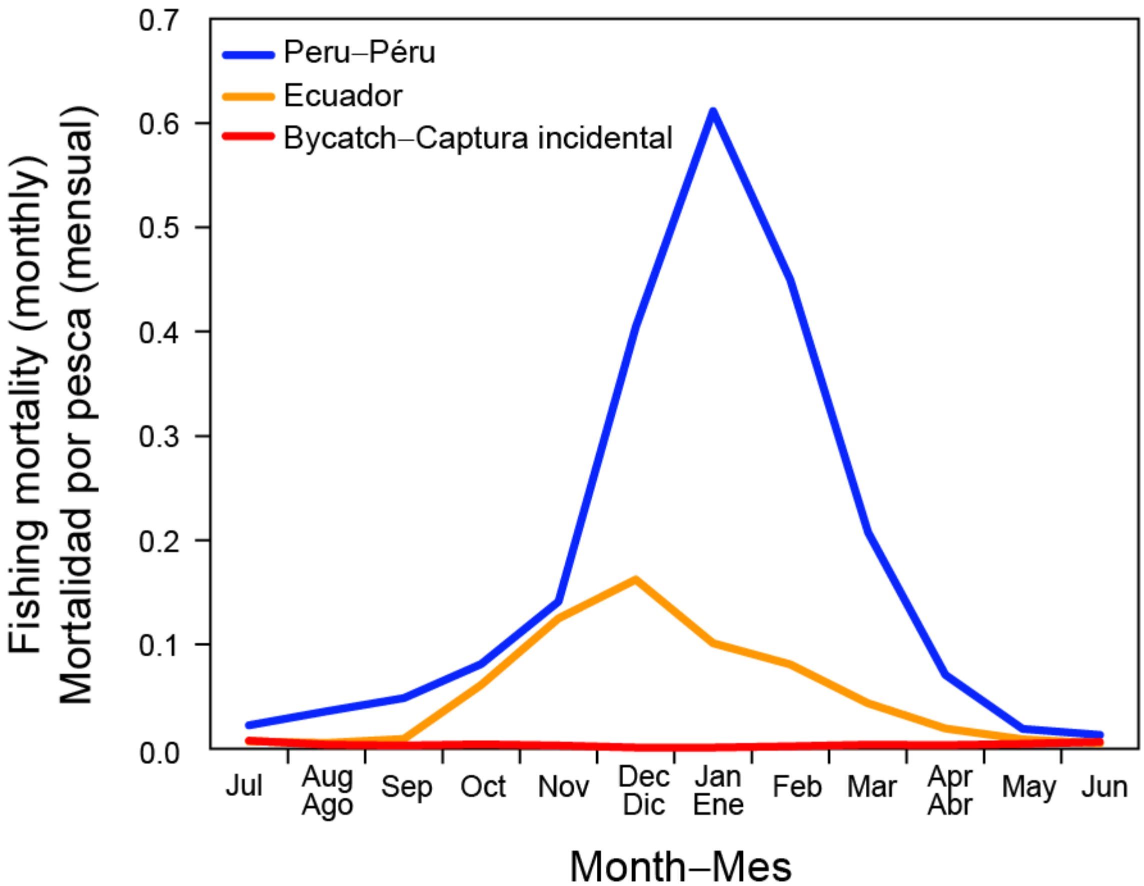


FIGURE 3. Monthly fishing mortality for each of the three fisheries modeled during the projection period.
FIGURA 3. Mortalidad por pesca mensual en cada una de las tres pesquerías modeladas en el periodo de proyección.

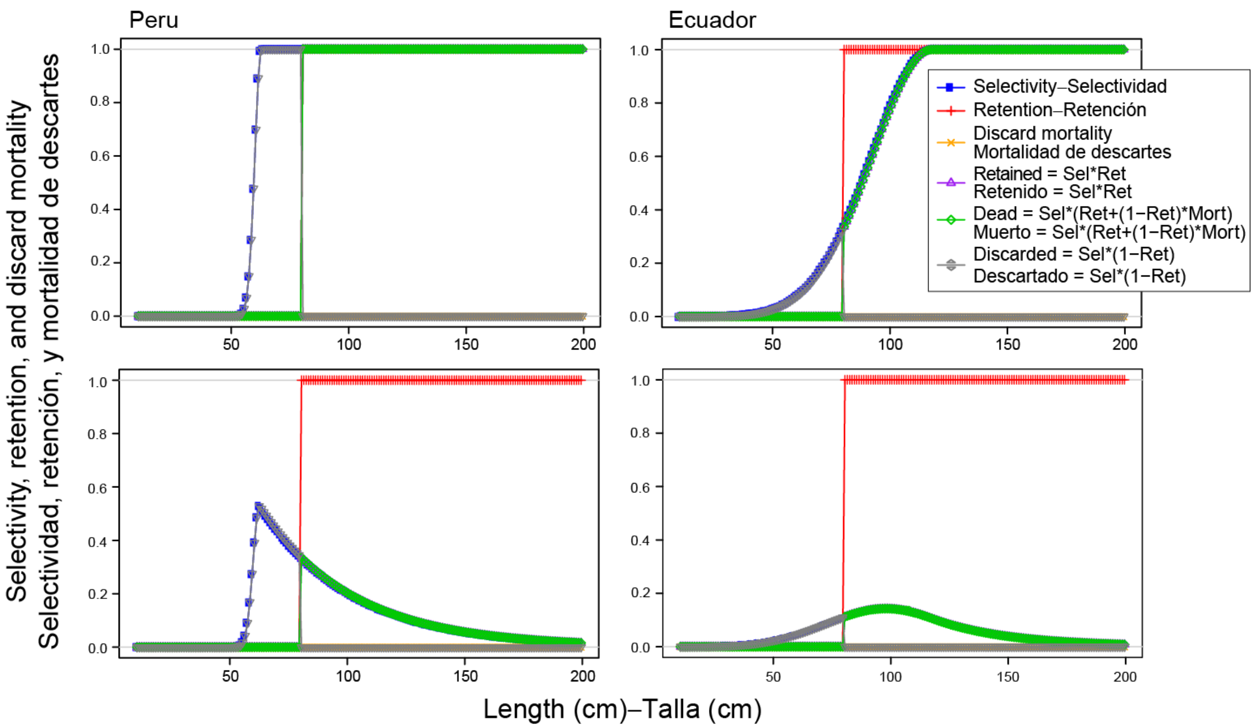
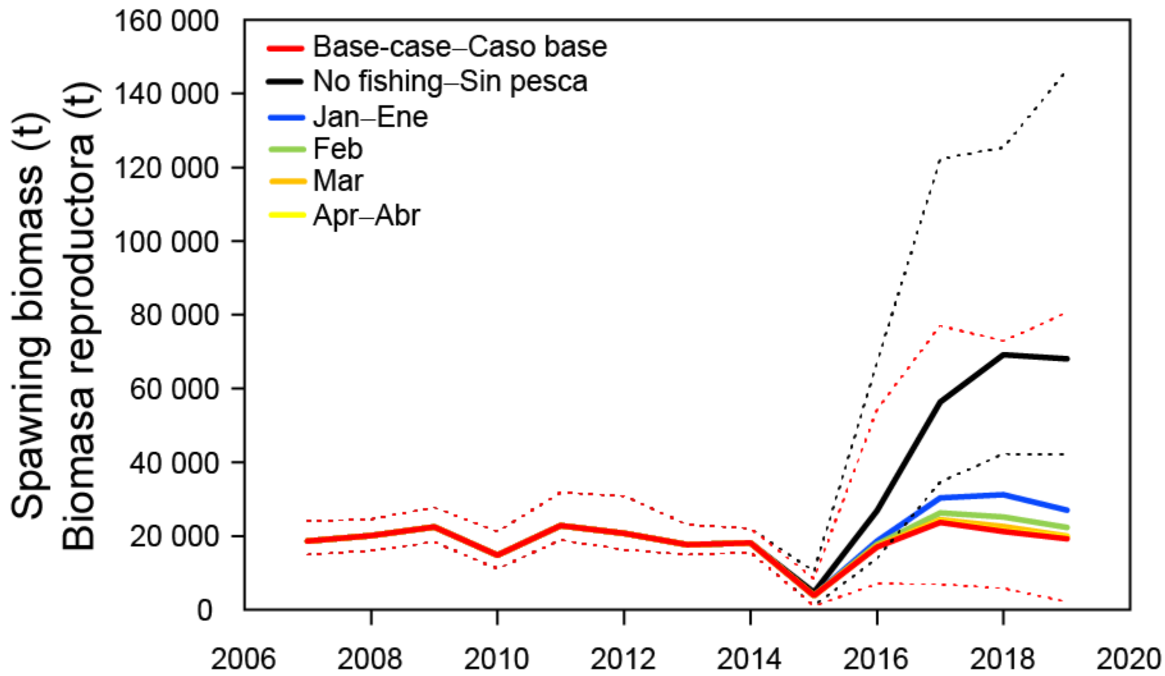


FIGURE 4. Selectivity, retention, and discard mortality curves for females (top panels) and males (bottom panels) in the fisheries of Peru (left panels) and Ecuador (right panels) corresponding to a minimum size limit of 80 cm.

FIGURA 4. Curvas de selectividad, retención, y mortalidad de descartes de hembras (paneles superiores) y machos (paneles inferiores) en las pesquerías de Perú (izquierda) y Ecuador (derecha) correspondientes a un límite de talla mínima de 80 cm.



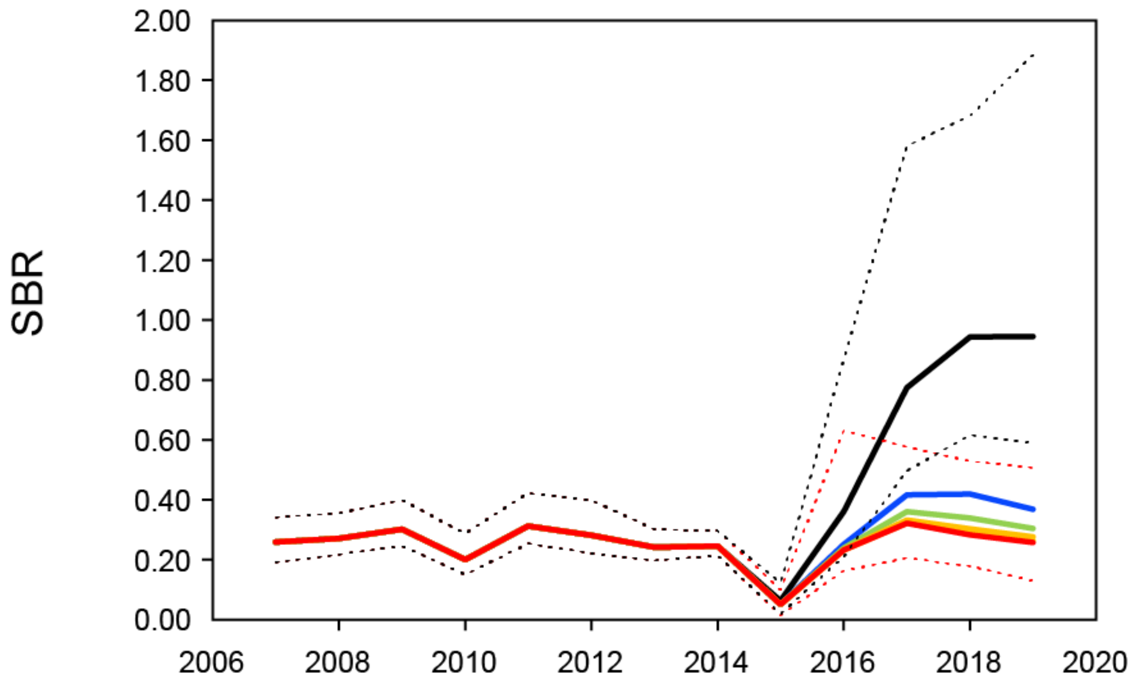


FIGURE 5. Projected spawning biomass, in tons (top panel), and SBR (see text; bottom panel) of dorado, 2015-2019, under six alternative scenarios (see Figure 2). The dotted lines represent the 95% confidence intervals.

FIGURA 5. Proyecciones de la biomasa reproductora, en toneladas (panel superior), y el SBR (ver texto; panel inferior) de dorado, 2015-2019, bajo seis escenarios alternativos (ver Figura 2). Las líneas de trazos representan los intervalos de confianza de 95%.

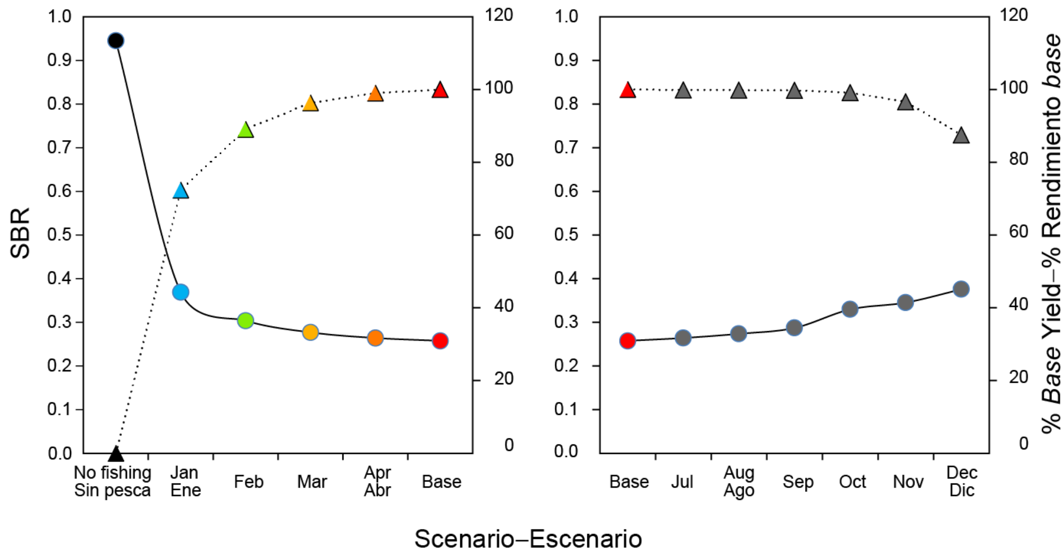


FIGURE 6. Predicted spawning biomass ratio (SBR, circles) in 2019, and total yield during 2015-2019 as a percentage of the *Base* scenario (triangles), under several alternative scenarios based on different fishery closing (left) and opening (right) dates.

FIGURA 6. Predicciones del cociente de biomasa reproductora (SBR, círculos) en 2019, y el rendimiento total durante 2015-2019 como porcentaje del escenario *Base* (triángulos), bajo varios escenarios alternativos basados en diferentes fechas de cierre (izquierda) y apertura (derecha) de la pesquería.

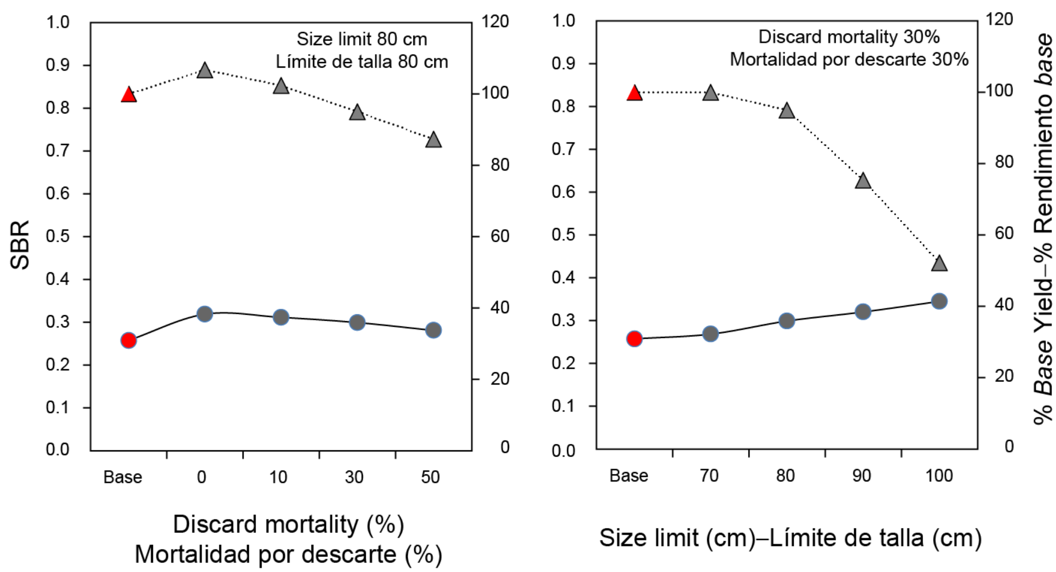


FIGURE 7. Predicted spawning biomass ratio (SBR, circles) in 2019, and total yield during 2015-2019 as a percentage of the *Base* scenario (triangles), based on a minimum size limit of 80 cm with discard mortalities between 0 and 50% (left panel) and a 30% discard mortality with alternative size limits between 70 and 100 cm (right panel).

FIGURA 7. Predicciones del cociente de biomasa reproductora (SBR, círculos) en 2019, y el rendimiento total durante 2015-2019 como porcentaje del escenario *Base* (triángulos), basadas en un límite de talla mínima de 80 cm con mortalidad de descartes de entre 0 y 50% (izquierda) y una mortalidad de descartes de 30% con límites de talla alternativos de entre 70 y 100 cm (derecha).

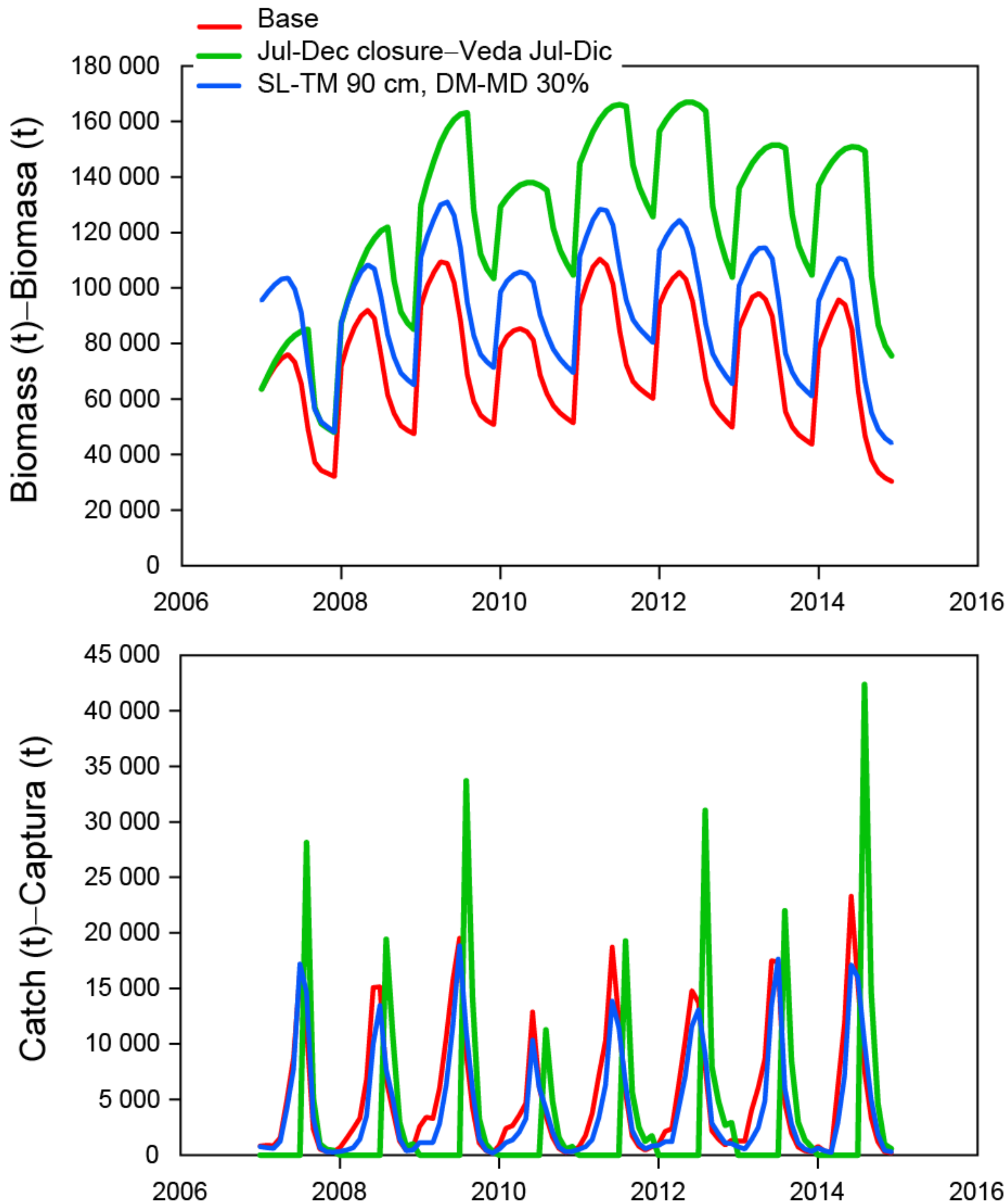


FIGURE 8. Simulated time series of monthly biomass (top) and catch (bottom) of dorado, in tons, from the retrospective model runs, from the *Base* scenario (red line), with a July-December closure (Scenario 12) (green line), and with a minimum size limit of 90 cm fork length and an assumed mortality rate of 30% for discarded fish < 90 cm (blue line).

FIGURA 8. Series de tiempo simuladas de biomasa mensual (arriba) y captura (abajo) de dorado, en toneladas, de las ejecuciones retrospectivas del modelo, del escenario *Base* (línea roja), con veda durante julio-diciembre (Escenario 12) (línea verde), y con un límite de talla mínima de 90 cm de talla furcal y una tasa de mortalidad supuesta de 30% de peces descartados de talla < 90 cm (línea azul).

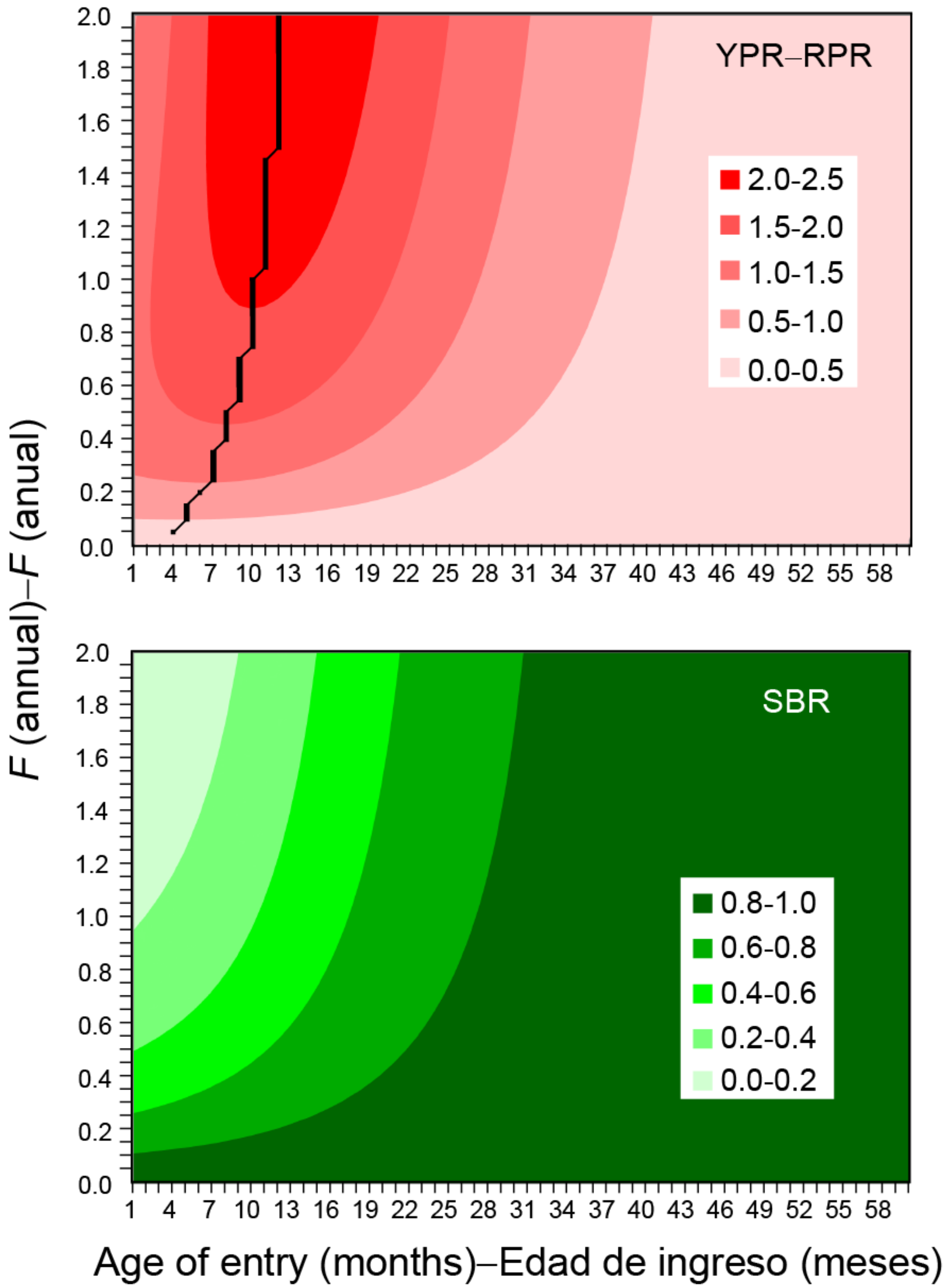


FIGURE 9. Yield per recruit (YPR, top panel) and spawning biomass ratio (SBR, bottom panel) as a function of age of entry to the fishery, in months, and annual fishing mortality (*F*). The black line in the YPR plot represents the age corresponding to the maximum YPR at each level of fishing mortality.

FIGURA 9. Rendimiento por recluta (RPR, panel superior) y cociente de biomasa reproductora (SBR, panel inferior) como función de edad de ingreso a la pesquería, en meses, y mortalidad por pesca anual (*F*). La línea negra en la gráfica de RPR representa la edad correspondiente al RPR máximo en cada nivel de mortalidad por pesca.