Stock assessment of swordfish (*Xiphias gladius*) in the Indian Ocean using A Stock-Production Model Incorporating Covariates (ASPIC)

Sheng-Ping Wang

Department of Environmental Biology and Fisheries Science, National Taiwan Ocean University, Keelung, Taiwan.

ABSTRACT

A Stock-Production Model Incorporating Covariates (ASPIC) was used to conduct the stock assessment for swordfish in the Indian Ocean. The stock status became to be pessimistic because of substantial increase in catches in recent years, especially for the catches from Indonesia and other fleets. The results from most of scenarios indicate the current status of swordfish may be overfishing but not subject to be overfished but there is a high risk of being overfishing and overfished.

1. INTRODUCTION

Swordfish in the Indian Ocean (*Xiphias gladius*) was historically taken mainly by Japan and Taiwan, but the catch was low. Before the 1990s, swordfish were mainly a non-targeted catch of industrial longline fisheries; catches increased relatively slowly in tandem with the development of coastal state and distant water longline fisheries targeting tunas. After 1990, catches increased sharply as a result of changes in targeting from tunas to swordfish by part of the Taiwanese longline fleet, along with the development of longline fisheries in Australia, France (La Réunion), Seychelles and Mauritius and arrival of longline fleets from the Atlantic Ocean (IOTC, 2016).

In this study, a non-equilibrium production model (A Stock-Production Model Incorporating Covariates, ASPIC) (Prager, 1994; 2013) was adopted to conduct the stock assessments of swordfish in the Indian Ocean by incorporating the standardized CPUE series from various fleets.

2. MATERIALS AND METHODS

The total catch data by fleets from 1950 to 2015 were provided by IOTC secretariat and the data were grouped into Taiwan (TWN), Japan (JPN), Spain (ESP), Indonesia (IDN) and other fleets (OTH) according to the CPUE series (Fig. 1). The standardized CPUE series were available from Taiwanese (1979-2016; Wang, 2017), and Japanese (1976-2015; Ijima et al., 2017), Spainish (2001-2015; Fernández-Costa et al., 2017) and Indonesian (2005-2015; Setyadji et al., 2017) longline fleets (Fig. 2). The stock assessment analysis was conducted by fitting the catch data and standardized CPUE series to ASPIC (version 5.34; Prager, 2013).

Although the catch data were available since 1950, the catches were very low before the late 1980s and CPUE series were only available since the mid-1970s. In addition, the results of preliminary runs of ASPIC indicated that the estimate of initial biomass (B1), which derived from the estimate of ratio of the initial biomass to carrying capacity (B1/K) was very unstable and sensitive to the initial values of estimated parameters. In this study, therefore, the time period of stock assessment was from 1975 to 2015.

This study conducted various scenarios for exploring the assessment results by fitting the model to different combinations of CPUE series. Wang et al. (2015) indicated that assuming time-blocks for both catchability may be appropriate to reflect the changes in fishing operations of Japanese and Taiwanese longline fleets, especially for Japanese data series. Therefore, the data series of Japanese fleet were also separated into the time series of 1975-1994 and 1995-2015. Table 1 shows the scenarios used in this study.

Based on the preliminary runs of ASPIC, problematic estimations were found when performing the generalized production function (Pella-Tomlinson model). Thus Schaefer and Fox models were adopted to conduct the stock assessment for each scenario. In addition, bootstrap runs were performed by 500 trials for obtaining the median estimates and confidence intervals for quantities.

3. ASSESSMENT RESULTS

The model fits to the CPUE series are shown in Fig. 3. The results indicated that the model estimated CPUE series generally fitted to trends of standardized CPUE series, except for extremely high or low values in some years. Prager (2013) indicated that a fundamental assumption of ASPIC is that all indices represent the abundance of the stock. ASPIC ended normally with convergence when only Taiwanese and Japanese CPUE series were used. However, negative correlations were detected between some indices when incorporating Spanish and Indonesian CPUE series. In addition, the estimations of bootstrap runs were obviously uncertain when Spanish and Indonesian CPUE series were used.

The trajectories of the relative biomass and fishing mortality to the MSY level, which were estimated based on the median of bootstrap runs, are shown in Fig. 4. The stock status became to be pessimistic because of substantial increase in catches in recent years, especially for the catches of Indonesia and other fleets (Fig. 1). The most pessimistic result was obtained when Fox model and inseparate catchability of Japanese data were used, while using Schaefer model and separate catchability of Japanese data resulted in the most optimistic results.

The median and 80% confidence intervals of key quantities are shown in Table 2. Prager (2013) indicated that "*the maximum sustainable yield (MSY), optimum effort and relative levels of stock biomass and fishing mortality (*B/B_{MSY} *and* F/F_{MSY}*) are more precise among the quantities and the relative estimates present a more precise picture of the condition of the stock. In contrast, absolute levels of stock biomass and related quantities, which include uncertainty in the estimate of catchability, are usually estimated much less precisely. When two or more data series are analyzed, estimated ratios of catchabilities are typically estimated more precise than estimates of each catchability. Also, K may be estimated imprecisely or inaccurately even when MSY and optimum effort are estimated well. This reflects the difficulty of translating relative biomass changes to an absolute scale. One cannot place nearly as much credence in the absolute estimates of stock size, fishing mortality, or any quantities that depend upon them. Absolute estimates of biomass (B) and fishing mortality (F) from ASPIC are provided for the modeler's information and are not intended for use as management guidelines*". Therefore, the absolute estimates of F_{MSY} and B_{MSY} are listed here for reference only.

Kobe plots with 80% bootstrap confidence surfaces around 2015 estimate for swordfish are shown Figs. 5 and 6. Except for the result from Fox model with inseparate catchability of Japanese data, the results from most of scenarios indicate the current status of swordfish may be overfishing but not subject to be overfished. However, the bootstrap confidence intervals indicate that there is a high risk of being overfishing and overfished.

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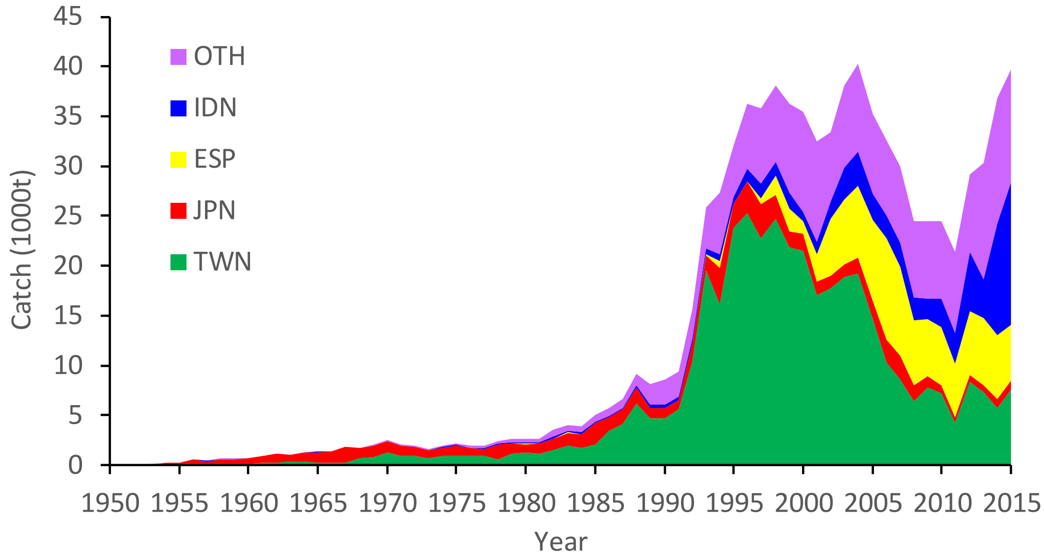


Fig. 1. Nominal catches of swordfish in the Indian Ocean from 1950 to 2015.

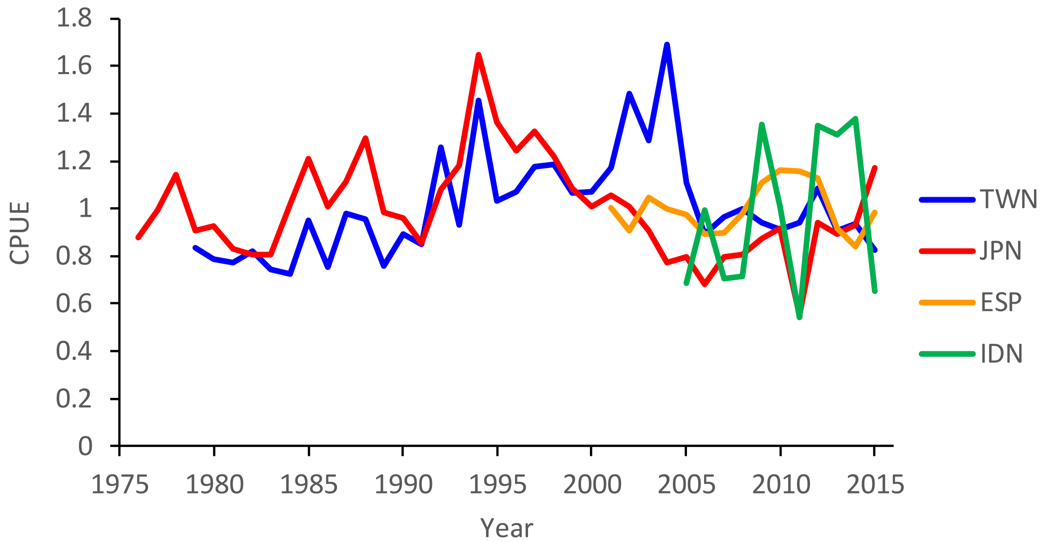
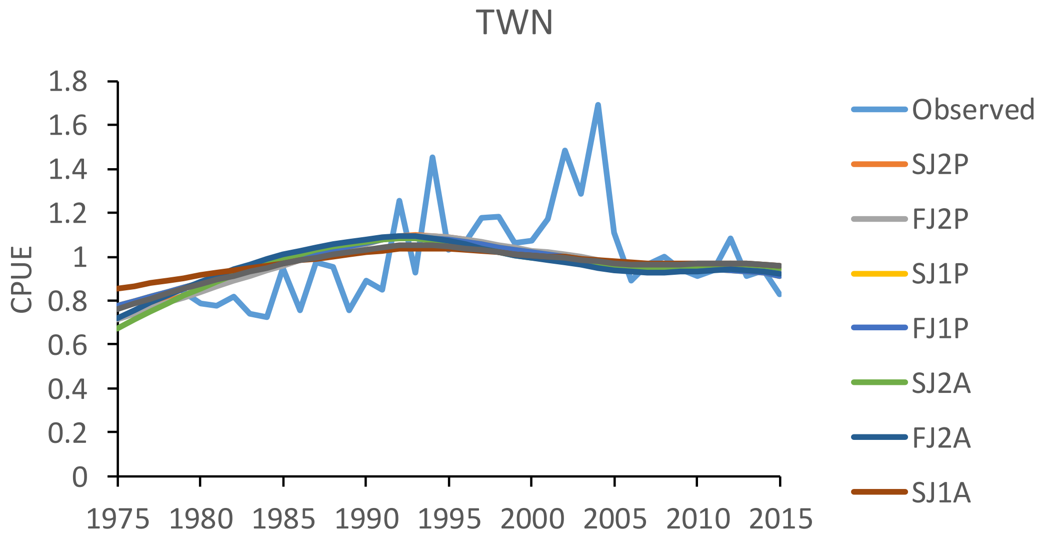


Fig. 2. Standardized CPUE series of swordfish in the Indian Ocean.



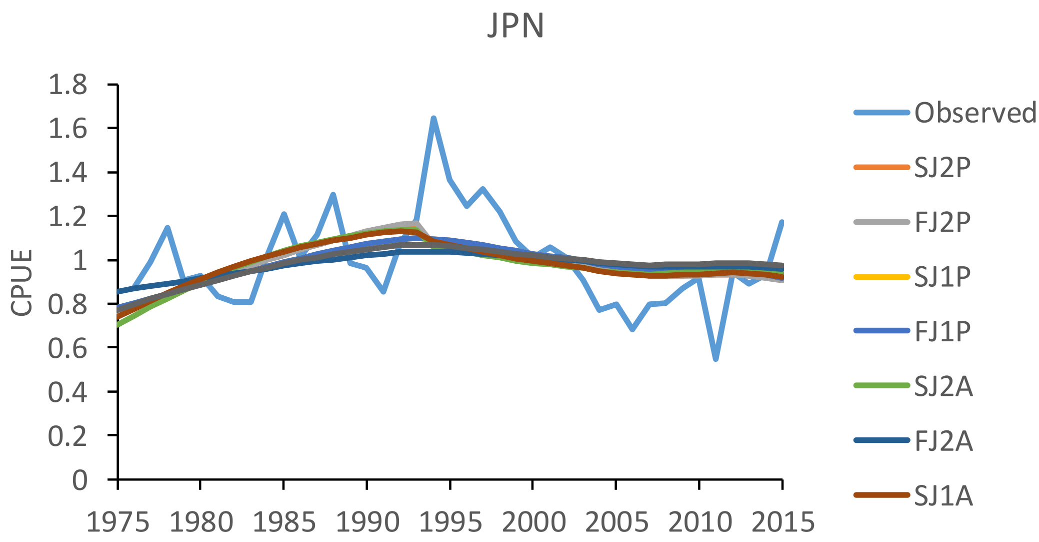
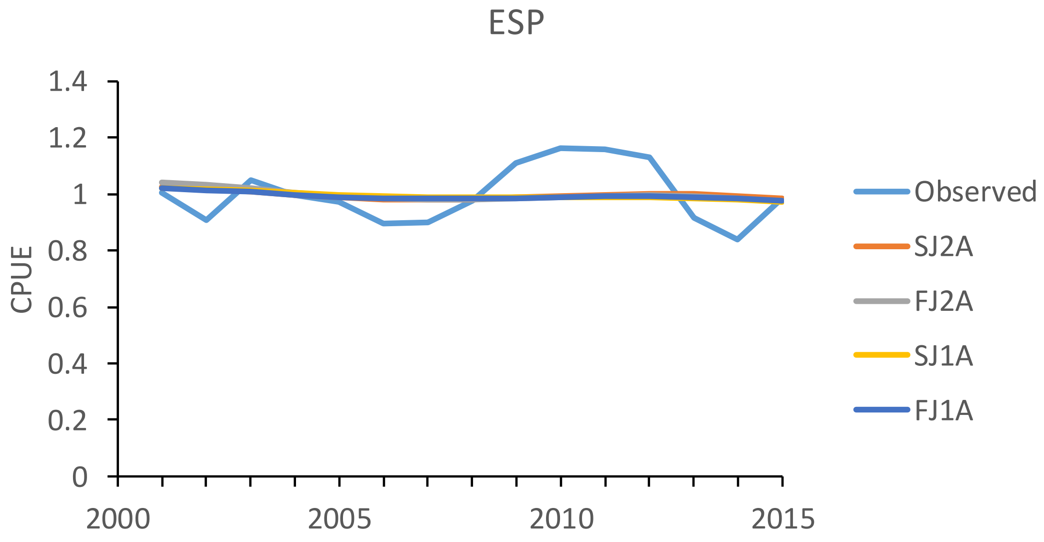


Fig. 3. Observed (standardized) and model-estimated CPUE series of swordfish in the Indian Ocean.



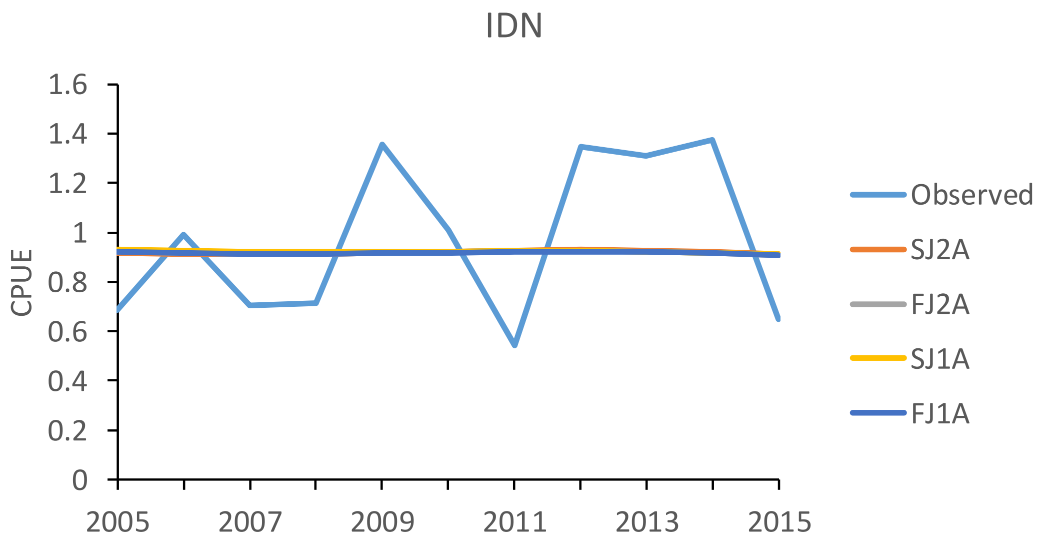


Fig. 3. (Continued).

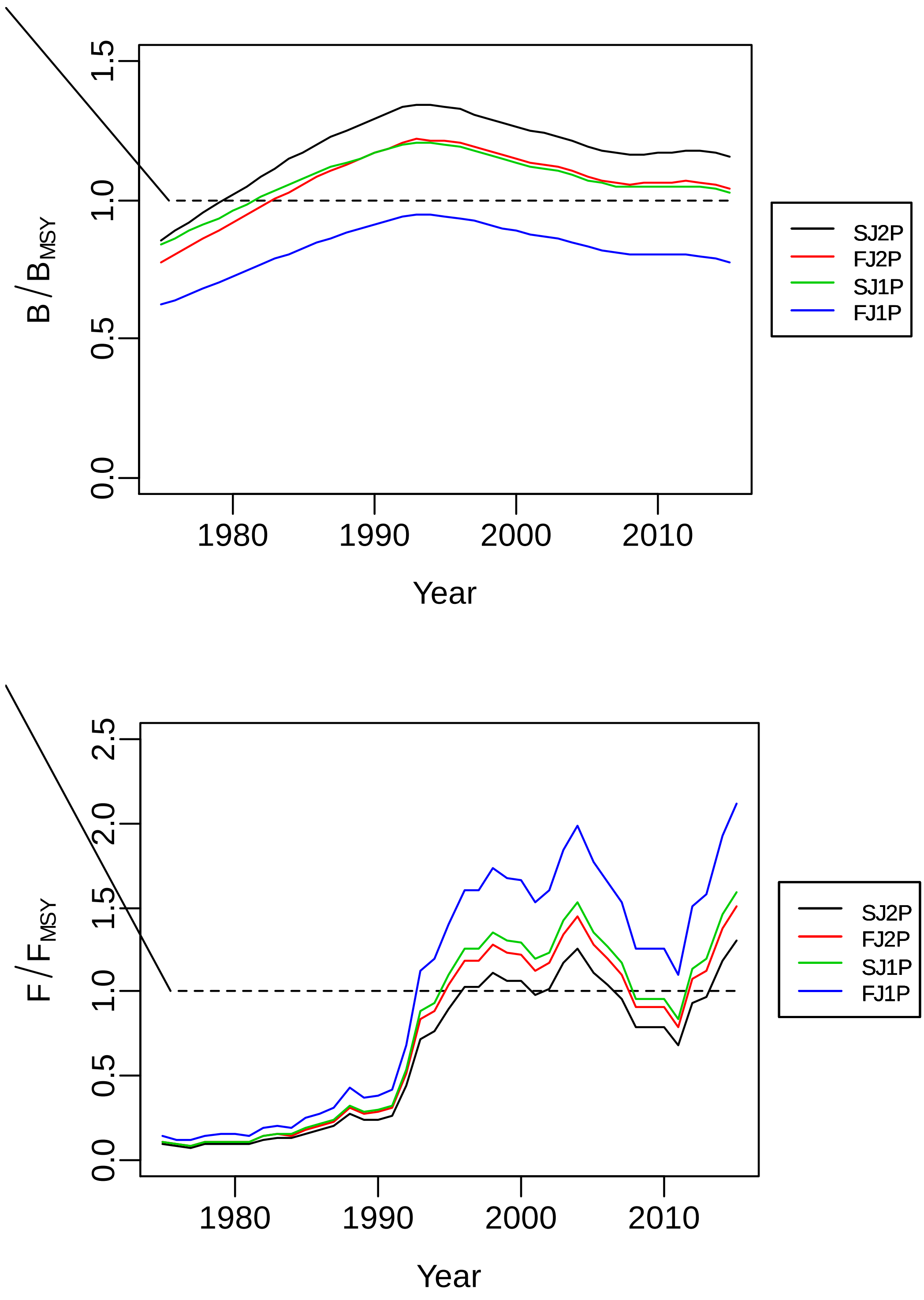


Fig. 4. The trajectories of the median of bootstrap estimates of the relative biomass and fishing mortality to the MSY level for swordfish in the Indian Ocean.

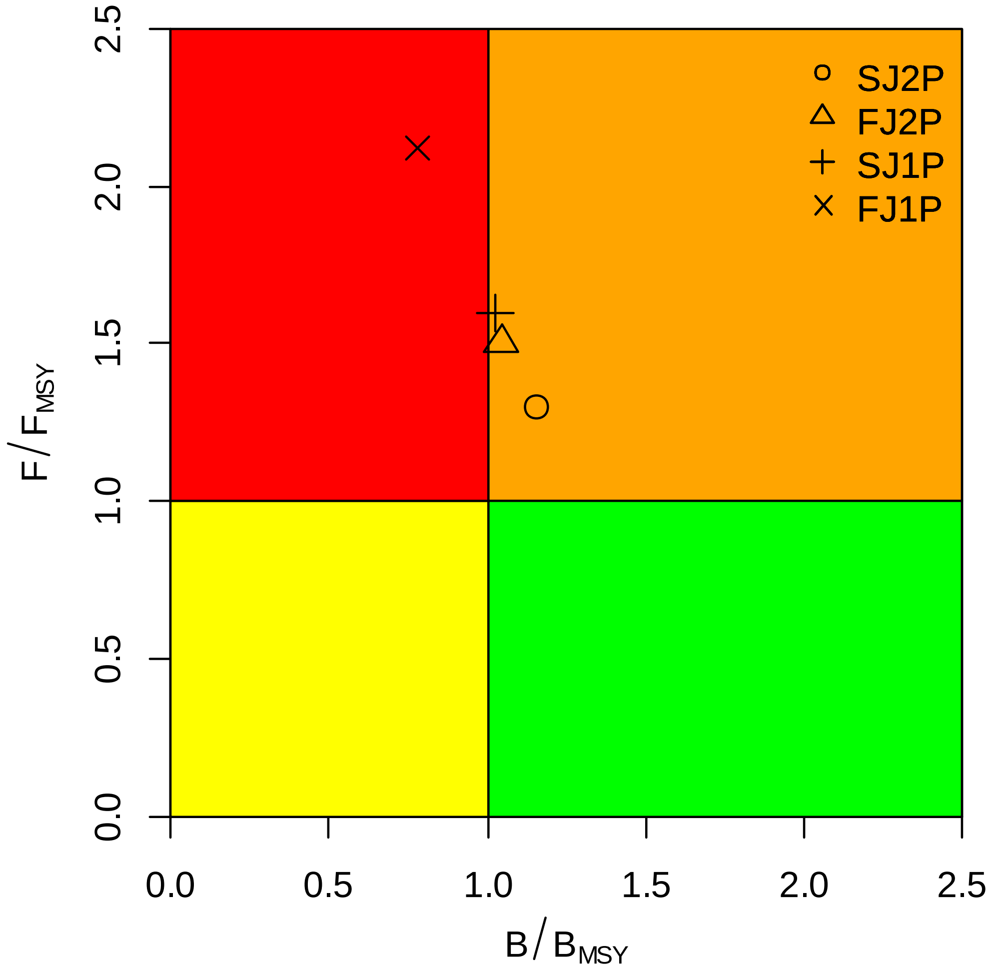


Fig. 5. Kobe plot for the median estimates in 2015 for swordfish in the Indian Ocean.

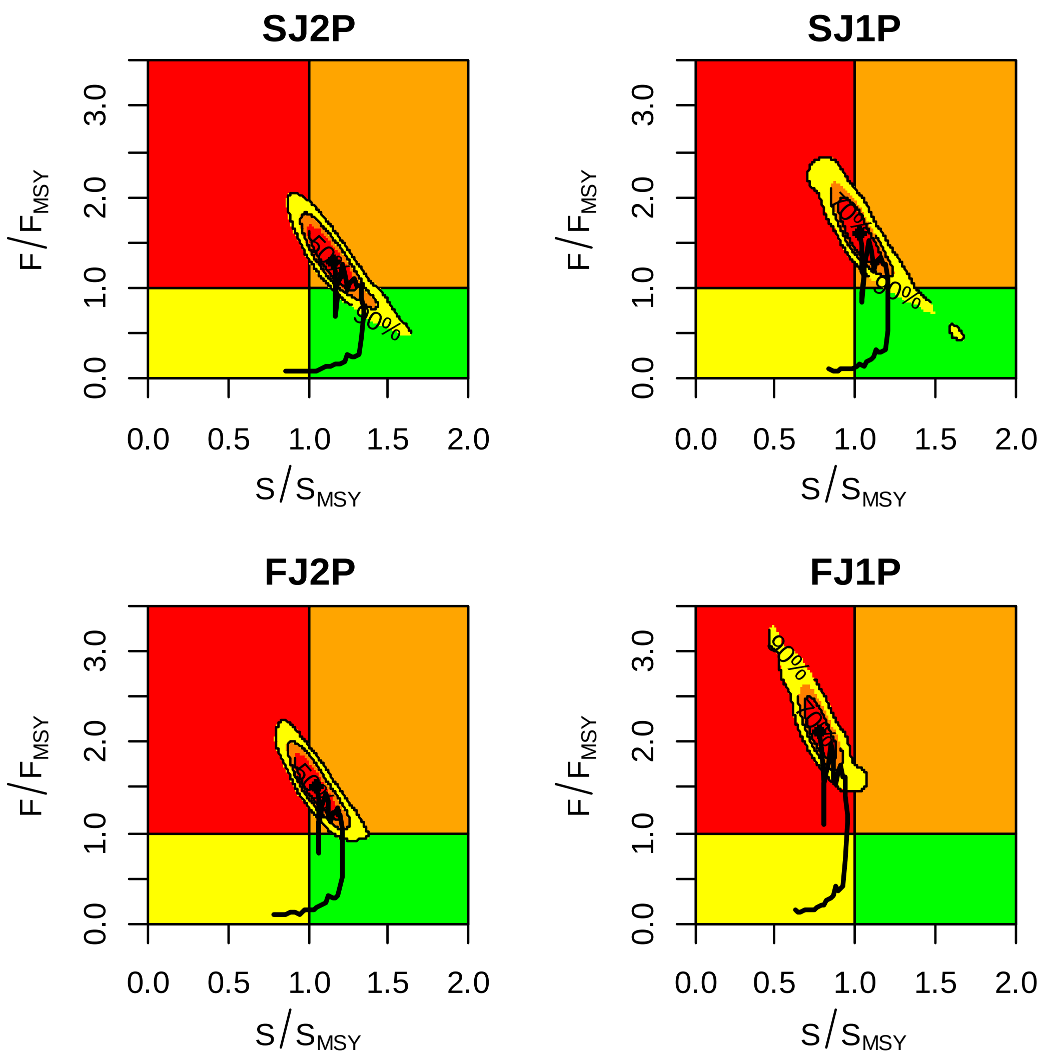


Fig. 6. Kobe plot with 90% bootstrap confidence surfaces around 2015 estimate for swordfish in the Indian Ocean.

Table 1. Scenarios used for the stock assessment of swordfish in the Indian Ocean.

Scenario	Model	CPUE	Assumption of catchability
SJ2P	Schaefer	TWN+JPN	2 catchability for JPN
FJ2P	Fox	TWN+JPN	2 catchability for JPN
SJ1P	Schaefer	TWN+JPN	1 catchability for JPN
FJ1P	Fox	TWN+JPN	1 catchability for JPN
SJ2A	Schaefer	TWN+JPN+ESP+IDN	2 catchability for JPN
FJ2A	Fox	TWN+JPN+ESP+IDN	2 catchability for JPN
SJ1A	Schaefer	TWN+JPN+ESP+IDN	1 catchability for JPN
FJ1A	Fox	TWN+JPN+ESP+IDN	1 catchability for JPN

Table 2. The estimates of key quantities for swordfish in the Indian Ocean.

Scenario	SJ2P	FJ2P	SJ1P	FJ1P	SJ2A	FJ2A	SJ1A	FJ1A
MSY	26,891	25,559	24,960	24,525	Problematic estimation			
	(23257,35937)	(22894,29787)	(21878,32415)	(22443,27669)				
F_{MSY}	0.353	0.311	0.261	0.239				
	(0.26,0.568)	(0.23,0.412)	(0.18,0.492)	(0.189,0.316)				
B_{MSY}	76,621	81,741	94,528	101,518				
	(55194,105532)	(63623,105776)	(62925,137521)	(78476,134124)				
F_{2015}/F_{MSY}	1.300	1.503	1.597	2.122				
	(0.774,1.767)	(1.095,1.961)	(0.892,2.158)	(1.499,2.844)				
B_{2015}/B_{MSY}	1.136	1.027	1.008	0.762				
	(0.96,1.42)	(0.871,1.234)	(0.826,1.351)	(0.57,1.046)				