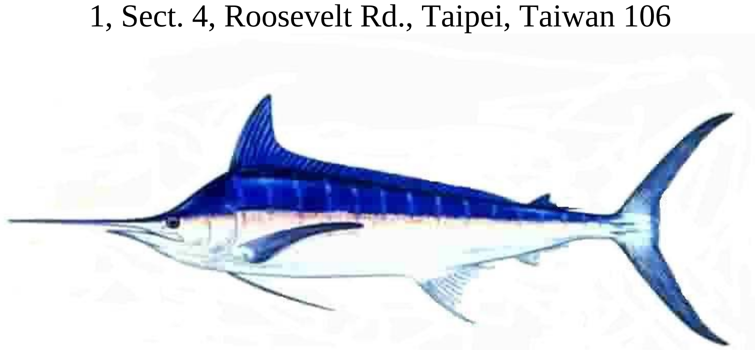
International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

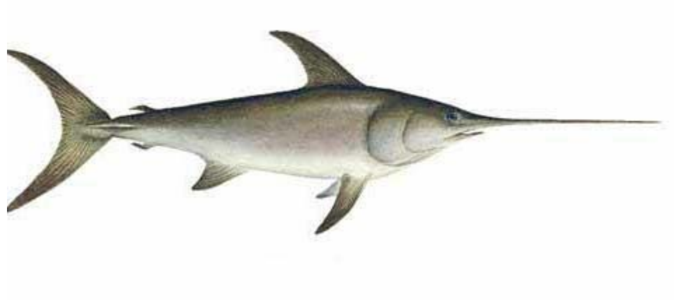
An Update of Stock Assessment for North Pacific Swordfish based on Two-Stock Scenario Using Age-Structured Models

Chi-Lu Sun
Institute of Oceanography
National Taiwan University
1, Sect. 4, Roosevelt Rd., Taipei, Taiwan 106

Nan-Jay Su
Institute of Oceanography
National Taiwan University
1, Sect. 4, Roosevelt Rd., Taipei, Taiwan 106

Su-Zan Yeh
Institute of Oceanography
National Taiwan University
1, Sect. 4, Roosevelt Rd., Taipei, Taiwan 106





Working document submitted to the ISC Billfish Working Group Workshop, 15-22 April 2010, Hakodate, Hokkaido, Japan. Document not to be cited without author's written permission.

An update of stock assessment for the North Pacific swordfish based on two-stock scenario using an age-structured model*

Chi-Lu Sun, Nan-Jay Su, and Su-Zan Yeh

Institute of Oceanography, National Taiwan University

Taipei, Taiwan

Abstract

Based on the two scenarios of spatial structure for swordfish stock in the North Pacific Ocean, an age-structured population dynamics model was fitted to catch, catch-rate, and length-frequency data for the main swordfish fisheries to examine the current status of the swordfish population in the North Pacific Ocean. Results indicate that the current spawning stock biomass (2006) was at a high fraction of its unfished level and that the current fishing intensity (2006) was less than F_{MSY} for different scenarios of stock structure of swordfish. The swordfish stock in the North Pacific Ocean appears to be relatively stable at the current level of exploitation. However, the two stocks of swordfish population need to be monitored carefully as the estimated current exploitation rate across all fleets is close to F_{MSY}.

1. Introduction

Swordfish (*Xiphias gladius*, Linnaeus 1758) is a cosmopolitan species distributed in tropical, subtropical, temperate, and sometimes cold waters of all oceans and adjacent seas (Nakamura, 1985). In the North Pacific Ocean (Fig. 1), the bulk of the swordfish catch has been taken by Japan, the United States (Hawaii and California), Taiwan and Mexico, with very small catches by Korea, Spain, and China, whose swordfish catch is estimated to be less than 4% of the total swordfish catch in the North Pacific Ocean (Wang et al., 2005).

This study is an update of Sun et al. (2009) to re-assess the current status of the swordfish population in the North Pacific with renewed data using an age-structured population dynamics model based on the two-stock scenario of the spatial structure of swordfish stock (Fig. 1) proposed by Ichinokawa and Brodziak (2008).

---

* A working paper submitted to the Intercessional Workshop of the Billfish Working Groups of ISC. 15-23 April 2010, Hakodate, Japan.

2. Materials and methods

2.1. Data used

Based on the two-stock scenario of the spatial structure of swordfish population in the North Pacific, the boundaries of the sub-areas 1 and 2 of the Pacific Ocean were established (Fig. 1) and the catch data of various fisheries were compiled separately for both of the sub-areas for use in the assessments (Figs. 2 and 3).

Under the two-stock scenario, catch data and standardized catch-rates of Japan, Taiwan, Korea, Hawaii, and California-based fleets were used in the assessments for the sub-area 1, except for catch-rate data of the Korean fleet that are not available (Fig. 4). In the sub-area 2, catch data of Japan, Taiwan, Korea, Spain, and Mexico were used; however, only the Japanese and Taiwanese longline standardized catch-effort data were obtained and included in the assessments for the sub-area 2 (Fig. 5).

Sex-aggregated length-frequency data of swordfish are available for the Japanese longline fisheries since 1970, and for the Hawaii- (since 1994) and California-based fleets (since 1980; see Fig. 4). These data were treated as input to fit a sex-pooled model for the assessments of the stock in the sub-area 1 of the North Pacific Ocean. In the sub-area 2, however, only the data from Japaneses fleets are available and used for the assessment (Fig. 5).

2.2. The population dynamics model

The population dynamics model that forms the basis for the assessment is an age-structured model modified from Wang et al. (2007) and considers pooled sexes from age 0 to 15 (age 15 being treated as a "plus group"). The model assumes that recruitment is related to spawning stock biomass according to a Beverton-Holt stock-recruitment relationship and that the deviations about this relationship are log-normally distributed. Owing to lack of length-frequency data before 1970, the recruitment deviations for the years prior to 1971 are all set to zero because there are no data which could inform year-class strength for these years whereas those for the years after 1970 are treated as free parameters of the assessment model.

The logistic curve, which assumes that the vulnerability of a fish increases monotonically to an asymptote with increasing length, is used most commonly in fisheries stock assessment models to represent selectivity for longline gears (e.g. Erzini et al., 1998; Sousa et al., 1999). The assumption that selectivity-at-length follows a logistic curve might be adequate to mimic the length-frequency data for the longline fleets. However, owing to lack of length-frequency data for the Taiwanese, Korean, and the other fleets in the both sub-areas, the selectivity ogives for the fleets without length-frequency samples are assumed to be the same with the Japanese longline fleet under the assumption of two-stock scenario.

2.3. Parameter estimation

The parameters of the model for which auxiliary information is available are listed in Table 1. The values for the parameters related to natural mortality (*M*), the steepness of the stock-recruitment relationship (*h*), and the extent of variation in recruitment (σ_v) cannot be determined from auxiliary information, nor can they be estimated reliably by fitting the model to the data and must therefore be pre-specified. In this study, three values of *M* are examined for the sensitivity analysis (taken as 0.2~0.3 yr^{-1}), whereas *h* is assumed to be 0.9 and σ_v to be 0.4 following Wang et al. (2007).

The objective function minimized to find the estimates of the 'free' parameters of the model includes two components (the data available for assessment purposes and the constraints based on *a priori* assumptions). The data available for assessment purposes based on two-stock scenario are: (1) the catches (assumed known without error), (2) the annual length-frequencies (pooled across sex to fit a sex-pooled model), and (3) the standardized catch-rate indices by fleet. Constraints are imposed on the extent to which the number of 0-year-olds can deviate from the underlying stock-recruitment relationship.

The model outputs are examined by key quantities of management interest as follows: (1) the spawning stock biomass (*S*); (2) the ratio of spawning stock biomass to that at which MSY is achieved (S/S_{MSY}); (3) the fishing intensity (*F*); (4) the ratio of the exploitation rate to that at which MSY is achieved (F/F_{MSY}). The current status of swordfish population for the two stocks is examined using the "Kobe plots".

3. Results and discussion

Figures 4 and 5 show the observed catch-rates and the model-predicted values based on different assuming levels of natural mortality for the four and two fleets operating in the sub-areas 1 and 2 respectively. The observed and model-predicted length-frequencies for those fleets are also illustrated in Figs. 4 and 5, for which results are aggregated across years for ease of presentation. The model-estimated catch-rates for each fleet (Japan, Hawaii, California, and Taiwan in sub-area 1 and Japan and Taiwan in sub-area 2) all generally follow the trends of standardized catch-rate indices, except for the earlier years which had no recruitment deviations to be estimated.

Figure 6 shows the time trajectory of the ratio of exploitation rates relative to F_{MSY} and the ratio of the spawning stock biomass to its MSY level (S_{MSY}) for different values assumed for natural mortality (M = 0.2~0.3 yr^{-1}). Generally, the exploitation rates for both stocks in the North Pacific Ocean are lower than (but close to) that at MSY level, except in the early years and in the 1990s, for which the fishing intensity somewhat exceeded the MSY level (Fig. 6). It should be noted that the high catch of swordfish in the late 1950s in the sub-area 1 leaded to decreased spawning stock biomass in the 1960s, but the stock recovered soon and approached to a maximum in 1980s. Something interesting is that, following the trend of catch-rates, the spawning stock biomass of two stocks of swordfish population in the North Pacific Ocean both showed a decreasing trend around 1980s, but the sub-area 2 stock recovered since 1994 while the sub-area 1 stock recovered after 2000.

Figure 7 shows the “Kobe Plots” for the two stocks of swordfish for different levels of assumed natural mortality. Current spawning stock biomass for the sub-area 1 stock is estimated to be lower than that at unfished level, but current biomass level seems obviously exceeded that at unfished level. Even assuming a lower level of natural mortality, the results still demonstrate that the spawning stock biomass of swordfish in the North Pacific is currently at a fairly high fraction of its initial level and that the exploitation rates are lower than that corresponding to the MSY level for both stocks of swordfish population in the North Pacific (Fig. 7).

Compared to Sun et al. (2009), catch, catch-rate, and length-frequency data were updated and used in this year’s assessments. For example, catches of swordfish caught by the California and Mexico-based fleets were included. The assessment results are similar for the sub-area 1 stock, but different for the sub-area 2 stock as the input data were incomplete in the last assessment. The results for sub-area 2 are getting much better and reliable, compared to last assessment with great uncertainty in the input data. However, information used for the assessments in this sub-area is quite limited (i.e. biological parameters might be different from those used for the sub-area 1 stock). Impacts of different growth patters between stocks and sex structure need to be explored and incorporated into the model to improve the assessment results.

References

Erzini, K., Goncalves, J.M.S., Bentes, L., Lino, P.G., 1998. Species and size selectivity in a 'red' sea bream longline 'métier' in the Algarve (southern Portugal). Aquat. Living Resour. 11, 1–11.

Ichinokawa, M., Brodziak, J., 2008. Stock boundary between possible swordfish stocks in the northwest and southeast Pacific judged from fisheries data of Japanese longliners. Working Paper ISC/08/BILLWG-SS/04. International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, 12-14 November 2008, Honolulu, Hawaii, U.S.A.

Nakamura, I., 1985. FAO species catalogue. Vol. 5. Billfishes of the World. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes and swordfishes known to date. FAO Fish. Synop. 125, 5.

Sousa, F., Isidro, E., Erzini, K., 1999. Semi-pelagic longline selectivity for two demersal species from the Azores-the black spot sea bream (*Pagellus bogaraveo*) and the bluemouth rockfish (*Helicolenus dactylopterus dactylopterus*). Fish. Res. 41, 25–35.

Sun, C.L., Su, N.J., Yeh, S.Z., 2009. Stock assessment of swordfish, Xiphias gladius, in the North Pacific Ocean using an age-structured population dynamics model. Working Paper ISC/09/BILLWG-2/13, Intercessional Workshop of the Billfish Working Groups of ISC. 19-26 May 2009, Busan, Korea.

Wang, S.P., Sun, C.L., Punt, A.E., Yeh, S.Z., 2005. Evaluation of a sex-specific age-structured assessment method for the swordfish, *Xiphias gladius*, in the North Pacific Ocean. Fish. Res. 73, 79–97.

Wang, S.P., Sun, C.L., Punt, A.E., Yeh, S.Z., 2007. Application of the sex-specific age-structured assessment method for swordfish, *Xiphias gladius*, in the North Pacific Ocean. Fish. Res. 84, 282–300.

Table 1. The values assumed for the parameters of the relationships between length and weight, length and age, and maturity and age.

Parameter	Value
Asymptotic length, L_∞ (cm)	220.0
Growth parameter, k (yr^{-1})	0.258
Age-at-zero-length, t_0 (yr)	–1.30
Length-weight, A	1.3528×10^{-6}
Length-weight, B	3.4297
Length-at-50%-maturity, L_m (cm)	143.68
Maturity slope, r_m	–0.1034
Maximum age, λ (yr)	15

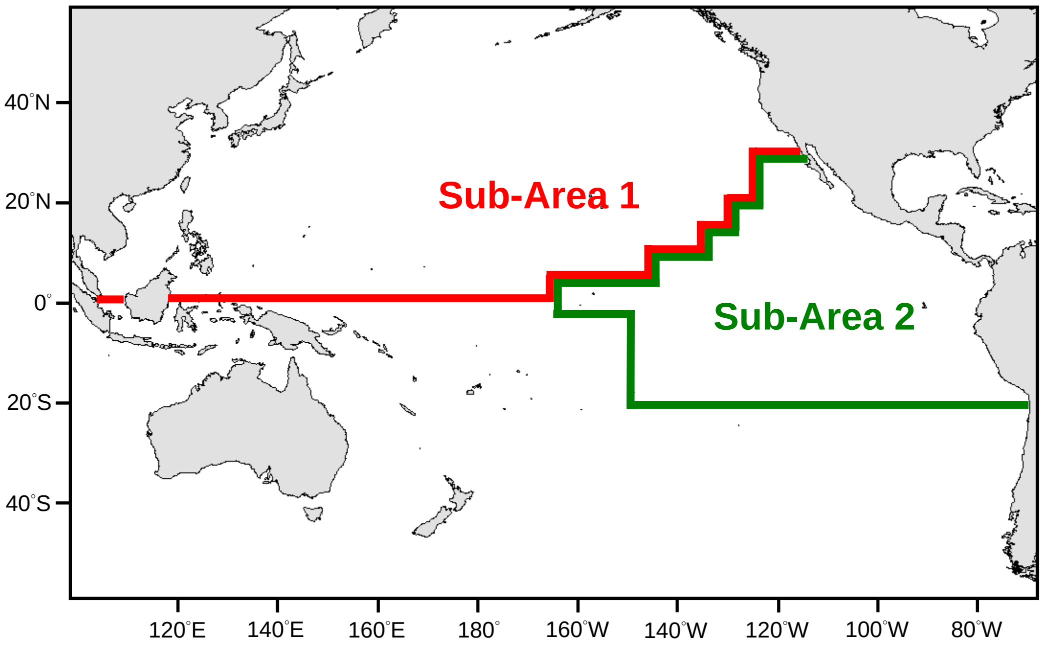


Fig. 1. The sub-area 1 (red line) and sub-area 2 (green line) of the Pacific Ocean for the two stocks of swordfish used in the assessment.

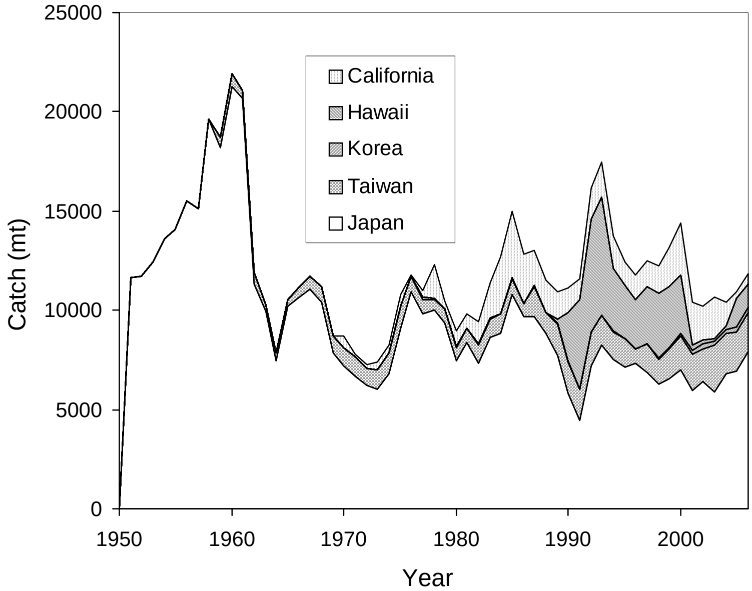


Fig. 2. Annual catches of swordfish by fleet in the sub-area 1 of the North Pacific Ocean for 1952-2006.

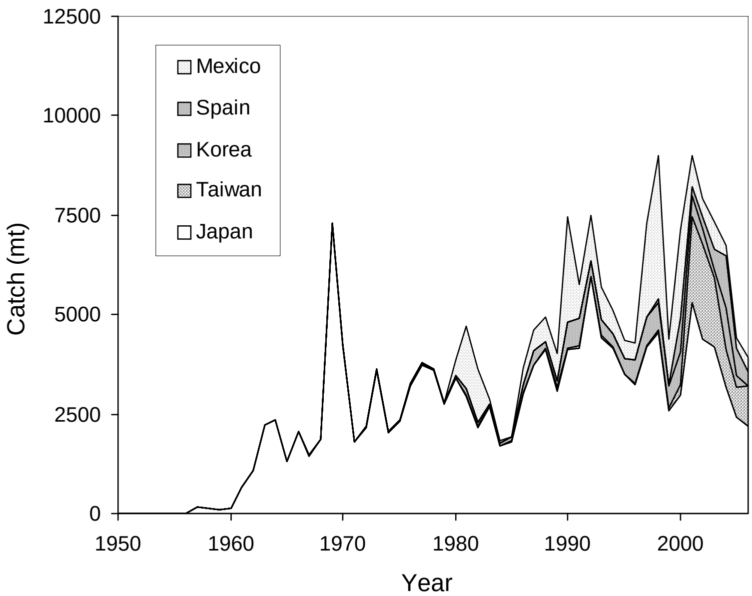


Fig. 3. Annual catches of swordfish by fleet in the sub-area 2 of the North Pacific Ocean for 1955-2006.

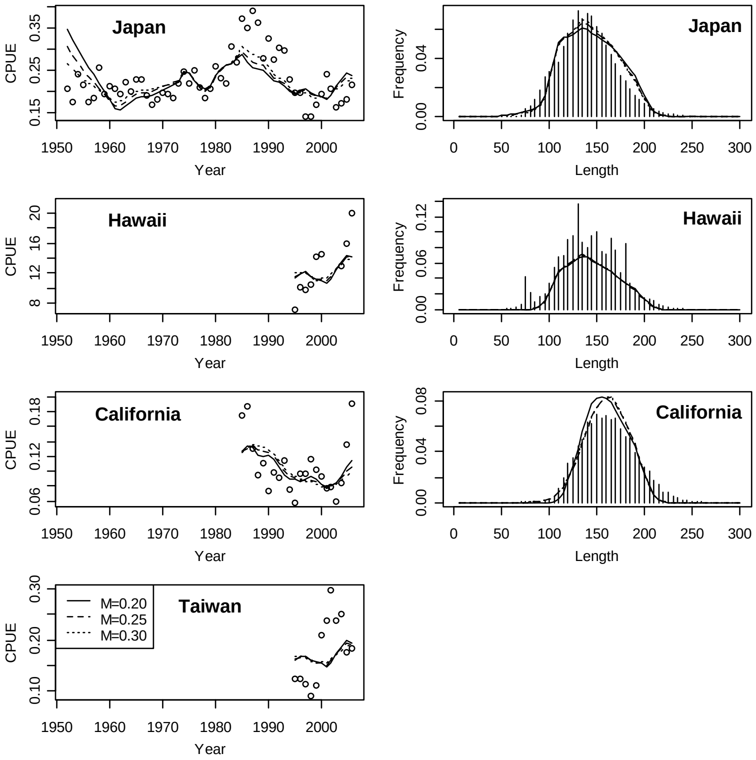


Fig. 4. Observed catch-rate and length-frequency data (points and histograms) and model-predicted values (lines) for the four fleets operating in the sub-area 1 of the North Pacific. Different values were assumed for natural mortality to fit the model.

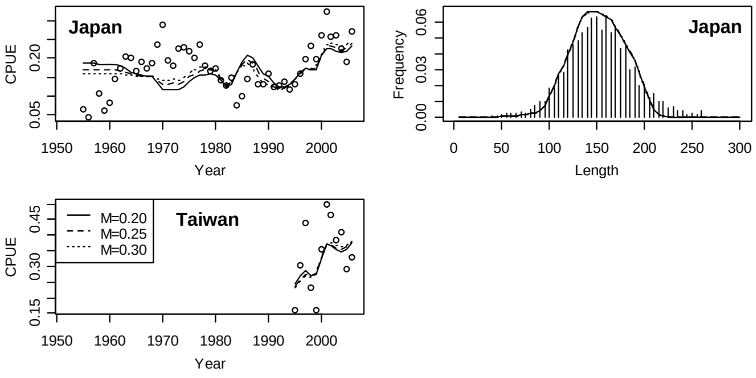


Fig. 5. Observed catch-rate and length-frequency data (points and histograms) and model-predicted values (lines) for the two fleets operating in the sub-area 2 of the North Pacific. Different values were assumed for natural mortality to fit the model.

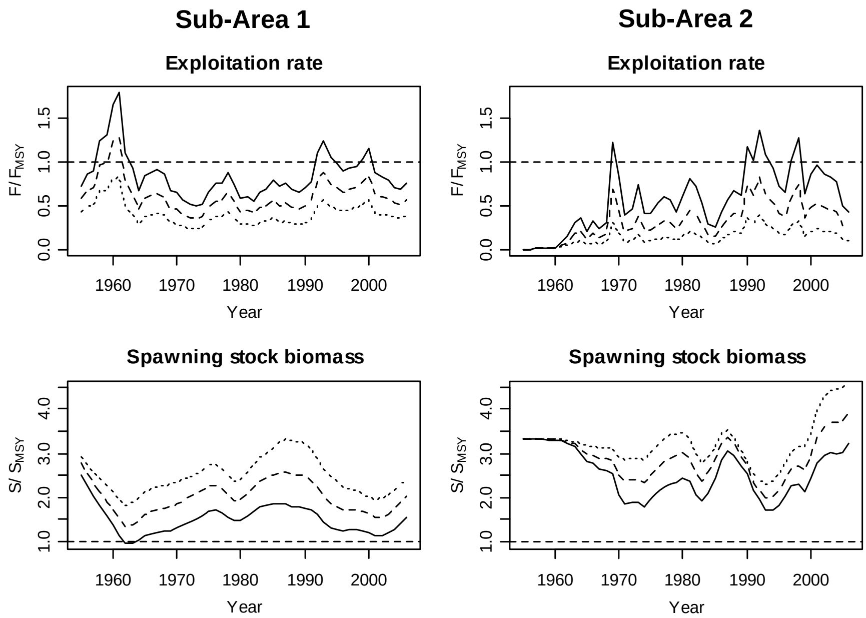


Fig. 6. Time trajectories of the exploitation rate relative to that at MSY (F/F_{MSY}) and the spawning stock biomass relative to its MSY level (S/S_{MSY}) for the two stocks of swordfish in the sub-areas 1 and 2 of the North Pacific Ocean. Different values were assumed for natural mortality to fit the model.

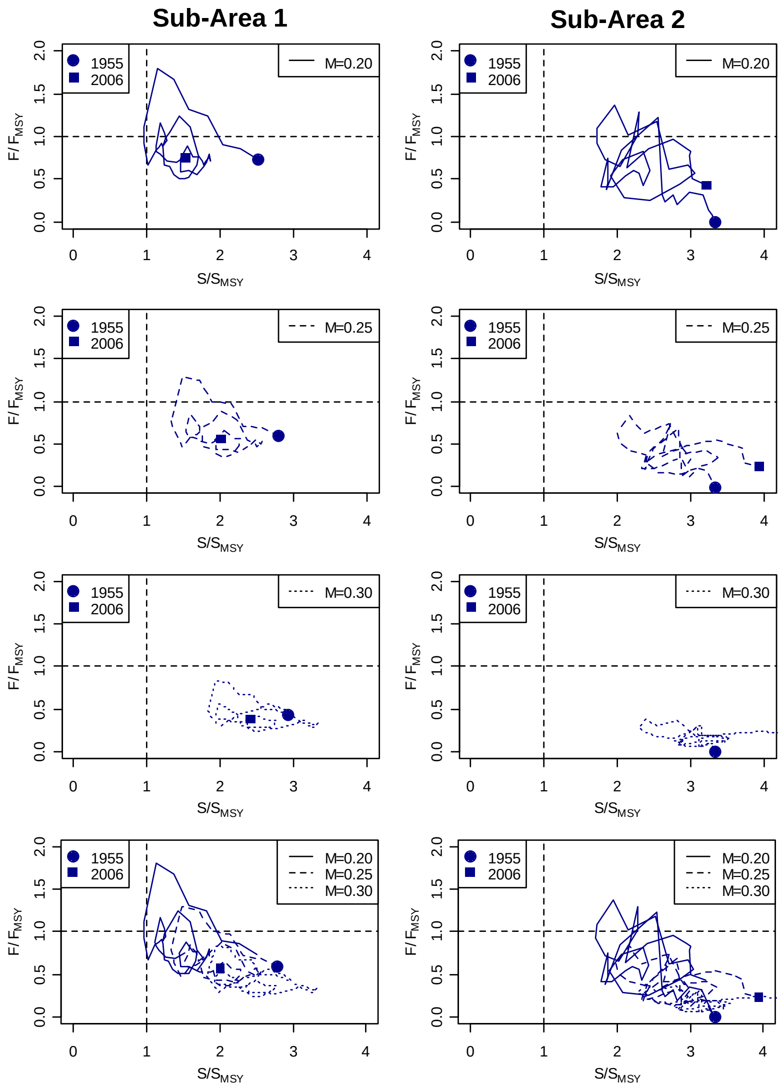


Fig. 7. The estimated exploitation rates relative to that at MSY (F/F_{MSY}) versus the estimated spawning stock biomass relative to that supports MSY (S/S_{MSY}) for the two stocks of swordfish in the sub-areas 1 and 2 of the North Pacific Ocean under different levels of natural mortality.