SCIENTIFIC COMMITTEE
EIGHTH REGULAR SESSION

7-15 August 2012
Busan, Republic of Korea

Annex 7 REPORT OF THE BILLFISH WORKING GROUP WORKSHOP

WCPFC-SC8-2012/ SA-IP-16

ISC[1]

[1] International Scientific Committee for Tuna and Tuna-like Species In the North Pacific Ocean

Annex 7

REPORT OF THE BILLFISH WORKING GROUP WORKSHOP

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

2-9 April 2012
Shanghai, China

1.0 OPENING OF BILLFISH WORKING GROUP (BILLWG) WORKSHOP

An intercessional workshop of the BILLWG of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) was convened in Shanghai, China from 2-9 April 2012. The goals of this workshop were: (1) to prepare and review stock assessment documentation and develop stock projections for Western and Central North Pacific (WCNPO) striped marlin, (2) to collect and review fishery data and nominal catch and nominal catch-per-unit effort (CPUE) data for Pacific blue marlin, (3) to review life history parameters and available biological data for Pacific blue marlin, and (4) to collect and review North Pacific swordfish catch data.

Professor Shuolin Huang, Vice President of Shanghai Ocean University, welcomed participants from China, Chinese Taipei, Japan, the United States of America (USA), and the Inter-American Tropical Tuna Commission (IATTC) (Attachment 1). The Chairman noted that no representatives from Canada, Mexico, Korea, or the Secretariat of the Pacific Community (SPC) were present.

2.0 MEETING LOGISTICS

2.1 Standard Meeting Protocols

The BILLWG Chairman Jon Brodziak noted that the efforts of the working group at this meeting would follow the scientific method with particular emphasis placed on empirical testing, open debate, documentation and reproducibility, reporting uncertainty, and peer review.

2.2 Computing Facilities

Computing facilities included a website for distribution of working papers, meeting documents, and other information, and also included a Wi-Fi wireless network access point to connect to the internet.

2.3 Adoption of Agenda

The meeting agenda was adopted (Attachment 2).

2.4 Assignment of Rapporteurs

Rapporteuring duties were assigned to Jon Brodziak, Yi-Jay Chang, Xiaojie Dai, Gerard DiNardo, Wenjiang Guan, Michael Hinton, Lyn Katahira, Ai Kimoto, Hui-Hua Lee, Nan-Jay Su, Chi-Lu Sun, Darryl Tagami, and Kotaro Yokawa. Lyn Katahira, although she did not attend the meeting in Shanghai, served as the lead rapporteur with overall responsibility of assembling the workshop report.

3.0 NUMBERING WORKING PAPERS AND DISTRIBUTION POTENTIAL

Working papers were distributed and numbered (Attachment 3). The working papers that were agreed to be posted on the ISC website where they will be available to the public were: ISC/12/BILLWG-1/02, ISC/12/BILLWG-1/03, ISC/12/BILLWG-1/04, ISC/12/BILLWG-1/05, ISC/12/BILLWG-1/06, ISC/12/BILLWG-1/08, and ISC/12/BILLWG-1/09. The working papers that will not be posted on the ISC website were: ISC/12/BILLWG-1/01 and ISC/12/BILLWG-1/07.

4.0 STATUS OF WORK ASSIGNMENTS

The WG reviewed the status of work assignments from the December 2011 ISC BILLWG workshop. These were:

- Submit finalized copies of all working papers presented at this meeting to the BILLWG Chair by 15 January 2011.
- At the April 2012 meeting, USA scientists will catalog data availability from the blue marlin recreational fishery and present it to the BILLWG.
- At the April 2012 meeting, each country will present working papers on blue marlin nominal reported catch, length composition and size data, and also summarize the history of each fishery. The BILLWG Chair also requested that each country provide information and maps of the spatial extent of their blue marlin fisheries.
- Complete a review of the past blue marlin stock assessment (Kleiber et al, 2003) and other relevant research.
- At the April 2012 meeting, update North Pacific swordfish catch by stock area in anticipation of the completion of a full stock assessment in 2013.
- Update North Pacific striped marlin and swordfish catch tables (Tables 1 and 2).

The BILLWG Chairman reported that these tasks were addressed and completed by participants during the meeting.

The BILLWG Chairman was also assigned a number of tasks. These tasks included:

- Contact Peter Williams at the SPC regarding blue marlin data holdings and submit a data request.
- Contact IATTC about sending a participant to the BILLWG.
- Contact SWFSC for blue marlin tagging data.
- Contact Mike Musyl (Pelagic Fisheries Research Program) to obtain a summary of his post-release survival research.
- Request blue marlin data from the WCPFC.
- Request blue marlin recreational catch data from New Zealand.
- Provide an outline for fishery description working papers to BILLWG members by January 2012.
- Form a sub-group to address recruitment modeling in WCNPO striped marlin projections and to develop a working paper on projections to be presented at the April 2012 meeting.

The BILLWG Chair reported that these tasks were addressed and completed by the end of the meeting, with the exception of obtaining blue marlin tagging data from the SWFSC and requesting blue marlin recreational data from New Zealand. It was noted that the IATTC may be able to assist with the tagging data from the SWFSC and that the Chair would identify a point of contact in New Zealand for the recreational data request.

5.0 ANNUAL BILLFISH CATCH/EFFORT (CATEGORY I, II, AND III DATA)

5.1 Review of current fishery data (Category I, II, & III data) on the ISC website

The status of annual striped marlin catches by country was reviewed based on catch tables in the Report of the Billfish Working Group Workshop (6-16 December 2011, Honolulu, Hawaii). The WG completed two tables for North Pacific striped marlin which showed the current year of striped marlin data available to the BILLWG (Table 1) and showed the date when these data are expected to be updated though 2011 (Table 2). The WG recommended that member countries separate their historical striped marlin catch into the two stocks areas. The acronym “DC” stands for “data coordinator” and identifies the person who is the point of contact for providing Category I, II, and III data to the ISC BILLWG.

Country	Category I	Category II	Category III	Comments
Canada	No data	No data	No data	DC: John Holmes
Mexico	2003	Unknown	Unknown	DC: Luis Fleischer
Korea	2010	Unknown	Unknown	DC: To be determined
Japan	2009	Unknown	Unknown	DC: Koji Uosaki
China	No data	Unknown	Unknown	DC: Xiaojie Dai Category II data were provided for 2001- 2010 data in April 2012
Chinese Taipei	2010	Unknown	Unknown	DC: Ren-Fen Wu Data include updated fishery-specific totals for 2006-2010
USA	2010	Unknown	Unknown	DC: John Childress Catch totals in 2010 seem low
Comments	Need to check ISC website – no access at this meeting.	Need to check ISC website – no access at this meeting.	Need to check ISC website – no access at this meeting.	

Table 1. Year of current ISC Category I, II, and III data for North Pacific striped marlin.

Country	Category I	Category II	Category III	Comments
Canada	No data	No data	No data	Not present
Mexico	Unknown	Unknown	Unknown	Not present
Korea	Unknown	Unknown	Unknown	Not present
Japan	July 2012	July 2012	July 2012	
China	May 2012	May 2012	May 2012	
Chinese Taipei	May 2012	May 2012	May 2012	
USA	May 2012	May 2012	May 2012	

Table 2. Expected ISC data update schedule through 2011 for North Pacific striped marlin.

6.0 COLLECT AND REVIEW NORTH PACIFIC SWORDFISH LIFE HISTORY AND CATCH DATA

6.1 Review of current fishery data (Category I, II, & III data) on the ISC website

The status of annual swordfish catches by country was reviewed based on catch tables in the Report of the Billfish Working Group Workshop (6-16 December 2011, Honolulu, Hawaii). The WG completed two tables for North Pacific swordfish, which is comprised of two stocks in the North Pacific (Figure 1). The first table showed the current year of swordfish Category I data available to the BILLWG (Table 3) and the second table showed the date when these data are expected to be updated though 2011 (Table 4). The WG recommended that member countries separate historical swordfish catch into the two stock areas.

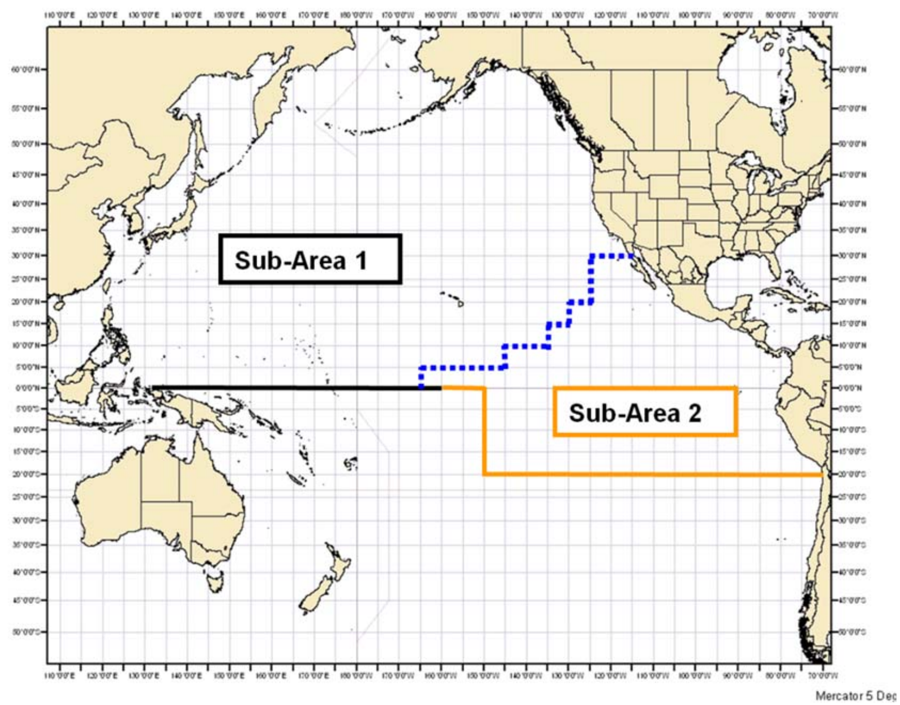


Figure 1. Swordfish stock areas in the North Pacific. Sub-Area 1 is the Western and Central North Pacific (WCNPO) swordfish stock and Sub-Area 2 is the Eastern North Pacific (EPO) swordfish stock.

Country	Area 1 WCNPO	Area 2 EPO	Comments
Canada	No data	No data	
Mexico	Unknown	2008	Not separated by stock
Korea	2007	2007	Not separated by stock
Japan	2009	2009	Not separated by stock
China	Unknown	Unknown	Data were provided for 2001- 2010 data in April 2012 but were not separated by stock
Chinese Taipei	2005	2005	Not separated by stock
USA	2010	2010	Not separated by stock
Comments		Total available from 2010 update	

Table 3. Current ISC Category I data for North Pacific swordfish. Data coordinator for each country is the same as in Table 1.

Country	Area 1 WCNPO	Area 2 EPO	Comments
Canada	Unknown	Unknown	Not present
Mexico	Unknown	Unknown	Not present
Korea	Unknown	Unknown	Not present
Japan	July 2012	July 2012	
China	May 2012	May 2012	Needs to process area-specific catch
Chinese Taipei	May 2012	May 2012	Needs to process area-specific catch
USA	May 2012	May 2012	Needs to process area-specific catch

Table 4. Expected ISC data update schedule through 2011 for North Pacific swordfish.

<u>Discussion</u>

It was noted that stock-separated catch data were available in the 2009 swordfish stock assessment and were also updated in the 2010 swordfish stock assessment update.

7.0 COLLECT AND REVIEW FISHERY DATA AND NOMINAL CATCH-PER-UNIT EFFORT DATA FOR PACIFIC BLUE MARLIN

7.1 Blue Marlin Catches in the North and South Pacific from WCPFC Data presented by Darryl Tagami (ISC/12/BILLWG-1/02)

This working paper presents catch summaries and distribution plots of blue marlin in the North Pacific and South Pacific from non-ISC member countries, as well as ISC member countries who are also members of the WCPFC. The data were provided by the WCPFC for longline catches of blue marlin only. The purpose was to provide the ISC BILLWG with billfish catch data not available in the ISC or ISC Working Groups data holdings. This represents the first time this blue marlin catch data has been made available to the ISC for stock assessment purposes.

Cumulative longline catch for blue marlin by WCPFC member countries were presented for comparative purposes. Japan (271,000 mt) and Chinese Taipei (187,000 mt) were the largest producers of blue marlin longline catch in the Pacific Ocean. For non-ISC member countries, Indonesia (20,000 mt) was the largest producer of blue marlin longline catch. Distribution of cumulative longline catches of blue marlin (in numbers caught) and effort (in thousands of hooks) were plotted for USA, Japan, Chinese Taipei, Korea, and China.

Discussion

The presenter noted the value of reviewing and visualizing catch distribution of blue marlin in the north and south Pacific since the blue marlin stock is considered to be a pan-Pacific stock. Since the ISC data holdings are restricted to the north Pacific, it was necessary to request longline data from the WCPFC whose Convention Area covers the western and central Pacific Ocean, both north and south of the equator. It was noted that some of the WCPFC member countries are also ISC member countries including Japan, Chinese Taipei, Korea, China, and the USA It was also noted that longline catch and effort from these ISC countries occurred both north and south of the equator.

The WG noted that each country differs in their spatial distribution of longline catch and effort in the Pacific. The catch and effort data for Korea and China were more concentrated near the equator while the catch and effort data for Japan and Chinese Taipei were widely distributed throughout the Pacific Ocean.

It was noted that the plots were generated from WCPFC Category II data, and that Category II annual longline catch totals may be smaller than Category I annual longline catch totals because some Category I catch data have no specific area.

7.2 A Long-Term Nominal Catch History for Blue Marlin in Hawaiian Waters presented by Darryl Tagami (ISC/12/BILLWG-1/03)

This working paper presented a 63-year (1948–2010) catch history for blue marlin (*Makaira nigricans*) in Hawaiian waters. The principal data source was the Hawaii Division of Aquatic

Resources (HDAR), which archives catch data from several types of fisheries (including longline, trolling, and handline). Landings of blue marlin (metric tons) were tabulated at quarterly and annual intervals. Maps depicting the distributions of blue marlin catches and effort for the Hawaii-based and American Samoa-based longline fisheries from logbook data were presented. Published results from the Hawaii longline fishery in recent years (1995–2003) that illustrate the effects of catch history correction were also presented. An updated corrected catch time series for 1995–2010 data with average weights and discard rates will be provided for the full assessment.

Discussion

It was noted that the catch history for only the Hawaii-based longline fishery was corrected, and that the trolling catch data may also need to be corrected.

The Hawaii-based longline fishery includes both shallow sets targeting swordfish and deep sets targeting tunas. It was noted that blue marlin are predominantly caught on deep-set trips. It was reported that 4,424 blue marlin were caught on deep set trips in 2011, while only 116 were caught on shallow-set trips.

7.3 A Review of Taiwan's Blue Marlin Fisheries in the Pacific Ocean, 1958-2010 presented by Nan-Jay Su (ISC/12/BILLWG-1/04)

Catch-effort data (1964-2010) and length data (2005-2010) from the Taiwanese distant-water longline fishery and catch-effort data (2007-2010) for the Taiwanese offshore longline fishery in the Pacific Ocean of blue marlin were collected in this study, as well as annual blue marlin catches from various offshore and coastal fisheries in waters off Taiwan during 1958-2010. The Taiwanese distant-water tuna longline fleet operated throughout the Pacific Ocean in the 1990s and 2000s, while the offshore longline fleet operated in the north Pacific Ocean. However, most of blue marlin harvested by these two fisheries was caught in tropical Pacific Ocean due to the relatively high abundance and high catch rates in tropical waters. In 2010, the largest proportion of blue marlin catch came from the offshore longline fishery which harvested 3,553 mt. In comparison, the catch of blue marlin from the Taiwanese distant-water longline fishery was 1,490 mt in 2010, and Small catches of blue marlin were also taken by various offshore and coastal fisheries, such as gillnets, harpoons, and set nets.

Discussion

It was noted that blue marlin catch data (Category II) for the Taiwanese distant-water longline fleet were available by quarter, but quarterly catch data for the offshore longline fleet were available only from 2007-2010.

It was noted that some blue marlin lengths (lower jaw fork lengths) were measured on board distant-water longline vessels using the sampling protocol that the first 30 fish caught (regardless of species) per set were measured by fishermen. These length frequency data can be summarized annually and quarterly for the distant-water longline fishery.

There were questions regarding the extent to which the misidentification of blue and black marlins was occurring in Taiwan's fisheries. It was reported that Taiwanese fishermen can distinguish between blue and black marlin because black marlin commands a higher price in the Taiwan market. Since black marlin is a coastal species, primarily harvested by the inshore fisheries, and blue marlin a pelagic species, harvested primarily by offshore and distant water longline fisheries, misidentification is not an important issue. It was noted that nominal CPUE for the distant-water longline fishery (1964-2010) and the offshore longline fishery (2007-2010) were also presented to the WG. It was further clarified that length data were available on a quarterly basis but that sample sizes would be small. It was suggested that billfish size data will be available for review but will be limited in scope and duration.

It was noted that blue marlin lengths were also available from the observer program data

7.4 Standardized Catch-Rates of Blue Marlin for Taiwanese Distant-Water Longline Fishery in the Pacific Ocean for 1964-2010 presented by Nan-Jay Su (ISC/12/BILLWG-1/05)

Catch-rates, or catch-per-unit effort (CPUE) of blue marlin in the Pacific Ocean caught by the Taiwanese distant-water longline fleet were standardized using generalized additive models. Category II data for 1964-2010 and logbook data with hooks per basket (HPB) information for 1995-2009 were used separately in this study. Results using the logbook data showed that the standardized catch-rates of blue marlin were generally stable over 1980-2000, but increased noticeably since 2000. Estimates of standardized CPUE showed a similar trend when HPB information was included in the standardization analysis

Discussion

The WG requested and received clarification on smoothing spline assumptions, latitude/longitude interactions, and differences in AIC values with and without the HPB information.

It was noted that environmental factors were not considered in the standardization of CPUE, but that including environmental factors may improve the amount of deviance explained by the GAM.

It was noted that aggregated data and not operational data were used, and thus there were only a few spatial cells with no blue marlin catch.

It was noted that HPB data were available for the distant-water longline fishery only from 1995-2009, while data without HPB were available from 1964-2010.

It was noted that the longline fishery had shifted fishing grounds in latitude rather than in longitude. It was suggested that CPUE standardization might be conducted separately by area, in order to estimate potential year-area interactions as fishing effort shifted. It was pointed out that the spatial distribution of fishing effort appeared to have expanded over time and that this feature should be considered in further analyses.

It was noted that the working paper presented an analysis of deviance table which should be a standard requirement for all ISC working papers on CPUE standardization.

7.5 Meta-analysis of Post-release Mortality in Striped *(Kajikia audax)* and Blue Marlin *(Makaira nigricans)* using Pop-up Satellite Archival Tags presented by Jon Brodziak (ISC/12/BILLWG-1/07)

The uncertainty about post-release survival is a management challenge in many fisheries for large pelagic species. Meta-analysis was used to estimate a summary effect for post-release mortality in striped (*Kajikia audax*) and blue marlin (*Makaira nigricans*) from published reports and ongoing research using pop-up satellite archival tags (PSATs). This analysis assumed that individual studies represented random samples of some population in which the underlying (infinite-sample) effect sizes have a distribution rather than a single value (i.e. random effects model). Non-reporting PSATs were not considered synonymous with mortality as many factors may cause electronic tag failure (Musyl et al. 2011). Post-release mortality estimates and 95% confidence intervals were weighted by sample size and number of studies assuming heterogeneity (i.e. random-effects model where each study was assumed to have its own post-release mortality rate and variance). There were no significant differences in post-release mortality rates between striped marlin studies (4 studies, 63 reporting PSATs) and the summary estimate of post release mortality was 25.4% (95% CI = 12.6 – 44.6%), which was significantly greater than 0 (Table 1 in WP). In blue marlin (8 studies, 95 reporting PSATs), no significant differences in post-release mortality could be demonstrated between studies and the summary estimate of post release mortality was 6.4% (95% CI = 2.8 – 14.0%), which was significantly greater than 0. Results suggested that the majority of striped and blue marlin survive when released from recreational fishing gear indicating catch-and-release may be a viable option to protect parental biomass in this fishery. Due to insufficient sample sizes and studies, estimates of post-release mortality in longline fisheries could not be made for either species.

Discussion

The WG noted the importance of attaining accurate estimates of post release mortality and the WG thanked the author for his contribution. It was noted that the author is conducting additional research on post release mortality and that the WG looks forward to hearing the results of this research in the future.

7.6 Overview of the Japanese Fisheries for Blue Marlin in the Pacific Ocean presented by Ai Kimoto (ISC/12/BILLWG-1/08)

This paper provided an overview of the Japanese longline fishery in the Pacific Ocean for blue marlin up to 2010 and presented information on temporal-spatial distribution of catch and effort, trends of total catch and effort, positive catch ratio, percentage of blue marlin caught in one operation, and nominal CPUE. Various Japanese fisheries have captured blue marlin in the Pacific Ocean since the 1950s, especially in tropical Pacific by distant-water longline vessels. The total effort by the distant-water longline fleet in the Pacific Ocean has decreased since 1990s, and the associated catch of blue marlin has also decreased. The nominal longline CPUE since 1967 in the tropical Pacific varied around its average during 1967 and 2010. Although the nominal CPUE in the 1950s was substantially higher than in the following years, it was expected that the fishery data in the 1950s overestimated the blue marlin catch due to the misidentification of marlin species. It was suggested that further careful consideration of data quality would be needed for the CPUE series and the catch data, which partially included black marlin in early years.

Discussion

It was noted that logbook data collection began in the mid-1960s. Prior to that, port interviews were conducted to collect data with the fishing vessels. These interviews with fishermen were considered to be less detailed and of lower quality than the logbook data.

It was reported that Japanese fishermen in the 1950s may have recorded all marlin species as blue marlin. The reason for this was that marlins were not in demand in the market then, and that fishermen were not familiar with differences among marlin species.

It was noted that there has been changes in the pattern of longline fishing effort over the decades, i.e. an eastward and southward expansion of effort. It was also noted that there were differences between CPUE in temperate and tropical areas.

7.7 Review of Size Data for Blue Marlin Caught by Japanese Fisheries in the Pacific Ocean Since 1970s presented by Ai Kimoto (ISC/12/BILLWG-1/09)

This document reviewed a total of 750,000 available size data, in eye fork length (EFL, cm) or processed weight (kg), of blue marlin caught by Japanese fisheries in the Pacific Ocean between 1970 and 2010. These size data were mainly collected from distant-water, offshore, and shallow-setting longline, and drift net, and were measured on boat, or at several fishing ports. All size composition data showed a similar trend among decennial periods. The frequency distributions in processed weight were similar between distant-water and offshore longline, and between shallow-setting longline and drift net. Sizes of blue marlin were larger for the offshore and shallow settings than for the distant-water longline and drift net, and these observed results were expected to be due to the differences in target species, depth of fishing gear, and operational areas among fleets. It was also shown that some unrepresentative data existed, e.g., small fishes with weights of 0-5 kg. Even though the amount of blue marlin size data seemed relatively large in comparison to other marlins caught by Japanese fisheries in the Pacific Ocean, it was suggested that further investigation and careful consideration of data quality would be required when these data were utilized for the stock assessment of blue marlin.

Discussion

It was noted that Japanese training vessel data contained questionable sex determinations for blue marlin. In particular, small testes and ovaries were not easily distinguishable. Questionable sex determinations for blue marlin were expected to be a general problem for all Japanese sex-specific data. This will be an ongoing issue for attempting to conduct sex-specific stock assessments.

It was noted that blue marlin caught by the distant-water longline fishery were gilled or gutted and headed. or filleted. In comparison, blue marlin caught by coastal fisheries were gilled and gutted, and offloaded fresh. Different conversion factors were used in each case to convert processed weights to whole weights.

It was noted that anecdotal information from fishermen indicated that blue marlin males tend to remain in tropical waters, while females tend to move to temperate waters. Also fishing at the northern fronts produced catches of the larger fish. It was noted that differences in blue marlin size by area may be more substantial than by season. Blue marlin tended to be larger in temperate areas, and in the offshore longline, shallow-setting longline, and driftnet fisheries.

It was noted that blue marlin fish lengths (eye fork lengths) were measured on board distant-water longline vessels with the sampling protocol that the first 20-30 fish caught (regardless of species) per set were measured by fishermen.

It was noted that the large number of small blue marlin in the 0-5 kg weight range reported by the distant-water longline fishery in the south temperate area strata was not likely a recruitment spike but instead, was likely to be erroneous data.

It was noted that in addition to the large sample size of blue marlin lengths, there were a large number of blue marlin weights from the distant-water longline, shallow-setting longline, and driftnet fisheries. It may be useful to convert the weight data into length data, if reliable conversion factors were available. However, this conversion may present problems for SS2 and SS3 assessment models for data with wider bin sizes (5 kg). In any case, there was a large amount of length data which was deemed sufficient to include in a structured assessment model.

7.8 Chinese Billfish Longline Data in the Pacific Ocean presented by Xiaojie Dai (presentation only)

The Chinese longline fishery started in 1988 with seven vessels. By 1994 there were 457 vessels which caught 14,062 mt in that year. Some of these vessels were formerly trawl vessels that were modified for longline operations. In 1998, the number of vessels decreased to 66 and the fleet targeted albacore, bigeye, and yellowfin tuna, as well as swordfish with these four species comprising 87% of the total catch. Since 2001, Shanghai Ocean University (SHOU) has been assigned the responsibility of compiling longline fishery data that were collected by the Association of Chinese Distant-water Fisheries, and is supported by the Bureau of Fisheries, Ministry of Agriculture. Since 2008, the longline catch data distinguished billfish catches as either blue marlin or striped marlin.

Discussion

It was noted that China has more active vessels fishing in the Pacific Ocean (>100 vessels) than in the Atlantic Ocean (<40 vessels) and Indian Ocean. China has cooperative fishing agreements with WCPFC member countries, including Kiribati, Cooke Islands, and Federated States of Micronesia. Monthly fishing data is faxed or emailed to the Association of Chinese Distant-water

Fisheries by fishing companies. Logbook data are submitted to SHOU and logbook data may be one year old or older when the logbook is submitted. Individual processed weights of high-value fish are recorded onboard the deep-longline vessel by fishermen. SHOU follows quality control procedures. These include: assigning quality grades to the data, cross checking the monthly fishing data with trade/sales data and logbook data, comparing observer data with the captain's data, and conducting an annual review of fishing vessels.

It was noted that China's observer program generally covers longline fishing operations during July through March. They hire 6-8 observers who spend 6-8 months on a longline trip. The annual coverage is designed to meet the requirements of the WCPFC and the IATTC.

It was noted that China collaborates with the SPC to provide its fishery data to the WCPFC.

8.0 PREPARE AND REVIEW STOCK ASSESSMENT DOCUMENTATION AND DEVELOP STOCK PROJECTIONS FOR WCNPO STRIPED MARLIN

8.1 Stock Assessment Document

The status of the NP striped marlin stock assessment was reviewed by the ISC BILLWG Chair. It was noted that the current assessment document will need to be reformatted as proposed by ISC11 (Annex 1) in preparation for an external independent review. It was noted that the review process will be discussed at ISC12.

8.2 Executive Summary

The importance of having an executive summary for the stock assessment document was discussed and there was agreement by the WG that a draft executive summary should be included as an Appendix in the final working group report. The ISC Chair reminded participants that this was discussed and endorsed at ISC11. A proposed outline for the summary was presented and discussed. It was agreed that Kobe Plots would be included in the summary in both SPR- and F-space. There was discussion on the intent of the section on conservation advice and it was agreed that this section would summarize stock status and the projection analyses. The WG agreed on the outline structure (Appendix 1) and members were tasked to craft sections of the summary for review and adoption at the workshop.

8.3 Stock Projections

8.3.1 Future Projections of Western and Central Pacific Striped Marlin presented by Hui-Hua Lee (ISC/12/BILLWG-1/01)

Based on the recent stock assessment of western and central North Pacific striped marlin stock, eight-year projections of catch and spawning biomass were conducted. This working paper explored the degree to which uncertainty from within the stock assessment and between alternative models influenced the uncertainty of future projections. In addition, different assumptions regarding the appropriate states of nature of production (R, R/S or SR curve) were used. A decision table based on projections using between model uncertainties described different harvest regimes (exploitation level and fishery allocation) across the states of nature governing future recruitment. Projections indicated that the current level of exploitation rate was likely to be sustainable unless projected recruitment in the future was directly linked to spawning biomass. Reductions in the fishing intensity were predicted to decrease stock risk and increase yield within six years. These results were based on both Bayesian methods and model averaging.

Discussion

The WG acknowledged the work of Lee and Piner to produce the projections. The time period 2007-2009 will be used as the current period in subsequent analyses, which is consistent with the stock assessment. To determine the impact of this change for the current period, a simplified set of projections were run. A proposed set of projection and summarization figures and tables were developed for the WG to consider and these were:

(1) Two recruitment hypotheses: a continuation of the recent recruitment pattern (random resampling of recruitment during 1994-2008) and a continuation of the long-term recruitment pattern in the assessment (random sampling of the stock-recruitment curve residuals during 1975-2008).
(2) Initial population size-at-age uncertainty for the projections was estimated by parametric bootstrapping where the MLE of the initial population size at age vector and its estimated covariance matrix formed the sampling distribution.
(3) Four harvest projection scenarios were to be run:
    a. Constant fishing mortality rate equal to the current fishing mortality rate, as indexed by the average F during 2007-2009.
    b. Constant fishing mortality rate equal to F_{MSY}.
    c. Constant fishing mortality rate equal to the average fishing mortality rate during 2001-2003.
    d. Constant catch equal to the 80% of the average catch during 2007-2009, a 20% catch reduction from the current catch level.

The WG reviewed the results of the proposed projections and determined that there were slight differences between the initial runs described in the working paper and the new runs with simplified assumptions. As a result, the WG agreed to use the proposed projections for the final projection analyses in the stock assessment as described as section 9.3.

9.0 ADOPTION OF ASSESSMENT DOCUMENTATION AND PROJECTIONS FOR WCNPO STRIPED MARLIN

9.1 Stock Assessment Document

The WG agreed that the current WCNPO striped marlin stock assessment document will need to be rewritten and that this document will be sent out for external review along with other pertinent working papers.

9.2 Executive Summary

The WG reviewed the proposed draft of the WCNPO striped marlin Executive Summary and after slight modifications it was adopted by the WG (Appendix 1).

9.3 Stock Projections

The WG agreed on a set of projections and summarizations that will constitute the projection analyses for the WCNPO striped marlin stock assessment for 2012-2017. These are:

(1) Two recruitment hypotheses: a continuation of the recent recruitment pattern (random resampling of recruitment during 1994-2008) and a continuation of the long-term recruitment pattern in the assessment (random sampling of stock-recruitment curve residuals during 1975-2008).
(2) Initial population size-at-age uncertainty for the projections as estimated by parametric bootstrapping where the maximum likelihood estimate (MLE) of initial population size at age is the mean and the estimated covariance matrix of initial population size at age is the covariance matrix for the multivariate normal sampling distribution.
(3) Four harvest projection scenarios:
    a. Constant fishing mortality rate equal to the current fishing mortality rate, as indexed by the average F during 2007-2009.
    b. Constant fishing mortality rate equal to F_{MSY}.
    c. Constant fishing mortality rate equal to the average fishing mortality rate during 2001-2003.
    d. Constant catch equal to the 80% of the average catch during 2007-2009, a 20% catch reduction from the current catch level.

It was agreed that results from the projections will form the basis of the conservation advice and be circulated for comment before the July 2012 ISC BILLWG Workshop and will be reviewed at that meeting.

10.0 OTHER BUSINESS

10.1 Revise Pacific Blue Marlin Stock Assessment Work Plan

10.1.1 Progress with Collaborative Partners

The WG acknowledged that the Chinese scientists provided their fishery data during the meeting and that the IATTC participant provided the IATTC blue marlin data. The BILLWG will collaborate with the WCPFC to obtain catch and effort data but progress needs to made to acquire the size frequency data. The WG recognized the difficulty of accessing non-digitized data from recreational fisheries and the WG will collaborate with data correspondents in Hawaii, New Zealand and Australia to acquire their recreational fisheries data.

10.1.2 Progress on Preparation of Assessment Data

The BILLWG Chair expressed his appreciation to all members for their submission of statistics including catch and effort data. The WG noted that the substantial progress was made on the task of providing the best available information on length or weight frequency distributions as well as standardized CPUE time series. It was expected that recreational data from USA fisheries would be compiled from tournament records and reviewed before being included in the stock assessment. It was also noted that Chinese catches of blue marlin covering a 10-year period were provided to the WG at this meeting and that these data will also be reviewed.

10.1.3 Progress on Assessment Modeling Approaches

The WG discussed potential stock assessment methods for blue marlin. The potential application of the length-based age structured Stock Synthesis model was discussed, and it was noted that the treatment of spatial information on fishery size composition by sex provided by Japanese and other fisheries would be an important consideration for developing a structured assessment model. The WG recognized that the application of alternative assessment modeling approaches, such as production models, would help to provide a robust set of modeling approaches for the blue marlin stock assessment.

10.1.4 Work Assignments

The WG discussed various tasks that would need to be completed to finish work assignments for the next intercessional BILLWG meeting. The WG discussed the need to present completed working papers on blue marlin standardized CPUEs at the next intercessional BILLWG workshop. The WG also discussed the importance of finalizing life history parameters for the blue marlin stock assessment. Methods to estimate the natural mortality rate and stock-recruitment steepness using either direct calculation or model-based estimation were discussed. Due to the potential lack of representative sex-specific size frequency data, the WG agreed that it was important to develop a combined-sex von Bertalanffy growth curve. The WG also discussed the need to obtain reproduction information from the published paper by Sun et al. The WG also discussed the need to develop a standard protocol to select representative length-weight relationship for the use in the blue marlin stock assessment. The ISC Chair was asked to contact scientists in IATTC, Japan, Southwest Fisheries Science Center and Pacific Islands Fisheries Science Center (Hinton, Yokawa, Sippel, Musyl, and Chiang) to summarize all available tagging data in the Pacific Ocean. The BILLWG Chair was asked to contact New Zealand to obtain recreational data. The BILLWG Chair was further asked to contact the ISC webmaster to update billfish information on the ISC webpage.

The BILLWG was assigned a number of tasks. The specific tasks were:

- Present complete working papers on blue marlin standardized CPUEs at the next intercessional BILLWG workshop. Approaches for standardizing CPUEs will be discussed at the July meeting.

- Explore methods to estimate natural mortality rate and steepness of blue marlin using empirical or model-based estimates.

- Given the lack of representative sex-specific size frequency data for blue marlin fisheries, develop a combined-sex von Bertalanffy growth curve.

- Obtain information on blue marlin reproductive ecology for use in the stock assessment from the published paper by Sun et al. (2009).

- WG was encouraged to develop a standard protocol to select representative length-weight relationships for the blue marlin stock assessment.

The BILLWG Chairman was also assigned a number of tasks. These were:

- Contact scientists from the IATTC, Japan, Southwest Fisheries Science Center and Pacific Islands Fisheries Science Center to summarize all available tagging data in the Pacific Ocean.

- Contact New Zealand to obtain recreational blue marlin fishery data.

- Contact ISC webmaster to update billfish information on the ISC webpage.

- Coordinate future meeting dates with members using an online poll system.

- Contact the Statistics Working Group Chair, Ren-fan Wu, about creating data codes for stock areas of striped marlin and swordfish.

10.2 North Pacific Swordfish Assessment Update

The WG agreed not to update swordfish assessment until the stock assessment of blue marlin is completed. The BILLWG Chair has updated catch for North Pacific swordfish and it was noted that separation of catch by stock area will be completed to compare to the catch table.

10.3 Future Meetings

Prior to ISC12 in Sapporo, Japan, the BILLWG will meet informally from 16-17 July 2012 to prepare and summarize the striped marlin stock assessment for presentation to the ISC Plenary. In December 2012-January 2013, the BILLWG will hold an intercessional meeting to complete data preparation for the blue marlin assessment including CPUE standardization; all the stock assessment data will be finalized at this meeting to be held in Honolulu, Hawaii. The WG will decide the dates of this meeting at the ISC Plenary meeting. Japan has offered to host the BILLWG meeting to conduct the blue marlin stock assessment in April 2013. The BILLWG Chair was also asked to coordinate future BILLWG meetings with members using an online polling system (e.g. Doodle).

11.0 COLLECT AND REVIEW LIFE HISTORY INFORMATION FOR PACIFIC BLUE MARLIN

11.1 A review of life history parameters for the Pacific Blue Marlin presented by Yi-Jay Chang (ISC/12/BILLWG-1/06)

Our understanding of the biology of blue marlin (*Makaira nigricans*) in the Pacific Ocean has increased over the last three decades, and this progress can be attributed to the development and application of a variety of novel tools. In this study, we provide a comprehensive examination of available data on the life history parameters of the Pacific blue marlin by re-examining current databases and literature. The review provides a detailed synthesis of the growth, reproductive biology, mortality, and stock-recruitment relationship to the ISC BILLWG for potential application in the stock assessments of the Pacific blue marlin. Knowledge of blue marlin stock structure and habitat preferences are also discussed.

Discussion

It was noted that the sex ratio of blue marlin reported by Sun et al. (2009) was 1:1, while females considerably outnumbered males in Shimose et al. (2009). The reason for this difference is likely due to sampling location, i.e., where sampling was conducted. Samples used in the Sun et al. (2009) analysis were from Taiwanese offshore waters and the South China Sea, while those of Shimose et al. (2009) were from the Yonaguni Island region of southwestern Japan.

The WG requested clarification and it was clarified that counts of oocytes used in the estimation of batch fecundity were accomplished using a subsampling approach (by weight), and not by directly counting all oocytes. It was noted that training on the evaluation of ovarian development, batch fecundity estimation, including oocyte identification and counting techniques, would be beneficial to scientists conducting similar research at Shanghai Ocean University.

The WG acknowledged the difficulty in measuring the body length of processed fishes as well as the availability of the length-processed weight conversion factors, and discussed whether there were any solutions available to member countries. The WG recognized the necessity of capacity building of member countries for the collection of biological information of billfishes, especially blue marlin, and encouraged further collaborations. Since blue marlin exhibit sexual dimorphism in growth, attempts should be made to develop sex-specific conversion factors for both length-weight relationships and growth rates. It was also noted that the potential range of natural mortality rates estimated for blue marlin is wide (Table 5 in the WP) and while M estimates are sex-specific, they are not age-specific. Attempts should be made to compute age- and sex-specific estimates for use in the upcoming assessment.

The WG discussed whether the results of this WP could be used to determine best biological parameters for use in the blue marlin assessment. It was pointed out that the intent of this WP was to compile available data, and not determine the adequacy of the data. The WG agreed with this interpretation and noted that future analyses would help to determine the best available life history parameters. Some suggestions to move forward were discussed; these included a meta-analysis of available studies and an analysis exploring the rigor used in the available estimates from this WP.

The WG noted that some of the presented data could be used to provide initial conditions for biological parameters. This included sex-specific size-at-maturity relationships from Sun et al. (2009) and the S-R steepness parameter (h) used by Kleiber et al. (2003) in their blue marlin stock assessment. The WG expressed concerns about the biological realism of the value of Steepness h = 0.5 for blue marlin, which is substantially lower than that used in the stock assessment of WCNPO striped marlin. Additional sources for information on h were also identified including meta-analysis work done by Myers et al. (1999), direct estimation of h using methods from Mangel et al. (2010), and inferring the value of steepness based on analogy with the blue marlin stock assessment conducted by ICCAT in the Atlantic Ocean.

11.2 Age Determination and Growth of Blue Marlin presented by Tamaki Shimose (presentation only)

Age determination of blue marlin using otolith daily growth increments (DGI) for juvenile and using fin spine sections for adults were carried out. Otolith DGI could be counted for only smaller individuals (<190 cm LJFL, N=20) and von Bertalanffy growth parameters were estimated to be L_{inf}=201 cm, K=2.51, and t_0=0.0356. From this von Bertalanffy growth formula, the expected length (LJFL) of one year old fish was calculated to be 184 cm, and this value was used to estimate the position of the first annulus in sectioned fin spine. Translucent bands on the sectioned dorsal spine were formed once a year in September, and were thought to be annual rings. Indistinct translucent bands were also observed but regarded as false annuli. Growth of blue marlin varied individually, and was generally fast up to five years. Females grew over to 200 cm LJFL in two years and over to 250 cm in five years. On the other hand, male growth rates were slower than females and males reached 176 cm in two years and subsequently only slightly grew further. Von Bertalanffy growth parameters were estimated to be L_{inf}=263 cm, K=0.483, t_0= -1.43 for female blue marline and L_{inf}=201 cm, K=0.387, t_0= -3.21 for male blue marlin by back-calculation method.

Discussion

The WG noted the limited sampling scope in this study and suggested that the size structure of this study may not represent the Pacific blue marlin population size structure. The WG also requested a direct comparison of growth estimates from the Chinese Taipei delegate and the Japanese delegate in the working session. It was pointed out that there is large variation among reported Pacific blue marlin growth estimates and this will need to be resolved for the stock assessment. Inconsistencies between maximum estimated size and maximum observed size were pointed out and it was explained that the larger fish were excluded from the analyses because their growth rings could not be accurately counted. It was noted by the WG that additional research on aging techniques is required for Pacific blue marlin. The feasibility of the estimation of combined-sex growth curve for use in the stock assessment was discussed although the WG noted that the blue marlin exhibits sexual dimorphism in growth.

11.3 Sexual Difference in the Migration Pattern of Blue Marlin Related to Spawning and Feeding Activities in the North Pacific Ocean presented by Tamaki Shimose (presentation only)

Blue marlin is a large oceanic teleost fish that exhibits seasonal latitudinal migrations. To estimate the seasonal habitat preferences of blue marlin, gonads and stomach contents were examined in three different areas of the western North Pacific Ocean between 2003 and 2009. Gonad samples were used to estimate the sex ratio and the maturity state and spawning potential of females. Stomach contents were used to estimate the relative amount of feeding in each area. In the Honshu area (central Japan, 33–37°N), females were collected during July to September but no evidence of spawning was observed. In the Yonaguni Island area (southern Japan, 24°N), both sexes were collected year-round with females dominating the sample collections. Some female spawning was confirmed during May to September. In the tropical Pacific area (5–20°N), both sexes were collected year round with male samples dominating the catch. In this area, spawning of some females was confirmed during April to October. The relative amount of blue marlin feeding was high in the Honshu and Yonaguni Island areas, but was low in the tropical ocean area regardless of season. The food habits data indicated that higher latitude areas are important feeding grounds and lower latitude areas are important spawning grounds for blue marlin in summer. Furthermore, sampling results also indicated that female body sizes were much larger than male sizes, and that female migrate into higher latitude areas than males. Results suggest that females may migrate to utilize rich feeding grounds, recover body condition after spawning and grow while males may not migrate latitudinally as much as females.

Discussion

It was pointed out that the proposed movement and feeding patterns were supported by limited data and the WG inquired as to the availability of tagging data to corroborate the proposed patterns. The WG noted that there was a blue marlin pop-up tagging program in Taiwan and that those data could be presented to the WG at its next meeting. The necessity of compiling and analyzing the existing traditional and PSAT tag data was discussed as a way to identify migration patterns as well as to understand the diving behavior of blue marlin. It was suggested that the WG could develop a new work plan for a tagging study. General agreement to conduct this study was obtained among participants and the IATTC and the Pacific Islands Fisheries Science Center agreed to take the lead on this study. The importance of the sex identification of tagged blue marlin was also emphasized, and the WG agreed to collaborate to develop biopsy techniques to collect tissues for sex identification concurrently with tag attachment. The WG group also noted that there was a blue marlin fishery around the Yonaguni Island. It pointed out that the blue marlin fishery around the Yonaguni Island was small. Currently, only a few years of data were available for this fishery. It was also noted that estimates of the maximum ages of Pacific blue marlin reported at this workshop were significantly less than those reported in the Atlantic Ocean.

11.4 Comparison of Growth Curves for Blue Marlin

The WG compared size-at-age curves for blue marlin by sex (Figure 2). Results indicated that blue marlin is sexually dimorphic with females growing more rapidly than males and attaining larger body sizes. The WG noted that there was also substantial variability in the expected size-at-age curves and that this was an important issue to resolve for the upcoming blue marlin stock assessment.

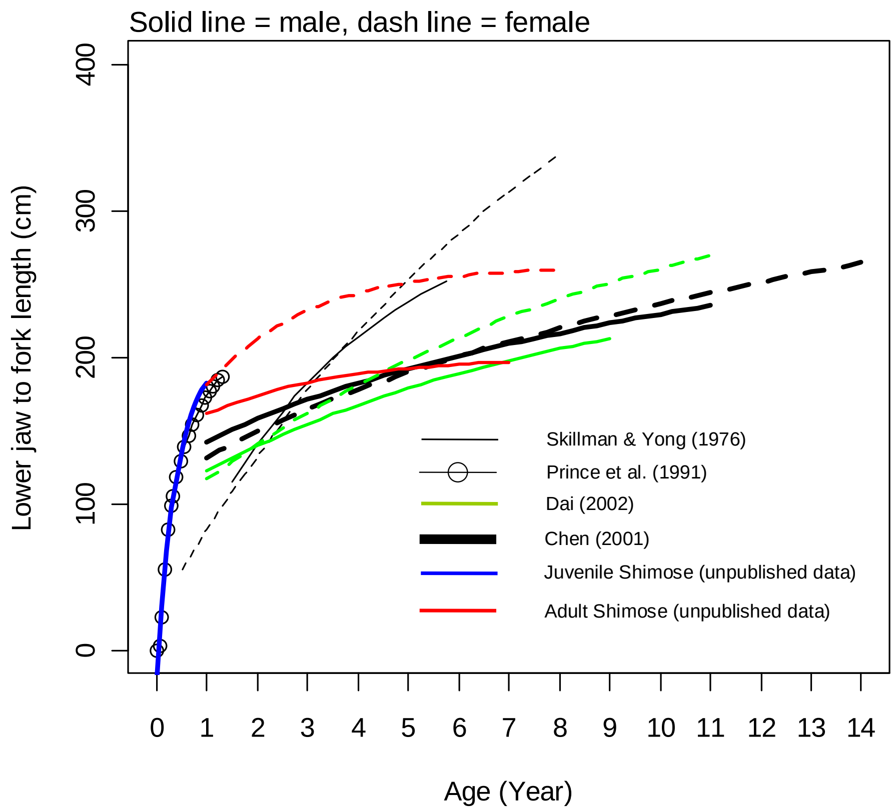


Figure 2. Growth curves for blue marlin.

12.0 ADJOURNMENT

The workshop was adjourned at 1:40 pm on 9 April 2012. The BILLWG Chairman expressed his appreciation to the rapporteurs and to all of the participants for their contributions and cooperation in completing a successful meeting.

13.0 REFERENCES

Mangel, M., J. Brodziak, and DiNardo, G. 2010. Reproductive ecology and scientific inference of steepness. Fish and Fisheries. 11:89-104.

Musyl, M., Domeier M., Nasby-Lucas N., Brill R., McNaughton, L., Swimmer,Y., Lutcavage, M., Wilson, S., Galuardi, B., and Liddle, J. 2011. Performance of pop-up satellite archival tags. Marine Ecology Progress Series 433:1-28.

Myers, R.A., Bowen, K.G. and Barrowman, N.J. 1999. Maximum reproductive rate of fish at low population sizes. Canadian Journal of Fisheries and Aquatic Sciences 56:2404–2419.

Shimose, T., Fujita, M., Yokawa, K., Saito, H., and Tachihara, K. 2009. Reproductive biology of blue marlin *Makaira nigricans* around Yonaguni Island, southwestern Japan. Fish. Sci. 75:109-119.

Sun, C.-L., Chang, Y.-J., Tszeng, C.-C., Yeh, S.-Z., and Su, N.-J. 2009. Reproductive biology of blue marlin (*Makaira nigricans*) in the western Pacific Ocean. Fish. Bull. 107:420-432.

Table 5. Striped marlin catches (in metric tons) by fisheries, 1952-2010. Blank (“ “) indicates no effort. Dash (“–“) indicates data not available. Zero (“0”) indicates a catch of less than 1 metric ton.

	Japan							Mexico			United States					Costa Rica	
Year	Distant-water and Offshore Longline	Coastal Longline	Other Longline	Small Mesh Gillnet	Large Mesh Gillnet	Other[3]	Japan Total	Longline	Sport[2]	Mexico Total	Longline	Troll	Handline	Sport[2]	US Total	Sport	WCPFC non-ISC Countries[4]
1951	2,494	-	673	-	0	1,281	4,448										
1952	2,901	-	722	-	0	1,564	5,187							23	23		
1953	2,138	-	47	-	0	954	3,139							5	5		
1954	3,068	-	52	-	0	1,088	4,207							16	16		
1955	3,082	-	28	-	0	1,038	4,148							5	5		
1956	3,729	-	59	-	0	1,996	5,785							34	34		
1957	3,189	-	119	-	0	2,459	5,767							42	42		
1958	4,106	-	277	-	3	2,914	7,300							59	59		
1959	4,152	-	156	-	2	3,191	7,501							65	65		
1960	3,862	-	101	-	4	1,937	5,904							30	30		
1961	4,420	-	169	-	2	1,797	6,388							24	24		
1962	5,739	-	110	-	8	1,912	7,769							5	5		
1963	6,135	-	62	-	17	1,910	8,124							68	68		
1964	14,304	-	42	-	2	2,344	16,692							58	58		
1965	11,602	-	19	0	1	2,794	14,416							23	23		
1966	8,419	-	112	0	2	1,570	10,103							36	36		
1967	11,698	-	127	0	3	1,551	13,379							49	49		
1968	15,913	-	230	0	0	1,043	17,186							51	51		
1969	8,544	600	3	0	3	2,668	11,818							30	30		
1970	12,996	690	181	0	3	1,032	14,902							18	18		11
1971	10,965	667	259	0	10	2,042	13,943							17	17		12
1972	7,006	837	145	0	243	993	9,224							21	21		13
1973	6,357	632	118	0	3,265	702	11,074							9	9		15
1974	6,700	327	49	0	3,112	775	10,963							55	55		17
1975	5,281	286	38	0	6,534	686	12,825							27	27		18
1976	5,136	244	34	0	3,561	585	9,560							31	31		15
1977	3,019	256	15	0	4,424	547	8,261							41	41		21
1978	3,957	243	27	0	5,593	546	10,366							37	37		21
1979	5,561	366	21	0	2,532	526	9,006							36	36		26
1980	6,378	607	5	0	3,467	536	10,993							33	33		32
1981	4,106	259	12	0	3,866	542	8,785							60	60		43

[1] Provisional data

[2] Estimated from catch in number of fish

[3] Contains bait fishing, net fishing, trapnet, trolling, harpoon, etc.

[4] Contains catches reported to the WCPFC by the Philippines, Indonesia, China, Vanuatru, Federated States of Micronesia, and Belize, totaled with the estimated unreported catch by the Philippines, Indonesia, Vanuatu, Federated States of Micronesia, and Be

[5] From ISC/11/PLENARY/10, National Report of Japan

Table 5. (Continued) Striped marlin catches (in metric tons) by fisheries, 1952-2010. Blank (“ “) indicates no effort. Dash (“–“) indicates data not available. Zero (“0”) indicates a catch of less than 1 metric ton.

	Japan							Mexico			United States					Costa Rica	
Year	Distant-water and Offshore Longline	Coastal Longline	Other Longline	Small Mesh Gillnet	Large Mesh Gillnet	Other[3]	Japan Total	Longline	Sport[2]	Mexico Total	Longline	Troll	Handline	Sport[2]	US Total	Sport	**WCPFC non-ISC Countries[4]**
1982	5,383	270	13	0	2,351	656	8,673							41	41		61
1983	3,722	320	10	22	1,845	827	6,746							39	39		59
1984	3,506	386	9	76	2,257	719	6,953							36	36		36
1985	3,897	711	24	40	2,323	733	7,728					18		42	60		51
1986	6,402	901	33	48	3,536	577	11,497	-				19		19	38		62
1987	7,538	1,187	6	32	1,856	513	11,132	-			272	30	1	28	331		137
1988	6,271	752	7	54	2,157	668	9,909	-			504	54		30	588		129
1989	4,740	1,081	13	102	1,562	537	8,035	-			612	24	0	52	688		101
1990	2,368	1,125	3	19	1,926	545	5,986	-	181	181	538	27	0	23	588		50
1991	2,845	1,197	3	27	1,302	507	5,881	-	75	75	663	41	0	12	716	106	61
1992	2,955	1,247	10	35	1,169	303	5,719	-	142	142	459	38	1	25	523	281	66
1993	3,476	1,723	1	-	828	708	6,736	-	159	159	471	68	1	11	551	438	60
1994	2,911	1,284	1	-	1,443	383	6,022	-	179	179	326	35	0	17	378	521	72
1995	3,494	1,840	3	-	970	283	6,590	-	190	190	543	52	0	14	609	153	68
1996	1,951	1,836	4	-	703	152	4,646	-	237	237	418	54	1	20	493	122	73
1997	2,120	1,400	3	-	813	163	4,499	-	193	193	352	38	1	21	412	138	55
1998	1,784	1,975	2	-	1,092	304	5,157	-	345	345	378	26	0	23	427	144	69
1999	1,608	1,551	4	-	1,126	184	4,473	-	266	266	364	28	1	12	405	166	68
2000	1,152	1,109	8	-	1,062	297	3,628	-	312	312	200	14	1	10	225	97	41
2001	985	1,326	11	-	1,077	237	3,636	-	237	237	351	42	2	-	395	151	50
2002	764	796	5	-	1,264	290	3,119	-	305	305	226	30	0	-	256	76	88
2003	1,013	842	3	-	1,064	203	3,124	-	322	322	552	29	0	-	581	79	105
2004	699	1,000	2	-	1,339	92	3,132	-	-	0	376	34	1	-	411	19 [1]	137
2005	562	668	1	0	1,214	98	2,543	-	-	0	511	20	0	-	531	- [1]	66
2006	623	539	1	0	1,190	95	2,448	-	-	-	611	21	0	-	632	-	42
2007	306	860	5	-	970	79	2,220	-	-	-	276	13	0	-	289	-	31
2008	390 [1]	609 [1]	10 [1]	- [1]	1,302[1]	97 [1]	2,408 [1]	-	-	-	426	14	0	-	440	-	154
2009	166 [1]	606 [1]	21 [1]	- [1]	821 [1]	90 [1]	1,704 [1]	-	-	-	256 [1]	10 [1]	0 [1]	-	266 [1]	-	41
2010	-	-	-	-	-	-	162 [5]	-	-	-	158 [1]	5 [1]	0 [1]	-	163 [1]	-	16
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] Provisional data
[2] Estimated from catch in number of fish
[3] Contains bait fishing, net fishing, trapnet, trolling, harpoon, etc.
[4] Contains catches reported to the WCPFC by the Philippines, Indonesia, China, Vanuatru, Federated States of Micronesia, and Belize, totaled with the estimated unreported catch by the Philippines, Indonesia, Vanuatu, Federated States of Micronesia, and Be
[5] From ISC/11/PLENARY/10, National Report of Japan

Table 5. (Continued) Striped marlin catches (in metric tons) by fisheries, 1952-2010. Blank (" ") indicates no effort. Dash ("–") indicates data not available. Zero ("0") indicates a catch of less than 1 metric ton.

Year	Chinese Taipei[2]												Korea			
	Distant-water Longline	High-seas Drift Gillnet	Offshore Longline	Offshore Gillnet	Offshore Others	Coastal Harpoon	Coastal Setnet	Gillnet & Other net	Coastal Longline	Coastal Others	Other	Chinese Taipei Total	Longline	High-seas Drift Gillnet	Korea Total	Grand Total
1951														-		4,448
1952												-	-	-	-	5,210
1953												-	-	-	-	3,144
1954												-	-	-	-	4,223
1955												-	-	-	-	4,153
1956												-	-	-	-	5,819
1957												-	-	-	-	5,809
1958			543								387	930	-	-	-	8,289
1959			391								354	745	-	-	-	8,311
1960			398								350	748	-	-	-	6,682
1961			306								342	648	-	-	-	7,060
1962			332								211	543	-	-	-	8,317
1963			560								199	759	-	-	-	8,951
1964			392								175	567	-	-	-	17,317
1965			355								157	512	-	-	-	14,951
1966			370								180	550	-	-	-	10,689
1967	2		385								204	591	-	-	-	14,019
1968	1		332								208	541	-	-	-	17,778
1969	2		571								192	765	-	-	-	12,613
1970	0		495								189	684	-	-	-	15,615
1971	0		449								135	584	0	-	0	14,556
1972	9		380								126	515	0	-	0	9,773
1973	1		568								139	708	0	-	0	11,806
1974	24		650								118	792	0	-	0	11,827
1975	64		732								96	892	0	-	0	13,761
1976	32		347								140	519	0	-	0	10,125
1977	17		524								219	760	43	-	43	9,126
1978	0		618								78	696	28	-	28	11,149
1979	26		432								122	580	-	-	-	9,648
1980	61		223								132	416	37	-	37	11,512
1981	17		491								95	603	-	-	-	9,490

[1] Provisional data

[2] Estimated from catch in number of fish

[3] Contains bait fishing, net fishing, trapnet, trolling, harpoon, etc.

[4] Contains catches reported to the WCPFC by the Philippines, Indonesia, China, Vanuatru, Federated States of Micronesia, and Belize, totaled with the estimated unreported catch by the Philippines, Indonesia, Vanuatu, Federated States of Micronesia, and Be

Table 5. (Continued) Striped marlin catches (in metric tons) by fisheries, 1952-2010. Blank (" ") indicates no effort. Dash ("–") indicates data not available. Zero ("0") indicates a catch of less than 1 metric ton.

Year	Chinese Taipei[2]												Korea			
	Distant-water Longline	High-seas Drift Gillnet	Offshore Longline	Offshore Gillnet	Offshore Others	Coastal Harpoon	Coastal Setnet	Gillnet & Other net	Coastal Longline	Coastal Others	Other	Chinese Taipei Total	Longline	High-seas Drift Gillnet	Korea Total	Grand Total
1982	7		397								138	542	39	-	39	9,356
1983	0		555								214	769	19	-	19	7,632
1984	0		965								330	1,295	23	-	23	8,342
1985	0		513								181	694	16	-	16	8,550
1986	0		179								148	327	61	-	61	11,985
1987	31		383								151	565	1	-	1	12,166
1988	7		457								169	633	11	-	11	11,270
1989	8		184								157	349	26	-	26	9,199
1990	2		137								256	395	315	-	315	7,515
1991	36		254								286	576	141	-	141	7,556
1992	1		219								197	417	318	-	318	7,466
1993	5		221								142	368	388	-	388	8,700
1994	1		137								196	334	1,045	-	1045	8,552
1995	27		83								82	192	307	-	307	8,109
1996	26		162	8	6	30	3	-	-	-	-	235	429	-	429	6,236
1997	59		290	9	-	33	3	-	2	-	-	396	1,017	-	1017	6,710
1998	90		205	15	-	19	6	1	9	-	-	345	635	-	635	7,122
1999	66		128	7	-	26	5	1	3	-	-	236	433	-	433	6,047
2000	153		161	17	1	29	6	1	1	-	-	369	537	-	537	5,209
2001	121		129	16	-	30	5	-	-	-	-	301	254	-	254	5,024
2002	251		226	14	-	6	8	1	-	-	-	506	188	-	188	4,539
2003	241		91	26	-	11	5	1	-	-	-	375	206	-	206	4,792
2004	261		95	8	1	7	5	2	-	1	-	380	75	-	75	4,154 [1]
2005	176		76	1	-	5	9	9	-	8	-	284	141	-	141	3,565 [1]
2006	-	-	-	-	-	-	-	-	-	-	-	123 [5]	56	-	56	3,301 [1]
2007	-	-	-	-	-	-	-	-	-	-	-	260 [5]	28	-	28	2,828 [1]
2008	-	-	-	-	-	-	-	-	-	-	-	196 [5]	-	-	56 [5]	3,254 [1]
2009	-	-	-	-	-	-	-	-	-	-	-	198 [5]	-	-	44 [5]	2,253 [1]
2010	-	-	-	-	-	-	-	-	-	-	-	183 [5]	-	-	30 [5]	554 [1]
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] Provisional data
[2] Estimated from catch in number of fish
[3] Contains bait fishing, net fishing, trapnet, trolling, harpoon, etc.
[4] Contains catches reported to the WCPFC by the Philippines, Indonesia, China, Vanuatru, Federated States of Micronesia, and Belize, totaled with the estimated unreported catch by the Philippines, Indonesia, Vanuatu, Federated States of Micronesia, and Be

Table 6. Swordfish catches (in metric tons) by fisheries, 1952-2010. Blank (" ") indicates no effort. Dash ("–") indicates data not available. Zero ("0") indicates a catch of less than 1 metric ton.

	Japan								Mexico	United States[6]					
										Hawaii	California				
Year	Distant-water and Offshore Longline	Coastal and Other Longline	Squid Driftnet and Driftnet	Harpoon[3]	Bait Fishing	Trapnet	Other[4]	Japan Total	All Gears	Longline	Longline	Gill Net	Harpoon	Unknown[7]	US Total
1951	7,246	115	10	4,131	88	78	10	11,678	-	-	-	-	-	-	-
1952	8,890	152	0	2,569	6	68	6	11,691	-	-	-	-	-	-	-
1953	10,796	77	0	1,407	20	21	87	12,408	-	-	-	-	-	-	-
1954	12,563	96	0	813	104	18	17	13,610	-	-	-	-	-	-	-
1955	13,064	29	0	821	119	37	41	14,111	-	-	-	-	-	-	-
1956	14,596	10	0	775	66	31	7	15,486	-	-	-	-	-	-	-
1957	14,268	37	0	858	59	18	11	15,251	-	-	-	-	-	-	-
1958	18,525	42	0	1,069	46	31	21	19,734	-	-	-	-	-	-	-
1959	17,236	66	0	891	34	31	10	18,267	-	-	-	-	-	-	-
1960	20,058	51	1	1,191	23	67	7	21,400	-	-	-	-	-	-	-
1961	19,715	51	2	1,335	19	15	11	21,147	-	-	-	-	-	-	-
1962	10,607	78	0	1,371	26	15	18	12,115	-	-	-	-	-	-	-
1963	10,322	98	0	747	43	17	16	11,244	-	-	-	-	-	-	-
1964	7,669	91	4	1,006	40	16	26	8,852	-	-	-	-	-	-	-
1965	8,742	119	0	1,908	26	14	182	10,991	-	-	-	-	-	-	-
1966	9,866	113	0	1,728	41	11	4	11,763	-	-	-	-	-	-	-
1967	10,883	184	0	891	33	12	5	12,008	-	-	-	-	-	-	-
1968	9,810	236	0	1,539	41	14	9	11,649	-	-	-	-	-	-	-
1969	9,416	296	0	1,557	42	11	14	11,336	-	-	-	-	-	-	-
1970	7,324	427	0	1,748	36	9	3	9,547	-	5	-	-	612	10	627
1971	7,037	350	1	473	17	37	31	7,946	-	1	-	-	99	3	103
1972	6,796	531	55	282	20	1	2	7,687	2	0	-	-	171	4	175
1973	7,123	414	720	121	27	23	2	8,430	4	0	-	-	399	4	403
1974	5,983	654	1,304	190	27	16	2	8,176	6	0	-	-	406	22	428
1975	7,031	620	2,672	205	58	18	2	10,606	-	0	-	-	557	13	570
1976	8,054	750	3,488	313	170	14	12	12,801	-	0	-	-	42	13	55
1977	8,383	880	2,344	201	71	7	2	11,888	-	17	-	-	318	19	354
1978	8,001	1,031	2,475	130	110	22	1	11,770	-	9	-	-	1,699	13	1,721
1979	8,602	1,038	983	161	45	15	4	10,848	7	7	-	-	329	57	393
1980	6,005	849	1,746	398	29	15	1	9,043	380	5	-	160	566	62	793
1981	7,039	727	1,848	129	58	9	3	9,813	1,575	3	0	473	271	2	749

[1] Catch data are currently unavailable for Republic of Korea, Philippines, and some other countries catching swordfish in the North Pacific.
[2] Catches by gear for 1952-1970 were estimated roughly using FAO statistics and other data. Catches for 1971-2002 are more reliably estimated.
[3] Contrains trolling and harpoon but majority of catch obtained by harpoon.
[4] For 1952-1970 "Other" refers to catches by net fishing and various unspecified gears.
[5] Offshore longline category includes some catches from harpoon and other fisheries but does not include catches unloaded in foreign ports.
[6] Estimated round weight of retained catch. Does not include discards.
[7] Unknown includes pole and line, purse seine, troll and troll/handline, half ring, and unspecified gears.

only one vessel fished so combined with Hawaii longline

Table 6. (Continued) Swordfish catches (in metric tons) by fisheries, 1952-2010. Blank (" ") indicates no effort. Dash ("–") indicates data not available. Zero ("0") indicates a catch of less than 1 metric ton.

	Japan								Mexico	United States[6]					
										Hawaii	California				
Year	Distant-water and Offshore Longline	Coastal and Other Longline	Squid Driftnet and Driftnet	Harpoon[3]	Bait Fishing	Trapnet	Other[4]	Japan Total	All Gears	Longline	Longline	Gill Net	Harpoon	Unknown[7]	US Total
1982	6,064	874	1,257	195	58	7	1	8,456	1,365	5	0	945	156	10	1,116
1983	7,692	999	1,033	166	30	9	2	9,931	120	5	0	1,693	58	7	1,763
1984	7,177	1,177	1,053	117	98	13	0	9,635	47	3	12	2,647	104	75	2,841
1985	9,335	999	1,133	191	69	10	0	11,737	18	2	0	2,990	305	104	3,401
1986	8,721	1,037	1,264	123	47	9	0	11,201	422	2	0	2,069	291	109	2,471
1987	9,495	860	1,051	87	45	11	0	11,549	550	24	0	1,529	235	31	1,819
1988	8,574	678	1,234	173	19	8	0	10,686	613	24	0	1,376	198	64	1,662
1989	6,690	752	1,596	362	21	10	0	9,431	690	218	0	1,243	62	56	1,579
1990	5,833	690	1,074	128	13	4	0	7,742	2,650	2,436	0	1,131	64	43	3,674
1991	4,809	807	498	153	20	5	0	6,292	861	4,508	27	944	20	44	5,543
1992	7,234	1,181	887	381	16	6	0	9,705	1,160	5,700	62	1,356	75	47	7,240
1993	8,298	1,394	292	309	43	4	1	10,341	812	5,909	27	1,412	168	161	7,677
1994	7,366	1,357	421	308	37	4	0	9,493	581	3,176	631	792	157	24	4,780
1995	6,422	1,387	561	423	34	7	0	8,834	437	2,713	268	771	97	29	3,878
1996	6,916	1,067	428	597	45	4	0	9,057	439	2,502	346	761	81	15	3,705
1997	7,002	1,214	365	346	62	5	0	8,994	2,365	2,881	512	708	84	11	4,196
1998	6,233	1,190	471	476	68	2	0	8,440	3,603	3,263	418	931	48	19	4,679
1999	5,557	1,049	724	416	47	5	0	7,798	1,136	3,100	1,229	606	81	27	5,043
2000	6,180	1,121	808	497	49	5	0	8,660	2,216	2,949	1,885	646	90	9	5,579
2001	6,932	908	732	230	30	15	0	8,847	780	220	1,749	375	52	5	2,401
2002	6,230	965	1,164	201	29	11	0	8,600	465	204	1,320	302	90	3	1,919
2003	5,376	1,063	1,198	149	28	4	0	7,818	671	147	1,812	216	107	0	2,282
2004	5,395	1,509	1,062	229	30	4	0	8,229	270	213	898	169	62	37	1,379
2005	5,359	1,294	956	187	337	3	0	8,136	235	1,622		220	76	0	1,918
2006	6,181	1,507	796	244	342	5	1	9,076	347	1,211		444	71	2	1,728
2007	6,109	2,016	829	122	367	2	1	9,446	383	1,735		484	58	0	2,277
2008	4,402 [1]	1,780 [1]	648 [1]	173 [1]	349 [1]	3 [1]	0 [1]	7,355 [1]	84	1,980		280	33	1	2,294
2009	4,400 [1]	1,548 [1]	682 [1]	239 [1]	249 [1]	3 [1]	0 [1]	7,121 [1]	-	1,813 [1]		172 [1]	34 [1]	1 [1]	2,020
2010	-	-	-	-	-	-	-	-	-	1,654 [1]		33 [1]	22 [1]	4 [1]	1,713
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] Catch data are currently unavailable for Republic of Korea, Philippines, and some other countries catching swordfish in the North Pacific.
[2] Catches by gear for 1952-1970 were estimated roughly using FAO statistics and other data. Catches for 1971-2002 are more reliably estimated.
[3] Contrains trolling and harpoon but majority of catch obtained by harpoon.
[4] For 1952-1970 "Other" refers to catches by net fishing and various unspecified gears.
[5] Offshore longline category includes some catches from harpoon and other fisheries but does not include catches unloaded in foreign ports.
[6] Estimated round weight of retained catch. Does not include discards.
[7] Unknown includes pole and line, purse seine, troll and troll/handline, half ring, and unspecified gears.

(shaded) only one vessel fished so combined with Hawaii longline

Table 6. (Continued) Swordfish catches (in metric tons) by fisheries, 1952-2010. Blank (" ") indicates no effort. Dash ("–") indicates data not available. Zero ("0") indicates a catch of less than 1 metric ton.

	Chinese Taipei[5]											Korea			
Year	Distant-water Longline	Offshore Longline	Offshore Gillnet	Offshore Others	Coastal Harpoon	Coastal Setnet	Coastal Gillnet & Other Net	Coastal Longline	Coastal Others	Other	Chinese Taipei Total	Longline	High-seas Drift Gillnet	Korea Total	Grand Total
1951												-	-	-	11,678
1952	-	-									-	-	-	-	11,691
1953	-	-									-	-	-	-	12,408
1954	-	-									-	-	-	-	13,610
1955	-	-									-	-	-	-	14,111
1956	-	-									-	-	-	-	15,486
1957	-	-									-	-	-	-	15,251
1958	-	-									-	-	-	-	19,734
1959	-	427								91	518	-	-	-	18,785
1960	-	520								127	647	-	-	-	22,047
1961	-	318								73	391	-	-	-	21,538
1962	-	494								62	556	-	-	-	12,671
1963	-	343								18	361	-	-	-	11,605
1964	-	358								10	368	-	-	-	9,220
1965	-	331								27	358	-	-	-	11,349
1966	-	489								31	520	-	-	-	12,283
1967	-	646								35	681	-	-	-	12,689
1968	-	763								12	775	-	-	-	12,424
1969	0	843								7	850	-	-	-	12,186
1970	-	904								5	909	-	-	-	11,083
1971	-	992								3	995	0	-	0	9,044
1972	-	862								11	873	0	-	0	8,737
1973	-	860								119	979	0	-	0	9,816
1974	1	880								136	1,017	0	-	0	9,627
1975	29	899								153	1,081	0	-	0	12,257
1976	23	613								194	830	0	-	0	13,686
1977	36	542								141	719	219	-	219	13,180
1978	-	546								12	558	68	-	68	14,117
1979	7	661								33	701	-	-	-	11,949
1980	10	603								76	689	64	-	64	10,969
1981	2	656								25	683	-	-	-	12,820

[1] Catch data are currently unavailable for Republic of Korea, Philippines, and some other countries catching swordfish in the North Pacific.
[2] Catches by gear for 1952-1970 were estimated roughly using FAO statistics and other data. Catches for 1971-2002 are more reliably estimated.
[3] Contrains trolling and harpoon but majority of catch obtained by harpoon.
[4] For 1952-1970 "Other" refers to catches by net fishing and various unspecified gears.
[5] Offshore longline category includes some catches from harpoon and other fisheries but does not include catches unloaded in foreign ports.
[6] Estimated round weight of retained catch. Does not include discards.
[7] Unknown includes pole and line, purse seine, troll and troll/handline, half ring, and unspecified gears.

Table 6. (Continued) Swordfish catches (in metric tons) by fisheries, 1952-2010. Blank (" ") indicates no effort. Dash ("–") indicates data not available. Zero ("0") indicates a catch of less than 1 metric ton.

	Chinese Taipei[5]											Korea			
Year	Distant-water Longline	Offshore Longline	Offshore Gillnet	Offshore Others	Coastal Harpoon	Coastal Setnet	Coastal Gillnet & Other Net	Coastal Longline	Coastal Others	Other	Chinese Taipei Total	Longline	High-seas Drift Gillnet	Korea Total	Grand Total
1982	1	855								49	905	48	-	48	11,890
1983	0	783								166	949	11	-	11	12,774
1984	-	733								264	997	48	-	48	13,568
1985	-	566								259	825	24	-	24	16,005
1986	-	456								211	667	9	-	9	14,770
1987	3	1,328								190	1,521	44	-	44	15,483
1988	-	777								263	1,040	27	-	27	14,028
1989	50	1,491								38	1,579	40	-	40	13,319
1990	143	1,309								154	1,606	61	-	61	15,733
1991	40	1,390								180	1,610	5	-	5	14,311
1992	21	1,473								243	1,737	8	-	8	19,850
1993	54	1,174								310	1,538	15	-	15	20,383
1994	-	1,155								219	1,374	66	-	66	16,294
1995	50	1,135								225	1,410	10	-	10	14,569
1996	9	701	2	-	19	10	-	-	-		741	15	-	15	13,957
1997	15	1,358	1	1	27	8	-	24	-		1,434	100	-	100	17,089
1998	20	1,178	8	-	17	15	1	-	-		1,239	153	-	153	18,114
1999	70	1,385	4	-	51	5	1	-	-		1,516	132	-	132	15,625
2000	325	1,531	5	-	74	5	1	1	-		1,942	202	-	202	18,599
2001	1,039	1,691	17	-	64	8	1	1	-		2,821	438	-	438	15,287
2002	1,633	1,557	7	1	1	16	1	1	-		3,217	439	-	439	14,640
2003	1,084	2,196	3	-	-	8	-	-	-		3,291	381	-	381	14,443
2004	884	1,828	5	-	-	7	1	-	3		2,728	410	-	410	13,016
2005	437	1,813	1	-	-	5	2	-	18		2,276	434	-	434	12,999
2006	-	-	-	-	-	-	-	-	-	-	-	477	-	477	11,629
2007	-	-	-	-	-	-	-	-	-	-	-	452	-	452	12,558
2008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,733
2009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9,141
2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,713
2011	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] Catch data are currently unavailable for Republic of Korea, Philippines, and some other countries catching swordfish in the North Pacific.
[2] Catches by gear for 1952-1970 were estimated roughly using FAO statistics and other data. Catches for 1971-2002 are more reliably estimated.
[3] Contrains trolling and harpoon but majority of catch obtained by harpoon.
[4] For 1952-1970 "Other" refers to catches by net fishing and various unspecified gears.
[5] Offshore longline category includes some catches from harpoon and other fisheries but does not include catches unloaded in foreign ports.
[6] Estimated round weight of retained catch. Does not include discards.
[7] Unknown includes pole and line, purse seine, troll and troll/handline, half ring, and unspecified gears.

Attachment 1. List of Participants

China

Yan Chen
Shanghai Ocean University
999 Hucheng Ring Road
Lingang New City Shanghai, China 210306
86-21-61900325, 86-21-61900304 (fax)
yanchen@shou.edu.cn

Xiaojie Dai
Shanghai Ocean University
999 Hucheng Ring Road
Lingang New City Shanghai, China 210306
86-21-61900325, 86-21-61900304 (fax)
xjdai@shou.edu.cn

Wenjiang Guan
Shanghai Ocean University
999 Hucheng Ring Road
Lingang New City Shanghai, China 210306
86-21-61900325, 86-21-61900304 (fax)
wjguam@shou.edu.cn

Siquan Tian
Shanghai Ocean University
999 Hucheng Ring Road
Lingang New City, Shanghai, China 210306
86-21-61900329, 86-21-61900304 (fax)
sqtian@shou.edu.cn

Jiangfeng Zhu
Shanghai Ocean University
999 Hucheng Ring Road
Lingang New City, Shanghai, China 210306
86-21-61900338, 86-21-61900304
jfzhu@shou.edu.cn

Chinese Taipei

Yi-Jay Chang
Institute of Oceanography
National Taiwan University
1, Sect. 4, Roosevelt Road
Taipei, Taiwan 106
886-2-23629842 (tel & fax)
d94241004@ntu.edu.tw

Nan-Jay Su
Institute of Oceanography
National Taiwan University
1, Sect. 4, Roosevelt Road
Taipei, Taiwan 106
886-2-23629842 (tel & fax)
nanjay@ntu.edu.tw

Chi-Lu Sun
Institute of Oceanography
National Taiwan University
1, Sect. 4, Roosevelt Road
Taipei, Taiwan 106
886-2-23629842 (tel & fax)
chilu@ntu.edu.tw

Su-Zan Yeh
Institute of Oceanography
National Taiwan University
1, Sect. 4, Roosevelt Road
Taipei, Taiwan 106
886-2-23629842 (tel & fax)
chilu@ntu.edu.tw

Japan

Ai Kimoto
Natl. Res. Inst. of Far Seas Fisheries
5-7-1 Orido, Shimizu
Shizuoka, Japan 424-8633
81-54-336-6035, 81-54-335-9642 (fax)
aikimoto@affrc.go.jp

Tamaki Shimose
Seikai National Fisheries Research Institute,
Fisheries Research Agency 148-446 Fukai-Ota, Ishigaki, Okinawa, Japan, 907-0451
81-980-88-2571, 81-980-88-2573 (fax)
shimose@affrc.go.jp

Kotaro Yokawa
Natl. Res. Inst. of Far Seas Fisheries
5-7-1 Orido, Shimizu
Shizuoka, Japan 424-8633
81-54-336-6044, 81-54-335-9642 (fax)
Yokawa@fra.affrc.go.jp

United States

Jon Brodziak
NOAA NMFS PIFSC
2570 Dole St.
Honolulu, HI 96822
808-983-2964, 808-983-2902 (fax)
Jon.Brodziak@noaa.gov

Gerard DiNardo
NOAA NMFS PIFSC
2570 Dole St.
Honolulu, HI 96822
808-983-5397, 808-983-2902 (fax)
Gerard.DiNardo@noaa.gov

Lyn Katahira
Joint Inst. for Mar. and Atmos. Res.
2570 Dole St.
Honolulu, HI 96822
808-983-2902, 808-983-2902 (fax)
Lyn.Wagatsuma@noaa.gov

Hui-Hua Lee
Joint Inst. for Mar. and Atmos. Res.
2570 Dole St.
Honolulu, HI 96822
808-983-5352, 808-983-2902 (fax)
Huihua.Lee@noaa.gov

Darryl Tagami
NOAA NMFS PIFSC
2570 Dole St.
Honolulu, HI 96822
808-983-5745, 808-983-2902 (fax)
Darryl.Tagami@noaa.gov

IATTC

Michael Hinton
Inter-American Tropical Tuna Commission
8604 La Jolla Shores Dr.
La Jolla, CA 92307-1508
858-546-7033, 858-546-7133 (fax)
mhinton@iattc.org

Attachment 2. Working Papers and Presentations

WORKING PAPERS

ISC/12/BILLWG-1/01	Future Projections of Western and Central Pacific Striped Marlin. Hui-Hua Lee, Kevin Piner, and Ian Taylor. (Huihua.Lee@noaa.gov)
ISC/12/BILLWG-1/02	Blue Marlin Catches in the North and South Pacific from WCPFC Data. Darryl Tagami, and Haiying Wang. (Darryl.Tagami@noaa.gov)
ISC/12/BILLWG-1/03	A Long-Term Nominal Catch History for Blue Marlin *Makaira nigricans* in Hawaiian Waters. William Walsh, Darryl Tagami, and Haiying Wang. (William.Walsh@noaa.gov)
ISC/12/BILLWG-1/04	A review of Taiwan's Blue Marlin Fisheries in the Pacific Ocean, 1958-2010. Chi-Lu Sun, Nan-Jay Su, Su-Zan Yeh, and Yi-Jay Chang. (Chilu@ntu.edu.tw)
ISC/12/BILLWG-1/05	Standardized Catch-Rates of Blue Marlin *(Makaira nigricans)* in the Pacific Ocean for Taiwanese Distant-Water Longline Fishery, 1964-2010. Chi-Lu Sun, Nan-Jay Su, and Su-Zan Yeh. (Chilu@ntu.edu.tw)
ISC/12/BILLWG-1/06	A Review of Life History Parameters of the Pacific Blue Marlin. Chi-Lu Sun, Yi-Jay Chang, Su-Zan Yeh, and Nan-Jay Su. (Chilu@ntu.edu.tw)
ISC/12/BILLWG-1/07	Meta-Analysis of Post-release Mortality in Striped *(Kajikia audax)* and Blue Marlin *(Makaira nigricans)* Using Pop-up Satellite Archival Tags. Michael Musyl. (Michael.Musyl@noaa.gov)
ISC/12/BILLWG-1/08	Overview of the Japanese Fisheries for Blue Marlin in the Pacific Ocean Up to 2010. Ai Kimoto and Kotaro Yokawa. (aikimoto@affrc.go.jp)
ISC/12/BILLWG-1/09	Review of Size Data for Blue Marlin Caught by Japanese Fisheries in the Pacific Ocean Since 1970s. Ai Kimoto and Kotaro Yokawa. (aikimoto@affrc.go.jp)

PRESENTATIONS

Chinese Billfish Longline Data in the Pacific Ocean. Xiaojie Dai. (xjdai@shou.edu.cn)

Age Determination and Growth of Blue Marlin. Tamaki Shimose, Kotaro Yokawa, and Katsunori Tachihara. (shimose@affrc.go.jp)

Sexual Difference in the Migration Pattern of Blue Marlin Related to Spawning and Feeding Activities in the North Pacific Ocean. Tamaki Shimose, Kotaro Yokawa, Hirokazu Saito, and Katsunori Tachihara. (shimose@affrc.go.jp)

Attachment 3. Agenda

INTERNATIONAL SCIENTIFIC COMMITTEE FOR TUNA AND TUNA-LIKE SPECIES IN THE NORTH PACIFIC

BILLFISH WORKING GROUP (BILLWG)

INTERCESSIONAL WORKSHOP AGENDA

Meeting Site: Shanghai Ocean University
999 Hucheng Huan Road
Shanghai 201306 China

Meeting Dates: April 2-9, 2012

Goals: Prepare and review stock assessment documentation and develop stock projections for Western and Central North Pacific striped marlin. Collect and review fishery data and nominal catch and nominal catch-per-unit effort data for Pacific blue marlin. Review life history parameters and available biological data for Pacific blue marlin. Collect and review North Pacific swordfish catch data.

DRAFT AGENDA

April 2 (Monday), 0915-1000 – Registration and Opening of Meeting

1. Opening of Billfish Working Group (BILLWG) Workshop
    a. Welcome and Opening of Meeting
    b. Introductions
    c. Group Photo

April 2 (Monday), 1020-1630

2. Meeting Logistics
    a. Standard Meeting Protocols
    b. Computing Facilities
    c. Adoption of Agenda
    d. Assignment of Rapporteurs

3. Numbering Working Papers and Distribution Potential

4. Status of Work Assignments

5. Annual Billfish Catch/Effort (Category I, II, & III data)
    a. Review of Recent Fishery Data and Information on ISC website (through 2011)

6. Collect and Review North Pacific Swordfish Life History and Catch Data
    a. New Life History Information
    b. Catch Data (Category I)

April 3 (Tuesday), 930-1700

7. Collect and Review Fishery Data and Nominal Catch and Nominal Catch-Per-Unit Effort Data for Pacific Blue Marlin
    a. Fishery Data and Definitions
    b. Nominal Catch by Fishery
    c. Nominal Catch-Per-Unit Effort by Fishery
    d. Tagging Data by Fishery
    e. Habitat Preference Data

April 4 (Wednesday), 930-1700

6,7. Complete Collection and Review of Fishery Data as Needed
    a. Fishery Data
    b. Discussion of Billfish Biology and Fisheries

8. Prepare and Review Stock Assessment Documentation and Develop Stock Projections for WCNPO Striped Marlin
    a. Stock Assessment Document
    b. Executive Summary
    c. Stock Projections

April 5 (Thursday), 930-1700

8. Prepare and Review Assessment Documentation and Projections for WCNPO Striped Marlin: Continued
    a. Stock Assessment Document
    b. Executive Summary
    c. Stock Projections

April 6 (Friday), 930-1700

8. Prepare and Review Assessment Documentation and Projections for WCNPO Striped Marlin: Continued
    a. Stock Assessment Document
    b. Executive Summary
    c. Stock Projections

9. Adoption of Assessment Documentation and Projections for WCNPO Striped Marlin
    a. Stock Assessment Document
    b. Executive Summary

   c. Stock Projections

10. Other Business
    a. Revise Pacific Blue Marlin Stock Assessment Work Plan
        (1) Progress with Collaborative Partners
        (2) Progress on Preparation of Assessment Data
        (3) Progress on Assessment Modeling Approaches
        (4) Work Assignments
    b. North Pacific Swordfish Assessment Update\

April 7 (Saturday), 930-1700

11. Collect and Review Life History Information for Pacific Blue Marlin
    a. Growth
    b. Length-Weight Relationship
    c. Maturity and Fecundity
    d. Natural Mortality Rate
    e. Stock-Recruitment Relationship

12. Rapporteurs and Participants Complete Report Sections

April 8 (Sunday), No Meeting

13. Complete Workshop Report and Circulate; WG Reviews Report

April 9 (Monday), 930-1300

14. Clearing of Report

15. Adjournment

Appendix 1. Executive Summary: Western and Central North Pacific Striped Marlin Stock Assessment

Executive Summary: Western and Central North Pacific Striped Marlin Stock Assessment

Jon Brodziak, Editor

NOAA Fisheries

Pacific Islands Fisheries Science Center

Honolulu, HI 96822, USA

Abstract

This working paper describes the Executive Summary for 2012 assessment of the Western and Central North Pacific striped marlin stock conducted by the Billfish Working Group of the International Scientific Committee on Tuna and Tuna-Like Species in the North Pacific. The Executive Summary summarizes assessment information on stock status, stock projections, and potential conservation advice, as well as providing information on stock identification and distribution, catches, data and assessment, biological reference points, and special comments.

Executive Summary

Western and Central North Pacific Striped Marlin Stock Assessment

Status of Stock: Estimates of population biomass of the Western and Central North Pacific (WCNPO) striped marlin stock (*Kajikia audax*) exhibit a long-term decline (Figure A-1.1). Population biomass (age-1 and older) averaged roughly 18,200 mt, or 42% of unfished biomass during 1975-1979, the first 5 years of the assessment time frame, and declined to 6,625 mt, or 15% of unfished biomass in 2010. Female spawning biomass is estimated to be 938 mt in 2010 (35% of SB_{MSY}, the female spawning biomass to produce MSY, Figure A-1.2). Fishing mortality on the stock (average F on ages 3 and older) is currently high (Figure A-1.3) and averaged roughly F = 0.76 during 2007-2009, or 24% above F_{MSY}. The predicted value of the spawning potential ratio (SPR, the predicted spawning output at current F as a fraction of unfished spawning output) is currently $SPR_{2007\text{-}2009}$ = 14% which is 19% below the level of SPR required to produce MSY. Recruitment averaged about 328 thousand recruits during 1994-2008, which was roughly 30% below the 1975-2010 average. No target or limit reference points have been established for the WCNPO striped marlin stock under the auspices of the WCPFC. Compared to MSY-based reference points, the current (2010) spawning biomass is 65% below SB_{MSY} and the current fishing mortality exceeds F_{MSY} by 24% (Figures A-1.4 and A-1.5). Therefore, overfishing is currently occurring relative to MSY and the stock is in a depleted state.

Projections: Stock projections for landings, spawning biomass, and fishing mortality of WCNPO striped marlin during 2012 to 2017 account for uncertainty in future stock size and recruitment. Two equally-plausible states of nature for future recruitment were assumed for the projections. These were: **Recent Recruitment** in which the recent recruitment pattern (1994-2008) was randomly resampled; and **Stock-Recruitment Curve** in which the residuals from the estimated stock-recruitment curve (1975-2008) were randomly resampled and added to expected recruitment. Projections were run using an age-structured simulation model and included estimation uncertainty for the initial population size at age.

Eight projected harvest scenarios[1] were analyzed: (1) constant fishing mortality equal to the current F ($F_{current}$ = 0.76), the 2007-2009 average; (2) constant fishing mortality equal to F_{MSY} (F_{MSY} = 0.61); (3) constant fishing mortality equal to the 2001-2003 average ($F_{2001\text{-}2003}$ = 0.90); (4) constant fishing mortality equal to the SPR of 0.2; (5) constant fishing mortality equal to the SPR of 0.3; (6) no fishing; (7) constant annual catch (2,500 mt) equal to a 20% reduction from the 2007-2009 average annual catch of 3,150 mt; (8) constant annual catch (3,600 mt = 20% reduction from the highest catches during 2000-2003). The six fishing mortality-based scenarios assumed current fishing mortality ($F_{current}$) during 2010-2011 while the two catch-based scenarios assumed a constant annual catch during 2010-2011. Projection results show percentiles of projected relative spawning biomass in 2017 (Table A-1.1) and the median female spawning stock biomass and the median catch for each of the eight harvest scenarios (Annex 1).

Table A-1.1. Percentiles of projected relative spawning stock biomass (SB_{2017}/SB_{2012}) in 2017.

Harvest Scenario	Recent Recruitment					Stock-Recruitment Curve				
	5th	25th	50th	75th	95th	5th	25th	50th	75th	95th
(1) $F = F_{current}$	0.85	1.03	1.14	1.23	1.36	0.83	1.09	1.29	1.51	1.82
(2) $F = F_{MSY}$	1.12	1.32	1.45	1.55	1.69	1.14	1.47	1.72	1.98	2.34
(3) $F = F_{2001\text{-}2003}$	0.72	0.87	0.98	1.06	1.18	0.66	0.88	1.06	1.25	1.52
(4) F = F20%	1.26	1.48	1.62	1.72	1.88	1.32	1.68	1.95	2.24	2.62
(5) F = F30%	1.90	2.18	2.35	2.48	2.68	2.08	2.56	2.91	3.28	3.79
(6) F = 0	4.93	5.49	5.82	6.06	6.47	5.43	6.33	7.07	7.81	8.72
(7) Catch = 2500 mt	1.41	1.97	2.33	2.67	3.1	1.63	2.49	3.23	4.03	5.28
(8) Catch = 3600 mt	0.98	1.18	1.48	1.80	2.25	1.05	1.51	2.20	3.01	4.37

[1]Details of the projection analyses are described in Appendix 2 of the April 2012 ISC Billfish Working Group Workshop Report.

Conservation Advice: Reducing fishing mortality would likely increase spawning stock biomass and would improve the chances of higher recruitment. If one uses the median to measure the central tendency of the distributions of projected spawning biomass (Annex 1), then the projection results suggest that fishing at F_{MSY} would lead to spawning biomass increases of roughly 45% to 72% from 2012 to 2017. Fishing at a constant catch of 2,500 mt would lead to potential increases in spawning biomass of 133% to 223% by 2017. In comparison, fishing at the current fishing mortality rate would lead to spawning biomass increases of 14% to 29% by 2017, while fishing at the average 2001-2003 fishing mortality rate would lead to a spawning biomass decrease of 2% under recent recruitment to an increase of 6% under the stock-recruitment curve assumption by 2017.

Table A-1.2. Reported catch (mt), population biomass (mt), spawning biomass (mt), relative spawning biomass (SB/SB_{MSY}), recruitment (thousands), fishing mortality (average ages 3 and older), relative fishing mortality (F/F_{MSY}), exploitation rate, and spawning potential ratio of Western and Central North Pacific striped marlin.

Year	2004	2005	2006	2007	2008	2009	2010	Mean[1]	Min[1]	Max[1]
Reported Catch	4047	3703	3706	3195	3691	2560	2560[2]	6011	2560	10528
Population Biomass	11679	9545	10371	8430	7414	5335	6625	14141	5335	24886
Spawning Biomass[3]	1731	2010	1992	1824	1625	1106	938	2439	909	5104
Relative Spawning Biomass	0.64	0.74	0.73	0.67	0.60	0.41	0.35	0.90	0.33	1.88
Recruitment (age 0)	116	434	125	204	133	349	326	453	116	1620
Fishing Mortality	0.58	0.56	0.62	0.58	0.86	0.84	0.75	0.79	0.53	1.46
Relative Fishing Mortality	1.22	0.95	0.92	1.01	0.95	1.41	1.37	1.30	0.86	2.38
Exploitation Rate	35%	39%	36%	38%	50%	48%	38%	44%	29%	69%
Spawning Potential Ratio	19%	19%	17%	19%	12%	13%	14%	14%	7%	21%

[1] During 1975-2010

[2] Assumed equal to 2009 value

[3] Female

Stock Identification and Distribution: The Western and Central North Pacific striped marlin stock is separated from the Eastern North Pacific stock based on newly-reported results of population genetic studies and empirical patterns in the spatial distribution of fishery catch-per-unit effort. The boundary of the Western and Central North Pacific stock is defined to be the waters of the Pacific Ocean west of 140°W and north of the equator.

Catches: Catches of WCNPO striped marlin have exhibited a long-term decline since the 1970s. Catches averaged roughly 8,100 mt per year during 1970-1979 and declined by roughly 50% to an average of roughly 3,800 mt per year during 2000-2009. Reported catches in 2009 totaled about 2,560 mt, which was the lowest reported catch since 1975 (Table A-1.2).

Data and Assessment: Catch data was collected from all ISC countries and from countries reporting catches to the WCPFC (Table 2). The growth curve was re-estimated using newly developed ageing data and value of steepness and natural mortality were also re-estimated using available biological information. Standardized catch-per-unit effort data used to measure trends in relative abundance were provided by Japan, USA, and Chinese Taipei. The stock assessment was conducted using the Stock Synthesis assessment model. The assessment model was fit to relative abundance indices and size composition data in a likelihood-based statistical framework. Maximum likelihood estimates of model parameters, derived outputs, and their variances were used to characterize stock status and to develop stock projections.

Biological Reference Points: Reference points based on maximum sustainable yield (MSY) were estimated in the Stock Synthesis assessment model. The point estimate of maximum sustainable yield (± 1 standard error) was MSY = 5378 mt ± 144. The point estimate of the spawning biomass to produce MSY (adult female biomass) was SB_{MSY} = 2713 mt ± 72. The point estimate of F_{MSY}, the fishing mortality rate to produce MSY (average fishing mortality on ages 3 and older) was F_{MSY} = 0.61 ± 0.01 and the corresponding equilibrium value of spawning potential ratio at MSY was SPR_{MSY} = 17.8% ± 0.1%.

Special Comments: The WCNPO striped marlin stock is expected to be highly productive due to its rapid growth and high resilience to reductions in spawning potential. The status of the stock is highly dependent on the magnitude of recruitment, which has been below its long-term average since 2004 (Table A-1.2). In addition, taking into account the fact that the WCNPO striped marlin stock is depleted, fishery catches in areas near the stock boundary should be closely monitored.

Figure A-1.1. Trends in population biomass and reported catch biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010.

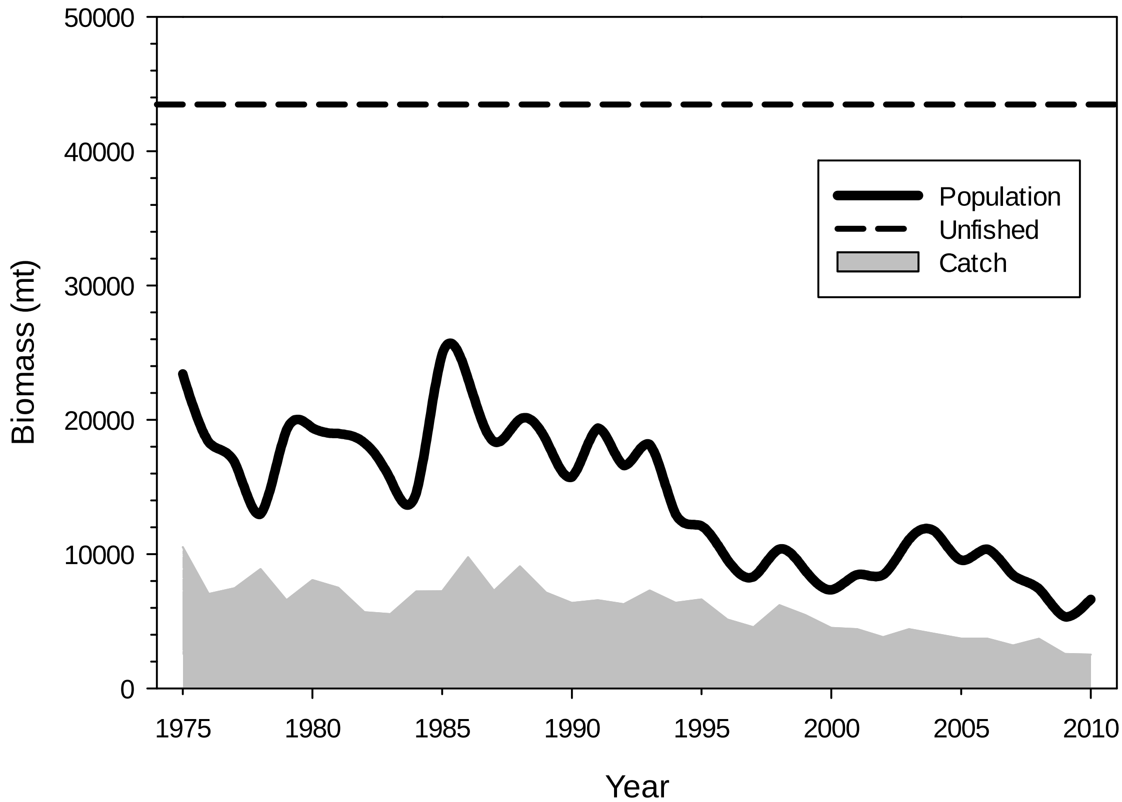


Figure A-1.2. Trends in estimates of spawning biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010 along with 80% confidence intervals.

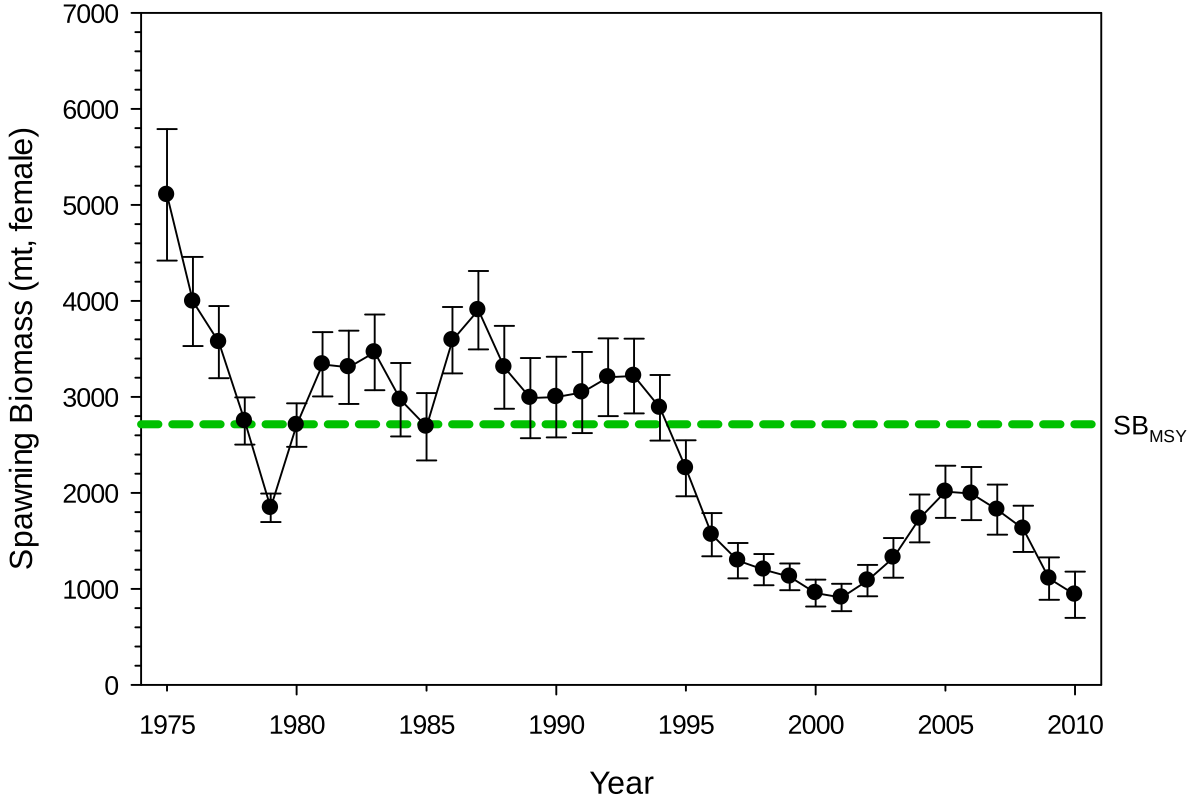


Figure A-1.3. Trends in estimates of fishing mortality of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010 along with 80% confidence intervals.

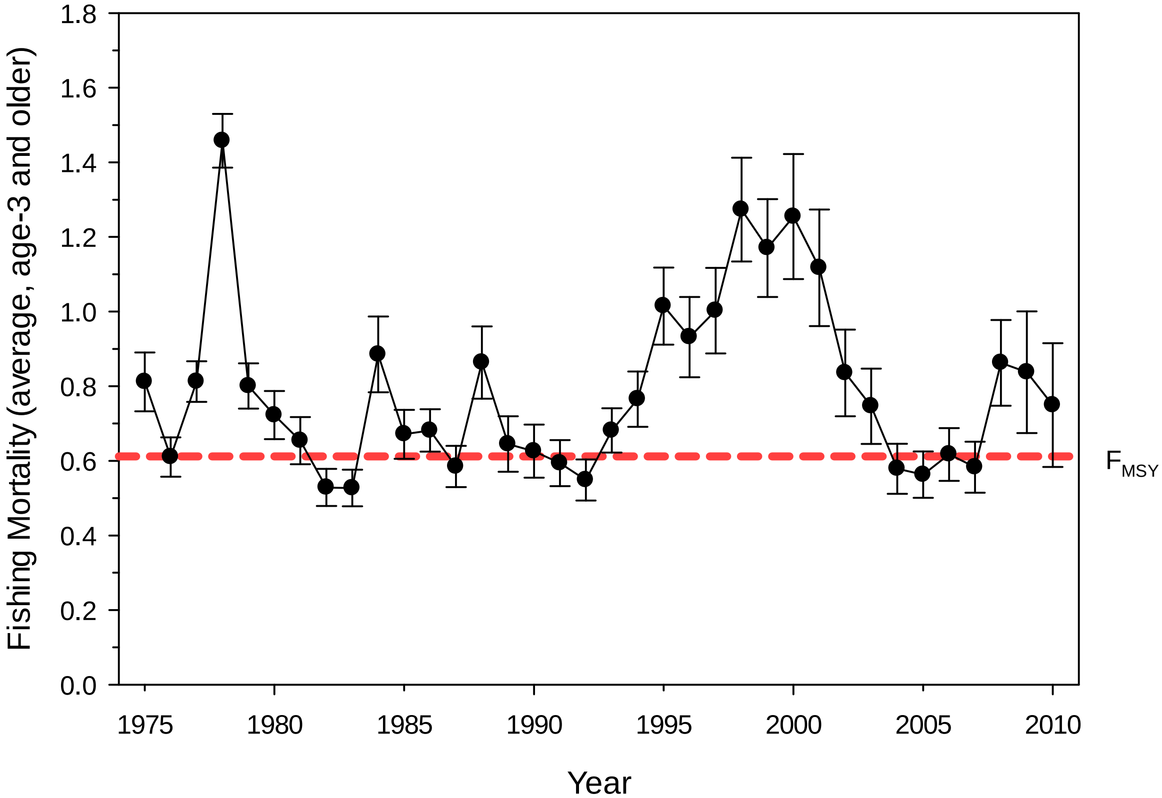


Figure A-1.4. Kobe plot of the trends in estimates of relative fishing mortality and relative spawning biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010.

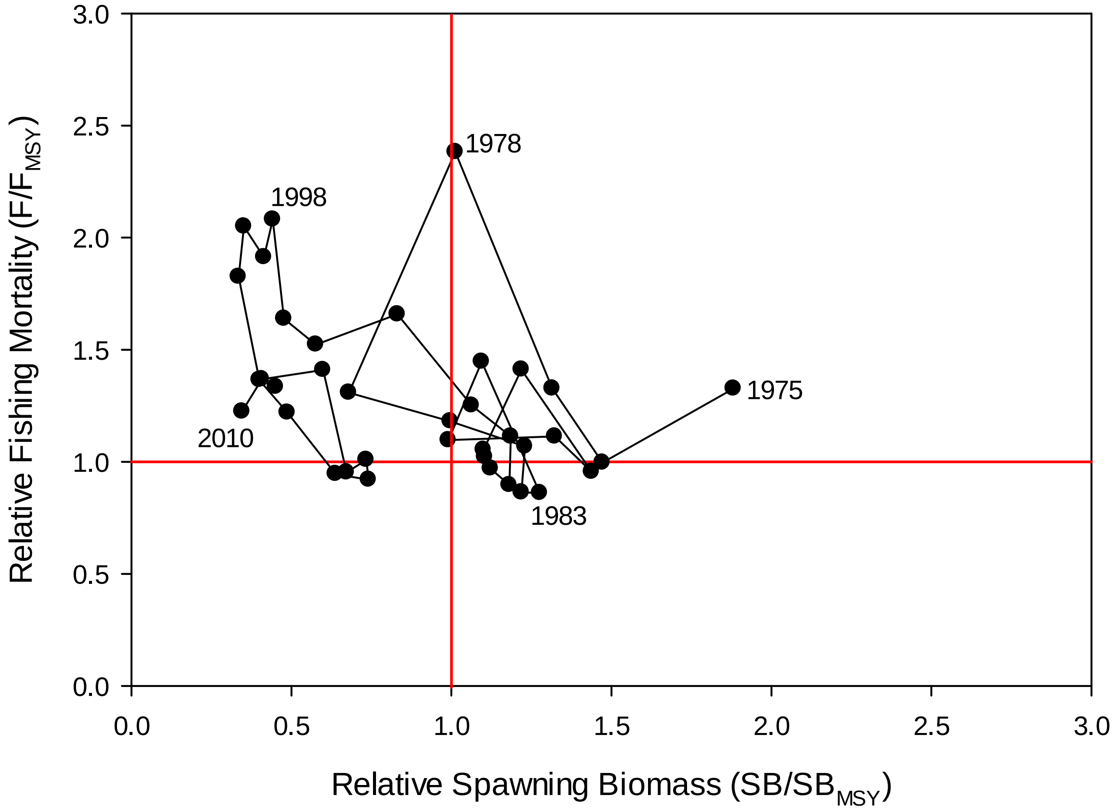
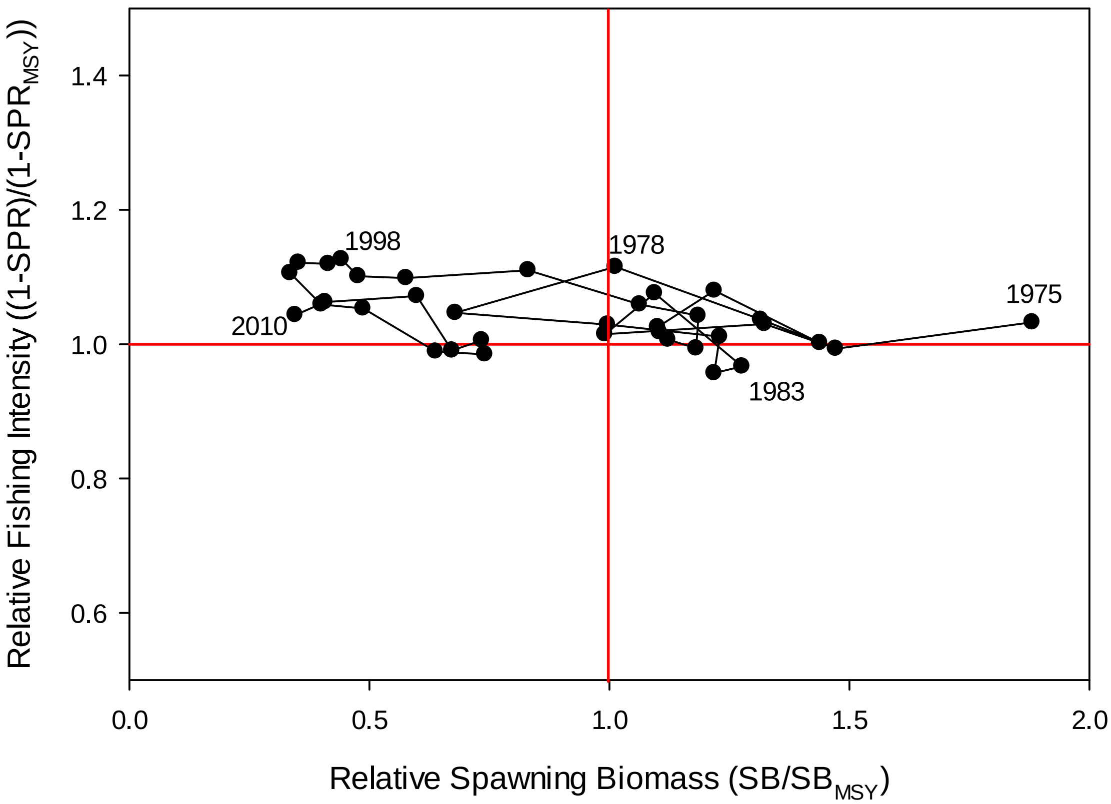


Figure A-1.5. Kobe plot of the trends in estimates of relative fishing intensity and relative spawning biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010.



Annex 1. Projection tables for WCNPO striped marlin under two states of nature: Recent Recruitment and Stock-Recruitment Curve.

Table A-1.A1.1. Projected values of median spawning biomass and catch under recent recruitment.

Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Scenario 1 Recent Recruitment Projection (Constant F = $F_{current}$, weights in mt)						
Spawning Biomass	1333	1439	1495	1510	1522	1525
Catch	3974	4113	4201	4240	4246	4224
Scenario 2 Recent Recruitment Projection (Constant F = F_{MSY}, weights in mt)						
Spawning Biomass	1333	1615	1790	1870	1916	1929
Catch	3267	3649	3868	3948	3971	3962
Scenario 3 Recent Recruitment Projection (Constant F = $F_{2001-2003}$, weights in mt)						
Spawning Biomass	1333	1320	1311	1309	1309	1306
Catch	4471	4403	4378	4402	4399	4376
Scenario 4 Recent Recruitment Projection (Constant F = $F_{20\%}$, weights in mt)						
Spawning Biomass	1333	1692	1936	2064	2133	2162
Catch	2955	3412	3663	3782	3818	3819
Scenario 5 Recent Recruitment Projection (Constant F = $F_{30\%}$, weights in mt)						
Spawning Biomass	1333	1942	2447	2792	3015	3135
Catch	2001	2559	2912	3108	3187	3220
Scenario 6 Recent Recruitment Projection (Constant F = 0 or no fishing, weights in mt)						
Spawning Biomass	1333	2491	3890	5340	6639	7755
Catch	0	0	0	0	0	0
Scenario 7 Recent Recruitment Projection (Constant Catch = 2,500 mt, weights in mt)						
Spawning Biomass	1640	2145	2641	3109	3499	3825
Catch	2500	2500	2500	2500	2500	2500
Scenario 8 Recent Recruitment Projection (Constant Catch = 3,600 mt, weights in mt)						
Spawning Biomass	1640	1845	2023	2188	2313	2419
Catch	3600	3600	3600	3600	3600	3600

Table A-1.A1.2. Projected values of median spawning biomass and catch under stock-recruitment curve.

Year	2012	2013	2014	2015	2016	2017
Scenario 1 Stock-Recruitment Curve Projection (Constant F = $F_{current}$, weights in mt)						
Spawning Biomass	1317	1431	1529	1610	1667	1703
Catch	3884	4154	4374	4543	4652	4745
Scenario 2 Stock-Recruitment Curve Projection (Constant F = F_{MSY}, weights in mt)						
Spawning Biomass	1317	1601	1838	2024	2160	2261
Catch	3195	3685	4066	4374	4583	4740
Scenario 3 Stock-Recruitment Curve Projection (Constant F = $F_{2001\text{-}2003}$, weights in mt)						
Spawning Biomass	1317	1314	1342	1362	1383	1394
Catch	4373	4431	4520	4586	4588	4648
Scenario 4 Stock-Recruitment Curve Projection (Constant F = $F_{20\%}$, weights in mt)						
Spawning Biomass	1317	1679	1985	2238	2423	2572
Catch	2890	3441	3878	4232	4491	4680
Scenario 5 Stock-Recruitment Curve Projection (Constant F = $F_{30\%}$, weights in mt)						
Spawning Biomass	1317	1923	2509	3033	3483	3830
Catch	1957	2574	3103	3533	3881	4139
Scenario 6 Stock-Recruitment Curve Projection (Constant F = 0 or no fishing, weights in mt)						
Spawning Biomass	1317	2468	3957	5692	7524	9320
Catch	0	0	0	0	0	0
Scenario 7 Stock-Recruitment Curve Projection (Constant Catch = 2,500 mt, weights in mt)						
Spawning Biomass	1625	2141	2787	3546	4386	5243
Catch	2500	2500	2500	2500	2500	2500
Scenario 8 Stock-Recruitment Curve Projection (Constant Catch = 3,600 mt, weights in mt)						
Spawning Biomass	1625	1854	2171	2584	3056	3568
Catch	3600	3600	3600	3600	3600	3600

Appendix 2. Future Projections of the Western and Central North Pacific Striped Marlin Stock

Hui-Hua Lee
Joint Institute for Marine and Atmospheric Research, University of Hawaii
Pacific Islands Fisheries Science Center
Honolulu, HI, USA

Kevin Piner
NOAA Fisheries
Southwest Fisheries Science Center
La Jolla, CA, USA

ISC BILLWG members

Abstract

Stock projections were conducted to evaluate the impact of various levels of fishing intensity on future spawning stock biomass and catch based on the recent stock assessment of WCNPO striped marlin stock. The stochastic projections were implemented to incorporate variability of terminal numbers at age in the stock assessment that were propagated forward in future possibilities and uncertainty of potential future recruitment process to reflect the incompleteness of knowledge about the state of nature and ultimately, cast the results in a probabilistic analysis. Decision table reported spawning stock biomass in terminal projection year (2017) relative to 2012 indicated that the current level of exploitation (rate or level) is likely to be sustainable. Fishing at MSY level ($F_{17.8\%}$) provides an expected safe level of harvest, where the average projected catch between 2012 and 2017 is approximately 70% and 76% of MSY for $R_{y=1994-2008}$ and SR, respectively. Reductions in the fishing are predicted to decrease some risk and would likely produce larger increase of yield in 2017 relative to 2012 than current level.

Introduction

In December 2011, the Billfish Working Group (BILLWG) of the International Scientific Committee completed the second full stock assessment (SA) of striped marlin found in the Western and Central area of the North Pacific (Piner *et al.* 2011 and BILLWG 2012a). The SA was conducted using Stock Synthesis (SS), an age structured and length based model of population dynamics (Methot 2005; 2011). Based on the life history of the species, the stock is assumed to be both productive (Piner and Lee 2011a; 2011b) and resilient (Brodziak 2011). Despite the productivity of the stock, the assessment results indicated that current fishing mortality (expressed as $F_{X\%}$ and defined as the average of 2007-2009) was above F_{MSY} and spawning biomass was below SB_{MSY} . Providing management bodies with alternative management options and their resulting effects on this stock are needed.

Stock assessment models simplify the causation of population dynamics into process, with the introduction of maximum complexity in those processes deemed the most important or best informed by the data. Important structural complexity in the striped marlin SA included: single sex annual model with observations and derived quantities evaluated on a quarterly timescale, natural mortality (*M*) was assumed to be age-specific, estimation of initial age structure, and fishery selectivity patterns for some fisheries were time varying. Other important structure in the SA model included: recruitment was based on the Beverton and Holt spawner recruit model and due to the long protracted spawning season and variability in juvenile growth, calculated spawning biomass used in the spawner-recruit (SR) relation and the timing of recruitment occurs in different seasons. Recruitment estimated in the model from 1975-2008, with the 2009 and 2010 taken from the spawner-recruit relation. The first quarter began on January 1st which was consistent with how data was developed (primarily CPUE). The assessment included sensitivity analyses to various assumed parameters. Finally we note that important complexity not included in the model was: sex-specificity, explicit spatial structure and time varying life-history traits.

Forecasts of future stock response to fishing can be done with much more simplified dynamic models as we no longer need to fit to observed data. The objectives of this paper were to 1) develop a simplified projection model to describe expected trends in future spawning biomass and catch. 2) evaluate in a stochastic projection various levels of uncertainty that reflect the incompleteness of knowledge about the state of nature governing the recruitment process. This includes uncertainty in the SA estimates of terminal population size. 3) Evaluate the role of fishing intensity on future spawning stock biomass and 4) cast the results in a probabilistic analysis.

Materials and Methods

Basic dynamics

Projections were performed using software developed for the US West Coast groundfish fisheries, the basic dynamics are annual and were described by Punt (2010) for version 3.12b using an age-structured population dynamics model:

$$N_{y,a} = \begin{cases} R_y & \text{if } a = 0 \\ N_{y-1,a-1}\, e^{-Z_{y-1,a-1}} & \text{if } 0 < a < a_{max} \\ N_{y-1,a_{max}-1}\, e^{-Z_{y-1,a_{max}-1}} + N_{y-1,a_{max}}\, e^{-Z_{y-1,a_{max}}} & \text{if } a = a_{max} \end{cases}$$

where *y* is the projecting year,

$N_{y,a}$ is the number of fish at age *a* in the start of year *y*,

R_y is the recruitment during year *y*,

a_{max} is the oldest age during year *y*,

$Z_{y,a}$ is the total mortality at age *a* during year *y*:

$$Z_{y,a} = M_a + F_y \sum_f S_a^f \eta^f$$

M_a is the instantaneous rate of natural mortality at age a,
F_y is the fishing mortality at fully-selected (i.e. $\sum_f S_a^f \eta^f \to 1$) age during year y,
S_a^f is the selectivity by fishery f at age a,
η^f is the relative weighting factor by fishery f determined by the proportion of maximum selectivity at age for each fishery in which $\sum_f \eta^f = 1$.

Annual fishing mortality is either specified or determined by solving the catch equation:

$$C_y^f = \sum_{a=0}^{a_{max}} \frac{w_a^f N_{y,a} S_a^f \eta^f F_y}{Z_{y,a}} (1 - e^{-Z_{y,a}}); \ C_y = \sum_f C_y^f$$

where w_a^f is the weight at age *a* caught by fishery *f*.

To do the projections, the following quantities from the stock assessment were required:

1. Terminal numbers at age (2010) to start projection;
2. Selectivity at age (S_a^f) for each fishery to govern age structure of catch by fishery;
3. Weight at age (w_a^f) for each fishery to govern the weight of catch within fishery;
4. Fecundity at age (φ_a) (population weight at age *proportion mature at age) to calculate spawning biomass which is $\sum_{a=0}^{15} \varphi_a N_{y,a}$;
5. Assumptions of future recruitment process;
6. Natural mortality to govern natural deaths;
7. Maximum age (a_{max}) treated as a plus group for projection.

Data structure for projections

Forecasts of future stock response to fishing were conducted with simplified dynamic models as observed data were not fit in projections. The model structure was simplified from the base-case stock assessment (Table A-2.1). The stock assessment calculated expected dynamics seasonally, but projections calculated dynamics (e.g. catch, spawning biomass) annually. Within the stock assessment, the first season started January 1st (January-March) which was consistent with how data was compiled. However, for projections the year began July 1st, which corresponded to the timing of recruitment in the stock assessment model (season 3). In the stock assessment model, natural mortality (*M*) was modeled as age specific, with each age-class moving to the next on January 1st and therefore subjected to the next age-classes *M*. Because our projections used a birth year, age specific *M* was a combination of the *M* from July-December and next January-June as was consistent with the stock assessment. Spawning biomass in the stock assessment model was calculated at the beginning of a protracted spawning season (season 2). In the projections, spawning biomass was calculated for July 1st. Numbers at age used to start the projection were from season 3 (July 1st) in the stock assessment model.

Compilation of fleet selectivity patterns and weights at age

The assessment model contained a total of 18 individual fisheries with 10 fisheries containing observations of the proportion of length at age. Fisheries without observations of the proportion of length at age were assumed to share a selectivity pattern with a similar fishery that was consistent with the assumptions in the stock assessment. To simplify projections the fisheries were reduced from 18 to 3 based on similarity of the selectivity patterns, defined as follows:

1. **Asymptotic fishery**: JPN_DRIFT (F5), JPN_OTHER_early (F11) and JPN_SQUID (F7) that was assumed to mirror the F5 selectivity pattern;
2. **Longline fishery**: All domed-shape selectivity patterns that did not take age 0 catch including the JPN_DWLL2 (F2), JPN_DWLL3 (F3), JPN_CLL (F4), JPN_OTHER_late (F12), TWN_LL (F13) and other fisheries that were assumed to have selectivity patterns that mirrored these fisheries;
3. **Age 0 fishery**: Domed-shaped selectivity patterns that allow age 0 catch including the JPN_DWLL1 (F1), HW_LL (F16) and WCPO_OTHER (F17).

Selectivity at age a by fishery f used in the projections was calculated using derived quantities obtained from the stock assessment model as:

$$S_a^f = \frac{C_a^f}{N_a}$$

where f is the aggregated fisheries used in the projections that have similar selectivity pattern, C_a^f is the aggregated catch (in numbers) by fishery f at age a, N_a is the number of fish at age a in the start of birth year. Selectivity was normalized (0-1) across ages for each fishery and averaged for the years 2007-2009.

Similarly, weight-at-age within fishery was the average of fishery weight-at-age for the season that most of the catch was taken during 2007-2009. Weight-at-age was taken from season 3 for asymptotic fishery and from season 1 for longline and age 0 fisheries.

Uncertainty

Different sources of uncertainty have been identified when conducting the stochastic projections (Francis and Shotton 1997). Three key sources of uncertainty were considered in the stochastic projections, the predicted numbers at age in the final year of the stock assessment (i.e. 2010), which were the first year of the projection, alternative processes that govern the future recruitment, and performance measure describing the future performance of the fishery under each of the alternative management options.

Initial population size-at-age

Initial population size-at-age uncertainty for the projections was simulated from the assumed multivariate normal distributions using parametric bootstrap method, where the maximum likelihood estimates (MLE) of the terminal population size at age vector from the stock assessment model and its estimated covariance matrix formed the sampling distribution. 100 uncorrelated samples were simulated from the number at age during the 2012 meeting (BILLWG 2012b). Some of the random multivariate normal samples contained small negative values, on the order of -0.0001, for one of the older age classes (age 10 above) that were converted to absolute values. This conversion had a negligible effect on the overall mean population size of the samples because the negative values were very small numbers.

State of nature (future recruitment process)

Alternative processes that govern the future recruitment were explored:

1. Recruitment (R): Re-sample estimates of recruitment (R_y) for a pre-specified set of historical years from the stock assessment that represents the likely future recruitment;
2. Recruits per Spawner (R/SB): Re-sample estimates of recruits per spawner ratio (R_y/SB_y) for a pre-specified set of historical years from the stock assessment that represents the likely future recruitment given the spawning biomass;
3. Spawner-recruit deviation (σ_R) around the spawner-recruit relation (SR): Recruitment deviations from the spawner-recruit relation estimated in the stock assessment were evaluated for temporal autocorrelation (Durbin-Watson) and that level of autocorrelation included in the analysis.

$$R_y = \frac{4hR_0SB_y}{SB_0(1-h)+SB_y(5h-1)}e^{\varepsilon_y-0.5\sigma_R^2}$$

$$\varepsilon_y = \rho\varepsilon_{y-1}+\sqrt{1-\rho^2}\delta_y;\ \ \delta_y \sim N(0,\sigma_R^2)$$

where ρ is the extent of temporal auto-correlation in the residuals about the stock-recruitment relationship, ε is the error follows a first-order autoregressive process and each δ_y is normally distributed with mean 0 and variance σ_R^2.

The future stock status of striped marlin is dependent on the true state of nature of the production of future recruits. Re-sampling R/SB implies a linear relationship of spawners and recruits. Harvest strategies that reduce spawning biomass will directly reduce recruitment and quickly drive the stock to unacceptable levels. In contrast, low exploitation levels result in unrealistic optimism as re-sampling R/SB implies no density dependent reduction in recruitment at large spawning stock sizes, which is to say there is no compensation (i.e., steepness = 0.2). If the true state of nature is R, this implies the other extreme. Namely, recruitment is not strongly tied to changes in spawning biomass and may imply a more environmentally driven stock hypothesis (i.e., steepness = 1). The use of expectations of SR relationship allows some extent of compensation rather than assuming either one of two extremes (constant recruitment or constant recruits/spawner), and is also more internally consistent in the assessment model assuming a particular form of SR model.

Mean of steepness was estimated as 0.87 from the independent study (Brodziak 2011). This suggested that the hypothesis of no compensation (re-sampling R/SB) is less plausible than compensation hypothesis (re-sampling R) or hypothesis of SR relation for the WCNPO striped marlin. BILLWG could not make decision on which process will best describe future recruitment. The projections were conducted using both recruitment (R) and spawner-recruit (SR) relation hypotheses to move forward.

Harvest scenarios

Projections started in 2010 (July 1st-June 30st) and continued through 2017. The first two years of the projection (2010, 2011) were assumed to have the current exploitation level ($F_{14\%}$) or imputed catch (2,500 mt) depending on the management options and fishery allocations defined in the stock assessment as the average of the period 2007-2009. Starting on July 1st, 2012, additional projections with varying fishing intensities were conducted. Spawning stock biomass (SB) in terminal projection year (2017) relative to 2012 was used as the performance measure to describe the future performance of the fishery by percentiles (5th, 25th, median, 75th and 95th) of 4,000 simulations (40 simulations for 100 samples of population sizes).

Projections were conducted 8 years, 6 levels of harvest rates and 2 levels of constant catches.

1. Constant $F_{X\%}$ levels (6 levels):
    - average during 2001-2003: $F_{12\%}$;
    - average during 2007-2009 defined as current: $F_{14\%}$;
    - F_{MSY}: $F_{17.8\%}$;
    - $F_{20\%}$;
    - $F_{30\%}$;
    - No fishing: $F_{100\%}$;

2. Constant catch (2 levels):
    - 80% of average catches during 2007-2009: 2,500 mt;
    - 80% of highest catches during 2000-2003: 3,600 mt (CMM 2010-01).

Results and discussion

Life history and fishery parameters used in the projections are given in Table A-2.2 and July 1st estimates of spawning biomass can be found in Appendix. The estimates of *M* at age are somewhat lower than the base case reflecting the birth year cycle. Selectivity at age and resulting weights at age for the aggregated 3 fleets are representative of the base case only.

Based on the recruitment time series (Figure A-2.1), projections resampled recruitments from 1994-2008 due to the lower and less variation recruitment estimated than early period (1975-1993). Recruitment prior to 1994 appeared to be from a somewhat higher spawning biomass estimates and corresponds to generally higher levels of recruitment. Recruitment from 2009-2010 were not re-sampled in the projections as those estimates were the expectations of the spawner-recruit (SR) relation.

The stock assessment assumed h=0.87 with σ_R=0.6 (model estimate=0.62). The same assumption was used to generate deviations from around the SR relation. A negative but insignificant temporal auto-correlation of recruitments were found from 1975-2008 (p=0.32) and only a small (9%) positive but insignificant correlation from 1994-2008 (p=0.46). Because the autocorrelation was generally weak, no autocorrelation was assumed in the deviations for the projections.

Results of projections were summarized in the decision table for alternative $F_{X\%}$ and catches (Table A-2.3). The decision table reported spawning stock biomass in terminal projection year (2017) relative to 2012, where alternative fishing intensities and catches were implemented. Projected trajectory of median spawning stock biomass and catch from 2012 to 2017 were shown in Table A-2.4 and Table A-2.5, respectively.

Constant $F_{X\%}$scenarios

When current (2007-2009) $F_{14\%}$ level is maintained, the stock is projected to have less than 25% probability of $SB_{2017} < SB_{2012}$ under the both recruitment hypotheses ($R_{y=1994-2008}$ and SR). If fishing increases to 2001-2003 level ($F_{12\%}$), the probability of $SB_{2017} < SB_{2012}$ increases to less than 75% for $R_{y=1994-2008}$ and 50% for SR. Conversely, if fishing reduces to MSY level ($F_{17.8\%}$) or lower, stock would have zero chance to fall below 2012 level for both recruitment hypotheses. When fishing reduces to $F_{30\%}$, spawning stock biomass will rebuild to SB_{MSY} level by 2015. If there is no fishing after 2012, SB will rebuild to the SB_{MSY} level by 2014.

Across all states of nature, fishing at the MSY level ($F_{17.8\%}$) provides an expected safe level of harvest, where the average projected catch between 2012 and 2017 is approximately 70% and 76% of MSY for $R_{y=1994-2008}$ and SR, respectively. In the next few year reducing fishing from the current level to MSY level would likely lead to some reduction in yield. Also, fishing at MSY level would likely produce larger increase of catches in 2017 relative to 2012 than current level.

Constant catch scenarios

When catch is reduced 20% from current level (average 2007-2009) which is about 2,500 mt, the stock is projected to have zero chance to fall below 2012 level for both states of nature. If catches increases to 3,600 mt (about 80% of average catches during 2000-2003), less than 25% chance of $SB_{2017} < SB_{2012}$ for $R_{y=1994-2008}$ and have zero chance to fall below 2012 level for SR.

Across all states of nature, constant catches at levels ≤2,500 mt appear sustainable and spawning stock biomass will rebuild to SB_{MSY} level by 2015. However catches at 3,600 mt begin to impart some risk especially under assumptions of $R_{y=1994-2008}$ and catches >3,600 mt may not be supported by the future exploitable biomass. It is also apparent that the uncertainty in stock trends (across states of nature and reasonable exploitation levels), as expressed by the largest % decline or increase, is quite a bit larger in the constant catch management practices than constant fishing intensity management practices. Therefore caution should be used if constant catch based management is considered.

There are additional sources of uncertainty that were not evaluated in the projections (Francis and Shotton 1997), in particular, model uncertainty and additional parameter uncertainty. This assessment included sensitivity analyses to various assumed parameters and it was noted that the assessment model was most sensitive to the assumptions about spawner-recruit steepness (*h)* and natural mortality (*M)*. Projections of this stock that integrate across different life history models could draw a more realistic conclusion of uncertainty in the percentiles describing the tails. One example of additional parameter uncertainty is the true strength of the 2009 and 2010 recruitments. The stock assessment sampled those recruitment levels from the expectations of the SR curve because of a lack of information in the model to inform those estimates. In the projections these same levels were assumed to be consistent with the stock assessment. As true recruitment is either above or below the expected, the short term forecast may be biased.

This stock assessment changed the fundamental productivity of the stock by increasing stock turnover (*M*) and resilience (*h*) based on the best available estimates (Brodziak 2011; Piner and Lee 2011a; 2011b). These changes have made the stock resistant to significant levels of fishing. Despite these optimistic changes in life history, the current stock biomass is low and increases in the exploitation level above that observed recently has a real probability of driving spawning biomass lower.

Reference

Billfish Working Group (BILLWG). 2012a. Report of the Billfish Working Group Meeting, 6-16 December, 2011, Honolulu, HI, USA. Annex 5. Report of the Twelve Meeting of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, Plenary Session. 18-23 July, 2012, Sapporo, Japan. Available at:

Billfish Working Group (BILLWG). 2012b. Report of the Billfish Working Group Meeting, 2-9 April, 2012, Shanghai, China. Annex 7. Report of the Twelve Meeting of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean, Plenary Session. 18-23 July, 2012, Sapporo, Japan. Available at:

Brodziak, J. 2011. Probable values of stock-recruitment steepness for north Pacific striped marlin. Working paper submitted to the ISC Billfish Working Group Meeting, 24 May-1 June 2011, Taipei, Taiwan. ISC/11/BILLWG-2/11: 13p.

CMM 2010-01. 2010. Conservation and Management Measure for North Pacific Striped Marlin. The Seventh Regular Session for the Western and Central Pacific Fisheries Commission. 6-10 December, 2010, Honolulu, Hawaii. Available at: http://www.wcpfc.int/conservation-and-management-measures

Francis, R.I.C.C. and Shotton, R. 1997. Risk in fisheries management: a review. Can. J. Fish. Aquat. Sci. 54: 1699-1715.

Methot, Jr., R.D. 2005. Technical description of the Stock Synthesis II assessment program. NOAA Fisheries, Seattle, WA, USA. 54 p.

Methot, Jr., R.D. 2011. User manual for stock synthesis. Model version 3.20. January 2011. NOAA Fisheries, Seattle, WA, USA, 165 p.

Piner, K.R. and Lee, H.-H. 2011a. Meta-analysis of striped marlin natural mortality. Working paper submitted to the ISC Billfish Working Group Meeting, 19-27 January 2011, Honolulu, Hawaii, USA. ISC/11/BILLWG-1/10: 09p. Available at: http://isc.ac.affrc.go.jp/pdf/BILL/ISC11BILLWG1_WP10.pdf

Piner, K.R. and Lee, H.-H. 2011b. Correction to Meta-analysis of striped marlin natural mortality. Working paper submitted to the ISC Billfish Working Group Meeting, 24 May-1 June 2011, Taipei, Taiwan. ISC/11/BILLWG-2/08: 01p. Available at: http://isc.ac.affrc.go.jp/pdf/BILL/ISC11BILLWG2_WP08.pdf

Piner, K.R., Lee, H.-H., Taylor, I.G., Katahira, L., Tagami, D., and DiNardo, G. 2011. Preliminary Striped marlin stock assessment. Working paper submitted to the ISC Billfish Working Group Meeting, 6-16 December 2011, Honolulu, Hawaii, USA. ISC/11/BILLWG-3/01: 34p. Available at: http://isc.ac.affrc.go.jp/pdf/BILL/ISC11BILLWG1_WP10.pdf

Punt, A.E. 2010. SSC Default Rebuilding Analysis: Technical specifications and User Manual. Jan. 2010.

Table A-2.1. Comparison of model structure of stock assessment model with projection model.

Model structure	Stock assessment	Projection
Dynamics calculated	Quarterly	Annually
Year	January-December	July-June
Spawning biomass calculated	April	July
Recruitment	July	July
Selectivity patterns (number of fisheries, age- or length- based assumption)	18, length	3, age
Age-based natural mortality changes	January 1st	July 1st

Table A-2.2. Age-specific model parameters used in the projection.

Age	Fecundity -at-age (season 3)	Natural mortality -at-age	Fishery 1 (young domed-shape)		Fishery 2 (domed-shape)		Fishery 3 (asymptotic-shape)	
			Weight -at-age	Selectivity -at-age	Weight -at-age	Selectivity -at-age	Weight -at-age	Selectivity -at-age
0	0.00	0.505	18.14	0.08	22.92	0.00	3.51	0.00
1	1.16	0.450	30.13	0.54	33.95	0.31	35.40	0.14
2	5.52	0.415	40.76	0.86	41.90	0.73	46.31	0.46
3	14.63	0.39	49.97	1.00	49.28	0.99	55.56	0.72
4	27.00	0.38	57.55	0.91	56.13	1.00	64.25	0.85
5	40.15	0.38	63.67	0.72	62.25	0.90	72.43	0.92
6	52.36	0.38	68.58	0.55	67.55	0.79	79.91	0.95
7	62.9	0.38	72.52	0.43	72.02	0.70	86.50	0.97
8	71.65	0.38	75.69	0.34	75.73	0.63	92.14	0.98
9	78.76	0.38	78.22	0.28	78.76	0.58	96.86	0.99
10	84.47	0.38	80.24	0.24	81.23	0.55	100.76	0.99
11	89.01	0.38	81.86	0.22	83.22	0.52	103.94	1.00
12	92.62	0.38	83.14	0.20	84.81	0.51	106.50	1.00
13	95.47	0.38	84.15	0.19	86.09	0.49	108.55	1.00
14	97.71	0.38	85.72	0.18	88.06	0.48	110.19	1.00
15	101.165	0.38	85.72	0.17	88.06	0.47	112.77	1.00

Table A-2.3. Decision table of projected percentiles of relative spawning stock biomass in 2017 relative to 2012 (SB_{2017}/SB_{2012}) for alternative states of nature (columns) and harvest scenarios (rows). Fishing intensity ($F_{X\%}$) alternatives are based on 12% (average 2001-2003), 14% (average 2007-2009 defined as current), 17.8% (MSY level), 20%, 30%, and 100% (no fishing). Catch alternatives are based on the 80% of average catches during 2007-2009 (2,500 mt) and 80% of average catches during 2000-2003 (3,600 mt). Red blocks indicate the declining trend of SB in 2017 from 2012 where SB_{2017}/SB_{2012} is less than one.

Run	Harvest scenario	Recent recruitment ($R_{y=1994-2008}$)					Beverton-Holt spawner-recruit relation (SR)				
		5th	25th	50th	75th	95th	5th	25th	50th	75th	95th
1	$F_{2001-2003} = F_{12\%}$	0.72	0.87	0.98	1.06	1.18	0.66	0.88	1.06	1.25	1.52
2	$F_{2007-2009} = F_{14\%}$	0.85	1.03	1.14	1.23	1.36	0.83	1.09	1.29	1.51	1.82
3	$F_{MSY} = F_{17.8\%}$	1.12	1.32	1.45	1.55	1.69	1.14	1.47	1.72	1.98	2.34
4	$F_{20\%}$	1.26	1.48	1.62	1.72	1.88	1.32	1.68	1.95	2.24	2.62
5	$F_{30\%}$	1.90	2.18	2.35	2.48	2.68	2.08	2.56	2.91	3.28	3.79
6	No fishing = $F_{100\%}$	4.93	5.49	5.82	6.06	6.47	5.43	6.33	7.07	7.81	8.72
7	Catch = 2,500 mt	1.41	1.97	2.33	2.67	3.10	1.63	2.49	3.23	4.03	5.28
8	Catch = 3,600 mt	0.98	1.18	1.48	1.80	2.25	1.05	1.51	2.20	3.01	4.37

Table A-2.4. Projected trajectory of median spawning stock biomass (*SB* in mt) for alternative states of nature (columns) and harvest scenarios (rows). Fishing intensity ($F_{X\%}$) alternatives are based on 12% (average 2001-2003), 14% (average 2007-2009 defined as current), 17.8% (MSY level), 20%, 30%, and 100% (no fishing). Catch alternatives are based on the 80% of average catches during 2007-2009 (2,500 mt) and 80% of average catches during 2000-2003 (3,600 mt). Green blocks indicate the projected *SB* is greater than MSY level (SB_{MSY}=2,713 mt).

Run	Harvest scenario	Recent recruitment ($R_{y=1994-2008}$)						Beverton-Holt spawner-recruit relation (SR)					
		2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
1	$F_{2001-2003} = F_{12\%}$	1333	1320	1311	1309	1309	1306	1317	1314	1342	1362	1383	1394
2	$F_{2007-2009} = F_{14\%}$	1333	1439	1495	1510	1522	1525	1317	1431	1529	1610	1667	1703
3	$F_{MSY} = F_{17.8\%}$	1333	1615	1790	1870	1916	1929	1317	1601	1838	2024	2160	2261
4	$F_{20\%}$	1333	1692	1936	2064	2133	2162	1317	1679	1985	2238	2423	2572
5	$F_{30\%}$	1333	1942	2447	2792	3015	3135	1317	1923	2509	3033	3483	3830
6	No fishing = $F_{100\%}$	1333	2491	3890	5340	6639	7755	1317	2468	3957	5692	7524	9320
7	Catch = 2,500 mt	1640	2145	2641	3109	3499	3825	1625	2141	2787	3546	4386	5243
8	Catch = 3,600 mt	1640	1845	2023	2188	2313	2419	1625	1854	2171	2584	3056	3568

Table A-2.5. Projected trajectory of catch (mt) for alternative states of nature (columns) and harvest scenarios (rows). Fishing intensity ($F_{X\%}$) alternatives are based on 12% (average 2001-2003), 14% (average 2007-2009 defined as current), 17.8% (MSY level), 20%, 30%, and 100% (no fishing). Catch alternatives are based on the 80% of average catches during 2007-2009 (2,500 mt) and 80% of average catches during 2000-2003 (3,600 mt).

Run	Harvest scenario	Recent recruitment ($R_{y=1994-2008}$)						Beverton-Holt spawner-recruit relation (SR)					
		2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
1	$F_{2001-2003} = F_{12\%}$	4471	4403	4378	4402	4399	4376	4373	4431	4520	4586	4588	4648
2	$F_{2007-2009} = F_{14\%}$	3974	4113	4201	4240	4246	4224	3884	4154	4374	4543	4652	4745
3	$F_{MSY} = F_{17.8\%}$	3267	3649	3868	3948	3971	3962	3195	3685	4066	4374	4583	4740
4	$F_{20\%}$	2955	3412	3663	3782	3818	3819	2890	3441	3878	4232	4491	4680
5	$F_{30\%}$	2001	2559	2912	3108	3187	3220	1957	2574	3103	3533	3881	4139
6	No fishing = $F_{100\%}$	0	0	0	0	0	0	0	0	0	0	0	0
7	Catch = 2,500 mt	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
8	Catch = 3,600 mt	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600	3600

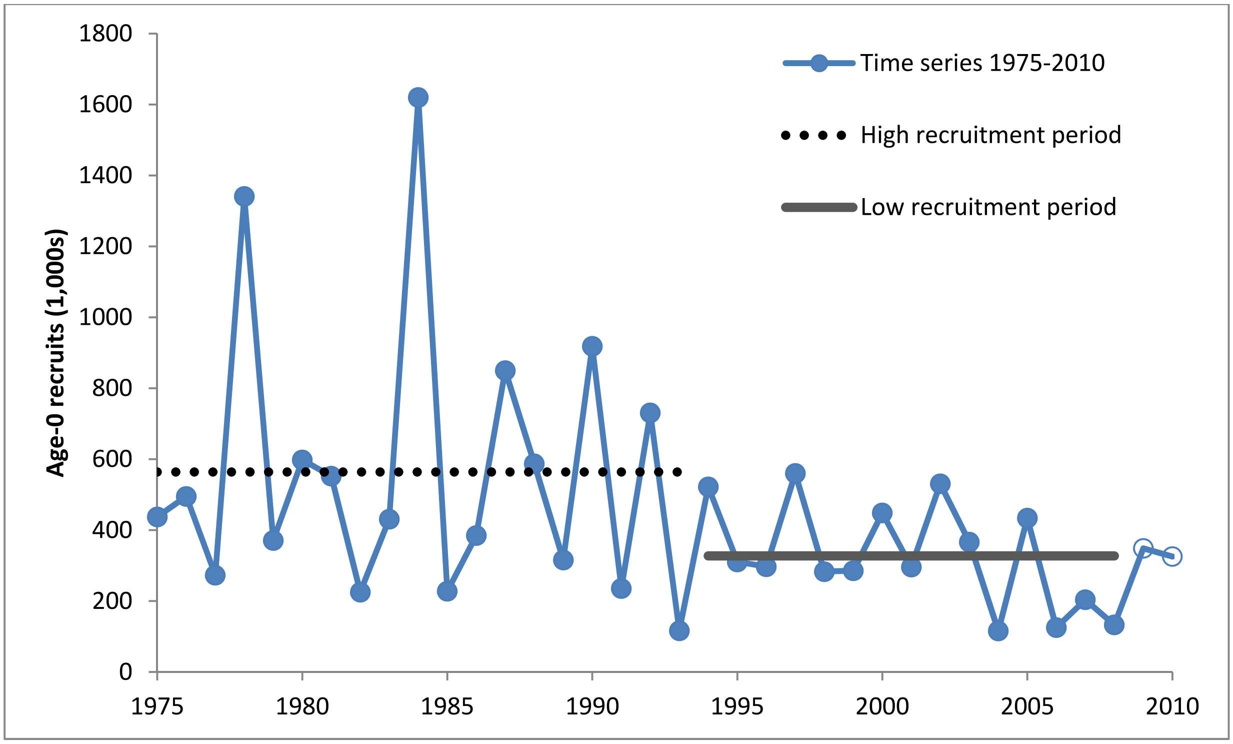


Figure A-2.1. Historical trends in recruitment of WCNPO striped marlin (age-0) estimated by the SS3 base-case model and the assumed periods of low recruitments used for future projection scenarios.

Attachment A-2.1

Input file (REBUILD.DAT) for Rebuilder version 3.12b. Exampled model was based on re-sampling recruitment for 1994-2008 using current (2007-2009) harvest rate (constant $F_{14\%}$).

#Title
SM 2011
Number of sexes
1
Age range to consider
0 15
Number of fleets
3
First year of projection (Yinit)
2010
First year the oY could have been zero
2010
Number of simulations
4000
Maximum number of years
200
Conduct projections with multiple starting values (0=No;else yes)
1
Number of parameter vectors
100
Is the maximum age a plus-group (1=Yes;2=No)
1
Generate future recruitments using historical recruitments (1) historical recruits/spawner (2) or a stock-recruitment (3)
1
Constant fishing mortality (1) or constant Catch (2)
1
Fishing mortality based on SPR (1) or F (2)
1
Pre-specify the year of recovery (or -1) to ignore
-1
Fecundity-at-age
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
0 1.16 5.52 14.63 27 40.15 52.36 62.9 71.65 78.76 84.47 89.01 92.62 95.47 97.71 101.165
Age specific information (females then males) weight / selectivity
wt and selex for "gender, fleet:" 1 1
18.138 30.132 40.759 49.969 57.554 63.668 68.579 72.523 75.687 78.221 80.244 81.855 83.135 84.151 85.716 85.716
0.082 0.539 0.864 1.000 0.908 0.724 0.552 0.425 0.339 0.282 0.245 0.220 0.203 0.191 0.182 0.171
wt and selex for "gender, fleet:" 1 2

22.916 33.952 41.905 49.277 56.128 62.255 67.551 72.019 75.726 78.764 81.230 83.218 84.812 86.085 88.063 88.063
0.000 0.311 0.730 0.987 1.000 0.902 0.790 0.699 0.631 0.582 0.548 0.523 0.505 0.492 0.482 0.468
wt and selex for "gender, fleet:" 1 3
3.508 35.398 46.314 55.562 64.246 72.434 79.908 86.496 92.137 96.864 100.761 103.935 106.497 108.552 110.191 112.774
0.000 0.143 0.464 0.718 0.855 0.921 0.955 0.972 0.983 0.989 0.993 0.995 0.997 0.998 0.999 1.000
M and current age-structure
#
0.505 0.45 0.415 0.39 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38 0.38
325.741 195.288 33.3391 17.0388 3.20836 3.7906 0.388353 0.514413 0.315897 0.0688192 0.0348344 0.00581874 0.00123893 0.000539158 7.09607E-05 4.26994E-05
Age-structure at the start of year Yinit
325.741 195.288 33.3391 17.0388 3.20836 3.7906 0.388353 0.514413 0.315897 0.0688192 0.0348344 0.00581874 0.00123893 0.000539158 7.09607E-05 4.26994E-05
Year Ynit^0
2010
recruitment and biomass
Number of historical assessment years
37
Historical data
year recruitment spawner in B0 in R project in R/S project
1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010
553.587 437.619 495.212 273.226 1341.2 371.167 598.323 552.392 225.432 431.128 1620.01 227.933 384.917 850.16 587.473 315.874 918.588 235.848 730.792 116.484 522.354 310.626 297.155 560.111 283.161 285.668 448.599 296.043 530.666 366.455 115.912 434.196 125.377 203.907 133.143 348.68 325.741
18480.35551 5261.380563 4128.805075 3686.649436 2722.718081 2043.020893 3004.158281 3538.663066 3437.225006 3474.213756 2809.672595 2887.839776 3676.045136 3726.565643 3079.070088 2937.42805 2972.531297 3040.115075 3178.396067 3079.507117 2750.813391 2158.828683 1437.121074 1204.071824 1146.902924 1134.50934 960.7501858 985.0652582 1169.504248 1418.171721 1886.872212 2064.654692 2037.92472 1870.837326 1579.37126 1088.321873 983.0446912
1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Number of years with pre-specified catches

catches for years with pre-specified catches

Number of future recruitments to override
0

```
# Process for overiding (-1 for average otherwise index in data list)
# Which probability to product detailed results for (1=0.5; 2=0.6; etc.)
8
# Steepness sigma-R, and auto-correlation
0.87 0.62 0
# Target SPR rate (FMSY Proxy)
0.178
# Discount rate (for cumulative catch)
0.1
# Truncate the series when 0.4B0 is reached (1=Yes)
0
# Set F to FMSY once 0.4B0 is reached (1=Yes)
0
# Maximum possible F for projection (-1 to set to FMSY)
-1
# Definition of recovery (1=now only;2=now or before)
1
# Projection type (1, 2, 3, 4, 5, 11 or 12)
11
"# Definition of the ""40-10"" rule"
.01 .02
# Calculate coefficients of variation (1=Yes)
0
# Number of replicates to use
10
# Random number seed
-99004
# File with multiple parameter vectors
Marlin.dat
# User-specific projection (1=Yes); Output replaced (1->9)
1 8
# Catches and Fs (Year; 1/2 (F or C); value); Final row is -1
2010 1 1.0718
2011 1 1.0718
2012 3 0.14
2013 3 0.14
2014 3 0.14
-1 -1 -1
# Fixed catch project (1=Yes); Output replaced (1->9); Approach (-1=Read in else 1-9)
0 2 -1
# Split of Fs
2010 0.13 0.48 0.39
2011 0.13 0.48 0.39
2012 0.13 0.48 0.39
-1 -1 -1 -1
# Five pre-specified inputs
```

.12 .14 .2 .25 .3
Years for which a probability of recovery is needed
2013 2014 2015 2016 2017 2018 2019 2020
Time varying weight-at-age (1=Yes;0=No)
0
File with time series of weight-at-age data
none
Use bisection (0) or linear interpolation (1)
0
Target Depletion
0.147
CV of implementation error
0