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STOCK ASSESSMENT OF BLUE MARLIN IN THE PACIFIC OCEAN IN 2013

WCPFC-SC9-2013/ SA-WP-09

BILLFISH WORKING GROUP[1]

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

Annex 10

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

17-22 July 2013
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ACKNOWLEDGEMENT

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EXECUTIVE SUMMARY

Stock Identification and Distribution: The Pacific blue marlin (*Makaira nigricans*) stock area consisted of all waters of the Pacific Ocean and all available fishery data from this area were used for the stock assessment. For the purpose of modeling observations of CPUE and size composition data, it was assumed that there was an instantaneous mixing of fish throughout the stock area on a quarterly basis.

Catches: Pacific blue marlin catches exhibited an increasing trend from the 1950's to the 1980's and then fluctuated without trend. In the 1990's the catch by Japanese fleets (Figure 1) decreased while the catch by Taiwanese, WCPFC, and some IATTC member countries increased (Figure 1). Overall, longline gear has accounted for the vast majority of Pacific blue marlin catches since the 1950's (Figure 2).

Data and Assessment: Catch and size composition data were collected from ISC countries (Japan, Taiwan, and USA), some IATTC member countries, and the WCPFC (Table 1). Standardized catch-per-unit effort data used to measure trends in relative abundance were provided by Japan, USA, and Chinese Taipei. The Pacific blue marlin stock was assessed using an age-, length-, and sex-structured assessment Stock Synthesis 3 (SS) model fit to time series of standardized CPUE and size composition data. Sex-specific growth curves and natural mortality were used because of the known sexual dimorphism of adult blue marlin. The value for steepness was $h = 0.87$. 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. The BILLWG also conducted several sensitivity analyses to evaluate the effects of changes in model parameters, including the data series used in the analyses, the natural mortality rate, the stock-recruitment steepness, the growth curve parameters, and the female age at 50% maturity.

Table 1. Reported catch (mt), population biomass (age-1 and older, mt), female spawning biomass (mt), relative female spawning biomass (SSB/SSB_{MSY}), recruitment (thousands of age-0 fish), fishing mortality (average F, ages-2 and older), relative fishing mortality (F/F_{MSY}), and spawning potential ratio of Pacific blue marlin.

Year	2005	2006	2007	2008	2009	2010	2011	Mean^1	Min^1	Max^1
Reported Catch	23,962	21,100	18,554	17,709	18,147	19,388	17,430	17,792	9,160	25,510
Population Biomass	73,812	70,945	72,102	72,453	70,694	76,089	78,663	99,151	70,694	128,228
Spawning Biomass	22,730	21,574	21,701	23,003	23,486	22,988	24,990	40,723	21,574	67,224

Relative Spawning Biomass	1.17	1.11	1.12	1.18	1.21	1.18	1.29	2.10	1.11	3.46
Recruitment (age 0)	914	889	718	689	1177	705	825	879	508	1177
Fishing Mortality	0.36	0.32	0.27	0.26	0.28	0.27	0.23	0.21	0.09	0.38
Relative Fishing Mortality	1.12	1.01	0.85	0.81	0.87	0.84	0.72	0.66	0.28	1.18
Spawning Potential Ratio	15%	18%	21%	23%	22%	22%	25%	31%	15%	56%

[1] During 1971-2011

Status of Stock: Estimates of total stock biomass show a long term decline. Population biomass (age-1 and older) averaged roughly 123,523 mt in 1971-1975, the first 5 years of the assessment time frame, but then declined by approximately 40% to an average of 78,663 mt in 2011 (Figure 3). Female spawning biomass was estimated to be 24,990 mt in 2011. Fishing mortality on the stock (average F, ages 2 and older) averaged roughly $F = 0.26$ during 2009-2011. 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 $SPR_{2009\text{-}2011} = 23\%$. The annual average in 2007–2011 was about 823×10^3 recruits, and there was no apparent long-term recruitment trend. The overall trends in spawning stock biomass and recruitment indicate a long-term decline in spawning stock biomass and suggest a fluctuating pattern without trend for recruitment (Figure 3). Kobe plots depict the stock status in relation to *MSY*-based reference points (see below) from the base case SS model (Figure 4). The Kobe plots indicate that the Pacific blue marlin spawning stock biomass decreased to the *MSY* level in the mid-2000's, and since then has increased slightly. The base case assessment model indicates that the Pacific blue marlin stock is currently not overfished and is not subject to overfishing relative to MSY-based reference points.

The population biomass of Pacific blue marlin was also estimated with three alternative stock assessment models (Figure 5). An age-structured, pooled-sexes model (AS) and an age-, length-, and sex-structured SS model were fitted to catch data from 1952 through 2011 and both models indicated that relative biomass declined by about 50% during the first 10 years of the time series. A hybrid production model indicated that relative biomass exhibited a more moderate decline throughout the 60-year period. Results from each of the alternative models were similar at the end of the assessment time series, which demonstrated the robustness of the assessment results. Overall the results of the alternative assessment models were consistent and showed that Pacific blue marlin biomass has declined but that the stock is not overfished and is not experiencing overfishing in recent years.

Projections: Deterministic stock projections were conducted in Stock Synthesis (SS) to evaluate the impact of various levels of fishing intensity on future female spawning stock biomass and yield for blue marlin in the Pacific Ocean. The future recruitment was based on the stock-recruitment curve. These calculations used all the multi-fleet, multi-season, size- and age-selectivity, and complexity in the assessment model to produce consistent results. Projections started in 2012 and continued through 2020 under 4 levels of fishing mortality ($F_{30\%}$ corresponds to the fishing mortality that produces 30% of the spawning potential ratio): (1) constant fishing mortality equal to the 2003-2005 average ($F_{2003-2005} = F_{16\%}$); (2) constant fishing mortality equal to $F_{MSY} = F_{18\%}$; (3) constant fishing mortality equal to the 2009-2011 average defined as current ($F_{23\%}$); and (4) constant fishing mortality equal to $F_{30\%}$. Results showed projected female spawning stock biomass and the catch for each of the four harvest scenarios (Table 2 and Figure 6).

Table 2. Projected values of Pacific blue marlin spawning stock biomass (mt) and catch (mt) under alternative harvest rate scenarios during 2012-2020.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Scenario 1: constant $\boldsymbol{F = F_{2003-2005}}$									
Spawning biomass	25,269	23,193	21,518	20,263	19,354	18,689	18,195	17,823	17,540
Catch	25,374	23,546	22,353	21,548	20,985	20,576	20,272	20,042	19,865
Scenario 2: constant $\boldsymbol{F = F_{MSY}}$									
Spawning biomass	25,490	24,142	22,996	22,106	21,452	20,968	20,605	20,331	20,121
Catch	23,296	22,173	21,412	20,887	20,519	20,252	20,055	19,906	19,793
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Scenario 3: constant $\boldsymbol{F = F_{2009-2011}}$									
Spawning biomass	25,924	26,112	26,169	26,177	26,188	26,200	26,212	26,221	26,229
Catch	19,235	19,154	19,106	19,078	19,066	19,061	19,060	19,061	19,062
Scenario 4: constant $\boldsymbol{F = F_{30\%}}$									
Spawning biomass	26,368	28,264	29,845	31,139	32,207	33,078	33,782	34,347	34,799
Catch	14,900	15,542	16,048	16,442	16,749	16,988	17,174	17,318	17,430

Biological Reference Points: Biological reference points were computed with the Stock Synthesis base case model (Table 3). The point estimate of maximum sustainable yield was *MSY* = 19,459 mt. The point estimate of the spawning biomass to produce *MSY* (adult female biomass) was SSB_{MSY} = 19,437 mt. The point estimate of F_{MSY}, the fishing mortality rate to produce *MSY* (average fishing mortality on ages 2 and older) was F_{MSY} = 0.32 and the corresponding equilibrium value of spawning potential ratio at *MSY* was SPR_{MSY} = 18%. The point estimate of $F_{20\%}$ was 0.29 and the corresponding estimate of $SSB_{20\%}$ was 26,324 mt.

Table 3. Estimated biological reference points derived from the Stock Synthesis base case model where "*MSY*" indicates maximum sustainable yield-based reference points, "20%" indicates reference points corresponding to a spawning potential ratio of 20%, *F* is the instantaneous annual fishing mortality rate, *SPR* is the annual spawning potential ratio, and SSB is female spawning stock biomass.

Reference point	**Estimate**
$F_{2009\text{-}2011}$ (age 2+)	0.26
$SPR_{2009\text{-}2011}$	23%
F_{MSY} (age 2+)	0.32
$F_{20\%}$ (age 2+)	0.29
SPR_{MSY}	18%
SSB_{2011}	24,990 mt
SSB_{MSY}	19,437 mt
$SSB_{20\%}$	26,324 mt
MSY	19,459 mt

Conservation Advice: Based on the results of the stock assessment the stock is not currently overfished and is not experiencing overfishing. The stock is nearly fully exploited. Stock biomass has declined since the 1970's and has been stable since the mid- 2000's with a slight recent increase. Because blue marlin is mostly caught as bycatch the direct control of catch amount is difficult. The WG recommend that the fishing mortality should not be increased from the current level to avoid overfishing.

Special Comments: The WG noted that the lack of sex specific size data and the simplified treatment of the spatial structure of Pacific blue marlin population dynamics were important sources of uncertainty.

Figure 1. Pacific blue marlin (*Makaira nigricans*) catches (mt) in the Pacific Ocean by country for Japan, Chinese-Taipei, the U.S.A., as well as other countries.

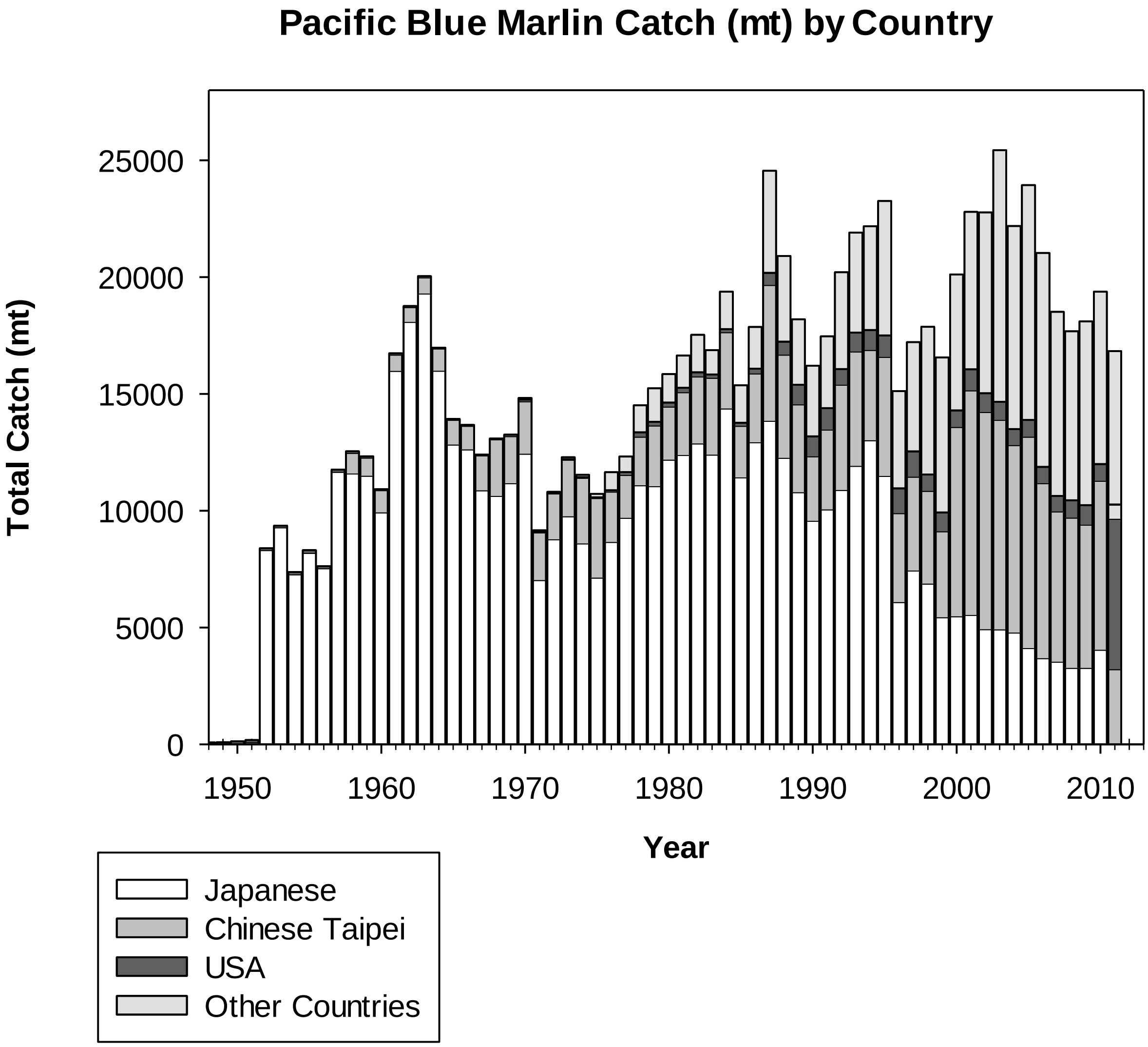


Figure 2. Blue marlin (*Makaira nigricans*) catch data (mt) by fishing gear from 1952-2011 used in the base case Stock Synthesis model.

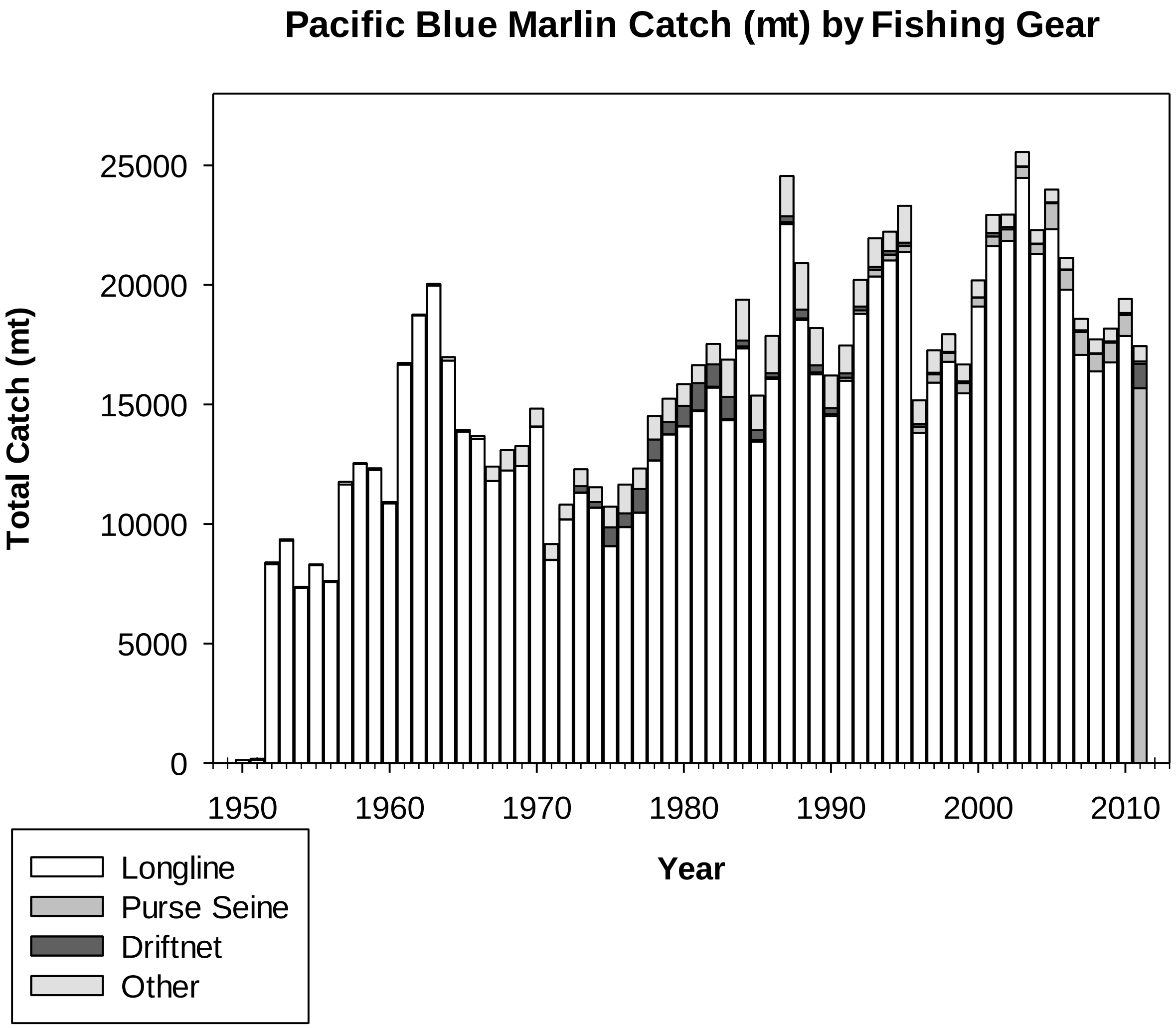


Figure 3. Estimates of female spawning stock biomass (top left panel), recruitment (top right panel), fishing mortality (bottom left panel) and fishing intensity (bottom right panel) from the Stock Synthesis base case model (point estimate, solid circle) with +/- 1.96 standard deviation shown (shaded area).

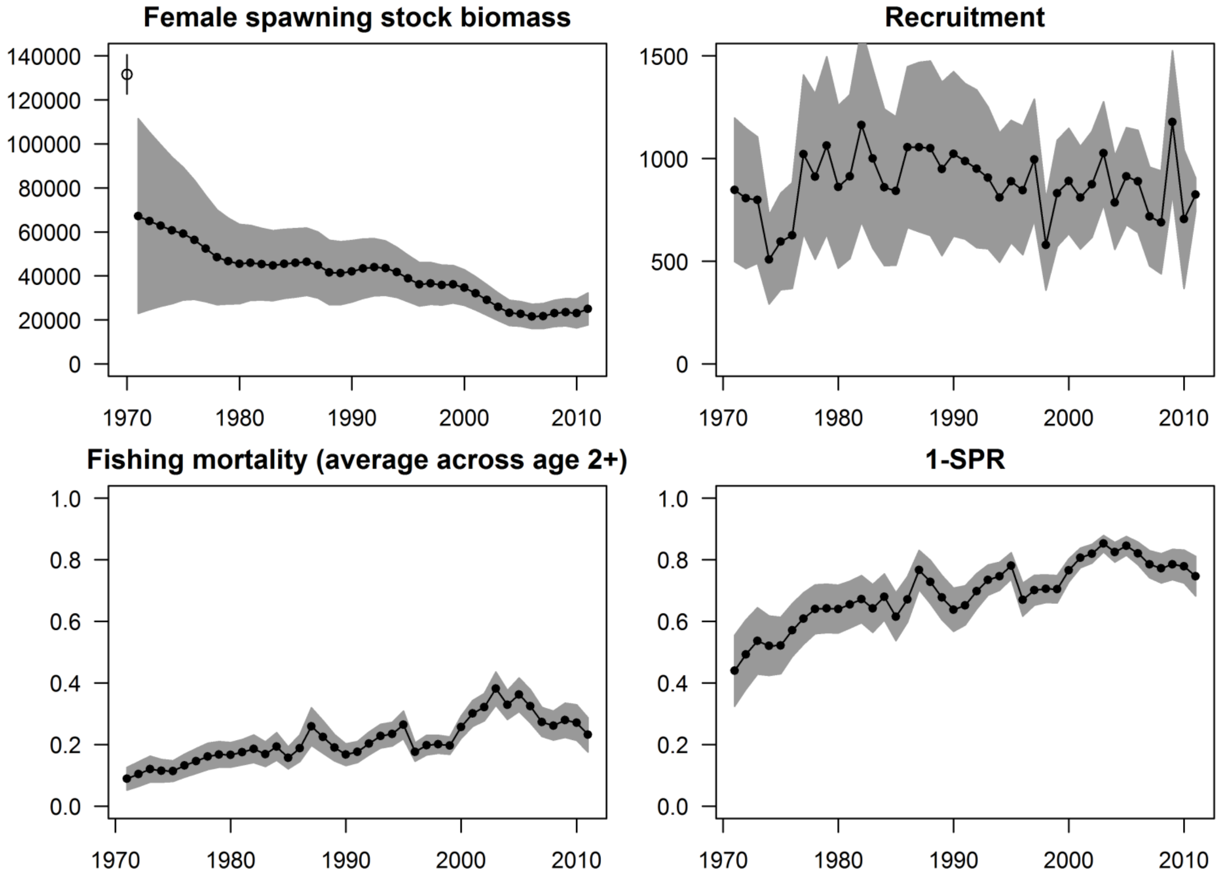


Figure 4. Kobe plots showing Pacific blue marlin stock status in relation to MSY-based reference points for the Stock Synthesis base case model with respect to relative fishing mortality (top panel) and relative SPR-based fishing intensity (bottom panel).

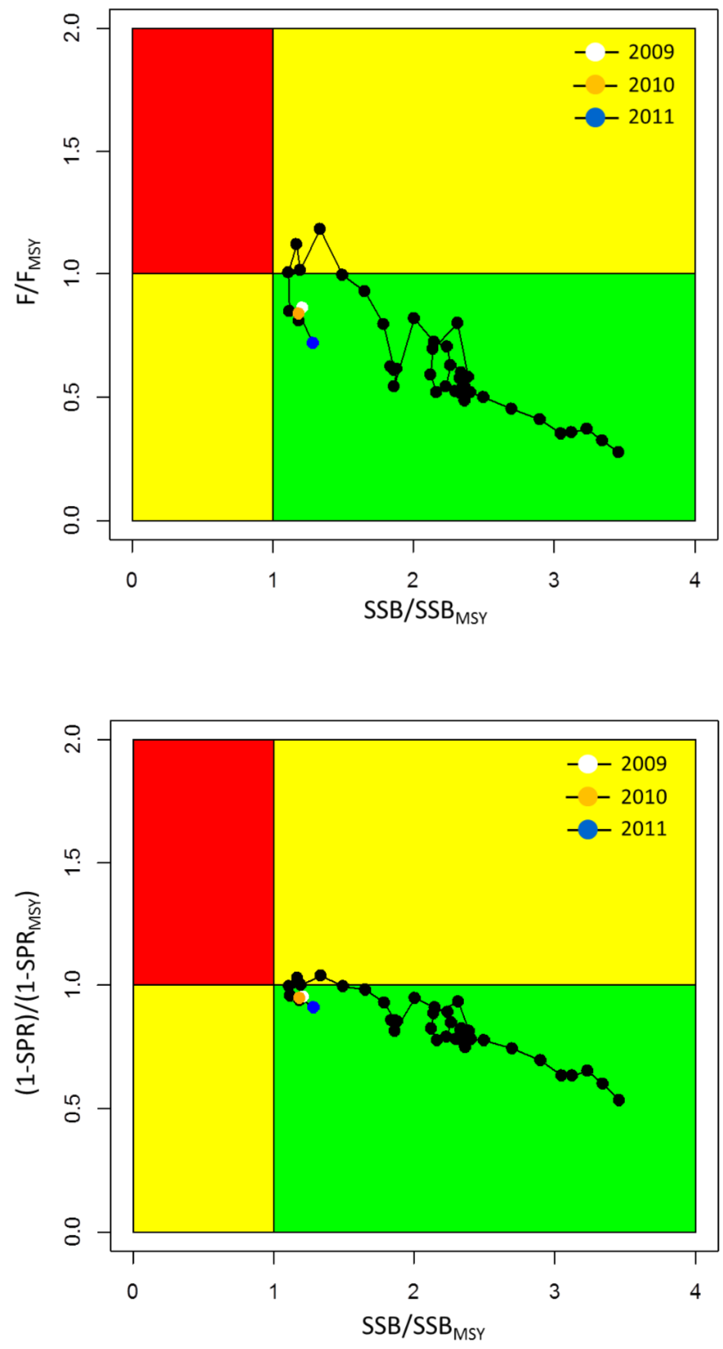


Figure 5. Comparison of estimates of relative spawning stock biomass (SSB/SSB_{MSY}) trends of Pacific blue marlin *Makaira nigricans* from the Stock Synthesis (SS) Base Case Model, the SS Model 5 using 1952-2011 catch data, the Age-Structured (AS) Model, and the Hybrid Production Model.

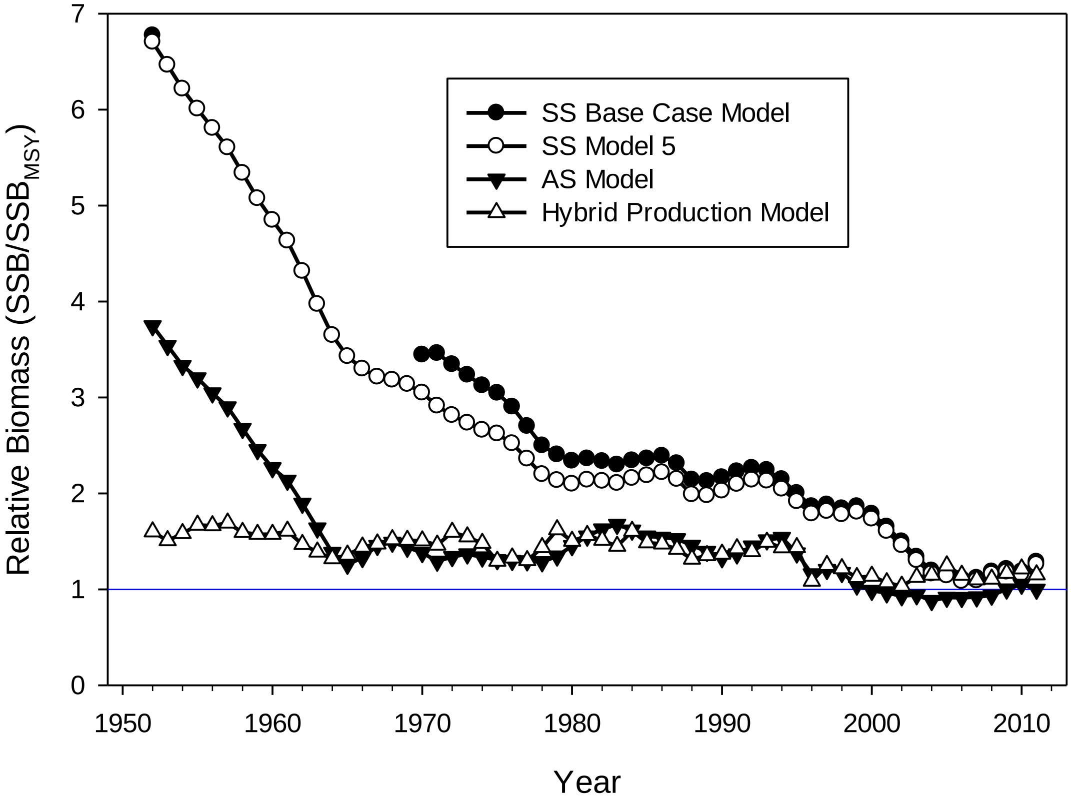
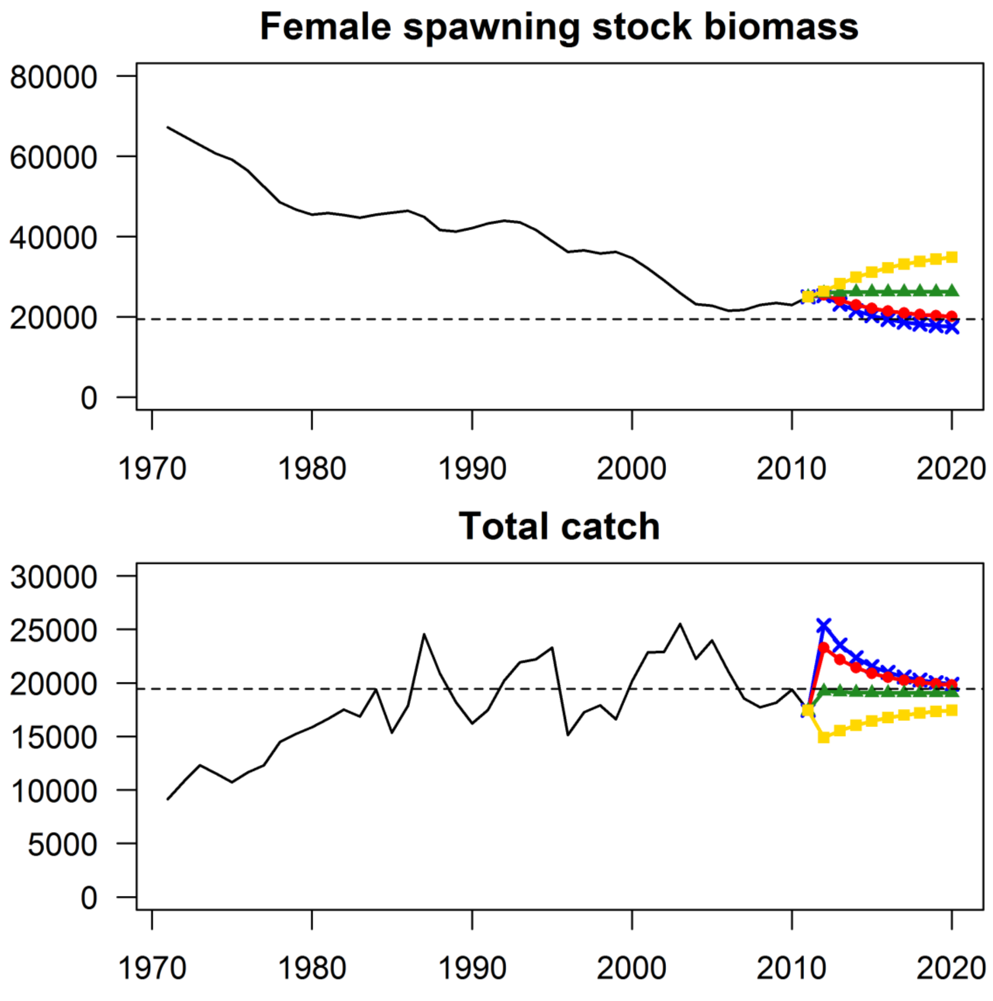


Figure 6. Historic and projected trajectories of female spawning biomass (SSB) and total catch from the Pacific blue marlin base case model. The solid black line shows the female spawning biomass estimates (top panel) and the catch biomass (bottom panel), and the projected estimates after 2012 indicate the prediction if fishing intensity ($F_{X\%}$) continue at (1) an average fishing intensity during 2003-2005 ($F_{2003-2005} = F_{16\%}$) indicated by blue line with cross symbols, (2) fishing intensity at *MSY* (F_{MSY} =$F_{18\%}$) indicated by red line with circles, (3) fishing intensity during 2009-2011 ($F_{2009-2011} = F_{23\%}$) indicated by green line with triangles, and (4) fishing intensity at $F_{30\%}$ indicated by yellow line with squares. The dashed horizontal lines show the associated MSY levels.



1 INTRODUCTION

The Billfish Working Group (BILLWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) is tasked with conducting regular stock assessments of billfishes, including swordfish and marlins, to estimate population parameters, summarize stock status, and develop scientific advice on conservation needs for fisheries managers. In order to assess population status, the BILLWG relies greatly on coordination and collaboration with multi-national and multi-regional fisheries management organizations (RFMOs).

The first international billfish assessment was conducted in 1977 at the billfish stock assessment workshop using limited biological information and fishery data (NMFS 1978); few and infrequent assessments had been conducted on billfish since then. The ISC Marlin Working Group was established in 2002 and merged with ISC Swordfish Working Group to form the ISC Billfish Working Group in 2007. The BILLWG currently consists of members from coastal states and fishing entities of the region (China, Japan, Korea, Mexico, Taiwan, USA) and participants from the Inter-American Tropical Tuna Commission (IATTC) and the Secretariat of the Pacific Community (SPC).

Previous assessments of blue marlin (*Makaira nigricans*) in the Pacific used two modeling approaches applied to the same data (1955-1997) and found that the stock was fully exploited but not overfished and overfishing was not occurring (Hinton 2001; Kleiber *et al.* 2002; 2003). During the latter years of this period, the fishing mortality was less than that which would provide harvest at the level of maximum sustained yield (F_{MSY}) and the spawning-stock biomass was greater than that which would produce harvest at maximum sustained yield (SSB_{MSY}). These assessments noted there was uncertainty surrounding the life history and biology of blue marlin, including sex-specific growth and natural mortality (M) rates; uncertainty about the quality and completeness of available data; and uncertainty about the structure of the assessment models.

In the years since those assessments were completed, there have been considerable advances in knowledge of blue marlin biology, including improved understanding of the growth of juveniles (Shimose 2008, unpublished PhD dissertation), sex-specific growth rates of adults (Chang *et al.* 2013), length at 50 percent maturity (Sun *et al.* 2009), and age- and sex-specific estimates of natural mortality rates (Lee and Chang 2013). Data were reviewed for completeness and to correct for species misidentified problems in the reported catch of blue marlin. The data were then recompiled for 1971-2011 for the high seas longline fisheries of Japan, Korea, and Taiwan which principally target tuna but also take the majority of the harvest of blue marlin in the Pacific, and for other fisheries, such as smaller-scale coastal longline, purse seine, and driftnet fisheries, in which blue marlin occasionally have been observed in the catch.

This report presents the results of the current assessment of blue marlin using new life history information and updated data using a sex-specific, size-based, age-structured, integrated (fitted to many different types of data) statistical stock assessment model. The stock assessment was conducted during May 20-28, 2013 in Shimizu, Japan (BILLWG 2013b) and the stock projections were developed during July 14-15, 2013 at Busan, Korea. The objectives of this assessment are to (1) understand the dynamics of Pacific blue marlin by estimating population parameters such as time series of recruitment, biomass and fishing mortality, (2) determine stock status by summarizing results relative to MSY-based limit reference points, and (3) formulate scientific information on conservation needs for fisheries managers based on projections using constant fishing mortality scenarios.

The results, conclusions, and conservation information recommended by the BILLWG are subject to approval by the ISC, after which they will be submitted to the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC) for review and management action. The relationships between the two Pacific regional fisheries management organizations and the ISC differ. A Memorandum of Cooperation (MOU) between the ISC and IATTC provides a mechanism for data exchange between the two organizations and allows IATTC scientific staff to participate as members on ISC working groups. In contrast, an MOU with the WCPFC specifically provides for the Northern Committee (NC) to make requests to the ISC and its working groups for scientific information and advice on highly migratory fish stocks in the North Pacific Ocean. The assessment documented in this report was approved by the ISC at the 13th Plenary Session in Busan, Korea, 17-22 July 2013 (ISC 2013).

2 BACKGROUND

2.1 Biology

2.1.1 Stock structure

Blue marlin (*Makaira nigricans*) is a cosmopolitan pecies found primarily in tropical and sub-tropical epipelagic waters of the Pacific, Indian, and Atlantic Oceans. Previous recognition by Nakamura (1985) of Indo-Pacific blue marlin as a separate species based on differences in lateral line patterns compared to Atlantic individuals is not supported by genetic differences at the species level (Graves and McDowell 1995; Collette *et al.* 2006), although inter-ocean population differences between Indo-Pacific and Atlantic samples were detected through the presence of distinct mtDNA lineages (Graves and McDowell 2003). In the Atlantic, a recent study that compared sequences of the mtDNA control region from individuals sampled across four major tropical regions found no evidence of more than one stock (McDowell *et al.* 2007). The last DNA-based stock structure study of Pacific blue marlin was published a decade ago by Graves and McDowell (2003). No evidence of population structuring was detected, so the current working hypothesis is that blue marlin consists of a single stock within the Pacific Ocean.

2.1.2 Reproduction

The reproductive dynamics of Pacific blue marlin are known directly from studies that sampled gonads from landings, and indirectly from spawning condition females captured at sea and larvae collected by surface plankton sampling.

Stained histological thin sections of preserved gonad material provide the most accurate means to estimate sex-specific length at median (50%) reproductive maturity ($L_{50\%}$). Two recent studies conducted in the western North Pacific by Sun *et al.* (2009) and Shimose *et al.* (2009) report female $L_{50\%}$ estimates of 179.76 ± 1.01 cm EFL (mean + standard error; posterior eye to fork length) for the Taiwan offshore longline fishery and 234 ± 24 cm LJFL (lower jaw to fork length) for the bait-trolling fishery off Yonaguni Island (Okinawa Prefecture), respectively. The latter estimate by Shimose *et al.* (2009) of female $L_{50\%}$ is equivalent to 178.80 cm EFL. The estimate of male $L_{50\%}$ at 130 ± 1 cm EFL by Sun *et al.* (2009) provides the only male $L_{50\%}$ estimate for the Pacific. This latter male $L_{50\%}$ estimate is uncertain due to limited access to a size range of males that fully included the transition between immature and newly matured. No other sex-specific $L_{50\%}$ estimates are available from the Pacific Ocean.

Reproductive development of blue marlin ovaries is indeterminate and oocytes develop asynchronously throughout the spawning season. For fecundity estimation, this necessitates the determination of batch fecundity based on estimating the number of released ripe oocytes per spawning. Batch fecundity estimates of individual spawning females range from 2.11 to 13.50 million eggs over a size range of 174-242 cm EFL in Taiwan waters (Sun *et al.* 2009). In waters off Yonaguni Island (Okinawa Prefecture), batch fecundity estimates are 1.89 to 16.54 million eggs over a size range of 204-246 cm LJFL (equivalent to 180-219 cm EFL). No other batch fecundity estimates are available for the Pacific Ocean. Based on only the Sun *et al.* (2009) study, the relationship between batch fecundity (BF) and length (EFL) is defined as:

$$\mathrm{BF} = 3.29 \times 10^{-12}\mathrm{EFL}^{5.31}$$

In the western North Pacific, the spawning season has been estimated based on histological studies, the gonadal-somatic index (GSI), and larval plankton collections. Based on histological evidence and the female GSI, spawning around Taiwan and Yonaguni Island waters corresponds with the period May-September (Shimose *et al.* 2009; Sun *et al.* 2009). Based on larval captures, spawning in the western North Pacific occurs during the 2nd, 3rd, and 4th quarters of the year, while larvae are rarely collected during the 1st quarter (Nishikawa *et al.* 1985).

In the central North Pacific, larval captures predominantly occur during July-August off the Kona coast of Hawaii Island with a few captures recorded as early as May or as late as September. Peak larval captures off the Kona coast are associated with sea surface salinities of 34.4-34.5 psu and sea surface temperatures of 26.2-28.0° C (Humphreys, unpublished data). The temporal-spatial plots provided by Nishikawa *et al.* (1985) indicate larval captures in the western and central South Pacific occurs primarily with the 4th quarter. In the eastern North and South Pacific, no larval captures east of 129° west longitude have been reported. Based on the criteria that females with GSI $\geq$ 3.1 are mature; however, potential spawning grounds may extend as far east as 110° west longitude along the eastern Pacific equatorial region and eastern South Pacific region during the 2nd, 3rd and 4th quarters, respectively (Nakano and Bayliff 1992).

2.1.3 Growth

Efforts to determine age and growth for billfish species are notoriously difficult to research because of their difficulty to sample, the minute size of their otoliths, reliance upon other hardparts for age determination, the rarity of smaller size classes in fishery catches, and reliance on longline and other distant water fisheries for obtaining samples. Age determinations for all billfishes, including blue marlin, have primarily relied on the interpretation and enumeration of growth marks within hardparts, specifically fin spines and sagittal otoliths. Fin spine preparations require cross-sectioning just posterior of the condyle to reveal internal annual growth marks while otoliths are typically transversely sectioned to reveal internal daily growth increments (DGIs). Annual growth marks within spine sections are particularly difficult to count due to the typically indistinct nature of these growth marks and the occurrence of vague partial marks. Otolith sections provide distinct DGIs out to about age-2; thereafter the DGIs become indistinct. Tag-recapture information is typically very limited as recapture rates are <1%. Because of these limitations, current length-at-age growth curves are most accurate during the rapid early portion of growth.

The rapid early growth phase of blue marlin, which is linear and among the fastest growth rates recorded for teleosts, has been determined based on otolith DGI counts. Length-at-age 1 (365 days) determination for the western Atlantic (Prince *et al.* 1991) and western Pacific (Shimose 2008, unpublished PhD dissertation) blue marlin is 174 cm and 170 cm LJFL, respectively (equivalent to 150 cm and 146 cm EFL, respectively). Prince *et al.* (1991) reported that small differences in growth rates between the sexes began to appear at 110-120 cm LJFL (equivalent to 92-101 cm EFL). The Shimose (2008) age & growth study off Yonaguni Island is the only available Pacific study that includes both DGI ages of young fish and annual mark enumeration of fin (dorsal) spine sections. Shimose (2008) was able to corroborate recognition of the 1st annulus within fin spine sections based on complementary otolith-based ages. This is an important consideration as many growth marks are typically present in the early portion of spine sections making accurate recognition of the 1st annulus difficult.

Longevity estimates remain tentative and unvalidated. An additional consideration of any growth study is to account for the high degree of sexual dimorphism exhibited by this species. This size dimorphism necessitates the development of sex-specific length-at-age growth curves as the maximum body weights reported for males (~140 kg) is far exceeded by the maximum (~700 kg) reported weight of females (Rivas 1975).

The others hardpart-based age studies of blue marlin used spine sections and were also conducted in the western Pacific (see Table 3 and Figs. 1-2 in Thomas *et al.* 2013; Table 1 in Chang *et al.* 2013). The age and growth study of Chen (2001; unpublished Master's thesis) provided sex-specific length-at-age von Bertalanffy growth equations (VBGE). The age and growth study of Hill (1986) used both sectioned vertebra and spines to estimate age but refrained from fitting a VBGE to the length-at-age data. Unfortunately, these studies did not have access to age 0-1 year individuals and therefore could not corroborate the determination of the first true annulus. Chang *et al.* (2013) recognized the inherent variability in the western North Pacific length-at-age growth studies and applied a Bayesian hierarchical meta-analysis approach to improve the model fit to the size-at-age data.

2.1.4 Movement

The Kona coast off Hawaii Island was the site of several early studies that attempted to track local-scale movements using acoustic transmitter tags. This region was the study site because blue marlin are seasonally abundant and close inshore there. Results indicated that blue marlin prefer warm water, typically within the mixed layer, and rarely descended below the top of the thermocline (Holland *et al.* 1990; Block *et al.* 1992). The observation that tagged fish typically moved away from the Kona coast was interpreted as an indication that blue marlin are probably not resident but rather that Hawaii lies along the path of a larger scale migration route that periodically brings them into these waters (Block *et al.* 1992).

Tag and recovery efforts for blue marlin within the Pacific have been concentrated in the areas of southern California and Hawaii. Summary results of conventional tag-recapture data from the Pacific NMFS Cooperative Billfish Tagging Program since the 1960's indicate that most re-captures are takedn in the general vicinity of their original tag-release location (Sippel *et al.* 2013). Several spectacular long-range movements within the Pacific have been documented but these are the exceptions. It remains unknown whether the extremely low recapture rate (0.6%) of tagged blue marlin is providing a biased view of the extent of movement in the Pacific.

Shimose *et al.* (2012) suggested that the seasonal north-south movement of blue marlin in the western North Pacific could be related to water temperatures, feeding opportunities, and reproductive cycles. One factor that is not understood is the possible influence of sexual dimorphism on long-distance movements.

2.2 Fisheries

Blue marlin is one of the most important bycatch species in the high seas fisheries of the Pacific Ocean (Molony 2005). A bycatch species is defined one with minor economic value or which constitutes a small proportion of the catch. The high seas fisheries taking blue marlin include primarily pelagic longline fisheries targeting tunas, as well as driftnet, harpoon, and purse seine fisheries (Bailey *et al.* 1996; Sakagawa 1989; Ueyanagi *et al.* 1989). Blue marlin are also taken in recreational fisheries and other small, specialized fisheries in various locales around the Pacific basin (for example: Hawaii recreational troll; de Sylva 1974; Dalzell and Boggs 2003).

During the 1950s and 1960s, Japanese distant-water and offshore longline fisheries accounted for more than 90% of the annual blue marlin harvests. These fisheries operated near Japan (20−40°N in the Eastern Hemisphere) in the 1950s. In the following decade, however, these fleets rapidly expanded their areas of operations throughout a broad expanse of the Pacific Ocean (Figure 2 and 5 in Kimoto and Yokawa 2012). During the expansion of the Japanese distant-water longline fisheries for tunas, blue marlin catches peaked during the mid 1960s, but then decreased rapidly thereafter. The decrease was not obviously related to operational practices because the shallow gear configuration typically used by the Japanese distant-water longline fishery remained relatively unchanged during this expansion period (Hinton and Nakano 1996). Small catches of blue marlin (8.2% of the total harvest) were also taken by Taiwanese offshore longliners during the 1960s.

It should be noted that some concerns were raised with regard to the Japanese longline fisheries data before 1970. First of all, abundance generated from spatially heterogeneous fishing effort due to the fishery eastward expansion of the fleets may not be representative the population in the Pacific. Second, blue and black marlin *Istiompax indica* catches may have been misidentified in the longline logbook data and fishery yearbooks catch data and reported as a single total during those years (Kimoto and Yokawa 2012; Kimoto and Yokawa 2013).

During the 1970s, the average annual reported catch of blue marlin in the Pacific Ocean was about 12,302 tons, of which 68% was taken by the Japanese distant-water and offshore longline fleets and about 20% was taken by the Taiwanese longline fleets. Longline effort for Japanese distant-water and offshore fleets became concentrated in tropical waters north and south of the equator in the 1970s (Figure 2 and 4 in Kimoto and Yokawa 2012). This could be the result of the development of a deep-set longline gear configuration to target bigeye tunas and several advanced technologies (e.g., new gear material, radar, radio navigation system, super-cold freezers, plotters and echo sounders), which may be more effective for catching tropical tunas and blue marlin (Sakagawa 1989; Ward and Hindmarsh 2007; Figure 5 in Kimoto and Yokawa 2012). In 1972, a large-mesh driftnet fishery was introduced into the high seas of the Western and Central North Pacific Ocean to target albacore *Thunnus alalunga*, skipjack tuna *Katsuwonus pelamis*, striped marlin *Kajikia audax*, and swordfish *Xiphias gladius*; about 4% of the blue marlin catch was also taken by the Japanese driftnet fishery in the 1970s (Uosaki 1998). Furthermore, catches of blue marlin by the Japanese coastal longline fleet, as well as catches by Korea and Hawaii longline fleets have also been observed since the mid-1970s.

Total blue marlin catches in the Pacific Ocean increased rapidly in the 1980s, reaching about 19,369 tons by 1984 and 24,547 tons by 1987. The total harvest of blue marlin during the decade was divided among the longline fisheries (93.4%), driftnet fishery (3.2%), and other fisheries (3.4%). The deep-set longlines were the predominant type of Japanese distant-water operations throughout the equatorial Pacific Ocean (Miyabe and Bayliff 1987). The catch of blue marlin by Taiwanese offshore longline fleets increased gradually beginning in 1980, attaining an average of about 3,026 tons for the decade. Catches were also taken by Japanese coastal longline fisheries in the 1980s, averaged 3,098 tons per year.

During the 1990s, blue marlins were harvested by longlining (94.7%), drift-netting (0.7%), purse seines (1.3%) and other fisheries (3.3%). There was a steep decline in the driftnet catches during the early-1990s to a low level due to the global moratorium on all high sea's large-scale driftnet fishing in 1992. Since then, catch from the small-scale drift net fisheries are from coastal waters of the Exclusive Economic Zones (EEZ) of each country. Total blue marlin catches, however, increased from 16,200 to 23,281 tons between 1990 and 1995, but then declined in 1996-1999, which reflected Pacific-wide decreases of effort in Japanese distant-water and offshore longliners (Figure 4 in Kimoto and Yokawa 2012). In contrast to the Japanese trend, the average catch of the Taiwanese offshore longliners was relatively stable throughout the 1990s around 3,673 tons per year. Compared with the 1980s, the Japanese coastal longline catch nearly doubled in 1993, when it reached its maximum (2,037 tons). This increase could be due to the installation of more powerful engine and implementing reel system and monofilament nylon for main line. During the 1990s, Japanese coastal longline catches varied between 1,000 and 1,800 tons per year. It should be noted a small amount of blue marlin catches was also recorded by Hawaii longline, troll and handline fisheries since the early 1990s (Boggs and Ito 1993; Walsh *et al.* 2005). Furthermore, there has also been an increasing pattern in the catches from other longline fisheries (i.e., Korea, China, Indonesia, French Polynesia etc.) since 1990, which contributed about 24% of the total catch for the decade.

From 2000-2009, 94.6% of the blue marlin was taken by longliners and an increased amount of blue marlin catch (3%) was taken by the purse seine fishery. After the decrease in effort by the Japanese distant-water longline fishery during 1990s, a large fraction of the blue marlin catch has been taken by the Taiwanese longline fleets (37.2%) and other longline fisheries (35.3% for Korea, China, Indonesia, French Polynesia, etc.) in the Pacific Ocean. The blue marlin catches reached the highest reported catch in 1993 where the reported catches totaled about 25,509 tons. Afterwards, the catch decreased significantly to around 18,000 tons and maintained at that level in 2010−2011.

3 DATA

Three types of data were used in this assessment: fishery-specific catches, length and weight measurements, and abundance indices derived from logbooks or obervers data. These data were compiled for 1971-2011. Data sources and temporal coverage of the datasets are summarized in Figure 3.1. Details of these data are presented below.

3.1 Spatial and temporal stratification

The entire Pacific Ocean was used for the assessment. It was assumed that there was instantaneous mixing of fish throughout the area at each quarterly time-step in the model. The assessment started in 1971. Although Japanese longline fisheries have catch data time series extending back to at least 1952, many of these records were obtained before the eastward expansion of fishing effort throughout the ocean (see Section 2.2). Abundance estimated from spatially heterogeneous fishing effort may not represent of the well-mixed population in the Pacific. Catch and size composition data were compiled by calendar quarter from 1971-2011.

3.2 Definition of fisheries

Sixteen fisheries were defined on the basis of country, gear type, and reported unit of catch (Table 3.1). These fisheries were considered to be relatively homogeneous, with greater differences in selectivity and catchability among fisheries than temporal changes in the parameters within fisheries. In the case of the Japanese distant-water-longline fishery, two fisheries were defined because of significant differences in data reporting and compilation before and after 1994 (Kanaiwa *et al.* 2013).

3.3 Catch and effort data

Estimates of total catches in each fishery by calendar quarter for 1971-2011 were compiled for fisheries F1, F2, F7, F8, and F14. Only annual catch data were available for other fisheries, so for these fisheries catch by quarter within year was estimated as one-fourth of the annual catch (Table 3.2 and Figure 3.2). Catch was reported in original units, which was weight for all but F8 and F14 which were reported in numbers of fish.

Catch and effort data were available for F1, F2, F7, and F10, and were used to develop standardized time series of catch-per-unit-effort (CPUE), which were assumed to be proportional to population size and were used as indices of relative abundance. Operational data used a spatial resolution of 5-degree longitude by 5-degree latitude (5x5 data) for Japanese longline fisheries. Monthly aggregated data were used at a spatial resolution of 5-degree longitude by 5-degree latitude (5x5 data) for Taiwan longline fisheries. Observer data with a resolution of 1-degree latitude by 1-degree longitude (1x1 data) were used for Hawaii-based longline fisheries. Details of sources of data used to derive these indices are described by the references cited in Table 3.3.

Delta lognormal generalized linear models (delta-GLM) was used to standardize CPUE for the 1975-1993 Japanese longline fishery (F1) and a habitat-based standardization model (HBS) was used to standardize CPUE for the 1994-2011 Japanese longline fishery (F2) (Kanaiwa *et al.*

2013). The former method applied to data from 1975 to 1993 considered main factors including year, quarter, location, number of hooks between float, and others depending on characteristic of the fishery. The latter method applied to data from 1994 to 2011 used three model components, fishing effort distribution (gear model), blue marlin distribution (habitat-preference model), and habitat distribution (habitat model). Generalized additive models (GAMs) were used to standardize abundance indices for Taiwan longline fisheries considering main factors including year, month, location and number of hooks between float (Sun *et al.* 2013a). A zero-inflated negative binomial GLM (ZINB) was used to obtain a standardized abundance index for the Hawaii longline fisheries considering main factors including year, quarter, set type, bait, and sea surface temperature, and interaction factors (Walsh *et al.* 2013).

Six standardized annual indices of relative abundance were developed for four fisheries (Table 3.3, Table 3.4, Figure 3.3). A season was assigned to each index based on the annual quarter in which the majority of catch is recorded. As for Japan longline fisheries, two temporally separate indices were defined as years: 1975-1993 and 1994-2011 to account for changes of operation (depth of hook), hook-per-basket (HPB) distribution, and targeted fish. Three indices (S4-S6) covering different time periods were separated from Taiwan longline fishery (F10) to account for the temporal effect of the fishing ground shift from the South Pacific Ocean to the whole Pacific Ocean since the 1980s and the shift in the target species from albacore to bigeye tuna since 2000. It is noted that very low annual catches were observed before 1978.

Visual inspection of all indices grouped by fishery type revealed conflicting trends among longline indices during the 1970s-1990s. The JPNEarlyLL index (S1) increased during 1975-1993, whereas TWNLL indices (S4-S5) showed a flat trend for 1971-1978 and a decline in 1979-1999. This slight decline was also observed in the of JPNLateLL index (S2). After that, a generally consistent trend among JPNLateLL index (S2) and TWNLL index (S6) were observed. However, there are conflicting tends between JPNLateLL index (S2) and HWLL index (S3) where HWLL showed a steep decline. It was noted that there was a low coverage rate in the observer dataset in 1994-1999. The coefficients of variation (CVs) of these indices estimated from GLM models were included to represent annual variability for each index.

3.4 Size frequency data

Eye fork lengths (EFL; cm) and processed weight (kg) of blue marlin for JPNLL (F1, F2, 1971-2011) and JPNDRIFT (F4) were measured to the nearest 1 or 5 cm or nearest 1 kg at the landing ports or onboard fishing depending on the sampling resolution. The processed weight data were converted to round weights and all size composition data were compiled by the National Research Institute of Far Seas Fisheries (NRIFSF), Japan (Kimoto and Yokawa 2013).

Eye fork lengths of fish taken by the HWLL fishery (F7, 1994-2011) were measured to the nearest 1 cm by observers on board fishing vessels (Walsh *et al.* 2013). Eye fork lengths for TWNLL fishery (F10, 2005-2010) were measured to the nearest 1 cm by crew members onboard fishing vessels and compiled by the Overseas Fisheries Development Council (OFDC) of Taiwan (Sun *et al.* 2012). Lengths from OthLL (F12, 1992-2011), PYFLL (F13, 1996-2011), and EPOPS (F14, 1991-2011) were measured to the nearest 2 cm.

In the stock synthesis, length- and weight-frequency data were compiled by calendar quarters and fisheries for 1971-2011. Length frequency data were available for seven fisheries, and weight frequency data for one (Figure 3.4.a-3.4.c). Since not all samples were known by sex, all samples were aggregated into frequency distributions. Length frequency data were compiled using 5-cm size bins from 80 to 320 cm for JPNEarlyLL (F1), JPNLateLL (F2), HWLL (F7), TWNLL (F10), and EPOPS (F14) (Figure 3.4.a) and using 10-cm bins from 80 to 320 cm for OthLL (F12) and PYFLL (F13) (Figure 3.4.b). To make consistent interpretation of population binning structure, 10-cm bins were complied for F12 and F13 because data were available for 2-cm bins. Weight frequency data were compiled using varying binning structure from 10 to 300 kg to account for the allometric length-weight relationship (Figure 3.4.c). The lower boundary of each bin was used to define each bin for all frequency data and each size frequency observation consisted of the actual number of blue marlin measured.

4 MODEL DESCRIPTION

The assessment was conducted using Stock Synthesis (Methot 2009; Methot and Wetzel 2013). Stock Synthesis is a sex-specific, size-based, age-structured, integrated (fitted to many different types of data) statistical stock assessment model. The initial step in the assessment was to establish the spatial distribution of the stock of blue marlin in the Pacific Ocean for which the population dynamics model was developed. This was followed by identifying available data inputs to the assessment, including indices of relative abundance, total retained catch and dead discards, and size measurements of blue marlin (see Section 3). These available inputs determined, to a great degree, the structure of the assessment model, such as whether it was possible to incorporate sex-specific parameters, and the definitions of fisheries. In addition to the data, estimates of a number of population characteristics or parameters that describe biological and fishery processes were obtained from studies of blue marlin of the Pacific Ocean or estimated from the obervations. These estimates were included in the assessment as assumed or fixed parameters (Table 4.1). Stock Synthesis was fitted to a suite of scenarios using the method of maximum likelihood. The value of the negative log-likelihood from each of the scenarios was used to evaluate and compare the results.

4.1 Stock Synthesis 3

Stock Synthesis (SS) is a stock assessment model that estimates the population dynamics of a stock through use of a variety of fishery dependent and fishery independent information. Although used primarily with groundfishesin past years, application to tunas and other migratory species in the Pacific Ocean has recently become increasingly frequent.

SS is composed of 3 subcomponents, 1) population subcomponent that recreates an estimate of the numbers/biomass at age of the population using estimates of natural mortality, growth, fecundity etc.; 2) an observational sub-component that consists of the observed (measured) quantities such as CPUE or proportion at length/age; and 3) a statistical sub-component that quantifies the fit of the observations to the recreated population using likelihoods. The model was implemented using Stock Synthesis (SS) Version 3.24f (Methot 2005; 2009; 2012; Methot and Wetzel 2013; http://nft.nefsc.noaa.gov/Stock_Synthesis_3.htm).

4.2 Biological and demographic assumptions

4.2.1 Maximum age

The maximum age bin in the model was 26 years. This bin served as the accumulator for all older ages. To avoid potential biases associated with the approximation of dynamics in the accumulator age, the maximum longevity was set at an age sufficient to result near zero (≈ 0.1 percent of a cohort) fish in this age bin.

4.2.2 Growth

Growth was rapid in both sexes. It was assumed that there is little sexual dimorphism in the first year of growth based on otolith microstructure counts (Shimose 2008, unpublished PhD dissertation). Sex-specific length-at-age relationships for ages greater than one year were based on meta-analyses of growth studies (Chang *et al.* 2013). Their hierarchical model with homogeneous variance (HBHV) for females was used in the assessment because the estimate of size-at-age one (144 cm) was very close to the estimated mean size (146 cm, CV = 7%) from Shimose (2008, unpublished PhD dissertation). Size-at-age one from their HBHV model for males was underestimated, so the HBHV model for males was refitted with the size-at-age one constrained to the fitted value for females (Figure 4.1).

In SS the relationship between eye fork length (cm) and age for the blue marlin (Figure 4.1) was parameterized as:

$$L_2 = L_\infty + (L_1 - L_\infty)e^{-K(A_2 - A_1)}$$

where L_1 and L_2 are the sizes associated with ages near the youngest A_1 and oldest A_2 ages in the data, L_∞ is the theoretical maximum length, and K is the growth coefficient. In this assessment, L_1 was 144 cm for both sexes at age 1. The L_2 values were 304.178 for females and 226 cm for males at age 26. K values were 0.107 and 0.211 for females and males, respectively. The L_∞ can be solved based on the length at age as:

$$L_\infty = L_1 + \frac{L_2 - L_1}{1 - e^{-K(A_2 - A_1)}}$$

The growth parameters K, L_1 and L_2 were fixed in the SS model. The CV for age 1 fish was assumed to be 0.14 for both sexes to account for variability in the sizes of fish observed, extra variance of disparate timing of recruitment, and regional and inter-annual variability in growth. CV on age 26 year fish were assumed to be 0.15 and 0.1 for female and male, respectively. The assumption of the larger uncertainty in the length at age of old fish was consistent with ageing study that has old fish sample (Hill 1986).

4.2.3 Weight at length

Weight-at-length relationships are used to convert between length and weight. Bivariate length-weight relationships indicated that eye-fork length (EFL) and weight (W) relationships differed between sexes (Brodziak 2013). The sex-specific length-weight relationships are:

$$W_L(\text{kg}) = 1.844 \times 10^{-5} L(\text{cm})^{2.956} \text{ for females}$$

$$W_L(\text{kg}) = 1.370 \times 10^{-5} L(\text{cm})^{2.975} \text{ for males}$$

where W_L is weight-at-length L. These weight-at-length relationships were applied as fixed parameters in the SS (Figure 4.2).

4.2.4 Sex specificity

A two-sex model was used for the assessment because of known differences in growth and growth rates, expected differences in natural mortality rates and the observed length-weight relationships. There is no data on sex of individual fish taken in the fisheries. The model did not include sex-based selectivity, and the sex-ratio at birth was fixed at 1:1. However, significant differences in the sex ratio of a cohort may be observed later in life as a result of sex-specific natural mortality rates, size-based selectivity, sexually-dimorphic growths on combination(s) thereof.

4.2.5 Natural mortality

Natural mortality (*M*) was assumed to be age- and sex-specific. Age-specific *M* estimates for Pacific blue marlin were derived from a meta-analysis of nine estimators based on empirical and life history methods to represent adult fish (Lee and Chang 2013). Males were considered fully mature at age one, and females at age four. After fish are fully mature, *M* was assumed to be a constant. There is no apparent secual dimorphism from ages, zero to one (Shimose 2008, unpublished PhD dissertation). Since there was no sexual dimorphism modeled for ages zero to one (Shimose 2008, unpublished PhD dissertation), *M* was the same for females and males over this period. A Lorenzen size-mortality relationship (Lorenzen 1996) was used to calculate the relative change of *M* between age 0 and age 1 (adult male) and rescale *M* at age 1 to represent *M* at age 0 for both female and male (Lee and Chang 2013). Female mortality is assumed to decline linearly from age 1 to fully mature age to account for size-dependent processes and cost-of-reproduction. The *M* estimators relied on a range of factors (e.g. length or age at maturity, maximum age, growth rate, asymptotic length, environmental factor) based on the same biological parameters used in this assessment. Age-specific estimates of *M* were fixed in the SS model as 0.42 year-1 for age 0, 0.37 year-1 for age 1, 0.32 year-1 for age 2, 0.27 year-1 for age 3, and 0.22 year-1 for age above 4 for female and 0.42 year-1 for age 0, 0.37 year-1 for age above 1 for male in this assessment (Figure 4.3).

4.2.6 Recruitment and reproduction

Spawning was found by Shimose *et al.* (2009) and Sun *et al.* (2009) to occur from late spring throughout summer (May-September) based on gonadal examination for females. In the SS model, spawning was assumed to occur in the beginning of second calendar quarter, which corresponds with the beginning of spawning cycle. The maturity ogive was based on Sun *et al.* (2009) but was refit using the parameterization used in the SS3 (Figure 4.4), where the size-at-50 percent-maturity was 179.76 cm and slope of the logistic function was -0.2039. Recruitment timing was assumed in the model to occur in the second quarter (April-June) on the basis of model fit in early runs, where second quarter recruitment gave greatly improved fit to fisheries 1, 2, 7, 10, 12, and 14, all of which take age 0 fish (Table 4.2).

A standard Beverton and Holt stock recruitment model was used in this assessment. The expected annual recruitment was the function of spawning biomass with steepness (h), virgin recruitment (R_0), and unfished equilibrium spawning biomass (SSB_0) corresponding to R_0 and were assumed to follow a lognormal distribution with standard deviation σ_R (Methot 2005; 2012; Methot and Wetzel 2013). Annual recruitment deviations were estimated based on the information available in the data and the central tendency that penalizes the log (recruitment) deviations for deviating from zero and assumed to sum to zero over the estimated period. Log-bias adjustment factor was used to assure that the estimated log-normally distributed recruitments are mean unbiased (Methot and Taylor 2011).

Recruitment variability (σ_R: the standard deviation of log-recruitment) was fixed and iteratively rescaled in the final model to match the expected variability at 0.32. The log of R_0 and annual recruitment deviates were estimated by the SS base-case model. The offset for the initial recruitment relative to virgin recruitment, R_1, was assumed to be negligible and fixed at 0. The choice of estimating years with information on recruitment was based on a model run with all recruitment deviations estimated (1971-2011). The CV of the recruitment estimates was plotted and it was assumed that data, especially size compositions (but other sources as well) provide information about individual year class strengths to inform recruitment magnitude when the CV is stabilized (Figure 4.5). Thus recruitment was estimated during 1971-2010 and used the SR expectations for 2011. Early data also have some information on recruitment from early cohort before 1971 and the variability of recruitment deviances often increase as the information goes down back in time (Methot and Taylor 2011). The attempt was to select the numbers of years for which young fish can be observed for the early cohort and estimate these initial recruitment deviances in the model. Five deviations were estimated prior to the start of the model. The 5-year period was chosen because early model runs showed little information on deviates more than 5 years prior to the beginning of the data because of the fast growth before they mature around age 3. Bias adjustment was used to account for lack of information of data for estimation of all recruitment deviations. This adjustment mostly affects the estimation of uncertainty not the population trajectory.

Steepness of the stock-recruitment relationship (h) was defined as the fraction of recruitment from a virgin population (R_0) when the spawning stock biomass is 20 percent of its virgin level (SSB_0). Studies indicated that h is poorly estimated due to little information in the data about this quantity (Magnusson and Hilborn 2007; Conn *et al.* 2010; Lee *et al.* 2012). Lee *et al.* (2012) has further concluded that steepness is estimable inside the stock assessment models when the model is correctly specified for relatively low productive stocks with good contrast in spawning stock biomass. Estimating h might be imprecise and biased without good contrast of data for blue marlin. Independent estimates of steepness incorporated biological and ecological characteristic of striped marlin in the western and central North Pacific Ocean (Brodziak and Mangel 2011) was reported that mean h was 0.87±0.05. Due to the fast-growing characteristic on the early life history stages for both striped marlin and blue marlin, a fixed value at 0.87 was borrowed from striped marlin in this assessment. It was noted that estimates are subject to uncertainty and further work needs to be done to evaluate the estimate.

4.2.7 Initial conditions

A model must assume something about the period prior to the start of the estimation of dynamics. Typically, two approaches are used. The first is to start the model as far back as necessary to assume the period prior to the estimation of dynamics was in an unfished or near unfished state. The other approach is to estimate (where possible) initial conditions usually assuming equilibrium catch. The equilibrium catch is the catch taken from a fish stock when it is in equilibrium assuming that removals and natural mortality are balanced by stable recruitment and growth. This equilibrium catch was then used to estimate the initial fishing mortality rates in the assessment model. Since the model started in 1971, the assumption for the first approach is not applicable for the blue marlin. Equilibrium catch taken by Japan longline early fishery, which was responsible for the majority of the historical catch, was estimated in the model. This allowed the model to start in 1971 at a depletion level that was consistent with the data. Also, the model included estimation of five recruitment deviations prior to 1971 to allow non-equilibrium age structure at the start of the model.

4.3 Fishery dynamics

Fishery dynamics describes the ways in which a given population is harvested by commercial or recreational fisheries. Changes in fishery patterns resulted from changes in target species and fishery activity (ex. locations), effects of various types of fishing gears, and environmental changes, etc. Two processes are modeled to describe the fishery dynamics, selectivity and catchability. Selectivity is used to characterize age/length-specific pattern for the fishery and catchability is used to scale vulnerable biomass.

4.3.1 Selectivity

This assessment is structured to be sex-specific, with separate growth curves and natural mortality for males and females. Because available size data were not identified to sex, the underlying assumption of selection by sex is that fish are equally vulnerable and taken by fisheries in a well-mixed ocean.

The selectivity patterns were not constrained by particular parametric structures (Methot and Wetzel 2013) and the influence of misfits of size composition was minimized in model dynamics (Francis 2011). Flexibility in the selection can be through domed shaped and time varying patterns. Selectivity pattern is fishery-specific and is assumed to be length-based for blue marlin because it affects the size distribution of the fish taken by the gear. Age-based selectivity is also invoked that allows age 0-26 to be fully selected for by JPNEarlyLL, JPNLateLL, HWLL, TWNLL, OthLL, PYFLL and EPOPS fisheries. The JPNDRIFT fishery was considered to select ages 1-26 based on the size distribution of the catch (Figure 3.4.c). In this assessment, selectivity patterns were estimated for all fisheries with length and weight composition data and those selectivity patterns were applied to the associated CPUE indices.

JPNEarlyLL was divided into two fisheries with two temporally separate indices at the point in time (1993/1994) that size composition sampling changed, because the changes in sample procedures provided the ability to account for known changes in fishing practices. In the case of PYFLL, two time blocks (time varying) of selection pattern estimation were used to explain a bimodal pattern that was expected to result from a change of fishing patterns (Figure 3.4b).

Different selectivity assumptions can have large influence on the expected size-frequency distribution and given the relative importance of size-frequency data in the model, on the total log-likelihood. Functional forms of double normal curves were used for all fisheries in the early model run (model 1 in Lee *et al.* 2013) to allow for various domed shapes, as well as for asymptotic shaped selectivity. A double normal curve is comprised of outer sides of two adjacent normal curves with separate variances for the upper and lower limbs of the distribution, and it has peaks joined by a horizontal line. A fit to this selectivity implies that a fishery selects a certain size range of fish (dome-shaped selectivity curve). The initial and final parameters of the selectivity patterns were assigned values of -999, which cause SS to ignore the first and last bins of the size frequency and allows SS to fit selectivity of small and large fish independently. The four estimated parameters describing dome-shaped selectivity (the beginning size for the plateau, the width of plateau, the ascending width, and the descending width) were estimated by the model.

A cubic spline was used for fitting to size composition data for F1 and F7, since it was not possible to obtain model solutions using the double-normal functional form due to extreme peaks in the size-composition data (Lee *et al.* 2013). The parameterization of the cubic spline function estimates a starting and ending gradient and a selectivity value at each node using a smoothing function to connect the nodes (cubic spline selectivity curve). Given its flexibility, the benefit of this function is not just to increase additional process but also reduce the potential misfit of size compositions without introducing too many highly-correlated nodes. Four nodes starting at 80 cm and ending at 320 cm with a total of five parameters were estimated for F1, and three nodes starting at 80 cm and ending at 200 cm with total of four parameters were estimated for F7. This amounted to one additional parameter in the selectivity functions for F1 and F7 when in comparison to other fisheries.

Selectivity patterns of fisheries without size composition data were mirrored to (assumed equal to) the selectivity patterns of fisheries with similar operations and areas for which a selectivity pattern was estimated. Mirrored selectivity patterns were based on expert opinions of members of the working group and were as follows:

- JPNCLL (F3) and JPNOth (F6) mirrored to JPNEarlyLL (F2);
- JPNBAIT (F5) mirrored to JPNDRIFT (F4);
- ASLL (F8) and HWOth (F9) mirrored to HWLL (F7);
- TWNOth (F11) mirrored to TWNLL (F10); and
- WCPFCPS (F15) and EPOOth (F16) mirrored to EPOPS (F14).

4.3.2 Catchability

Catchability (q) was estimated assuming that survey indices are proportional to vulnerable biomass with a scaling factor of q. It was assumed that q was constant over time for all indices.

4.4 Environmental influences

The base-case model does not explicitly model an environmental series or covariates. However, environmental impacts are indirectly included in the recreation of past dynamics for JPNLateLL index (Kanaiwa *et al.* 2013 and Section 3.3).

4.5 Observation models for the data

The fitting to three data components determine the value of the log-likelihood function. They are the total catch data, the CPUE indices, and the size-frequency data. The observed total catch data are assumed to be unbiased and relatively precise and were fitted with a lognormal error distribution with standard error (SE) equal to 0.05. The small CVs were for computational convenience to avoiding having to solve the Baranov equation iteratively in the multiple fisheries assessment. An unacceptably poor fit to catch was defined as models that when fitted did not remove greater than 99 percent of the observed total catch from any fishery.

The probability distributions for the CPUE indices were assumed to be lognormal with SE in log space, which was assumed to be the equivalent of the CV (typically SD/estimate) in natural space described in each CPUE paper. A minimum average CV for indices of 0.14 was assumed for each series following the modeling of a simple smoother on the CPUE data outside the model and then estimating the residual variance. Series with average CV < 0.14 were scaled to CV = 0.14 through the addition of a constant. Series with average CV > 0.14 were input as given.

The probability distributions for the size frequency data were assumed to be multinomial with distributions of the error variance determined by the effective sample size (*effN*). In commercial fisheries, the sample measurements of size of fish are usually not a random sample of individual fish from the entire population, rather they are a samples of clusters (trips or sets). Effective sample size is usually lower than the actual number of fish sampled, since within cluster variance is significantly lower than the variance in the population. To obtain random sample from population, approximations of the clusters were taken from an analysis of the relationship with number of trips sampled in the HWLL fleet which found around 10 fish per trip for marlin (Piner *et al.* 2013). Thus for all longline fisheries (F1, F2, F7, F10, F12, F13), sample size was assumed to be number of fish measured/10, and it was the number of fish measured for JPNDRIFT and EPOPS (F4, F14). The minimum quarterly sample size was fixed at 2.5 (i.e. 25 samples/10) and the maximum quarterly sample size was fixed at 50 to restrict the influence of size frequency on model fit to the CPUE indices. Most sample sizes were 50 for F1, F2, F4, F10, and F14. These samples were highly precise and exhibited little variability among samples within fisheries. In order to retain the relative among sample variability when fitting the models, a single iteration of the model was made. The effective sample sizes estimated in this tuning fit were then reduced by a scalar based on the regression (through the origin) of the tuning model run input sample sizes against the estimated effective sample sizes obtained from the tuning model run (MacCall 2003; Maunder 2011).

4.6 Weighting of data components

Integrated statistical stock assessment model such as stock synthesis used a variety of fishery dependent information. Data used In Pacific blue marlin assessment include CPUE indices and size-frequency data from various fleets. Because data are usually fit simultaneously and are often in conflict about the information they provide, data need to be “weighted” based on the precision or importance of the data. Two alternative approaches are used to weight the data: a) statistical or b) subjective. The statistical approach typically uses the maximum likelihood estimates of the variance or sample size to measure the fit to each data component (Deriso *et al.* 2007; Maunder 2011). Unfortunately, statistical approaches are thought to put too much weight on composition data, often due to un-modeled selection processes or variation in the selection process. This has led to subjective weighting of different data components to balance or prioritize the information from all data types (Fournier and Archibald 1982).

A recent paper by Francis (2011) argued that indices of abundance are the most important type of data and require special care to insure they are well fit in the stock assessment model. The importance of indices of abundance in population modeling is due to their being a direct measure of the relative. In contrast, composition data are at best indirect measures of population scale that require simultaneously knowing about the selection mechanisms of the fishery and the age structure of the population. Thus, they are much less informative about population scale.

In this assessment, index data were prioritized in the estimation of the dynamics. Prioritization of a data component in the structuring of a model can be achieved by increasing the emphasis on that component or by reducing the emphasis of conflicting data components. Reducing the contribution of a data component in the statistical fitting of the model can be achieved through reduced model weightings (e.g. increasing the variance or reducing the sample size used in likelihood functions) or increasing the number of parameters used to fit that data component. Increasing the number of parameters (model process) used in fitting to the data component reduces its influence, because the additional parameters give more flexibility to account for more of the residual misfit, which is often the source of unwanted influence on estimated dynamics.

Because composition data are often the cause of the problem (Francis 2011), additional parameters in the selectivity pattern process or weightings given to the composition data is often the solution. Additional selection model process can take the form of time varying selection (e.g., F13 in Section 4.3.1), more flexible selection patterns (e.g., F1 and F7 in Section 4.3.1), or by dividing the total data into more discrete fleets with separate estimated selection patterns (e.g., F1 and F2 in Section 4.3.1).

Data-weighting is inversely related to dataset uncertainty given to each data component in the negative log-likelihood function. More uncertain dataset due to small effective sample size or imprecise estimates were given less weight. The contribution of observation error to data-weighting is the variance in datasets attributable to random sampling of a population. Determining dataset-weighting from variety of data source is complicated when the dataset’s uncertainty contains unknown process and model-specification errors. However, total uncertainty in datasets could be quantified with auxiliary information and statistical theory when these datasets were fitting into a model.

4.7 CPUE indices included

A key assumption of the modeling is that the values in a CPUE series are proportional to stock abundance. Those that are should be consistent and in relative agreement. If two or more abundance indices show conflicting trends, then at least one of the indices is not representative of relative abundance. All series considered for use in the assessment had strong and weak points; therefore an objective method was used to segregate the CPUE indices into two separate data sets based on a down-weighting analyses and correlation analyses. These two separate data sets presented two different population trajectories.

In the model runs for down weighting analyses, likelihood components for indices derived from the same fishery were treated as one component with respect to inclusion or exclusion from the base model, because it was considered unlikely that a fishery would be representative in one time period but not another. Each likelihood component (excluding that for catch) was sequentially down-weighted in separate model runs. CPUE indices were determined to provide consistent information if down-weighting these indices led to loss of fit in the other indices. The results indicated that the JPNLL (S1, S2) and TWNLL (S4, S5, S6) were consistent (Table 4.3). The other index including HWLL (S3) represents the different population trajectories after 1995.

Correlation analyses among time series of CPUE indices were examined. Unlike in the down weighting analyses, indices derived from the same fishery were treated as separate components. For example, two indices from two time stratifications (1975-1993, 1994-2011) for Japan longline fisheries were analyzed. Pearson correlation coefficients (ρ) were interpreted as measuring the association among pairs of CPUE series showing similar results with down-weighting analyses (Table 4.4). There is no strong correlation ($|\rho| \geq 0.5$) among CPUE time series. For moderate correlation ($0.4 \leq |\rho| < 0.5$), there were positive correlation among JPNLateLL (S2) and TWNLL (S6) and negative correlation among HWLL (S3) and TWNLL (S5).

Based on the correlation and down-weighting analyses, JPNLL (S1, S2) and TWNLL (S4, S5, S6) were fitted and contributed to the total likelihood as one candidate model (CPUE subset 1). HWLL (S3) along with early index from JPNEarlyLL (S1) to inform early population dynamic was fitted as an alternative model (CPUE subset 2). The authors note that having a priori knowledge of the “best” representative index of abundance is preferable (e.g. fishery independent survey) but given that only the fishery dependent indices of relative abundance were available, a selection process such as that used was necessary.

4.8 Diagnostics

Model diagnostics are useful in determining when a model needs additional or alternative structure to eliminate model misspecification and conflict between components. Diagnostics used in the assessment are discussed as follows: likelihood profile of virgin recruitment, residual analysis, and retrospective analysis.

4.8.1 Likelihood profile of virgin recruitment

Likelihood profile of global scale parameter become a popular method to diagnose where conflicts in the data occur and if a low priority data component is too influential on estimates of scale in integrated models (Lee *et al.* in review). To evaluate the influence of each data component on the model’s estimate of scale, a global scaling parameter R_0 was profiled over a range of estimates in the model. The profile quantified how much loss of fit to each data component resulted from changing the population scale. Data components with a large amount of information on population scale will show significant degradation in fit as population scale was changed from the best estimate. In SS, R_0 is an ideal global scaling parameter because the unfished (virgin) level of recruitment is proportional to unfished biomass. The profile consisted of running a series of models with the $\ln(R_0)$ parameter fixed (not estimated) at a range of values above and below that estimated within the model. The range of R_0 reflected a plausible range in unfished stock.

Because SS is a statistical model that quantifies fit using maximum likelihood, negative log-likelihood (NLL) was used to evaluate degradation of model fit. For each profile run, NLL was computed for each component. After completing all profile runs, each component's degradation in fit (DNLL) was computed by subtracting the components minimum NLL (best fit) across all profile runs from the NLL of the component from each profile run. A separate DNLL was computed for each data component in the model. A DNLL= 0 indicates that data component was the most consistent with that fixed population scale. The range of DNLL within a data component and across all profile runs was the likelihood gradient for that component. The gradient represented the amount of model information on scale from that data source given the model's structure.

4.8.2 Residual analysis

Residuals analysis is the most common method to evaluate model performance, where discrepancies between observed and predicted values are examined (Cox and Snell 1968). Patterns in the residuals could be evaluated through summary statistics or directly, e.g., via plots. The variance of the residuals between the observed and predicted values should also be compared to evaluate the statistical assumptions on which the observation model is based. If the variance of the residuals differs substantially from that which is assumed, the weighting factors in the objective functions are not likely appropriate. However, lack of residual patterns is not a guarantee that there is no model misspecification because the parameters may be estimated to compensate for misspecification (Maunder and Punt 2013).

4.8.3 Retrospective analysis

Retrospective analysis is another common fishery modeling diagnostic if there is a systematic inconsistency among a series of estimates of population size based on increasing or decreasing periods of data (Cadrin and Vaughn 1997; Mohn 1999; Cadigan and Farrell 2005). Two types of retrospective patterns were defined: historical and within-model (Legault 2009). The historical retrospective analysis is conducted by examining the results of each final assessment for a number of years in a row and determining whether there was a consistent pattern of overestimating or underestimating assessment values in successive years. This type of retrospective pattern can be caused by changes in the data, type of assessment model, or assessment model assumptions. The within-model retrospective analysis uses the same data, type of assessment model, and assessment model formulation and repeatedly eliminate one year of data from the analysis while using the same method and assumptions. The within-model retrospective patterns are most useful for determining an internal inconsistency derived form the data because the only changes in the different runs are the number of years of data in the model. Since the previous assessment was conducted in 10 years ago for blue marlin, the first approach is not applicable to evaluate systematic inconsistency resulted from recent assessments. In this assessment, the retrospective analysis is refered to within-model retrospective analysis.

4.9 Convergence

Convergence to a global minimum was examined by a randomization of the initial parameter values based on sampling from a uniform distribution centered at the input parameter values of with upper and lower bounds of +/- 10% and and a randomization of the order of phases used in the optimization of likelihood components. Models were refitted to these random changes. Improved fit (relative to the base model) would confirm that the model had not converged to the global solution.

4.10 Sensitivity to alternative assumptions

Sensitivity analyses examine the effects of plausible alternative model assumptions or configurations relative to the base-case model results. The sensitivity analyses presented in this assessment document (Table 4.5) are categorized into three themes, including (1) data and (2) biology. For each sensitivity run, comparisons of spawning stock biomass and fishery intensity trajectories, fits to the data if necessary, and changes in the fitted negative log-likelihood values were completed. The attempt is to identify major source of uncertainty in the base case assessment. The authors note that many additional sensitivity runs were conducted in the development of the base case (e.g. bin definitions, initial conditions, alternative data sets etc.) that are beyond the scope of this paper to describe.

4.11 Future projections

Deterministic stock projections were conducted in Stock Synthesis (SS) to evaluate the impact of various levels of fishing intensity on future spawning stock biomass and yield (Methot and Wetzel 2013). SS calculated the absolute future recruitment based on the spawner-recruitment relationship and estimated spawning biomass and yield that would occur if fishing intensity were maintained at this rate. These calculations utilized all the multi-fleet, multi-season, size- and age-selectivity, and complexity in the estimation model, so produced results that are entirely consistent with the assessment result.

Projections started in 2012 and continued through 2020 under 4 levels of harvest rates.

- constant fishing mortality equal to the 2003-2005 average ($F_{2003-2005} = F_{16\%}$);
- constant fishing mortality equal to $F_{MSY}= F_{18\%}$;
- constant fishing mortality equal to the 2009-2011 average defined as current ($F_{23\%}$);
- constant fishing mortality equal to $F_{30\%}$.

5 RESULTS

5.1 Model convergence

There is no evidence of substantial differences in the estimate of the natural logarithm of unfished recruitment ($\ln(R_0)$) and total likelihood showing a better fit (Figure 5.1) in the randomization tests. Based on these results, it is concluded that the model is relatively stable with no evidence of lack of convergence to the global minimum.

5.2 Diagnostics

5.2.1 Likelihood profile of virgin recruitment

Results of the profile over fixed values of global scale parameter ($\ln(R_0)$) for base case model are presented in Table 5.1. Values represent the degradation in model fit (DNLL: negative log-likelihood for each component - the minimum component negative log-likelihood across profile). Value in parenthesis indicates the estimate of $\ln(R_0)$ for base case. The degradation in fit (DNLL) was summarized into three groups: (1) a significant likelihood gradient (>10 DNLL units); (2) a moderate likelihood gradient (between 5 - 10 DNLL units); and (3) a minimal likelihood gradient (<5 DNLL units).

The R_0 profile table was used to (1) identify how much information there is on scaling from that likelihood component by examining the changes in likelihood (DNLL) across different values of R_0 (columns). A value of zero indicates that the data component fit best at that fixed $\ln(R_0)$ value; and (2) identify where conflicts in the data occur by examining the changes in likelihood (DNLL) across different data sources where R_0 is estimated (rows).

No significant likelihood gradient was identified in profile analysis for the base case model. The moderate likelihood gradient for F1 was noted in the R_0 profile along with F2 and F12. All other fleets (F4, F7, F10, F13, and F14) had minimal gradients. Likelihood gradients for S1 and S2 were minimal and moderate, respectively. The degree of gradients for the most informative prioritized index (S2) was similar to that for informative size composition data (F1 and F2). In summary, the gradients of likelihood resulting from majority of size-composition data is minimum, and therefore the CPUE indices were influential in driving the model in the fitting process. Furthermore, the base case model resulted in an internally consistent model regarding scale, demonstrated by composition component DNLL <3 units and index component DNLL<2 units at the R_0 when estimated.

The aurthors noted that much of the conflict between data components was resolved and profile gradients within components were reduced by introducing more flexible selection patterns. A more flexible non-parametric selection pattern better approximated the peaked nature of the data (see Section 4.3.1), eliminating a significant portion of the misfit that was responsible for the profile gradients from the early model run (model 1 in Lee *et al.* 2013). Introducing time-varying selection for another composition data component had the same effect, albeit at the cost of twice the parameters. Resolving the internal conflicts in the model resulted in overall better model performance as judged by the retrospective analysis (Lee *et al.* in review and Section 5.2.3).

There will be situations where additional model process cannot easily be added and data weights may need to be adjusted to prioritize data. In the base case model, this was the situation for the composition from F2. Additional model run using the cubic spline for F2 improved the fit to the season 1 and season 2 data but degraded the fit to the season 3 and season 4, resulting in a stronger likelihood gradient in F2 than base case (results not shown). This means that the seasonal patterns evident in the composition data could not be improved with addition of a more flexible selection pattern. An alternative solution would be to split F2 into separate seasonal fisheries with separate selection patterns. Unfortunately, this was not an option, because the primary index (S2) was an annual estimate associated with F2 size data. Although splitting the CPUE data was outside the scope of this assessment, the location of population scale from the F2 composition data was generally consistent with the other data components, which indicated a lack of conflict over scale.

5.2.2 Residual abalysis

The performance of the base-case model was assessed by comparing input data with predictions for two data types: abundance indices and size compositions. Abundance indices provide direct information about stock trends and composition data inform about strong and weak year classes and the shape of selectivity curves (Francis 2011).

5.2.2.1 Abundance indices

The model fits to the CPUE indices by fishery are provided in Figure 5.2 and Table 5.2. The fit to the CPUE indices were summarized into two groups: (1) those in which indices contributed to the total likelihood, were influential to the dynamics with root-mean-squared-error (RMSE) < 0.3; and (2) those in which indices did not contribute to the total likelihood.

The base case model generally followed JPNEarlyLL and JPNLateLL (S1, S2), and TWNLL (S4, S5, S6) with RSME < 0.3. The fit to these tuning indices were generally within the 95 percent CI. Since the majority (>50-60 percent) of catch comes from longline fisheries for S1, S2, and S6, these indices were considered primary indices and thought to be the most reliable source of CPUE as indices of relative abundance. These three models statistically fit S1 and S2 and TWNLL (S4, S6) well with RSME < 0.2. These indices indicate a slight upward trend from 1976-1981, show no trend from 1982-1992, exhibit a moderate negative trend from 1994-1998, and show no trend thereafter. Although not included in the likelihood of the fitted models, index HWLL (S3) was included in the model to allow comparison of the fitted and observed trends. The model did not fit S3 well, indicating that this index was not consistent with the other data included in these models.

The authors also note that fits of models resulted in a smaller RMSE for S4 and S5 than inputted CV. The early model run suggest that rescale these two indices to RMSE would deteriorate the fit to S1, a principal abundance index.

5.2.2.2 Size composition

The model fits the size modes in data aggregated by fishery and season fairly well given the estimated effective sample sizes (*effN*), where mean and sum of the effective sample sizes from the model predications are presented in the Figure 5.3 and Table 5.3, respectively. Effective sample size (*effN*) is the model estimate of the statistical precision. Larger *effN* indicates a better fit. In general, average statistical fits for *effN* ≥ 30 indicate reasonably good fit to the composition information.

Pearson residual plots are presented for the model fits to each size composition data (Figure 5.4), where the open and filled circles represent positive and negative residuals, respectively. The positive or negative residuals are determined by the difference between predictions and observations. The areas of the circles are proportional to the absolute values of the residuals.

The base case model statistical fitted the observations well, especially for fisheries with the most flexible selectivity patterns and large sample sizes. For all fisheries, precision of model predictions is greater than that of observations for base case model (Table 5.3) and no substantial residual pattern when using the most flexible selectivity patterns (Figure 5.4). The greatest level of model misfit appears to be from three fisheries, F2, F7, and F13. F2 and F7 had seasonal variability in size-composition, and F13 had small sample sizes. The misfits to the size composition data for JPNLateLL (F2) occurred at particular size bins indicating extreme peak of distribution for season 1 and season 2 and overfit at the same size bins for season 4 (Figure 5.3 and 5.4). The seasonal variability in F2 and F7 may indicate spatial variability in growth, movement of cohorts, or fluctuations in the catchability and/or selectivity of the fish. The likelihood profile across R_0 for F7 and F13 did not show a strong gradient, meaning that misfit of F7 and F13 size-composition data would have little influence on model results. However, misfit for F2 indicates same level of gradient as primary index (S2) and consistent location of population scale with other data components (see Section 5.2.1).

5.2.3 Retrospective analysis

Retrospective analyses for the base case model indicated that there was a moderate retrospective pattern of overestimating spawning biomass and underestimating fishing intensity in recent years (Figure 5.5).

5.3 Model parameter estimates

5.3.1 Selectivity

The size selectivity curves from the base model are shown in Figure 5.6 and estimates are presented in Table 5.4. For most of fisheries, domed shape selectivity patterns were estimated expect for the second period of F13, which is consistent with the fact that available fishery dependent data may not always catch large size of fish. Temporal variations in the selectivity were captured by the time blocks employed for F13 suggesting the selectivity of larger sizes of fish was low in 1996-2002 and high in more recent years (2003-2011). A relatively new approach for modeling selectivity curves, using a cubic spline function over length not only greatly improved the fit to size composition for F1 and F7 but also the precision of parameter estimates describing the descending limb of selectivity curves for F2 and F12 (Lee *et al.* 2013) where selectivity was estimated as domed shape .

The base case model precisely estimated parameter of beginning size for the plateau with small CV (< 4 %) for fisheries estimated by double normal selectivity (F2, F4, F10, F12, F13, and F14); however, among these fisheries, there is large uncertainty about the parameter describing the width of plateau. Some fisheries selected smaller range of plateau suggesting a narrower domed shape (F4, F10, first period of F13, and F14) and F2 and others selected wider range of plateau suggesting either a wider domed shape (F2) or an asymptotic shape (the second period of F13). Size obervations were able to inform ascending shape for double normal selectivity for most of these fisheries with less precise estimates (CV < 20%) except for F13, where F13 had small sample sizes and fewer observations in the large size of fish. The least precise estimates of selectivity parameters were in F7, where the seasonality of size composition could casue the poor estimates for all three nodes.

The estimated selectivity patterns for most longline fisheries are decidedly domed expect for the second period of F13. Whether this result reflects gear operations (such as depth, bait, etc.) or is related to the spatial distribution of the fleet relative to the size-structure of the population is not clear. Additional work to address on a finer spatial distribution of catch by size and associated fishing effort should be considered to better understand the fisheries and improve their definition in future models. A third possibility is that this reflects a bias in the size sampling process, but this is thought to be less likely. Uncertainty in the life history parameters (growth and mortality) is also influential in the degree of dome-shaped selectivity.

5.3.2 Catchability

Catchability coefficient (q) was estimated in the model as a single value for each index (Table 5.2). Catchability was allowed to change through time by separating the time series into two fisheries based on known changes in fishing practices of the Japan distant-water longline fisheries (F1, F2). Although CPUE indices are assumed to be proportional to vulnerable biomass with a scaling factor of q, this does not imply that the proportion of biomass taken by a fishery (q* *biomass*) can be fully explained by dome-shaped selectivity. In other words, higher q means higher availability to the fishery but cannot be directly interpreted as higher population biomass, since the proportion taken is determined in part by selectivity.

5.4 Stock assessment results

Results from the base case assessment model were used to determine trends in population biomass, spawning biomass, recruitment and fishing intensity of the Pacific blue marlin stock for 1971-2011.

5.4.1 Biomass

Estimates of population biomass (age-1 and older) experienced a long-term decline during 1971-2011 (Table 5.5 and Figure 5.7). Since the assessment model has a quarterly time step, there are four estimates of total biomass for each year. For presentation purposes, population biomass estimates in the beginning of the year (season 1) are shown. Decadal averages showed roughly 115,160 t during 1971-1979, 109,448 t during 1980-1989, 101,376 t during 1990-1999, 76,576 t during 2000-2009, and 77,376 t in 2010-2011.

Female spawning biomass also exhibited a declining trend during 1971-2011 (Table 5.5 and Figure 5.7). Estimates of spawning biomass are in the beginning of spawning cycle (season 2) averaged roughly 57,665 t or 44% of unfished spawning biomass during 1971-1979, 44,692 t or 34% of unfished spawning biomass during 1980-1989, 39,822 t or 30% of unfished spawning biomass during 1990-1999, 25,753 t or 20% of unfished spawning biomass during 2000-2009, and 23,989 t or 18% of unfished spawning biomass in 2010-2011. Precision of estimates gradually improved through time with averages of CV = 27% during 1971-1979, 18% during 1980-1989, 13% during 1990-2009, and 15% in 2010-2011.

5.4.2 Recruitment

Recruitment variability (σ_R: the standard deviation of log-recruitment) was estimated at 0.32 (see Section 4.2.6 and Figure 5.8). Recruitment (age-0 fish) estimates indicated a long-term fluctuation around its mean (Table 5.5 and Figure 5.8) around 881 thousand recruits. Recruitment was low in the early of time series (1971-1976) with average of 697 thousand recruit, several strong year classes recruited to the fisheries with average of 984 thousand recruits during 1977-1990 following by several weak year classes and fewer larger recruitment events with average of 864 thousand recruits during 1991-2010. Estimates were less precise during 1971-1990 (average CV = 21%) than during 1991-2010 (average CV = 17%). Recruitment prior to 1990 appeared to be from somewhat higher spawning biomasses and corresponds to generally higher levels of recruitment. The 2011 estimate was the expectations of the spawner-recruit (SR) relation.

5.4.3 Fishing mortality

Two metrics describing fishing intensity were used in this assessment, an average fishing mortality over age 2 and older and female spawning potential ratio (*SPR*). A weighted average of fishing mortality over age 2 and older was approximated as the difference between accumulated survivors over ages without fishery in log space and accumulated survivors over ages with fishery in log space. Female spawning potential ratio (*SPR*) is the ratio of female spawning biomass per recruit given a particular fishing intensity and stock's biological characteristics divided by the spawning biomass per recruit with no fishing (Goodyear 1993). It is a measure of residual population under fishing and a comparable measure with fishing mortality is 1-*SPR*. *SPR* has a maximum value of unity and declined toward zero as fishing intensity increases. Although *SPR* may not be a straightforward measure of the actual mortality, it incorporates all aspects of multi-fleet fishing intensity and the life history of the stock with no subjectivity in the weighting of each age and fishery. Both metrics were estimated inside the Stock Synthesis assessment model to maintain the consistency of estimation.

Estimates of fishing mortality (average on ages 2 and older) and 1-*SPR* showed consistent patterns (Table 5.5 and Figure 5.9). Estimated fishing mortality and 1-*SPR* are moderately low and gradually increase from the early 1970s to the 1990s, increase in the early 2000s in response to higher catches (Figure 3.2) and the lower levels of adult biomass (Figure 5.4.1), after which they have declined to allow 23 percent of virgin spawning biomass per recruit and in the most recent years (2009-2011). Estimates for fishing mortality and 1-SPR were precise with CV ≤11% and 5%, respectively. Current fishing intensity for this assessment was defined by the BILLWG as the average of estimates from 2009 to 2011 to account for uncertainty and fluctuation of estimates.

5.5 Biological reference points

A suite of candidate F-based biological reference points (F_{MSY}, $F_{20\%}$, SPR_{MSY}) were estimated in this assessment where F is the instantaneous annual fishing mortality rate averaged across age 2 and older and SPR is the annual female spawning potential ratio (Table 5.6). The point estimate of maximum sustainable yield (± 1 standard error) was MSY = 19,459 t ± 623. The point estimate of the spawning biomass to produce MSY and 20% of spawning potential ratio were SSB_{MSY}= 19,437 t ± 653 and $SSB_{20\%}$= 26,324 t ± 909, respectively. The point estimate of F_{MSY}, the fishing mortality rate to produce MSY (average fishing mortality on ages 2 and older) and $F_{20\%}$, the fishing mortality rate to produce 20% of spawning potential ratio, were F_{MSY}= 0.32 ± 0.004 and $F_{20\%}$ = 0.29 ± 0.003, respectively. The corresponding equilibrium values of spawning potential ratio at MSY was SPR_{MSY} = 18% ± 0.0005.

5.6 Sensitivity to alternative assumptions

The BILLWG identified important sebsutuvuty runs (Table 4.5 and see Section 4.10) to examine the effects of plausible alternative model assumptions and data. For each sensitivity run, comparisons of spawning stock biomass and fishery intensity trajectories were completed.

5.6.1 Data series

5.6.1.1 Alternative stock trend

The purpose of this sensitivity run is to examine the effect of fitting to the HWLL index with a recent trend that was inconsistent with the CPUE series used in the base case model (Figure 3.3). The inclusion of the HWLL CPUE index produced a declining trend in spawning biomass and an increasing trend in fishing intensity since the early-2000s (Figure 5.10).

5.6.1.2 Excluding weight composition data for JPNDRIFT

The purpose of this sensitivity run is to examine the effect of eliminating only weight composition data (JPNDRIFT) used in the base case model. This scenario was investigated because the quality of the size composition data from this sources was considered to be questionable by some WG members (Figure 3.4.c). The results showed that the exclusion of the Japanese driftnet size composition data had a negligible effect on estimates of spawning biomass and fishing intensity (Figure 5.10).

5.6.1.3 Excluding length composition data for PYFLL

The purpose of this sensitivity run is to examine the effect of eliminating length composition data for PYFLL used in the base case model. This scenario was investigated because the quality of the size composition data from this sources was considered to be questionable by some WG members (Figure 3.4.b). The results showed that the exclusion of the French Polynesia longline size composition data had a negligible effect on estimates of spawning biomass and fishing intensity (Figure 5.10).

5.6.2 Biological assumptions

5.6.2.1 Natural mortality rate

The purpose of this sensitivity run is to examine the effect of natural mortality assumptions. Two model runs were conducted to assume higher or lower natural mortality for adult with juvenile *M* scaled as in the base case model. The high *M* scenario increased the natural mortality rates of females and males from the base case model by 0.1 year^{-1} and the low *M* scenario decreased the rates by 0.1 year^{-1} (Figure 5.11.a).

Results for the high *M* scenario indicated that there would be a higher level of spawning biomass and a lower level of fishing intensity over the time series. Similarly, the lower *M* scenario produced a lower level of spawning biomass and a higher level of fishing intensity (Figure 5.11.b). While the pattern in trends in spawning biomass and fishing intensity were relatively similar for the base case and alternative *M* models, this sensitivity analysis indicated that the base case model results were sensitive to the natural mortality rate.

5.6.2.2 Stock-recruitment steepness

The purpose of this sensitivity run is to examine the effect of steepness assumptions. Three model runs were conducted to assume higher or lower steepness values (h=0.65, 0.75, and 0.95) than the base case (h=0.87). Results indicated that lower steepness produced higher estimates of spawning biomass and lower estimates of fishing intensity (Figure 5.12). Similarly, a higher steepness produced a lower spawning biomass and higher fishing intensity. The pattern in trends in spawning biomass and fishing intensity were relatively similar for the base case and alternative *h* models. Overall, the base case model results showed lower sensitivity to steepness in comparison to natural mortality rate.

5.6.2.3 Growth curve

The purpose of this sensitivity run is to examine the effect of growth assumptions. Two model runs were conducted to assume larger or smaller size for oldest fish than the base case (L_∞= 316 cm for female and L_∞= 226 cm for male). In the high growth scenario, a 10 % increase in L_∞ for both females and males, while in the low growth scenario a 10 % decrease in L_∞ for both females and males. A corresponding Brody growth coefficient *K* that is consistent with the size-at-age-1 for the base case was used for each scenario (Figure 5.13.a). The third growth scenario assumed that the growth paramaters for males from Chang *et al.* (2013) were representative.

Results of the sensitivity analysis indicated that spawning biomass was sensitive to the values of L_{inf} and K and that the low growth and Chang *et al.* scenarios would produce higher biomasses and lower fishing intensities (Figure 5.13.b). The pattern in trends in spawning biomass and fishing intensity were relatively similar for the base case and the alternative growth models. Overall, the results indicated that the base case model results were sensitive to the blue marlin growth curve parameters.

5.6.2.4 Size-at-50-percent maturity

The purpose of this sensitivity run is to examine the effect of alternative maturity schedules for female blue marlin. Two model runs were conducted to assume larger or smaller size-at-50-percent maturity ($L_{50\%}$= 179.76 cm) than the base case (Figure 5.14.a). The high $L_{50\%}$ scenario increased the size-at-50-percent maturity of females from the base case model by 10% ($L_{50\%}$= 197.736 cm) and the low $L_{50\%}$ scenario decreased the size-at-50-percent maturity by 10% ($L_{50\%}$= 161.784 cm). Results for the high scenario indicated that a larger size-at-50-percent maturity reduced spawning biomasses and increased fishing intensities (Figure 5.14.b), while a lower $L_{50\%}$ produced higher spawning biomasses and lower fishing intensities. The pattern in trends in spawning biomass and fishing intensity were relatively similar for the base case and the alternative maturity schedules. Overall, the results indicated that the base case model results were sensitive to the blue marlin size-at-50-percent maturity.

5.7 Future projections

Projected trajectory of spawning stock biomass (*SSB*) and yield from 2012 to 2020 were shown in Table 5.7 and 5.8 and Figure 5.15 and 5.16. When current ($F_{2009-2011} = F_{23\%}$) level is maintained, the stock is projected to be stable at roughly 26,200 t by 2020, which is above spawning stock biomass at *MSY* level. If fishing increases to *MSY* level, the projected *SSB* is estimated to have gradually decreased and by 2020, it is about spawning stock biomass at *MSY* level. If fishing further increases to the 2003-2005 level ($F_{16\%}$), the projected *SSB* would be below spawning stock biomass at *MSY* level by 2015. Conversely, if fishing reduces to $F_{30\%}$, the projected *SSB* would gradually increase. Fishing at the current level ($F_{23\%}$) or *MSY* level ($F_{18\%}$) provide an expected safe level of harvest, where the average projected catch between 2012 and 2020 is approximately about *MSY*.

6 STOCK STATUS

6.1 Stock status

Results from the base case assessment model were used to determine trends in population biomass, spawning biomass, and fishing intensity of the Pacific blue marlin stock during 1971-2011. Estimates of population biomass and female spawning biomass exhibit long-term decline trends (Figure 5.7). Estimated fishing mortality and 1-SPR gradually increase from the early 1970s to the early 2000s and declined in the most recent years (2009-2011). Current fishing mortality was defined by the BILLWG as the average of estimates for 2009-2011 to account for uncertainty and fluctuation of estimates of recent years.

No target or limit reference points have been established for the Pacific blue marlin stock under the auspices of the WCPFC. Compared to MSY-based reference points, the current (2011) spawning biomass is 29% above SSB_{MSY} and the current fishing mortality (average across 2009-2011) is inferior to F_{MSY} and $1-SPR_{MSY}$ by 19% and 6%, respectively (Figure 6.1 and 6.2). Therefore, the blue marlin stock in the Pacific Ocean currently is not being overfished and is not in an overfished state.

6.2 Conservation advice

Based on the results of the stock assessment the stock is not currently overfished and is not experiencing overfishing. The stock is nearly fully exploited but recent biomass trends may suggest a slight increase in biomass. Because blue marlin is mostly caught as bycatch, the direct control of catch amount is difficult. The WG recommend that the fishing mortality should not be increased from the current level to avoid overfishing.

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TABLES

Table 3.1. Fisheries in the assessment of blue marlin. DWLL – distant water longline; OSLL – offshore longline; COLL – coastal and other longline; DRIFT – high sea large-mesh driftnet and coastal driftnet; GN – gillnet; HAR – harpoon.

Fishery	Alpha Code	Fishing entities
F1	JPNEarlyLL	Japan DWLL & OSLL
F2	JPNLateLL	Japan DWLL & OSLL
F3	JPNCLL	Japan COLL
F4	JPNDRIFT	Japan DRIFT
F5	JPNBait	Japan bait fishing
F6	JPNOth	Japan other gears
F7	HWLL	United States (Hawaii) LL
F8	ASLL	United States (American Samoa) LL
F9	HWOth	United States (Hawaii) troll & handline
F10	TWNLL	Taiwan DWLL
F11	TWNOth	Taiwan OSLL, COLL, GN & HAR
F12	OthLL	Various flags[1] longline
F13	PYFLL	French Polynesia longline
F14	EPOPS	Various flags[2] purse seine
F15	WCPFCPS	Various flags[3] purse seine
F16	EPOOth	French Polynesia troll & handline, HAR

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[1] Australia, Belize, China, Cook Islands, Costa Rica, Fiji, Indonesia, Kiribati, Korea, Marshall Islands, Mexico, Federated States of Micronesia, New Caledonia, Niue, New Zealand, Papua New Guinea, Philippines, Samoa, Senegal, Spain, Solomon Islands, Tonga, Tuvalu, Vanuatu, Vietnam

[2] Ecuador, Honduras, México, Nicaragua, Panamá, El Salvador, Spain, Venezuela, Vanuatu, USA

[3] Australia, China, Ecuador, Federated States of Micronesia, Indonesia, Kiribati, Marshall Islands, Mexico, New Zealand, Papua New Guinea, Philippines, Solomon Islands, El Salvador, Spain, Tuvalu, Vanuatu, Korea, Japan, USA

Table 3.2. Estimates of total catch (t) by fishery by calendar quarter for 1971-2011.

Yr	Seas	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
1971	1	1897.7	0.0	28.2	0.0	1.5	12.3	9.8	0.0	0.0	26.0	483.8	15.0	0.0	0.0	2.0	0.0
1971	2	1667.4	0.0	28.2	0.0	1.5	12.3	8.2	0.0	0.0	26.0	483.8	15.0	0.0	0.0	2.0	0.0
1971	3	1894.5	0.0	28.2	0.0	1.5	12.3	2.9	0.0	0.0	26.0	483.8	15.0	0.0	0.0	2.0	0.0
1971	4	1404.1	0.0	28.2	0.0	1.5	12.3	0.5	0.0	0.0	26.0	483.8	15.0	0.0	0.0	2.0	0.0
1972	1	2546.8	0.0	52.8	2.0	1.7	13.0	0.5	0.0	0.0	50.8	439.8	15.8	0.0	0.0	2.3	0.0
1972	2	2241.3	0.0	52.8	2.0	1.7	13.0	0.7	0.0	0.0	50.8	439.8	15.8	0.0	0.0	2.3	0.0
1972	3	2123.2	0.0	52.8	2.0	1.7	13.0	0.1	0.0	0.0	50.8	439.8	15.8	0.0	0.0	2.3	0.0
1972	4	1581.5	0.0	52.8	2.0	1.7	13.0	0.2	0.0	0.0	50.8	439.8	15.8	0.0	0.0	2.3	0.0
1973	1	2855.0	0.0	52.8	65.9	5.7	33.5	0.3	0.0	0.0	56.3	550.5	18.8	0.0	0.0	3.5	0.0
1973	2	2606.6	0.0	52.8	65.9	5.7	33.5	0.7	0.0	0.0	56.3	550.5	18.8	0.0	0.0	3.5	0.0
1973	3	1661.1	0.0	52.8	65.9	5.7	33.5	8.2	0.0	0.0	56.3	550.5	18.8	0.0	0.0	3.5	0.0
1973	4	2001.9	0.0	52.8	65.9	5.7	33.5	5.9	0.0	0.0	56.3	550.5	18.8	0.0	0.0	3.5	0.0
1974	1	2493.9	0.0	45.5	56.6	15.2	12.8	3.1	0.0	0.0	40.3	662.5	21.8	0.0	0.0	1.8	0.0
1974	2	2081.2	0.0	45.5	56.6	15.2	12.8	5.2	0.0	0.0	40.3	662.5	21.8	0.0	0.0	1.8	0.0
1974	3	1740.5	0.0	45.5	56.6	15.2	12.8	17.3	0.0	0.0	40.3	662.5	21.8	0.0	0.0	1.8	0.0
1974	4	1757.2	0.0	45.5	56.6	15.2	12.8	9.3	0.0	0.0	40.3	662.5	21.8	0.0	0.0	1.8	0.0
1975	1	1585.3	0.0	116.6	195.5	36.4	19.9	9.1	0.0	0.0	37.0	814.8	33.8	0.0	0.0	1.8	0.0
1975	2	1269.2	0.0	116.6	195.5	36.4	19.9	8.6	0.0	0.0	37.0	814.8	33.8	0.0	0.0	1.8	0.0
1975	3	1614.8	0.0	116.6	195.5	36.4	19.9	9.1	0.0	0.0	37.0	814.8	33.8	0.0	0.0	1.8	0.0
1975	4	1188.0	0.0	116.6	195.5	36.4	19.9	6.2	0.0	0.0	37.0	814.8	33.8	0.0	0.0	1.8	0.0
1976	1	1469.6	0.0	107.3	142.9	49.9	79.4	3.6	0.0	0.0	44.0	493.3	191.6	0.0	0.0	1.5	0.0
19	2	181	0.0	10	14	49	79.	5.2	0.	0.0	44.	493	191	0.	0.	1.5	0.

76		7.9		7.3	2.9	.9	4		0		0	.3	.6	0	0		0
19		205		10	14	49	79.	23.	0.		44.	493	191	0.	0.		0.
76	3	0.3	0.0	7.3	2.9	.9	4	4	0	0.0	0	.3	.6	0	0	1.5	0
19		180		10	14	49	79.	27.	0.		44.	493	191	0.	0.		0.
76	4	7.7	0.0	7.3	2.9	.9	4	4	0	0.0	0	.3	.6	0	0	1.5	0
19		210		12	24	47	38.	23.	0.		36.	421	164	0.	0.		0.
77	1	0.5	0.0	9.5	5.5	.7	4	8	0	0.0	3	.8	.1	0	0	2.3	0
19		203		12	24	47	38.	23.	0.		36.	421	164	0.	0.		0.
77	2	3.5	0.0	9.5	5.5	.7	4	2	0	0.0	3	.8	.1	0	0	2.3	0
19		183		12	24	47	38.	54.	0.		36.	421	164	0.	0.		0.
77	3	8.0	0.0	9.5	5.5	.7	4	4	0	0.0	3	.8	.1	0	0	2.3	0
19		187		12	24	47	38.	22.	0.		36.	421	164	0.	0.		0.
77	4	7.5	0.0	9.5	5.5	.7	4	7	0	0.0	3	.8	.1	0	0	2.3	0
19		232		20	21	49	98.	19.	0.		15.	505	285	0.	0.		0.
78	1	9.9	0.0	6.9	7.4	.2	1	4	0	0.0	8	.0	.1	0	0	2.0	0
19		262		20	21	49	98.	70.	0.		15.	505	285	0.	0.		0.
78	2	9.8	0.0	6.9	7.4	.2	1	0	0	0.0	8	.0	.1	0	0	2.0	0
19		212		20	21	49	98.	81.	0.		15.	505	285	0.	0.		0.
78	3	9.0	0.0	6.9	7.4	.2	1	8	0	0.0	8	.0	.1	0	0	2.0	0
19		170		20	21	49	98.	23.	0.		15.	505	285	0.	0.		0.
78	4	5.3	0.0	6.9	7.4	.2	1	2	0	0.0	8	.0	.1	0	0	2.0	0
19		226		18	12	41	66.	21.	0.		10	543	354	0.	0.		0.
79	1	9.3	0.0	6.9	6.2	.3	4	4	0	0.0	5.5	.5	.9	0	0	3.3	0
19		276		18	12	41	66.	55.	0.		10	543	354	0.	0.		0.
79	2	1.7	0.0	6.9	6.2	.3	4	2	0	0.0	5.5	.5	.9	0	0	3.3	0
19		214		18	12	41	66.	62.	0.		10	543	354	0.	0.		0.
79	3	8.6	0.0	6.9	6.2	.3	4	3	0	0.0	5.5	.5	.9	0	0	3.3	0
19		218		18	12	41	66.	20.	0.		10	543	354	0.	0.		0.
79	4	4.3	0.0	6.9	6.2	.3	4	2	0	0.0	5.5	.5	.9	0	0	3.3	0
19		341		17	21	34	28.	19.	0.		12	445	301	0.	0.		0.
80	1	0.3	0.0	1.6	3.5	.4	8	7	0	0.0	2.5	.8	.1	0	0	3.3	0
19		275		17	21	34	28.	48.	0.		12	445	301	0.	0.		0.
80	2	5.6	0.0	1.6	3.5	.4	8	2	0	0.0	2.5	.8	.1	0	0	3.3	0
19		214		17	21	34	28.	68.	0.		12	445	301	0.	0.		0.
80	3	5.3	0.0	1.6	3.5	.4	8	6	0	0.0	2.5	.8	.1	0	0	3.3	0
19		207		17	21	34	28.	37.	0.		12	445	301	0.	0.		0.
80	4	5.4	0.0	1.6	3.5	.4	8	5	0	0.0	2.5	.8	.1	0	0	3.3	0
19		278		20	28	46	35.	32.	0.		11	557	336	0.	0.		0.
81	1	5.4	0.0	0.6	6.5	.2	2	5	0	0.0	5.8	.8	.1	0	0	7.5	0
19		308		20	28	46	35.	48.	0.		11	557	336	0.	0.		0.
81	2	5.0	0.0	0.6	6.5	.2	2	7	0	0.0	5.8	.8	.1	0	0	7.5	0
19		228		20	28	46	35.	76.	0.		11	557	336	0.	0.		0.
81	3	1.9	0.0	0.6	6.5	.2	2	1	0	0.0	5.8	.8	.1	0	0	7.5	0
19		195		20	28	46	35.	32.	0.		11	557	336	0.	0.		0.
81	4	1.2	0.0	0.6	6.5	.2	2	9	0	0.0	5.8	.8	.1	0	0	7.5	0
19	1	307	0.0	17	23	42	61.	28.	0.	0.0	76.	640	390	0.	0.	10.	0.

82		3.8		6.5	4.9	.3	0	5	0		0	.5	.3	0	0	5	0
19		315		17	23	42	61.	52.	0.		76.	640	390	0.	0.	10.	0.
82	2	2.1	0.0	6.5	4.9	.3	0	4	0	0.0	0	.5	.3	0	0	5	0
19		254		17	23	42	61.	64.	0.		76.	640	390	0.	0.	10.	0.
82	3	2.3	0.0	6.5	4.9	.3	0	3	0	0.0	0	.5	.3	0	0	5	0
19		204		17	23	42	61.	34.	0.		76.	640	390	0.	0.	10.	0.
82	4	9.5	0.0	6.5	4.9	.3	0	7	0	0.0	0	.5	.3	0	0	5	0
19		299		25	22	56	10	15.	0.		68.	753	243	0.	0.	16.	0.
83	1	7.2	0.0	8.7	9.0	.8	8.7	1	0	0.0	0	.8	.4	0	0	8	0
19		275		25	22	56	10	35.	0.		68.	753	243	0.	0.	16.	0.
83	2	3.7	0.0	8.7	9.0	.8	8.7	8	0	0.0	0	.8	.4	0	0	8	0
19		191		25	22	56	10	56.	0.		68.	753	243	0.	0.	16.	0.
83	3	8.2	0.0	8.7	9.0	.8	8.7	6	0	0.0	0	.8	.4	0	0	8	0
19		211		25	22	56	10	35.	0.		68.	753	243	0.	0.	16.	0.
83	4	6.5	0.0	8.7	9.0	.8	8.7	1	0	0.0	0	.8	.4	0	0	8	0
19		396		31	60.	45	10	18.	0.		95.	720	376	0.	0.	21.	0.
84	1	8.5	0.0	8.4	5	.7	5.8	9	0	0.0	5	.5	.9	0	0	5	0
19		327		31	60.	45	10	22.	0.		95.	720	376	0.	0.	21.	0.
84	2	2.0	0.0	8.4	5	.7	5.8	2	0	0.0	5	.5	.9	0	0	5	0
19		254		31	60.	45	10	67.	0.		95.	720	376	0.	0.	21.	0.
84	3	7.4	0.0	8.4	5	.7	5.8	3	0	0.0	5	.5	.9	0	0	5	0
19		246		31	60.	45	10	28.	0.		95.	720	376	0.	0.	21.	0.
84	4	5.4	0.0	8.4	5	.7	5.8	7	0	0.0	5	.5	.9	0	0	5	0
19		320		25	10	74	86.	29.	0.		53.	499	383	0.	0.	17.	0.
85	1	6.3	0.0	5.4	0.4	.5	1	8	0	0.0	0	.3	.3	0	0	3	0
19		271		25	10	74	86.	38.	0.		53.	499	383	0.	0.	17.	0.
85	2	8.3	0.0	5.4	0.4	.5	1	7	0	0.0	0	.3	.3	0	0	3	0
19		166		25	10	74	86.	45.	0.		53.	499	383	0.	0.	17.	0.
85	3	5.4	0.0	5.4	0.4	.5	1	4	0	0.0	0	.3	.3	0	0	3	0
19		176		25	10	74	86.	22.	0.		53.	499	383	0.	0.	17.	0.
85	4	2.0	0.0	5.4	0.4	.5	1	5	0	0.0	0	.3	.3	0	0	3	0
19		336		21	43.	91	37.	34.	0.		46.	690	429	0.	0.	16.	0.
86	1	0.8	0.0	9.3	8	.5	1	5	0	0.0	0	.8	.1	0	0	5	0
19		361		21	43.	91	37.	53.	0.		46.	690	429	0.	0.	16.	0.
86	2	6.6	0.0	9.3	8	.5	1	4	0	0.0	0	.8	.1	0	0	5	0
19		230		21	43.	91	37.	74.	0.		46.	690	429	0.	0.	16.	0.
86	3	1.7	0.0	9.3	8	.5	1	9	0	0.0	0	.8	.1	0	0	5	0
19		207		21	43.	91	37.	46.	0.		46.	690	429	0.	0.	16.	0.
86	4	5.9	0.0	9.3	8	.5	1	2	0	0.0	0	.8	.1	0	0	5	0
19		274		37	63.	70	29.	34.	0.	70.	49.	140	107	0.	0.	18.	0.
87	1	3.7	0.0	3.6	0	.3	8	9	0	8	5	3.3	3.4	0	0	3	0
19		350		37	63.	70	29.	60.	0.	70.	49.	140	107	0.	0.	18.	0.
87	2	6.6	0.0	3.6	0	.3	8	2	0	8	5	3.3	3.4	0	0	3	0
19		315		37	63.	70	29.	85.	0.	70.	49.	140	107	0.	0.	18.	0.
87	3	3.7	0.0	3.6	0	.3	8	8	0	8	5	3.3	3.4	0	0	3	0
19	4	229	0.0	37	63.	70	29.	58.	0.	70.	49.	140	107	0.	0.	18.	0.

87		6.0		3.6	0	.3	8	7	0	8	5	3.3	3.4	0	0	3	0
19		379		35	90.	57	34.	36.	0.	74.	80.	102	898	0.	0.	17.	0.
88	1	6.3	0.0	5.4	5	.3	9	2	0	0	0	4.3	.2	0	0	8	0
19		288		35	90.	57	34.	34.	0.	74.	80.	102	898	0.	0.	17.	0.
88	2	3.9	0.0	5.4	5	.3	9	6	0	0	0	4.3	.2	0	0	8	0
19		195		35	90.	57	34.	10	0.	74.	80.	102	898	0.	0.	17.	0.
88	3	2.4	0.0	5.4	5	.3	9	2.1	0	0	0	4.3	.2	0	0	8	0
19		147		35	90.	57	34.	91.	0.	74.	80.	102	898	0.	0.	17.	0.
88	4	5.8	0.0	5.4	5	.3	9	1	0	0	0	4.3	.2	0	0	8	0
19		226		30	73.	97	30.	70.	0.	91.	11	829	677	0.	0.	21.	0.
89	1	9.0	0.0	7.7	8	.2	7	9	0	3	1.3	.3	.4	0	0	5	0
19		244		30	73.	97	30.	11	0.	91.	11	829	677	0.	0.	21.	0.
89	2	6.9	0.0	7.7	8	.2	7	5.1	0	3	1.3	.3	.4	0	0	5	0
19		210		30	73.	97	30.	14	0.	91.	11	829	677	0.	0.	21.	0.
89	3	0.2	0.0	7.7	8	.2	7	6.0	0	3	1.3	.3	.4	0	0	5	0
19		193		30	73.	97	30.	14	0.	91.	11	829	677	0.	0.	21.	0.
89	4	1.5	0.0	7.7	8	.2	7	5.1	0	3	1.3	.3	.4	0	0	5	0
19		235		29	63.	62	43.	73.	0.	84.	10	581	730	0.	0.	23.	0.
90	1	7.7	0.0	3.0	0	.5	3	6	0	3	9.3	.8	.9	8	0	8	0
19		217		29	63.	62	43.	13	0.	84.	10	581	730	0.	0.	23.	0.
90	2	1.8	0.0	3.0	0	.5	3	0.4	0	3	9.3	.8	.9	8	0	8	0
19		131		29	63.	62	43.	21	0.	84.	10	581	730	0.	0.	23.	0.
90	3	6.5	0.0	3.0	0	.5	3	5.5	0	3	9.3	.8	.9	7	0	8	0
19		186		29	63.	62	43.	97.	0.	84.	10	581	730	0.	0.	23.	0.
90	4	8.0	0.0	3.0	0	.5	3	2	0	3	9.3	.8	.9	8	0	8	0
19		241		32	44.	42	16.	50.	0.	96.	18	674	728	5.	0.	33.	0.
91	1	7.1	0.0	6.6	3	.3	2	7	0	8	0.0	.0	.2	8	0	8	0
19		267		32	44.	42	16.	15	0.	96.	18	674	728	5.	0.	33.	0.
91	2	5.6	0.0	6.6	3	.3	2	3.4	0	8	0.0	.0	.2	8	0	8	0
19		146		32	44.	42	16.	18	0.	96.	18	674	728	5.	0.	33.	0.
91	3	8.9	0.0	6.6	3	.3	2	7.8	0	8	0.0	.0	.2	8	0	8	0
19		177		32	44.	42	16.	14	0.	96.	18	674	728	5.	0.	33.	0.
91	4	4.1	0.0	6.6	3	.3	2	2.9	0	8	0.0	.0	.2	8	0	8	0
19		276		40	41.	37	12.	80.	0.	75.	30.	109	981	20	0.	35.	0.
92	1	9.6	0.0	3.3	3	.6	5	3	0	3	5	5.0	.2	.0	0	3	0
19		274		40	41.	37	12.	95.	0.	75.	30.	109	981	20	0.	35.	0.
92	2	8.5	0.0	3.3	3	.6	5	7	0	3	5	5.0	.2	.0	0	3	0
19		179		40	41.	37	12.	13	0.	75.	30.	109	981	20	0.	35.	0.
92	3	0.6	0.0	3.3	3	.6	5	1.9	0	3	5	5.0	.2	.0	0	3	0
19		159		40	41.	37	12.	59.	0.	75.	30.	109	981	20	0.	35.	0.
92	4	9.0	0.0	3.3	3	.6	5	7	0	3	5	5.0	.2	.0	0	3	0
19		262		50	35.	46	21.	27.	0.	84.	11	111	959	53	31	35.	0.
93	1	1.9	0.0	9.2	9	.7	9	8	0	8	2.3	0.8	.8	.8	.1	5	0
19		270		50	35.	46	21.	79.	0.	84.	11	111	959	53	30	35.	0.
93	2	4.8	0.0	9.2	9	.7	9	3	0	8	2.3	0.8	.8	.8	.8	5	0
19	3	202	0.0	50	35.	46	21.	21	0.	84.	11	111	959	53	31	35.	0.

93		6.3		9.2	9	.7	9	4.4	0	8	2.3	0.8	.8	.8	.0	5	0
19		211		50	35.	46	21.	14	0.	84.	11	111	959	53	31	35.	0.
93	4	1.9	0.0	9.2	9	.7	9	5.3	0	8	2.3	0.8	.8	.8	.3	5	0
19			303	37	38.	34	17.	91.	0.	83.	15	815	101	42	15	35.	0.
94	1	0.0	6.5	7.7	6	.9	5	4	0	5	0.8	.5	7.0	.2	.2	3	0
19			300	37	38.	34	17.	11	0.	83.	15	815	101	42	24	35.	0.
94	2	0.0	4.1	7.7	6	.9	5	5.8	0	5	0.8	.5	7.0	.2	.3	3	0
19			243	37	38.	34	17.	24	0.	83.	15	815	101	42	24	35.	0.
94	3	0.0	3.1	7.7	6	.9	5	7.8	0	5	0.8	.5	7.0	.2	.0	3	0
19			266	37	38.	34	17.	69.	0.	83.	15	815	101	42	26	35.	0.
94	4	0.0	0.1	7.7	6	.9	5	6	0	5	0.8	.5	7.0	.2	.6	3	0
19			274	44	34.	42	16.	27.	0.	87.	81.	119	129	93	23	36.	0.
95	1	0.0	3.9	6.6	9	.8	5	8	0	8	5	2.8	3.4	.0	.0	0	0
19			265	44	34.	42	16.	15	0.	87.	81.	119	129	93	25	36.	0.
95	2	0.0	9.9	6.6	9	.8	5	0.9	0	8	5	2.8	3.4	.0	.3	0	0
19			217	44	34.	42	16.	21	0.	87.	81.	119	129	93	23	36.	0.
95	3	0.0	5.6	6.6	9	.8	5	7.6	0	8	5	2.8	3.4	.0	.3	0	0
19			173	44	34.	42	16.	17	0.	87.	81.	119	129	93	22	36.	0.
95	4	0.0	7.2	6.6	9	.8	5	3.1	0	8	5	2.8	3.4	.0	.2	0	0
19			134	27	26.	44		16	0.	11	46.	906	897	87	10	40.	0.
96	1	0.0	2.1	4.9	3	.3	9.8	0.5	1	0.3	8	.5	.6	.8	.5	0	0
19			130	27	26.	44		14	0.	11	46.	906	897	87	25	40.	0.
96	2	0.0	8.9	4.9	3	.3	9.8	0.9	9	0.3	8	.5	.6	.8	.7	0	0
19			105	27	26.	44		20	2.	11	46.	906	897	87	19	40.	0.
96	3	0.0	6.1	4.9	3	.3	9.8	8.5	7	0.3	8	.5	.6	.8	.6	0	0
19			951	27	26.	44		11	3.	11	46.	906	897	87	26	40.	0.
96	4	0.0	.5	4.9	3	.3	9.8	0.0	0	0.3	8	.5	.6	.8	.7	0	0
19			120	23	18.	58		45.	4.	10	26.	977	102	62	23	44.	0.
97	1	0.0	7.9	8.0	7	.3	8.4	2	4	5.5	0	.5	9.3	.6	.1	8	0
19			161	23	18.	58		16	4.	10	26.	977	102	62	33	44.	0.
97	2	0.0	5.1	8.0	7	.3	8.4	5.0	2	5.5	0	.5	9.3	.6	.1	8	0
19			167	23	18.	58		27	5.	10	26.	977	102	62	46	44.	0.
97	3	0.0	9.5	8.0	7	.3	8.4	9.1	2	5.5	0	.5	9.3	.6	.1	8	0
19			164	23	18.	58		16	2.	10	26.	977	102	62	50	44.	0.
97	4	0.0	2.9	8.0	7	.3	8.4	7.0	4	5.5	0	.5	9.3	.6	.0	8	0
19			160	27	13.	70		77.	4.	66.	52.	940	145	44	37	45.	0.
98	1	0.0	9.2	2.7	5	.6	6.6	8	4	0	3	.5	7.8	.7	.7	5	0
19			148	27	13.	70		62.	3.	66.	52.	940	145	44	36	45.	0.
98	2	0.0	7.6	2.7	5	.6	6.6	1	3	0	3	.5	7.8	.7	.8	5	0
19			125	27	13.	70		17	7.	66.	52.	940	145	44	43	45.	0.
98	3	0.0	7.3	2.7	5	.6	6.6	6.4	0	0	3	.5	7.8	.7	.7	5	0
19			106	27	13.	70		10	4.	66.	52.	940	145	44	44	45.	0.
98	4	0.0	7.8	2.7	5	.6	6.6	8.3	7	0	3	.5	7.8	.7	.1	5	0
19			116	27	18.	42		74.	4.	83.	32.	888	149	81	50	38.	0.
99	1	0.0	7.4	2.9	9	.6	2.7	9	6	0	8	.0	4.8	.6	.7	3	0
19	2	0.0	989	27	18.	42	2.7	81.	4.	83.	32.	888	149	81	88	38.	0.

99			.2	2.9	9	.6		5	8	0	8	.0	4.8	.6	.9	3	0
19			997	27	18.	42		21	5.	83.	32.	888	149	81	65	38.	0.
99	3	0.0	.0	2.9	9	.6	2.7	0.2	6	0	8	.0	4.8	.6	.4	3	0
19			934	27	18.	42		91.	6.	83.	32.	888	149	81	28	38.	0.
99	4	0.0	.6	2.9	9	.6	2.7	0	4	0	8	.0	4.8	.6	.4	3	0
20			100	30		48		64.	9.	58.	28.	199	130	70	48	46.	0.
00	1	0.0	3.6	4.5	5.2	.5	5.7	6	9	8	5	7.3	6.9	.5	.9	0	0
20			797	30		48		57.	8.	58.	28.	199	130	70	38	46.	0.
00	2	0.0	.1	4.5	5.2	.5	5.7	6	5	8	5	7.3	6.9	.5	.2	0	0
20			119	30		48		19	5.	58.	28.	199	130	70	49	46.	0.
00	3	0.0	8.4	4.5	5.2	.5	5.7	5.0	1	8	5	7.3	6.9	.5	.7	0	0
20			102	30		48		14	8.	58.	28.	199	130	70	17	46.	0.
00	4	0.0	5.0	4.5	5.2	.5	5.7	0.3	5	8	5	7.3	6.9	.5	.9	0	0
20			924	29	39.	33		27.	11	73.	14	225	153	71	34	47.	0.
01	1	0.0	.6	0.8	8	.9	3.4	7	.7	5	6.3	7.5	6.6	.0	.0	3	0
20			991	29	39.	33		11	25	73.	14	225	153	71	40	47.	0.
01	2	0.0	.1	0.8	8	.9	3.4	8.2	.4	5	6.3	7.5	6.6	.0	.0	3	0
20			109	29	39.	33		27	21	73.	14	225	153	71	42	47.	0.
01	3	0.0	1.7	0.8	8	.9	3.4	4.8	.9	5	6.3	7.5	6.6	.0	.3	3	0
20			105	29	39.	33		12	43	73.	14	225	153	71	53	47.	0.
01	4	0.0	4.1	0.8	8	.9	3.4	0.2	.9	5	6.3	7.5	6.6	.0	.4	3	0
20			109	21	26.	37		75.	86	57.	12	219	181	24	32	51.	0.
02	1	0.0	8.6	5.7	1	.1	4.4	2	.3	8	3.8	9.8	1.8	.5	.8	3	0
20			103	21	26.	37		12	71	57.	12	219	181	24	93	51.	0.
02	2	0.0	6.7	5.7	1	.1	4.4	5.4	.1	8	3.8	9.8	1.8	.5	.2	3	0
20			842	21	26.	37		15	40	57.	12	219	181	24	61	51.	0.
02	3	0.0	.4	5.7	1	.1	4.4	5.4	.4	8	3.8	9.8	1.8	.5	.5	3	0
20			811	21	26.	37		40.	55	57.	12	219	181	24	49	51.	0.
02	4	0.0	.7	5.7	1	.1	4.4	9	.6	8	3.8	9.8	1.8	.5	.5	3	0
20			123	24		43		26.	39	52.	30	194	251	77	31	53.	0.
03	1	0.0	5.8	5.3	9.1	.8	4.2	4	.9	5	1.8	0.0	4.8	.5	.6	5	0
20			947	24		43		18	48	52.	30	194	251	77	49	53.	0.
03	2	0.0	.8	5.3	9.1	.8	4.2	1.7	.5	5	1.8	0.0	4.8	.5	.1	5	0
20			712	24		43		13	44	52.	30	194	251	77	71	53.	0.
03	3	0.0	.4	5.3	9.1	.8	4.2	0.2	.7	5	1.8	0.0	4.8	.5	.7	5	0
20			811	24		43		97.	51	52.	30	194	251	77	59	53.	0.
03	4	0.0	.8	5.3	9.1	.8	4.2	0	.6	5	1.8	0.0	4.8	.5	.5	5	0
20			104	28		48		95.	27	47.	36	164	202	58	31	56.	0.
04	1	0.0	3.6	6.5	4.9	.0	6.6	4	.4	0	4.0	3.0	2.0	.6	.0	5	0
20			747	28		48		13	37	47.	36	164	202	58	52	56.	0.
04	2	0.0	.1	6.5	4.9	.0	6.6	1.9	.6	0	4.0	3.0	2.0	.6	.9	5	0
20			693	28		48		12	33	47.	36	164	202	58	39	56.	0.
04	3	0.0	.0	6.5	4.9	.0	6.6	5.9	.0	0	4.0	3.0	2.0	.6	.3	5	0
20			911	28		48		55.	37	47.	36	164	202	58	37	56.	0.
04	4	0.0	.5	6.5	4.9	.0	6.6	1	.8	0	4.0	3.0	2.0	.6	.7	5	0
20	1	0.0	111	24	9.1	48	4.4	55.	14	46.	37	188	219	49	48	21	0.

05			1.7	6.4		.0		9	.6	8	6.5	5.0	7.9	.2	.4	2.0	0
20			697	24		48		17	20	46.	37	188	219	49	74	21	0.
05	2	0.0	.3	6.4	9.1	.0	4.4	0.6	.0	8	6.5	5.0	7.9	.2	.3	2.0	0
20			639	24		48		14	30	46.	37	188	219	49	56	21	0.
05	3	0.0	.7	6.4	9.1	.0	4.4	1.3	.7	8	6.5	5.0	7.9	.2	.4	2.0	0
20			437	24		48		71.	48	46.	37	188	219	49	42	21	0.
05	4	0.0	.7	6.4	9.1	.0	4.4	8	.6	8	6.5	5.0	7.9	.2	.5	2.0	0
20			589	24		34		43.	38	40.	41	145	200	68	36	15	26
06	1	0.0	.7	6.9	7.9	.7	4.9	2	.1	0	9.5	2.0	0.0	.4	.5	2.8	.3
20			719	24		34		13	34	40.	41	145	200	68	61	15	26
06	2	0.0	.1	6.9	7.9	.7	4.9	3.4	.8	0	9.5	2.0	0.0	.4	.7	2.8	.3
20			600	24		34		12	44	40.	41	145	200	68	39	15	26
06	3	0.0	.2	6.9	7.9	.7	4.9	5.8	.4	0	9.5	2.0	0.0	.4	.2	2.8	.3
20			597	24		34		12	51	40.	41	145	200	68	44	15	26
06	4	0.0	.1	6.9	7.9	.7	4.9	6.6	.6	0	9.5	2.0	0.0	.4	.9	2.8	.3
20			786	27	18.	39		50.	56	32.	31	129	162	83	35	20	26
07	1	0.0	.9	6.2	7	.8	7.9	6	.0	3	7.8	0.3	2.8	.8	.0	6.0	.5
20			537	27	18.	39		11	43	32.	31	129	162	83	35	20	26
07	2	0.0	.5	6.2	7	.8	7.9	2.7	.2	3	7.8	0.3	2.8	.8	.7	6.0	.5
20			452	27	18.	39		93.	54	32.	31	129	162	83	17	20	26
07	3	0.0	.4	6.2	7	.8	7.9	4	.4	3	7.8	0.3	2.8	.8	.9	6.0	.5
20			388	27	18.	39		82.	79	32.	31	129	162	83	40	20	26
07	4	0.0	.4	6.2	7	.8	7.9	5	.3	3	7.8	0.3	2.8	.8	.7	6.0	.5
20			510	28		49	11.	42.	47	45.	22	138	154	56	37	14	28
08	1	0.0	.5	7.2	7.9	.9	3	8	.2	3	7.5	0.8	2.5	.4	.7	8.0	.5
20			525	28		49	11.	10	48	45.	22	138	154	56	42	14	28
08	2	0.0	.5	7.2	7.9	.9	3	4.6	.1	3	7.5	0.8	2.5	.4	.8	8.0	.5
20			429	28		49	11.	15	33	45.	22	138	154	56	25	14	28
08	3	0.0	.6	7.2	7.9	.9	3	0.1	.7	3	7.5	0.8	2.5	.4	.8	8.0	.5
20			377	28		49	11.	12	48	45.	22	138	154	56	23	14	28
08	4	0.0	.3	7.2	7.9	.9	3	0.8	.7	3	7.5	0.8	2.5	.4	.3	8.0	.5
20			550	27	14.	39		66.	64	45.	33	119	167	57	21	15	32
09	1	0.0	.1	3.8	3	.4	7.6	3	.3	3	4.5	6.8	8.2	.4	.1	8.8	.8
20			396	27	14.	39		15	60	45.	33	119	167	57	34	15	32
09	2	0.0	.8	3.8	3	.4	7.6	6.4	.9	3	4.5	6.8	8.2	.4	.4	8.8	.8
20			398	27	14.	39		17	47	45.	33	119	167	57	56	15	32
09	3	0.0	.2	3.8	3	.4	7.6	8.9	.3	3	4.5	6.8	8.2	.4	.7	8.8	.8
20			582	27	14.	39		67.	50	45.	33	119	167	57	61	15	32
09	4	0.0	.0	3.8	3	.4	7.6	1	.4	3	4.5	6.8	8.2	.4	.9	8.8	.8
20			704	36	23.	55		37.	39	37.	37	143	153	58	37	17	31
10	1	0.0	.5	5.5	1	.6	7.6	2	.0	5	2.5	5.5	8.7	.1	.3	2.0	.5
20			657	36	23.	55		14	59	37.	37	143	153	58	53	17	31
10	2	0.0	.3	5.5	1	.6	7.6	2.1	.3	5	2.5	5.5	8.7	.1	.5	2.0	.5
20			452	36	23.	55		14	44	37.	37	143	153	58	51	17	31
10	3	0.0	.4	5.5	1	.6	7.6	3.7	.9	5	2.5	5.5	8.7	.1	.2	2.0	.5
20	4	0.0	419	36	23.	55	7.6	74.	45	37.	37	143	153	58	35	17	31

10			.8	5.5	1	.6		6	.3	5	2.5	5.5	8.7	.1	.6	2.0	.5
20			599	23	24.	58		44.	23	48.	33	127	144	58	27	21	31
11	1	0.0	.6	9.0	4	.5	9.1	5	.9	8	2.8	7.8	3.7	.1	.2	7.5	.5
20			580	23	24.	58		11	33	48.	33	127	144	58	51	21	31
11	2	0.0	.2	9.0	4	.5	9.1	0.7	.1	8	2.8	7.8	3.7	.1	.1	7.5	.5
20			436	23	24.	58		98.	23	48.	33	127	144	58	43	21	31
11	3	0.0	.9	9.0	4	.5	9.1	0	.6	8	2.8	7.8	3.7	.1	.9	7.5	.5
20			272	23	24.	58		68.	28	48.	33	127	144	58	23	21	31
11	4	0.0	.8	9.0	4	.5	9.1	4	.7	8	2.8	7.8	3.7	.1	.3	7.5	.5

Table 3.3. Available standardized indices (CPUE) of relative abundance for blue marlin in the Pacific Ocean, where the highlights indicate indices were used and fitted in the SS3 base-case assessment model based on the correlation and down-weighting analyses. See Table 3.1 for fishery numbers and acronyms.

Index	Fishery Description	Time series	Reference
S1	JPNEarlyLL (F1)	1975-1993	Kanaiwa *et al.* 2013
S2	JPNLateLL (F2)	1994-2011	
S3	HWLL (F7)	1995-2011	Walsh *et al.* 2013
S4	TWNLL (early) (F10)	1971-1978	Sun *et al.* 2013a
S5	TWNLL (mid) (F10)	1979-1999	
S6	TWNLL (late) (F10)	2000-2011	

Table 3.4. Blue marlin annual abundance indices developed for the SS3 base-case model. Units are number of fish per 1,000 hooks for all longline indices. Main season refers to annual quarters where 1 = Jan-Mar, 2 = Apr-June, 3 = July-Sept, and 4 = Oct-Dec.

Index	JPNEarlyLL	JPNLateLL		HWLL	TWNLL	
	S1	S2	S3	S4	S5	S6
Main Season	1	1	3	1	1	1
1971				0.054		
1972				0.058		
1973				0.059		
1974				0.056		
1975	0.3330			0.053		
1976	0.3295			0.062		
1977	0.2474			0.051		
1978	0.3993			0.053		
1979	0.4565				0.158	
1980	0.4682				0.131	
1981	0.5483				0.136	
1982	0.5462				0.124	
1983	0.4389				0.121	
1984	0.6967				0.129	
1985	0.4762				0.145	
1986	0.4919				0.119	
1987	0.4822				0.104	
1988	0.4593				0.112	
1989	0.4760				0.119	
1990	0.4626				0.106	
1991	0.4433				0.131	
1992	0.4535				0.083	
1993	0.5674				0.122	
1994		4.296			0.125	
1995		5.040	0.639		0.089	
1996		2.664	0.660		0.091	
1997		3.959	0.569		0.081	
1998		3.619	0.559		0.078	
1999		2.883	0.229		0.096	
2000		3.104	0.515			0.203
2001		2.702	0.385			0.220
2002		2.556	0.230			0.187
2003		3.033	0.311			0.253
2004		3.560	0.267			0.246
2005		3.300	0.207			0.312
2006		3.375	0.300			0.261
2007		3.027	0.133			0.243
2008		3.037	0.202			0.210
2009		3.691	0.200			0.211

2010	3.602	0.153	0.265
2011	2.972	0.187	0.224

Table 4.1. Key life history, recruitment parameters, and selectivity parameters used in the population dynamics model. The Estimated column defines if the parameters were estimated within the dynamics model, fixed at a specific value or iteratively re-scaled to the models estimate.

Parameter (unit)	Value	Estimated
natural mortality (*M*, age-specific^{-yr})	female: 0.42-0.22 male: 0.42-0.37	fixed
length_at_1 yr (EFL cm)	female: 144 male: 144	fixed
length_at_26 yr (EFL cm)	female: 304.178 male: 226	fixed
VonBert_*K*	female: 0.107 male: 0.211	fixed
$w=aL^b$ (kg)	female: 1.844E-05, 2.956 male: 1.37E-05, 2.975	fixed
Size at 50-percent-maturity (EFL cm)	female: 179.76	fixed
spawner-recruit steepness (*h*)	0.87	fixed
unfished Recruitment Ln(R_0)		estimated
standard deviation of recruitment	0.32	re-scaled
initial age structure	5 years	estimated
recruitment deviations	1971-2010	estimated
selectivity		estimated
catchability		estimated

Table 4.2. Results of the test of seasonality of recruitment. Column headings are total likelihood followed by the change in likelihood from season 2 for each length composition component. A negative value indicates better fit (highlighted in green), and a positive value indicates worse fit (highlighted in red).

	-Log-likelihood			
Season / Fishery	**1**	**2**	**3**	**4**
JPNEarlyLL	25.7	0.0	48.5	56.9
JPNLateLL	23.7	0.0	35.7	54.9
JPNDRIFT	0.1	0.0	0.1	0.1
HWLL	1.2	0.0	34.8	27.0
TWNLL	3.5	0.0	1.9	3.5
OthLL	5.6	0.0	12.3	14.6
PYFLL	-0.2	0.0	-2.4	-3.7
EPOPS	0.3	0.0	3.0	2.8
Total	1078.6	1023.1	1152.6	1173.1

Table 4.3. Results of the test of consistency between CPUE indices based on downweight (DW) analyses. Column headings are the change in likelihood from the model where all the indices were fitted for each index component. The blanks indicate very little likelihood contributions (weight=0.001) to these components. A negative value indicates better fit (highlighted in green), and a positive value indicates worse fit (highlighted in red).

Indices DW	S1	S2	S3	S4	S5	S6
S1 &S2			-13.2	0.0	-0.6	6.6
S3	0.0	-11.6		0.0	-0.1	-4.0
S4, S5, S6	0.0	5.4	-5.1			

Table 4.4. Correlation matrix between CPUE indices. Lower diagonal values are correlation coefficient and upper diagonal values indicate number of overlapped years.

	S1	S2	S3	S4	S5	S6
S1 (1975-1993)		0	0	4	15	0
S2 (1994-2011)	NA		17	0	6	12
S3 (1995-2011)	NA	0.36		0	5	12
S4 (1971-1978)	0.20	NA	NA		0	0
S5 (1979-1999)	0.15	0.15	-0.48	NA		0
S6 (2000-2011)	NA	0.46	-0.27	NA	NA	

Table 4.5. Sensitivity analyses of the Pacific blue marlin base-case model.

Data

- Alternative stock trend: fit to JPNEarlyLL and HWLL CPUE time series (S1, S3);
- Drop weight compositions for JPNDRIFT fishery (F4);
- Drop length compositions for PYFLL fishery (F13);

Biological assumptions

- Natural mortality rate (*M*):
    - low M schedule with adult *M*=0.12 females and adult *M*=0.27 for males, where juvenile *M* scaled as the base case;
    -
    - high M schedule with adult *M*=0.32 females and adult *M*=0.47 for males, juvenile *M* scaled as the base case;
- Stock-recruitment steepness (*h*): *h*=0.65, 0.75, and 0.95;
- Growth curve:
    - Smaller fish: Length at maximum reference age to be L_{max}= 205. Use a Brody growth coefficient K that is consistent with the size-at-age 1 in the base case;
    - Larger fish: Length at maximum reference age to be L_{max}= 225 cm. Use a Brody growth coefficient K that is consistent with the size-at-age 1 in the base case;
    - Use growth parameters for males from Chang *et al.* (2013):
- Size-at-50-percent maturity ($L_{50\%}$): $L_{50\%}$=197.736 cm and $L_{50\%}$=161.784 cm.

Table 5.1. Results of the profile over fixed values of ln(R_0) from base case model. Values represent the negative log-likelihood for each component minus the minimum component negative log-likelihood across profile. Changes in likelihood across different values of R_0 can be thought of as how much information there is on scaling from that likelihood component. A value of zero indicates that the data component fit best at that fixed ln(R_0) value. Value in parenthesis indicates the estimate of ln(R_0) when freely estimated. Data components designated by (F) are fleet composition data, and those by (S) are CPUE series treated as indices of relative abundance. Values are rounded to nearest integer.

Estimate of ln(R_0)	ln(R_0)	Composition data components								Index data components					
		F1	F2	F4	F7	F10	F12	F13	F14	S1	S2	S3	S4	S5	S6
	6.5	8	7	0	3	0	0	2	1	2	7	0	0	2	1
	6.6	4	4	0	3	0	0	1	1	0	6	0	0	1	1
	6.7	0	1	0	3	0	1	1	0	0	4	0	0	1	0
	6.8	0	0	0	2	0	2	0	0	1	2	0	0	1	0
(6.86)	6.9	1	1	0	1	0	3	0	1	1	1	0	0	0	0
	7.0	1	3	1	0	1	4	0	2	2	0	0	0	0	0
	7.1	1	4	1	0	1	5	1	3	2	0	0	0	0	0

Table 5.2. Analytical estimates of catchability for CPUE indices, inputted mean variance by data component (input CV+VarAdj) and model estimated mean variance for the base case where root mean squared error (RMSE) is a measure of the statistical fit to the indices of abundance. Smaller RMSE indicates better fit. The italics in parentheses indicate the indices were not fitted into the model.

Index	Fishery Description	no of years	Catchability (q)	Input CV	VarAdj	Input + VarAdj	RMSE for base case
S1	JPNEarlyLL (F1)	19	0.000528	0.03	0.11	0.14	0.14
S2	JPNLateLL (F2)	18	0.003776	0.02	0.12	0.14	0.16
S3	HWLL (F7)	17	*(0.000394)*	0.07	0.07	0.14	*(0.48)*
S4	TWNLL (early) (F10)	8	6.69E-05	0.64	0	0.64	0.09
S5	TWNLL (mid) (F10)	21	0.000142	0.45	0	0.45	0.21
S6	TWNLL (late) (F10)	12	0.000363	0.14	0	0.14	0.17

Table 5.3. Input mean variance by data component (Mean *N* input) and model estimated mean variance (Mean *effN*) where effective sample size (*effN*) is the models estimate of the statistical precision. Larger *effN* indicates a better fit.

Fishery	N of observations	Mean *N* input	Mean *effN* for base case
F1	92	30.00	249.59
F2	72	30.00	122.38
F4	19	30.00	121.68
F7	59	14.50	61.35
F10	23	30.00	408.63
F12	70	26.49	85.14
F13	40	6.95	19.38
F14	82	30.00	209.53

Table 5.4. List of selectivity parameter values estimated in the base-case model for the Pacific blue marlin assessment.

Parameter	Value	StDev	Estimated
Size-based selectivity for F1			
Gradient at the first node	0.08	0.01	X
Gradient at the last node	-0.23	0.07	X
Node 1 (80 cm)	-2.59	0.35	X
Node 2 (145 cm)	3.59	0.07	X
Node 3 (190 cm)	3.02	N.A.	fixed at previous estimate
Node 4 (320 cm)	-4.84	2.37	X
Size-based selectivity for F2			
Beginning size for the plateau	160.25	1.69	X
Width of plateau	-0.78	0.62	X
Ascending width	6.31	0.14	X
Descending width	9.28	0.98	X
Size-based selectivity for F4			
Beginning size for the plateau	229.27	2.30	X
Width of plateau	-12.40	86.02	X
Ascending width	6.45	0.13	X
Descending width	5.88	0.33	X
Size-based selectivity for F7			
Gradient at the first node	0.07	0.01	X
Gradient at the last node	0	N.A.	fixed
Node 1 (80 cm)	-3.58	32.37	X
Node 2 (160 cm)	1.64	32.37	X
Node 3 (200 cm)	0.78	32.37	X
Size-based selectivity for F10			
Beginning size for the plateau	174.63	3.55	X
Width of plateau	-11.83	91.78	X
Ascending width	6.98	0.19	X
Descending width	8.60	0.43	X
Size-based selectivity for F12			
Beginning size for the plateau	172.63	2.00	X
Width of plateau	-10.85	102.17	X
Ascending width	6.49	0.14	X
Descending width	10.09	0.60	X
Size-based selectivity for F13			
Time block for 1996-2002			
Beginning size for the plateau	92.87	0.62	X
Width of plateau	-12.86	81.40	X
Ascending width	-4.55	25.84	X
Descending width	5.48	0.17	X
Time block for 2003-2011			
Beginning size for the plateau	181.84	5.86	X
Width of plateau	2.97	1.36	X

Ascending width	6.87	0.32	X
Descending width	1.41	106.48	X
Size-based selectivity for F14			
Beginning size for the plateau	227.02	2.36	X
Width of plateau	-11.86	91.49	X
Ascending width	7.25	0.07	X
Descending width	8.42	0.32	X

Table 5.5. Time series of estimates of age 1+ biomass, female spawning stock biomass (*SSB*), recruitment (*R*), fishing mortality (*F*), spawning potential ratio (*SPR*), and associated relative quantity from the base-case model for the Pacific blue marlin assessment.

Year	Age 1+ biomass (t)	Female spawning stock biomass (*SSB*, in t)	Relative S*SB* to virgin *SSB* (*SB/SB*$_0$)	Relative SSB to the *MSY* level (*SSB/Sbmsy*)	Age 0 recruitment (1,000)	Fishing mortality (*F*, Average age 2+)	Relative *F* to the *MSY* level (*F/F*$_{msy}$)	Spawning potential ratio (*SPR*)	Relative fishing intensity to the *MSY* level (*(1-SPR)/(1-SPR)*$_{msy}$)
1971	128228	67223.9	0.51	3.46	847.39	0.089	0.28	0.560	0.54
1972	126441	64970.3	0.49	3.34	806.42	0.104	0.32	0.508	0.60
1973	125202	62840.3	0.48	3.23	798.28	0.120	0.37	0.464	0.65
1974	122197	60704.7	0.46	3.12	508.00	0.115	0.36	0.480	0.63
1975	115545	59190.7	0.45	3.05	595.63	0.114	0.35	0.479	0.64
1976	108231	56388.6	0.43	2.90	625.33	0.132	0.41	0.429	0.70
1977	102154	52452.3	0.40	2.70	1020.97	0.146	0.45	0.391	0.74
1978	103013	48516.4	0.37	2.50	912.00	0.161	0.50	0.361	0.78
1979	105431	46697.3	0.35	2.40	1063.16	0.168	0.52	0.358	0.78
1980	108424	45429.6	0.35	2.34	861.21	0.166	0.52	0.360	0.78
1981	109461	45870.6	0.35	2.36	912.49	0.175	0.54	0.346	0.80
1982	108171	45342.1	0.34	2.33	1163.02	0.186	0.58	0.328	0.82
1983	110827	44657.1	0.34	2.30	1000.81	0.168	0.52	0.358	0.78
198	11469	45491.	0.35	2.34	860.05	0.194	0.60	0.321	0.83

4	6	1							
1985	111398	45907.3	0.35	2.36	841.97	0.156	0.49	0.385	0.75
1986	110138	46419.3	0.35	2.39	1055.99	0.188	0.58	0.329	0.82
1987	109619	44906.3	0.34	2.31	1055.66	0.259	0.80	0.233	0.93
1988	105767	41604.9	0.32	2.14	1050.18	0.224	0.70	0.272	0.89
1989	105983	41289.3	0.31	2.12	949.33	0.190	0.59	0.323	0.83
1990	107155	42069	0.32	2.16	1022.74	0.167	0.52	0.363	0.78
1991	110035	43297.2	0.33	2.23	987.13	0.176	0.55	0.349	0.79
1992	111717	43974.2	0.33	2.26	950.13	0.203	0.63	0.302	0.85
1993	109563	43561.4	0.33	2.24	907.48	0.228	0.71	0.266	0.89
1994	104508	41676.9	0.32	2.14	810.39	0.234	0.73	0.254	0.91
1995	98429.4	38886.2	0.30	2.00	888.77	0.264	0.82	0.220	0.95
1996	91817.3	36193.8	0.27	1.86	845.18	0.176	0.54	0.330	0.82
1997	93541.6	36573.6	0.28	1.88	994.74	0.198	0.61	0.299	0.85
1998	95273.5	35785.9	0.27	1.84	579.93	0.201	0.62	0.294	0.86
1999	91717.9	36200.8	0.28	1.86	830.63	0.196	0.61	0.296	0.86
2000	88202.5	34689.8	0.26	1.78	890.59	0.256	0.79	0.235	0.93
2001	85703.4	32093.3	0.24	1.65	809.60	0.301	0.93	0.194	0.98
2002	80699.1	29092.3	0.22	1.50	874.90	0.321	1.00	0.181	1.00
2003	76674.6	25971.8	0.20	1.34	1026.16	0.382	1.18	0.148	1.04
2004	74479.1	23190.4	0.18	1.19	785.03	0.328	1.02	0.176	1.00
2005	73811.5	22730.4	0.17	1.17	913.93	0.362	1.12	0.155	1.03
2006	70944.7	21573.7	0.16	1.11	888.59	0.325	1.01	0.180	1.00
200	72102	21701	0.16	1.12	718.14	0.273	0.85	0.215	0.96

7	.4								
2008	72452.5	23002.5	0.17	1.18	689.36	0.261	0.81	0.228	0.94
2009	70694.4	23486.4	0.18	1.21	1177.36	0.279	0.87	0.216	0.96
2010	76089.4	22987.6	0.17	1.18	705.21	0.271	0.84	0.222	0.95
2011	78662.5	24989.8	0.19	1.29	824.59	0.232	0.72	0.253	0.91

Table 5.6. Estimated biological reference points derived from the base case model for the Pacific blue marlin assessment where “*MSY*” indicates maximum sustainable yield-based reference points, “*20%*” indicates reference points corresponding to a spawning potential ratio for 20%, *F* is the instantaneous annual fishing mortality rate, *SPR* is the annual female spawning potential ratio, and *SSB* is female spawning stock biomass.

Reference point	**Estimate**
$F_{2009\text{-}2011}$ (age 2+)	0.26
$SPR_{2009\text{-}2011}$	0.23
SSB_{2011}	24990 t
F_{MSY} (age 2+)	0.32
$F_{20\%}$ (age 2+)	0.29
SPR_{MSY}	0.18
SSB_{MSY}	19437 t
$SSB_{20\%}$	26324 t
MSY	19459 t

Table 5.7. Projected trajectory of female spawning stock biomass (SSB in t) for alternative harvest scenarios. Fishing intensity ($F_{X\%}$) alternatives are based on 16% (average 2003-2005), 18% (MSY level), 23% (average 2009-2011 defined as current), and 30%. Green blocks indicate the projected SSB is greater than MSY level (SSB_{MSY}=19,437 t).

Run	Harvest scenario	Beverton-Holt spawner-recruit relation (SR)								
		2012	2013	2014	2015	2016	2017	2018	2019	2020
1	$F_{2003-2005} = F_{16\%}$	25269	23193	21518	20263	19354	18689	18195	17823	17540
2	$F_{MSY} = F_{18\%}$	25490	24142	22996	22106	21452	20968	20605	20331	20121
3	$F_{2009-2011} = F_{23\%}$	25924	26112	26169	26177	26188	26200	26212	26221	26229
4	$F_{30\%}$	26368	28264	29845	31139	32207	33078	33782	34347	34799

Table 5.8. Projected trajectory of yield (t) for alternative harvest scenarios. Fishing intensity ($F_{X\%}$) alternatives are based on 16% (average 2003-2005), 18% (MSY level), 23% (average 2009-2011 defined as current), and 30%. MSY=19459 t.

Run	Harvest scenario	Beverton-Holt spawner-recruit relation (SR)								
		2012	2013	2014	2015	2016	2017	2018	2019	2020
1	$F_{2003-2005} = F_{16\%}$	25374	23546	22353	21548	20985	20576	20272	20042	19865
2	$F_{MSY} = F_{18\%}$	23296	22173	21412	20887	20519	20252	20055	19906	19793
3	$F_{2009-2011} = F_{23\%}$	19235	19154	19106	19078	19066	19061	19060	19061	19062
4	$F_{30\%}$	14900	15542	16048	16442	16749	16988	17174	17318	17430

FIGURES

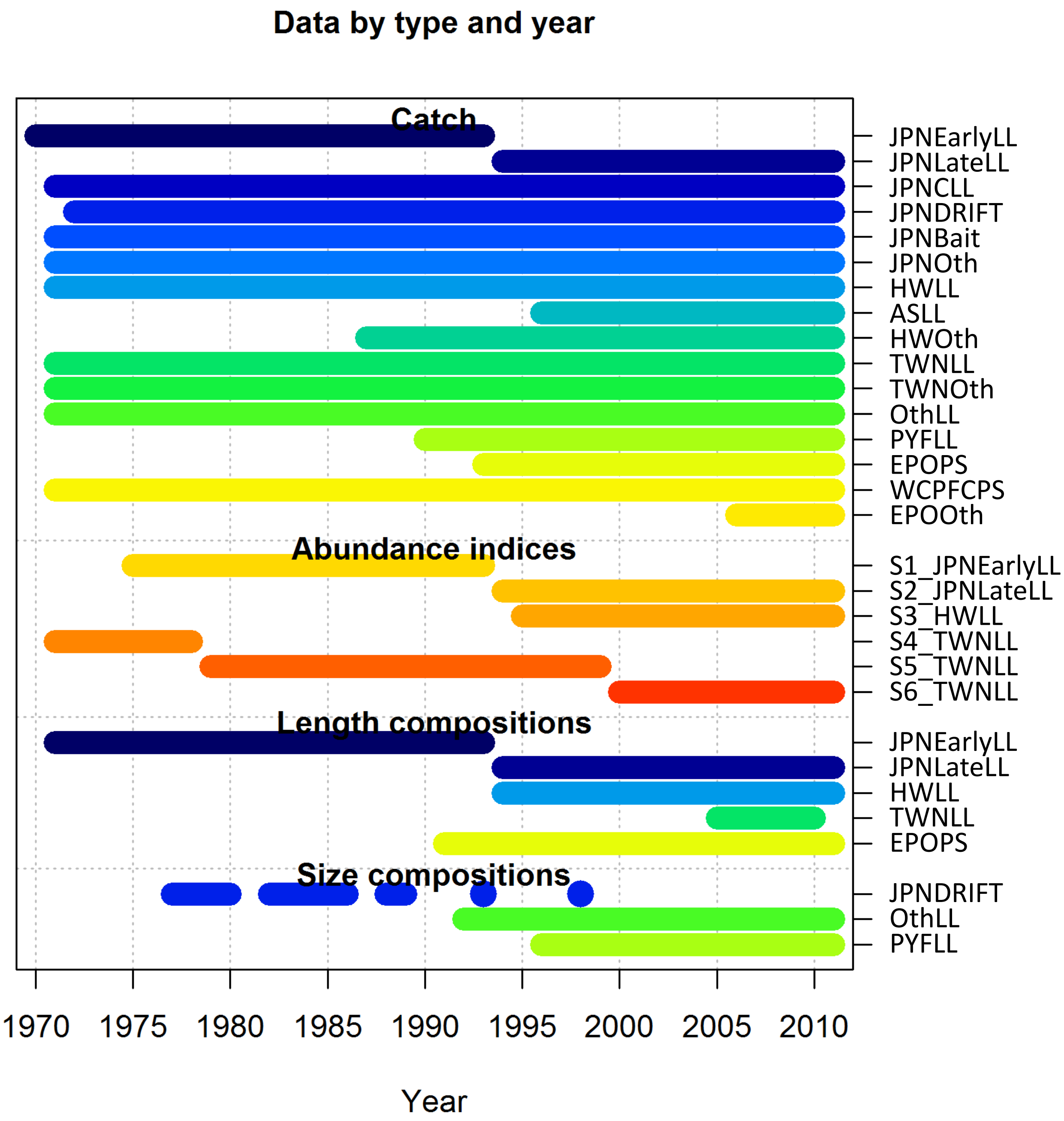


Figure 3.1. Available temporal coverage and sources of catch, CPUE and length/weight composition for the Pacific blue marlin.

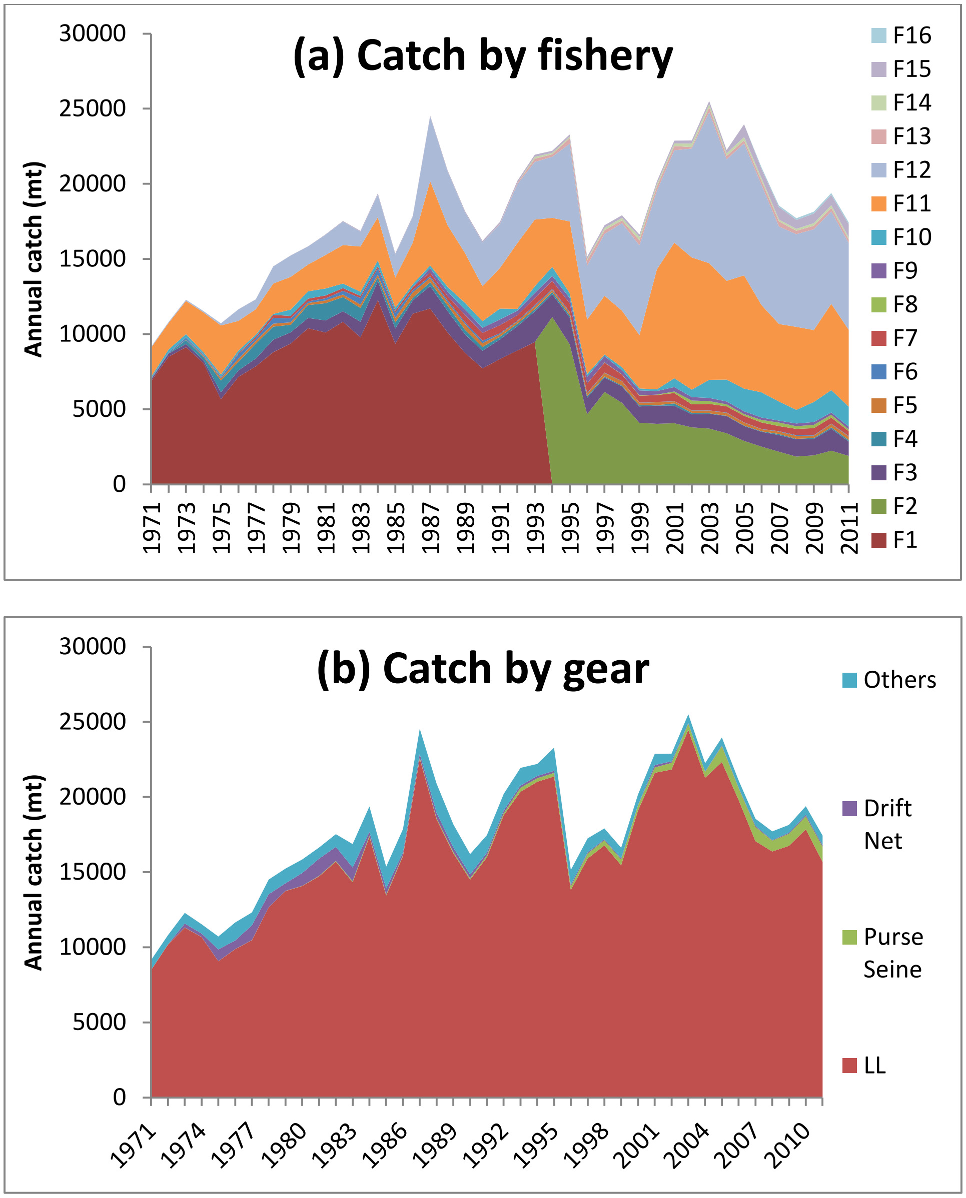


Figure 3.2. Catch (t) of Pacific blue marlin by year and fishery (upper panel) and by year and gear (lower panel). Fisheries with catch reported in numbers were converted into t inside the stock assessment model. The Other category in (b) refers to miscellaneous gears including bait, net, trap, and coastal fisheries.

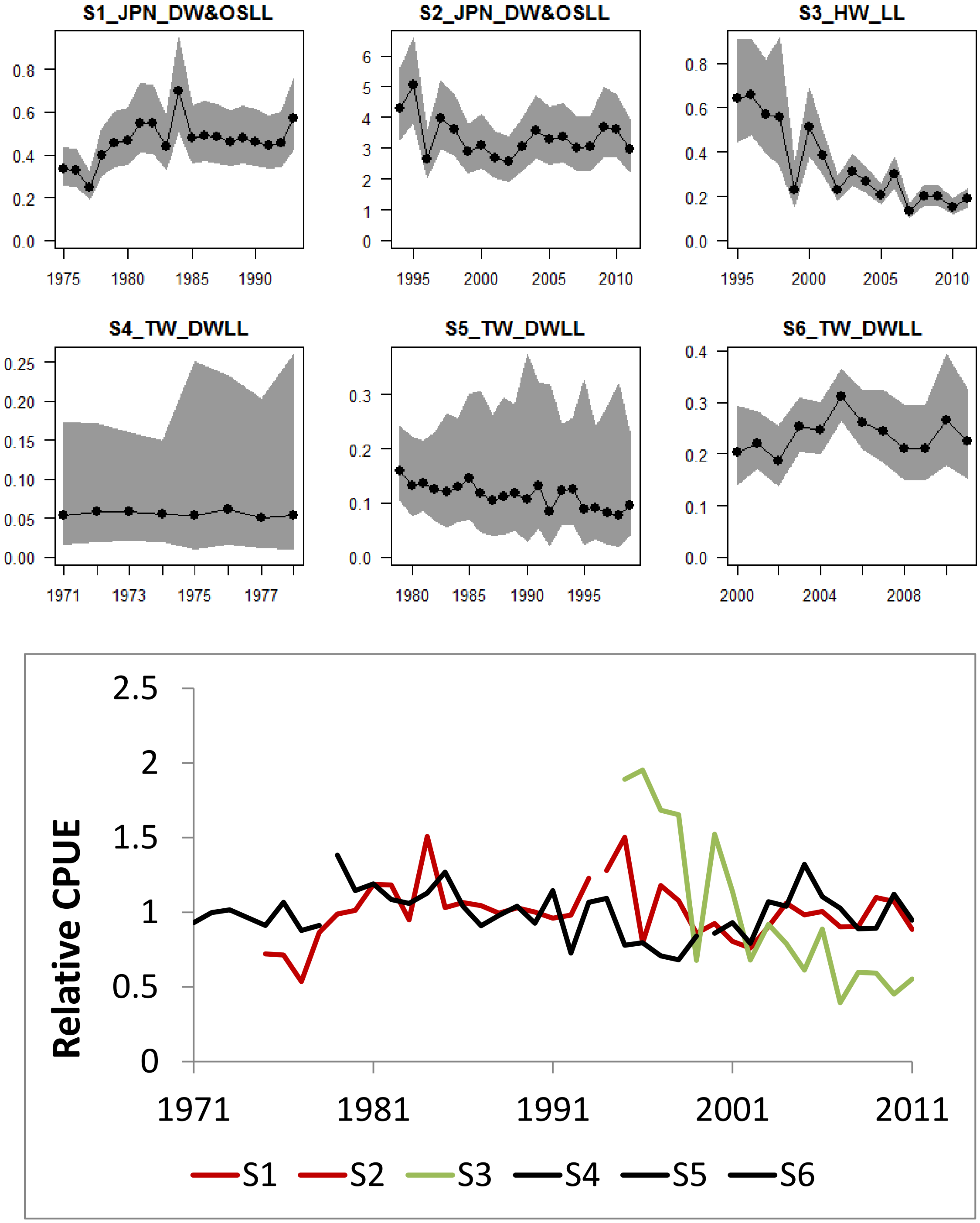


Figure 3.3. Plot of the observed CPUE by fishery. Upper panel present the individual index where the gray areas indicate the estimated 95% confidence intervals around the CPUE values used in the SS model. Lower panel present the relative CPUE where values are re-scaled by the mean of each index for comparison purposes.

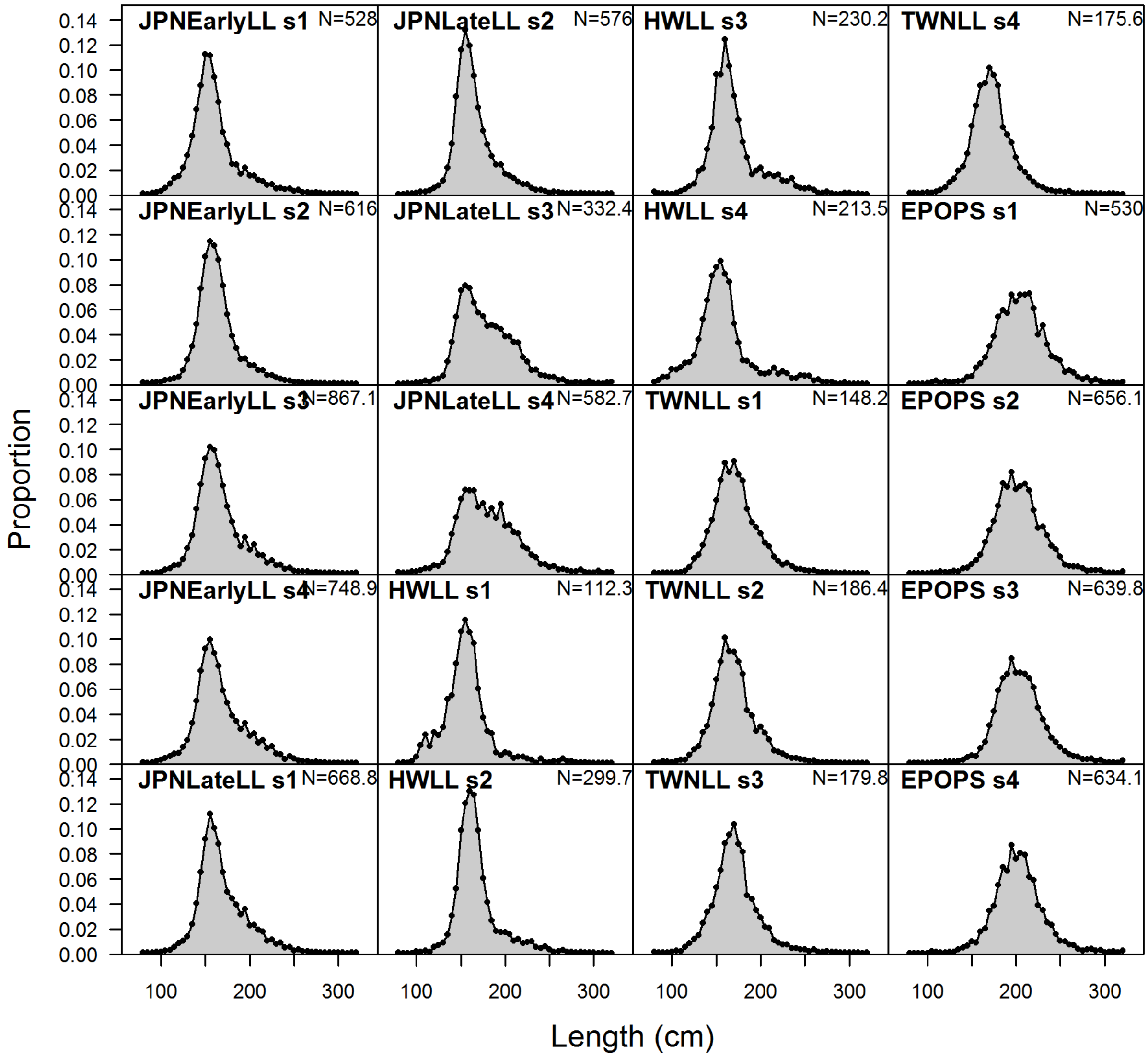


Figure 3.4.a. Observed proportion at length from fisheries F1, F2, F7, and F14. Samples were aggregated across year by fishery and season where N indicates input sample size.

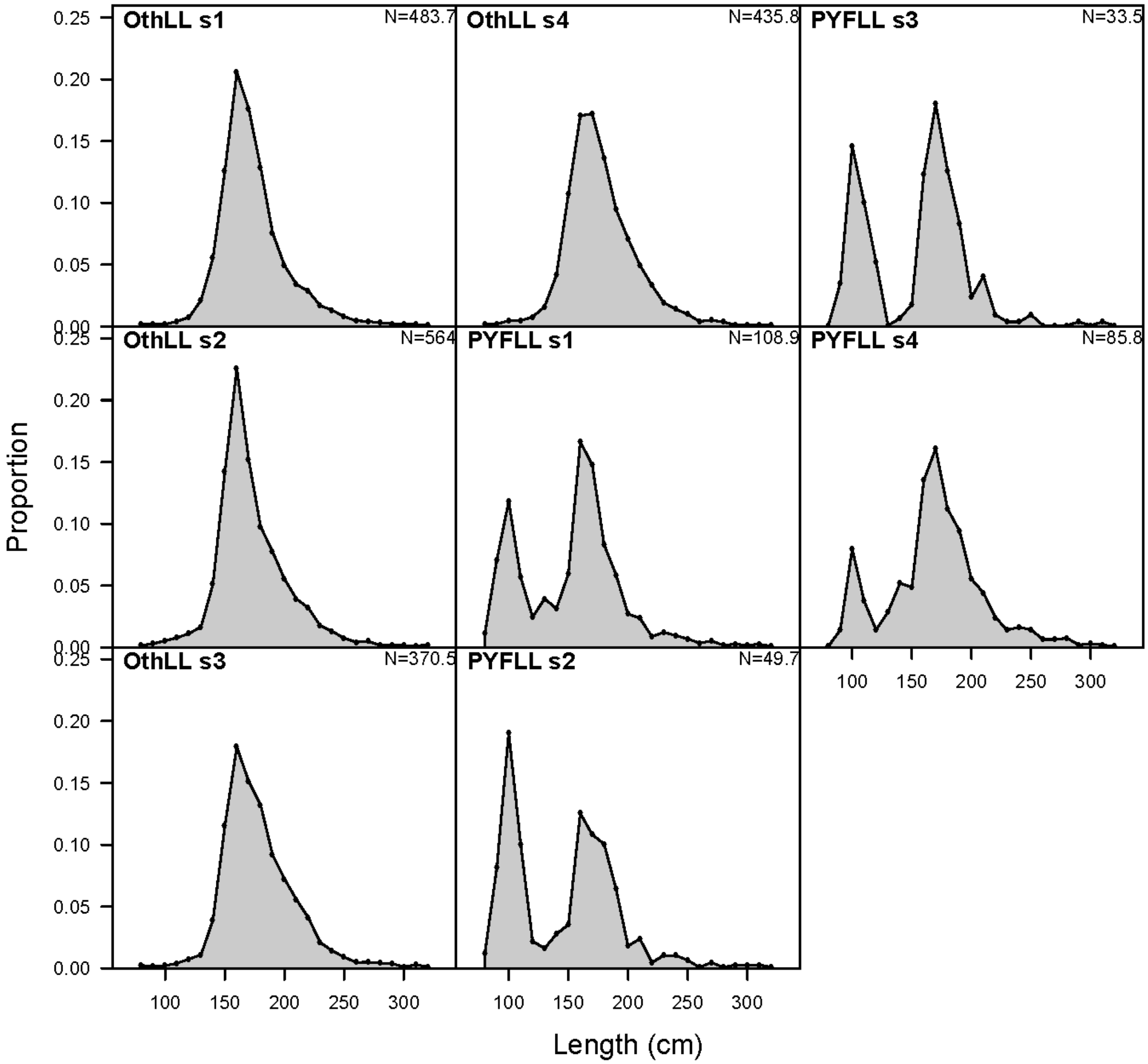


Figure 3.4.b. Observed proportion of fish at length from fisheries F12 and F13. Samples were aggregated across year by fishery and season.

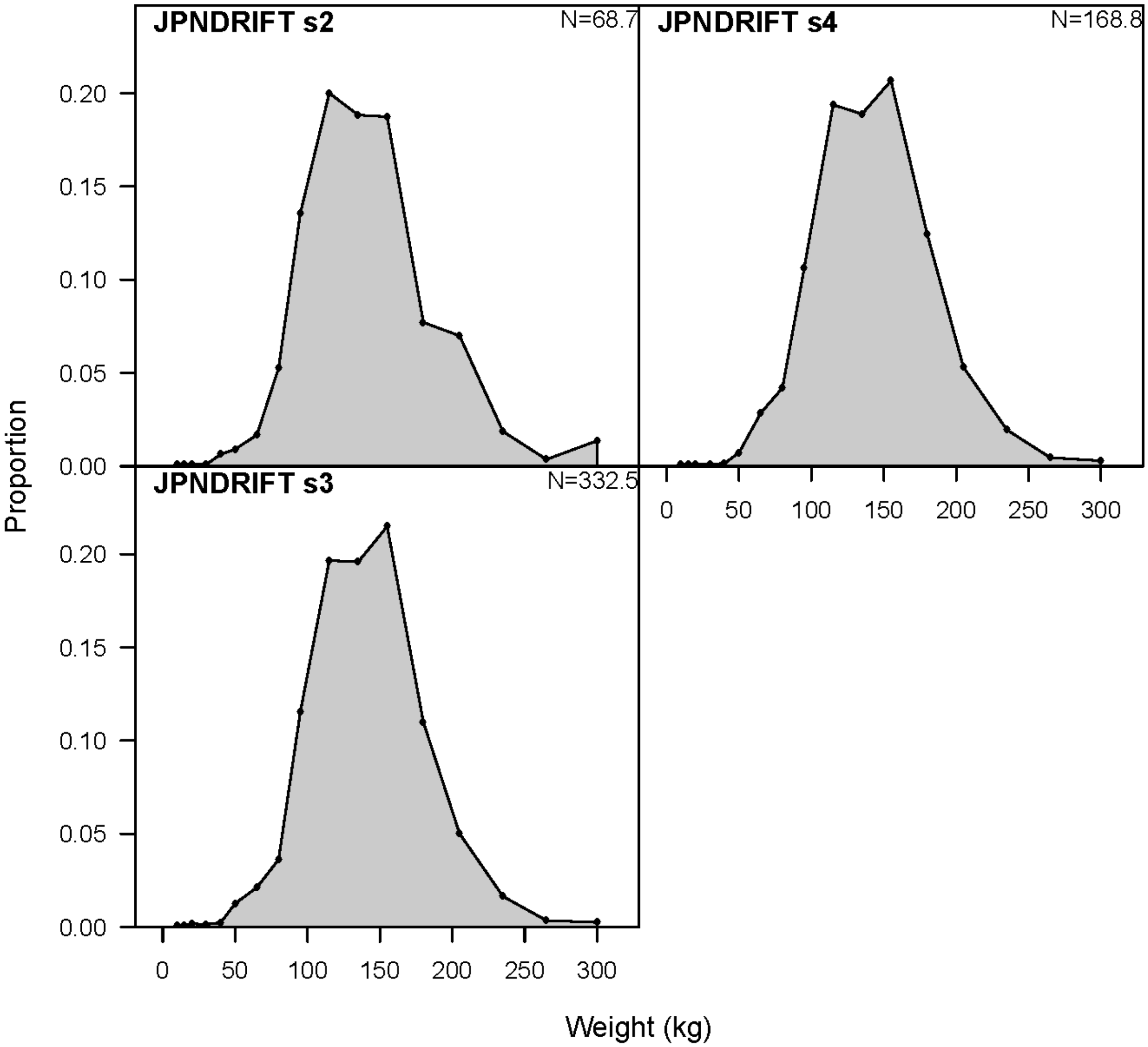


Figure 3.4.c. Observed proportion of fish at weight from fishery F4. Samples were aggregated across year by fishery and season.

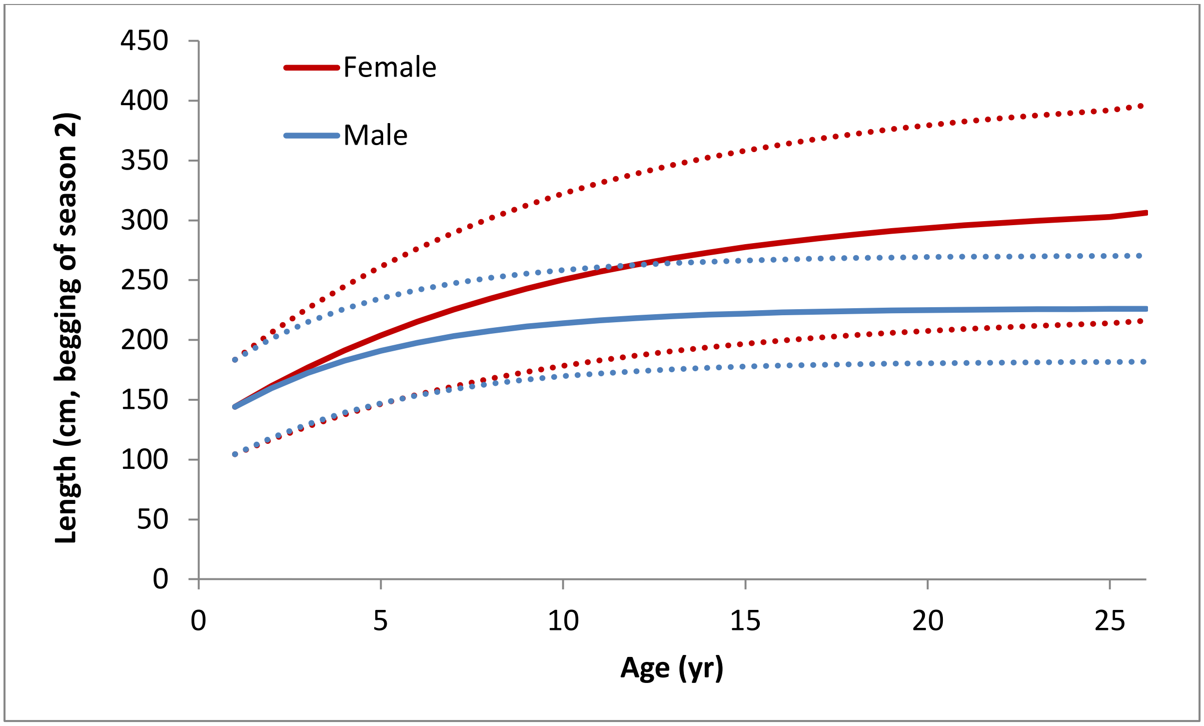


Figure 4.1. Plot of the WG length at age based on Shimose's otolith microstructure studies (2008, unpublished PhD dissertation) and meta-analyses from Chang *et al.* (2013) where red lines represent female and blue lines represent male. The dotted lines represent the inputted CV of length at age 1 and length at age 26 in the stock assessment model.

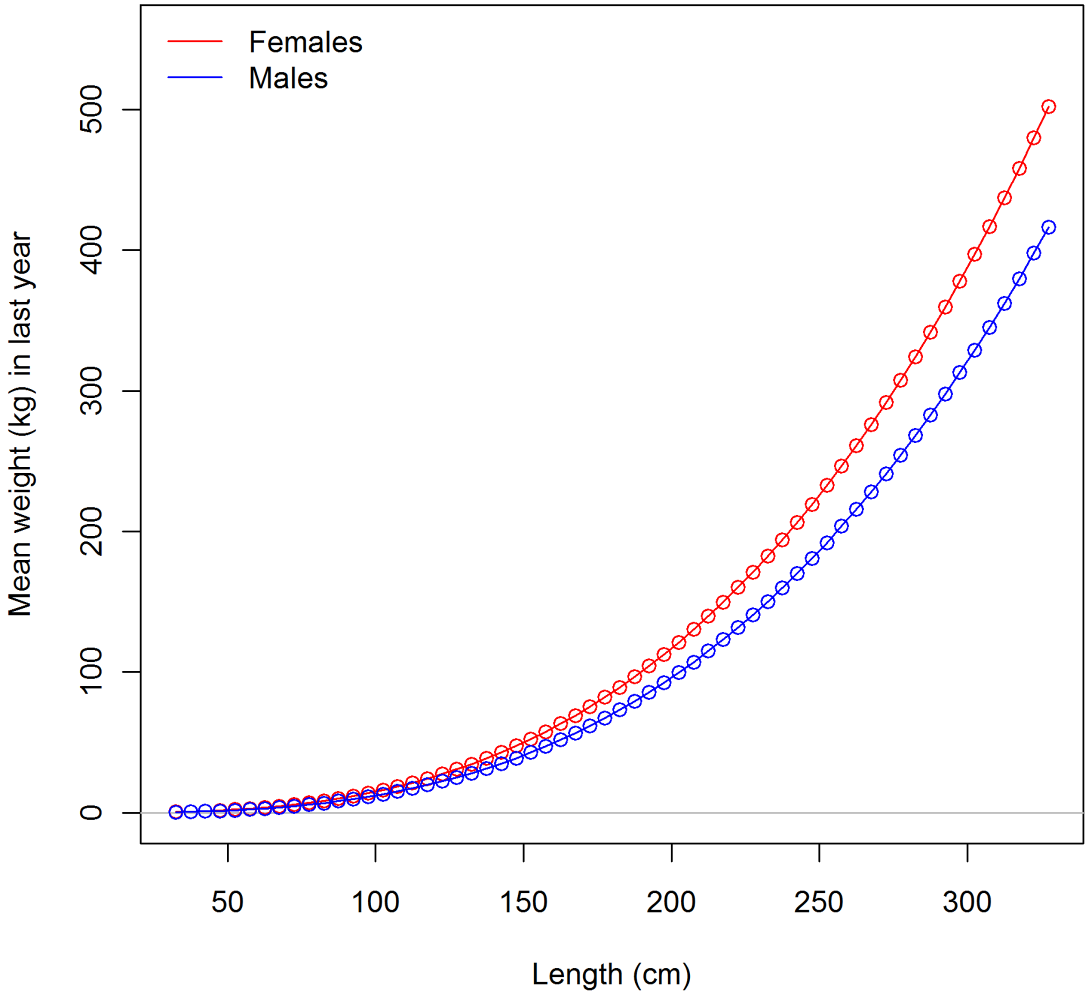


Figure 4.2. Weight at length used in the stock assessment model where red line represent female and blue line represent male.

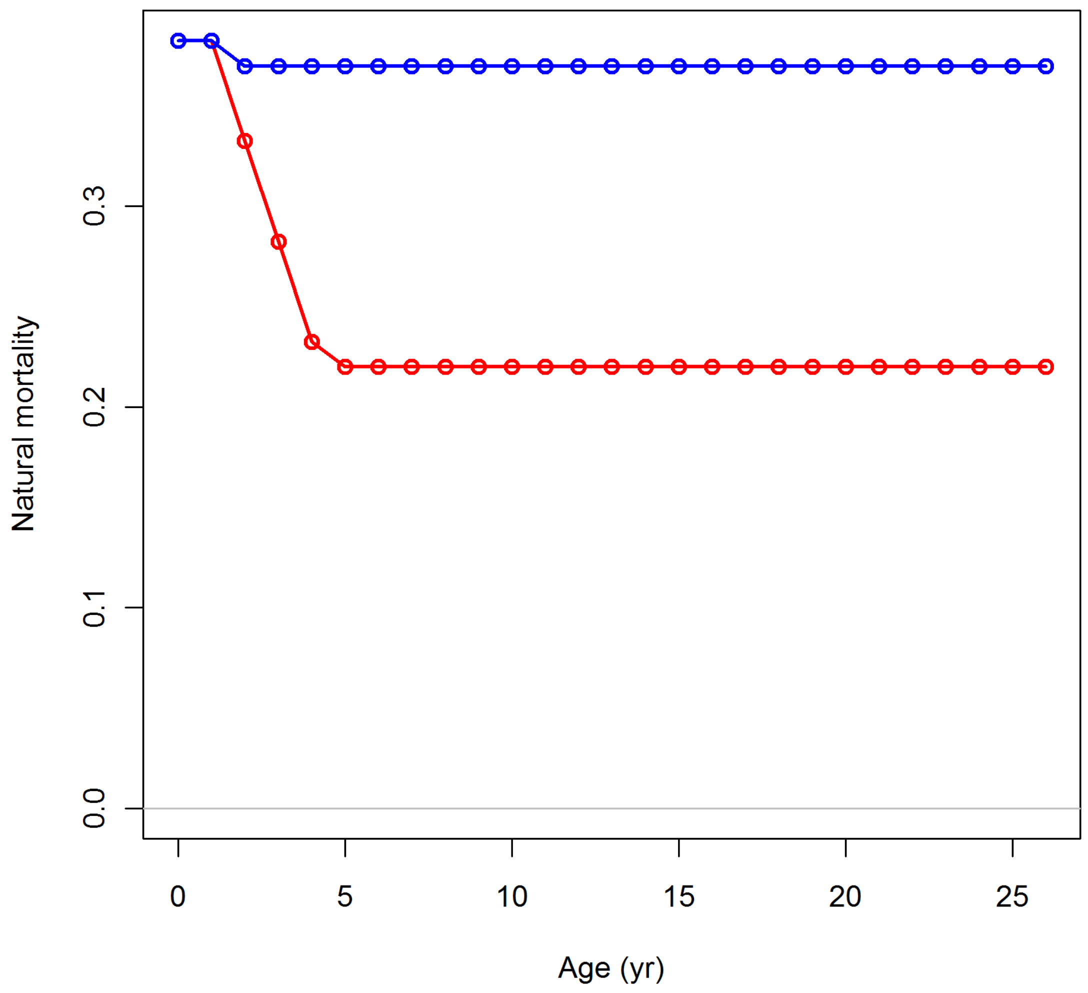


Figure 4.3. Natural mortality at age assumed in the population dynamics model where red line represent female and blue line represent male.

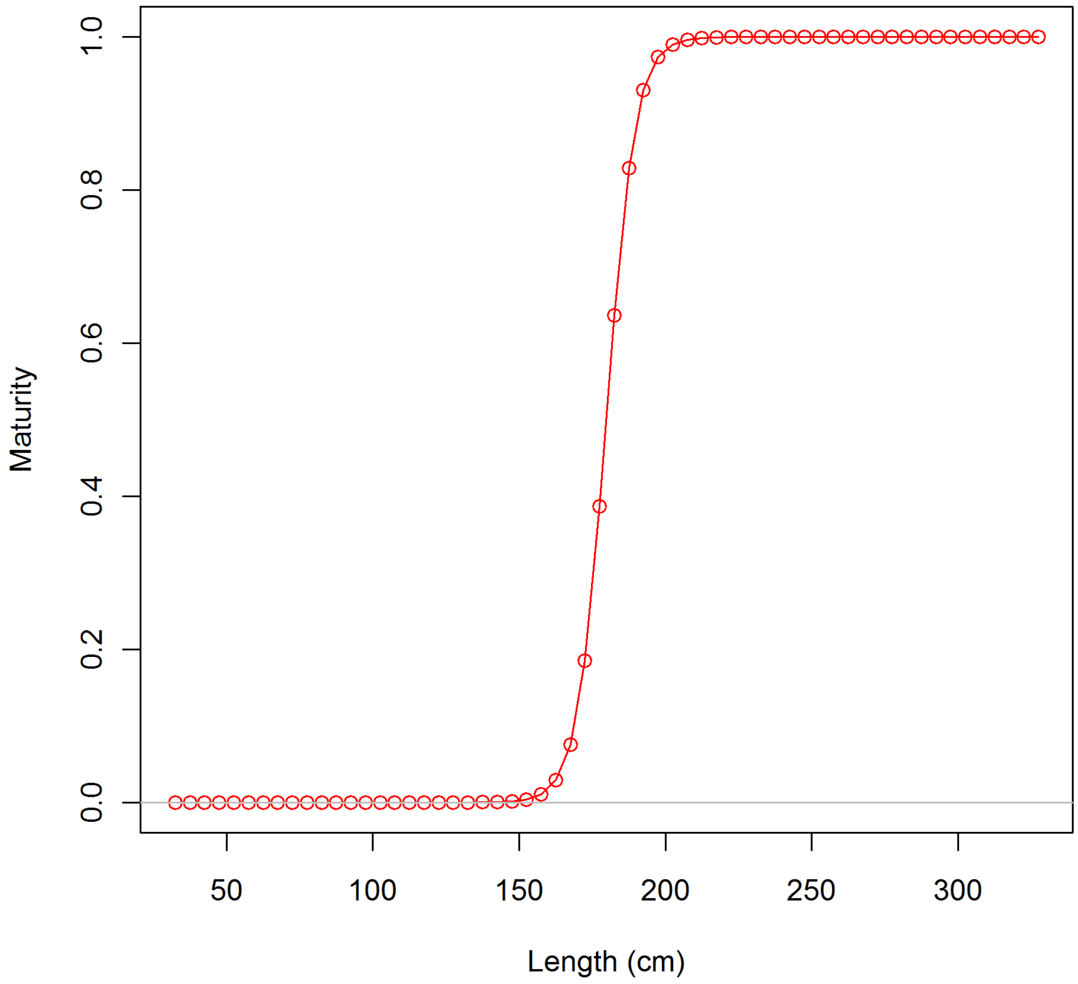


Figure 4.4. Maturity-at-length (eye fork length) for female Pacific blue marlin used in the stock assessment model where the size-at-50 percent-maturity was 179 cm.

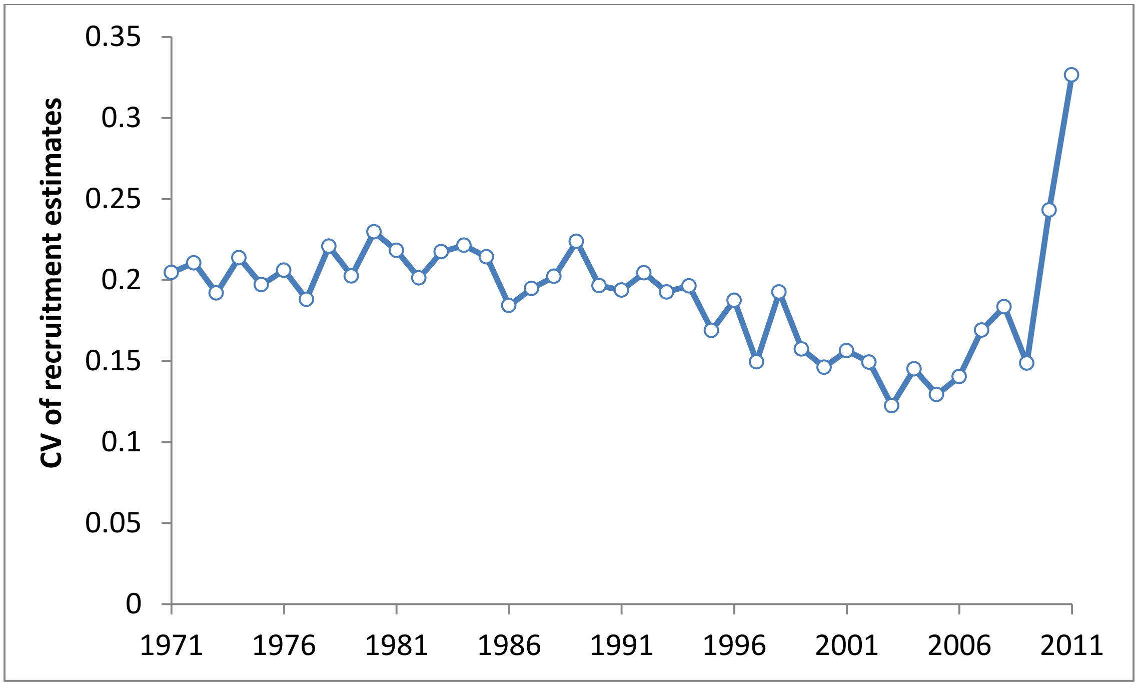


Figure 4.5. Coefficient of variation (CV) of estimated recruitment from 1971-2011.

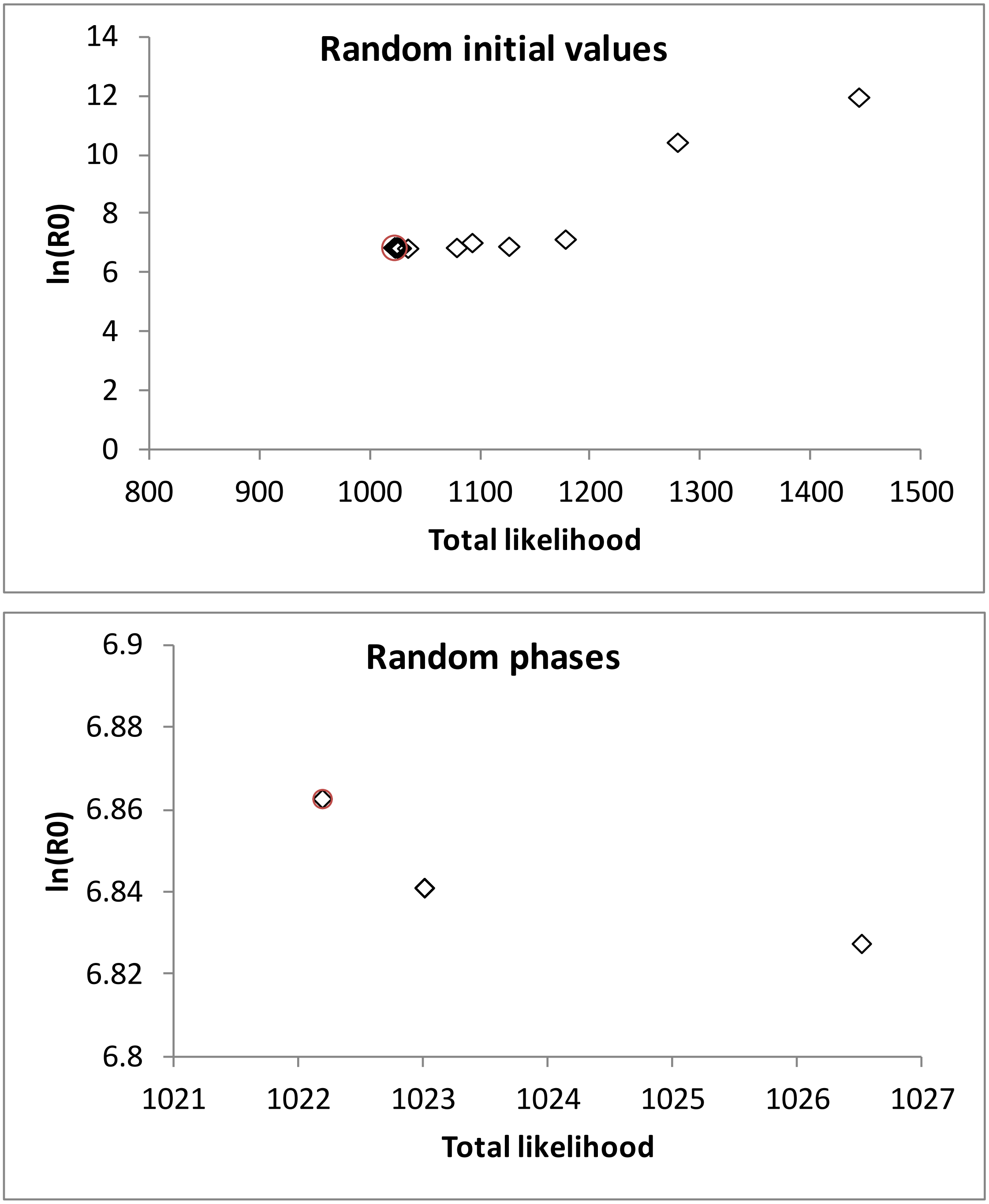
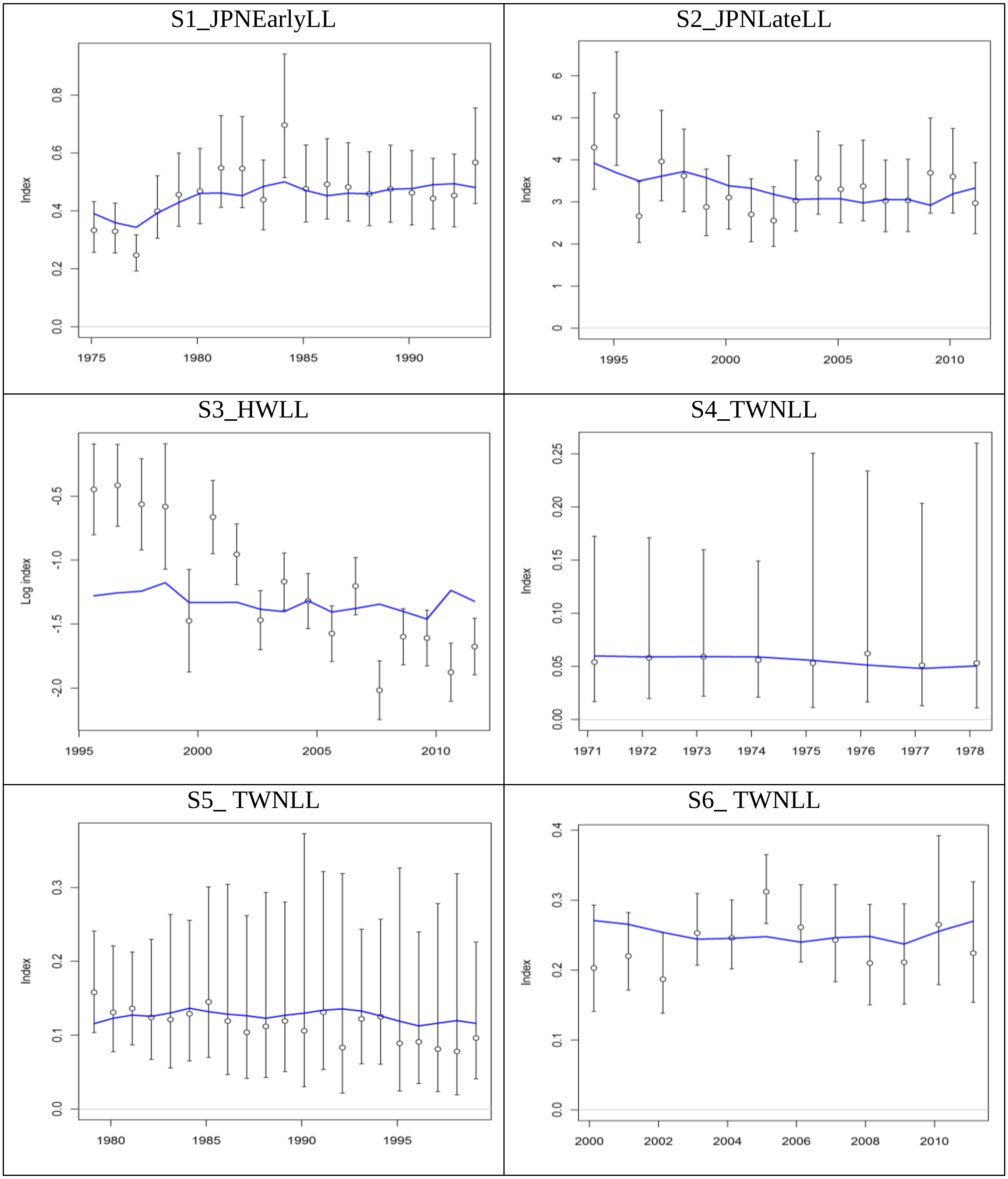


Figure 5.1. Plot of estimated ln(R_0) (y-axis) and total ending likelihood (x-axis) for randomization of starting values of the model (upper panel) and randomization of phases of the model (lower panel) for the base case model. Circle represents the base model and diamonds represent random changes of the model.


S1_JPNEarlyLL

S2_JPNLateLL

S3_HWLL

S4_TWNLL

S5_ TWNLL

S6_ TWNLL

Figure 5.2. Model fits (solid line) to standardized CPUE (open circle with$\pm 1.96\sigma$) used in the Pacific blue marlin stock assessment for the Japanese distant-water and offshore longline fisheries 1971-1993 (S1_JPNEarlyLL) and 1994-2011 (S2_JPNLateLL) and the Taiwanese distant-water longline fisheries 1967-1978 (S4_TWNLL), 1979-1999 (S5_TWNLL), and 2000-2011 (S6_TWNLL).

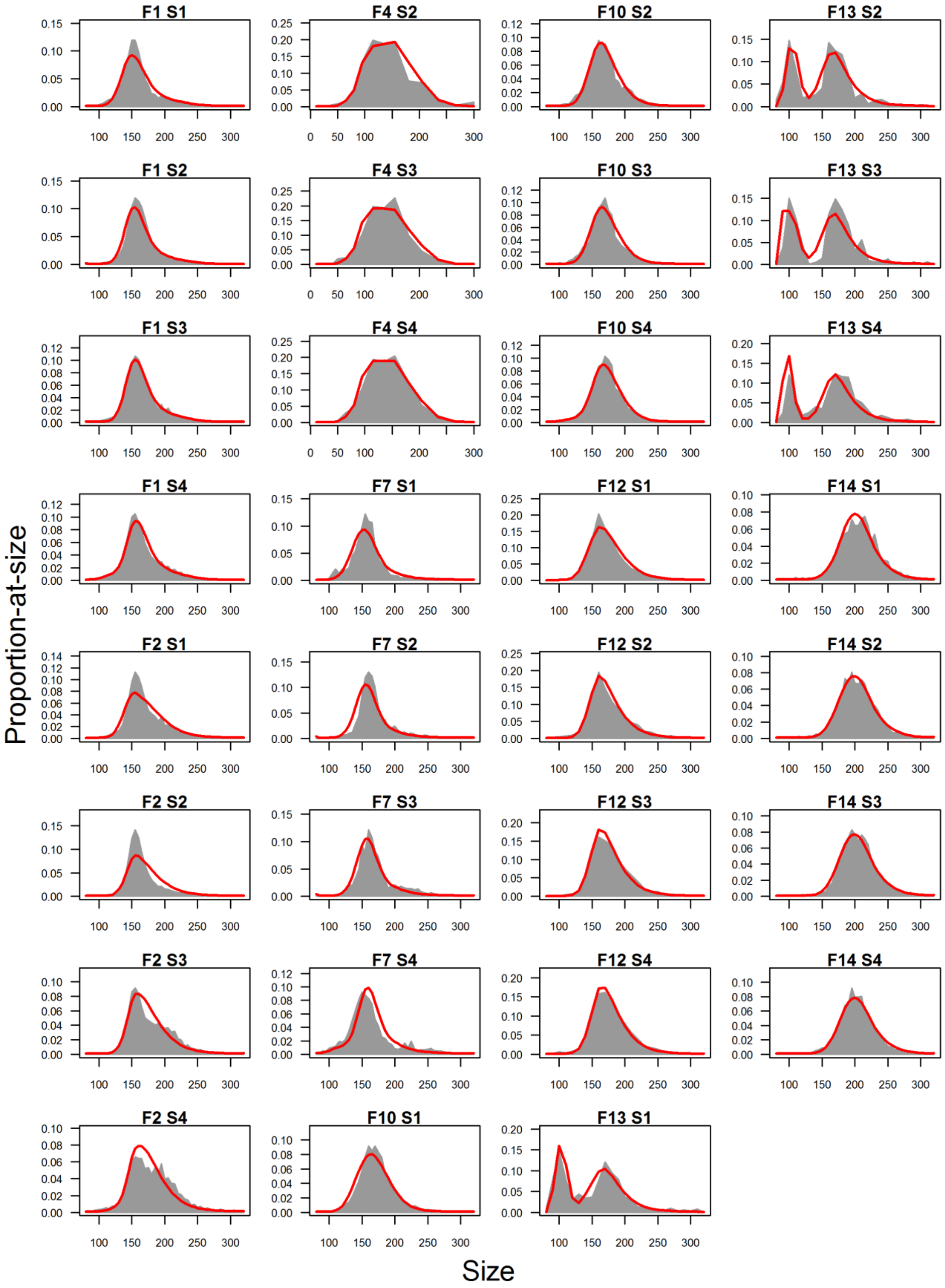


Figure 5.3. Comparison of observed (gray shaded area) and model predicted (red line) size compositions for fisheries used in the Pacific blue marlin stock assessment (F1, F2, F4, F7, F10, F12, F13, and F14 – see Table 3.1 and Figure 3.1 for fishery description and their temporal coverage).

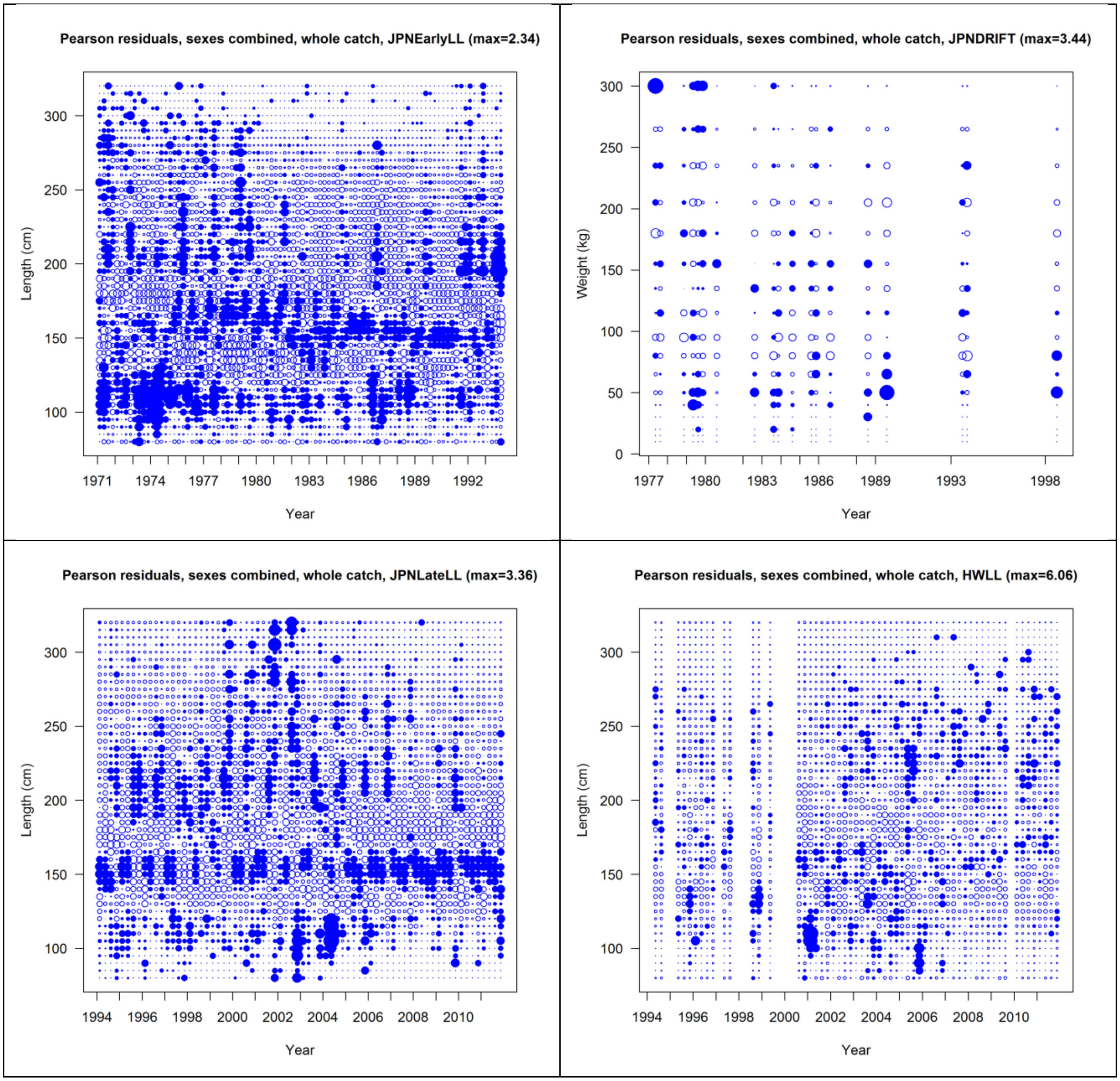


Figure 5.4. Pearson residual plots of model fits to the size-composition data for the Pacific blue marlin fisheries used in the assessment model (F1, F2, F4, F7, F10, F12, F13, and F14 – see Table 3.1 and Figure 3.1 fishery description). The filled and hollow blue circles represent observations that are higher and lower than the model predictions, respectively. The areas of the circles are proportional to the absolute values of the residuals.

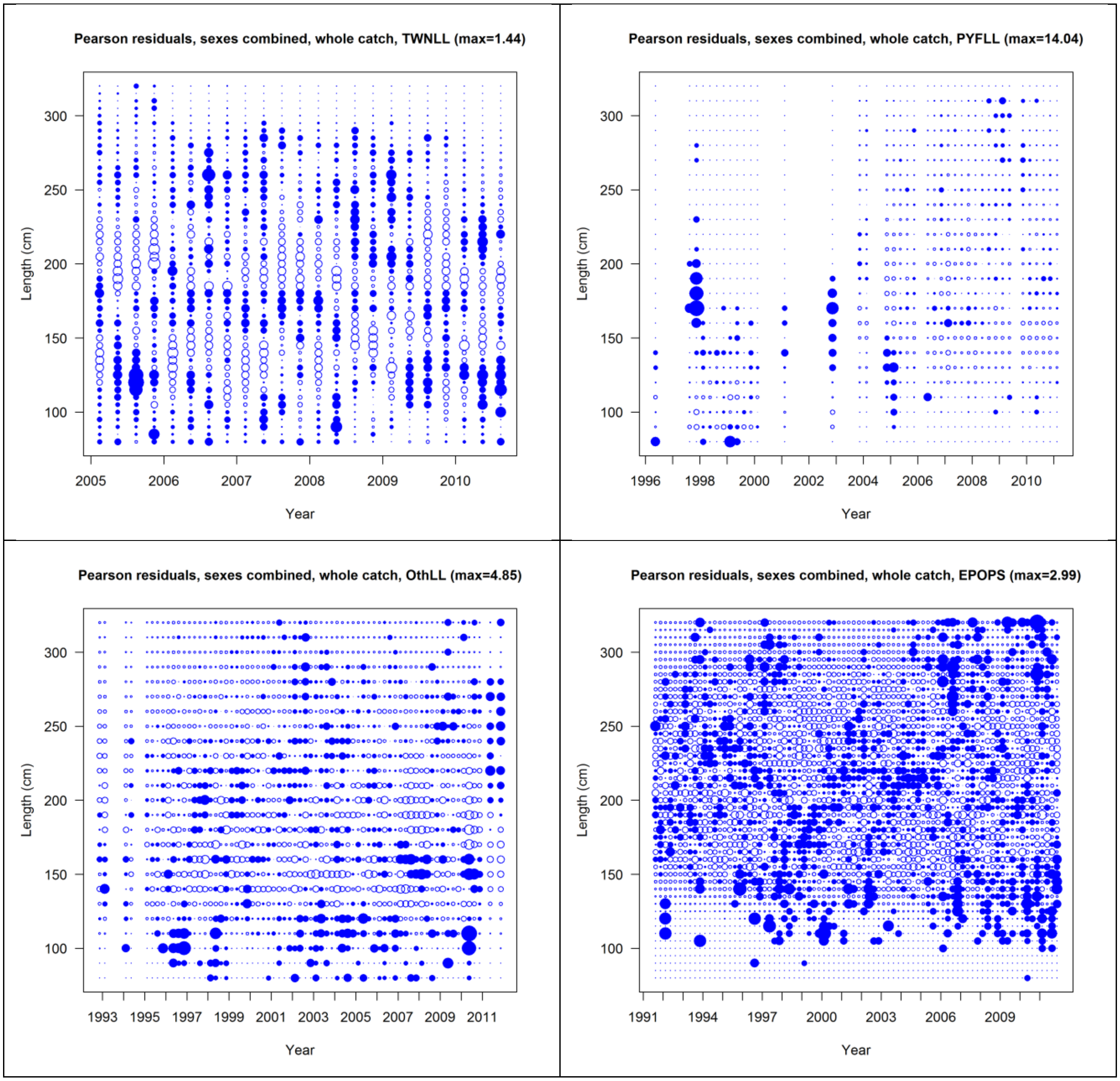


Figure 5.4. Continued.

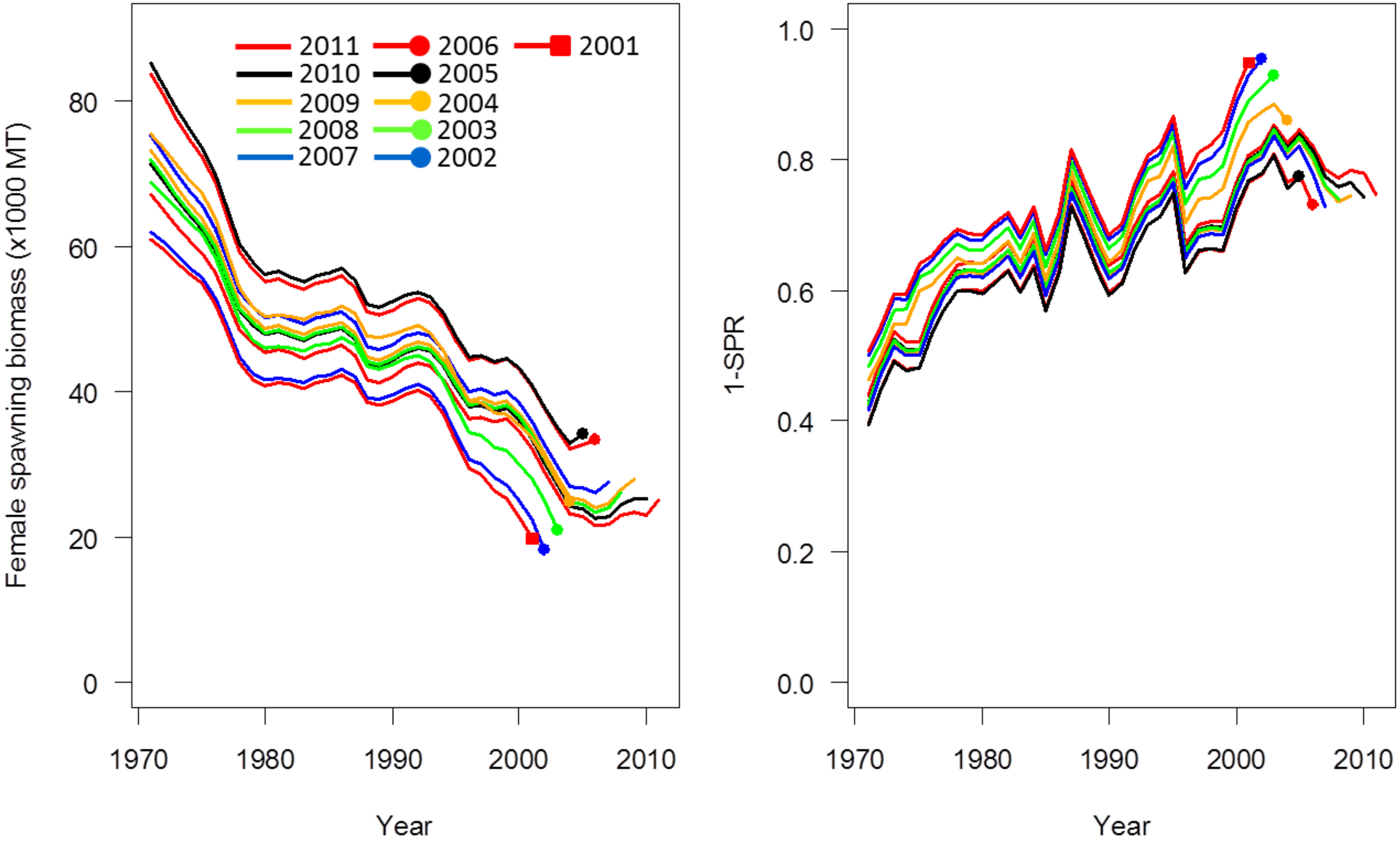


Figure 5.5. Ten-year retrospective analyses of female spawning biomass and fishing intensity (1-SPR) for the Stock Synthesis base case model.

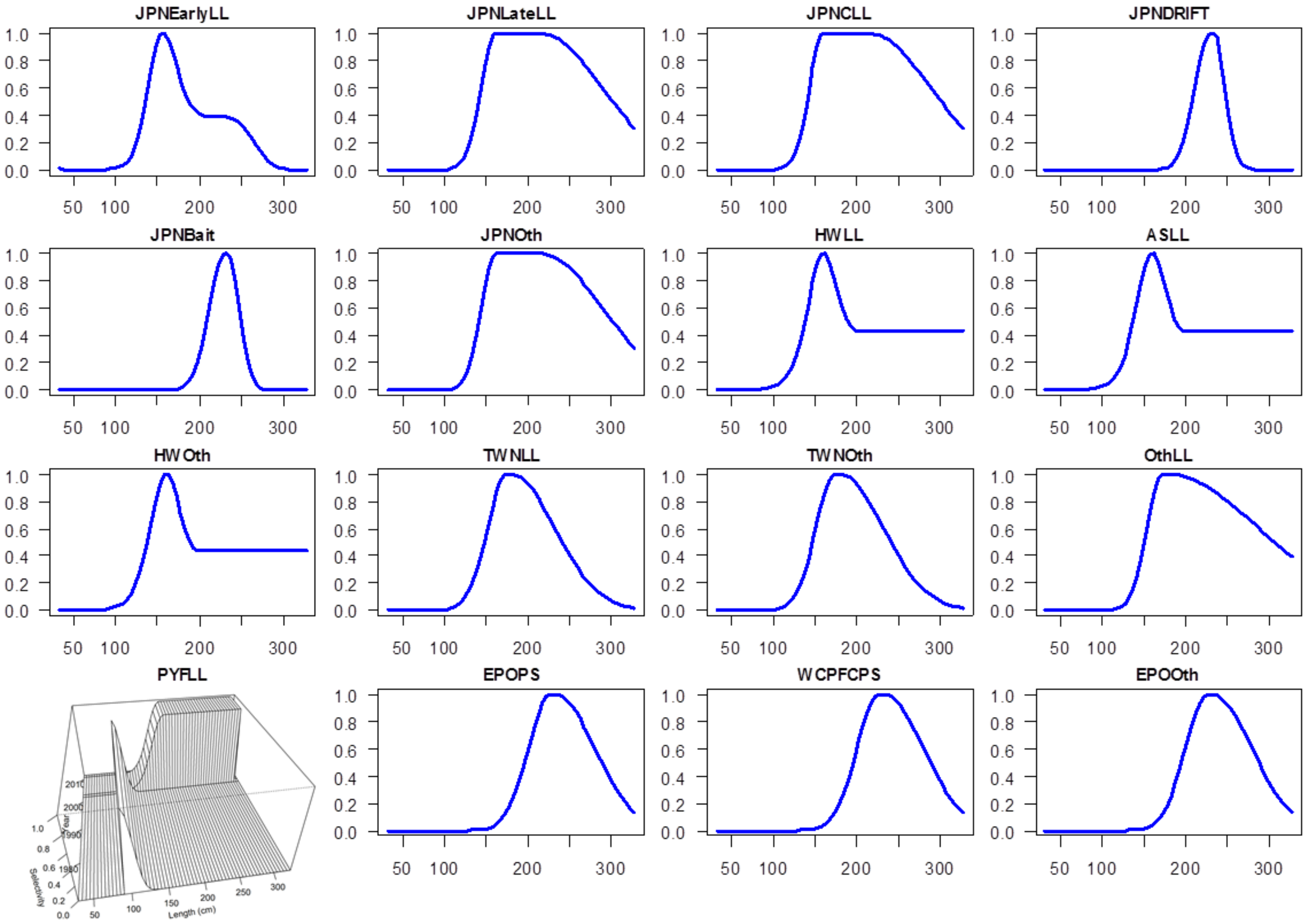


Figure 5.6. Size selectivity of fisheries estimated by the Pacific blue marlin assessment model Fisheries with time varying selectivity patterns are displayed in 3-D plots. See Table 1 for fishery definitions.

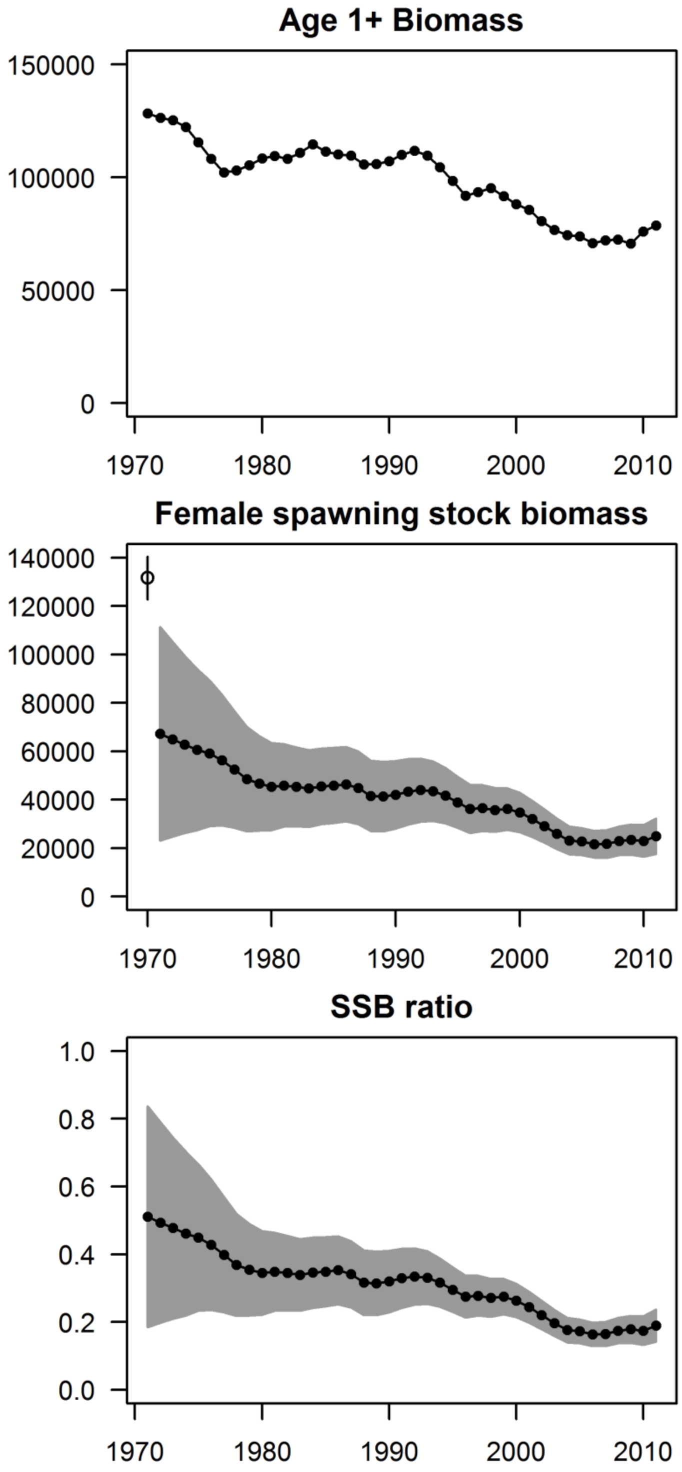


Figure 5.7. Time series of estimated total biomass (age 1 and older, t), female spawning biomass (t), and female spawning stock biomass relative to the virgin female spawning stock biomass (SSBratio) of blue marlin in the Pacific. The solid circles represent the maximum likelihood estimates of each quantity and the gray areas indicate the estimated 95% confidence intervals around the quantity. The solid circle represents the virgin spawning biomass.

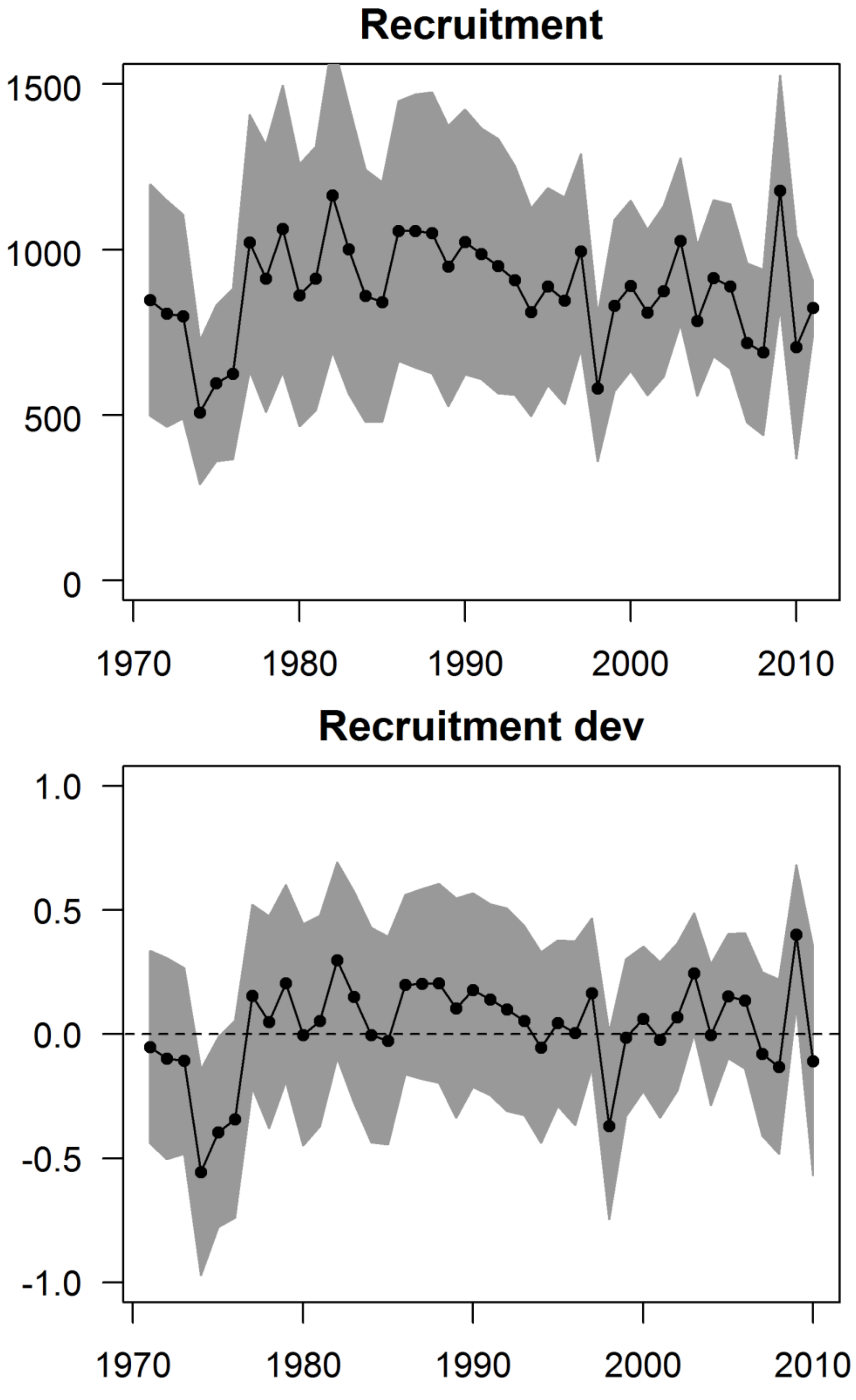
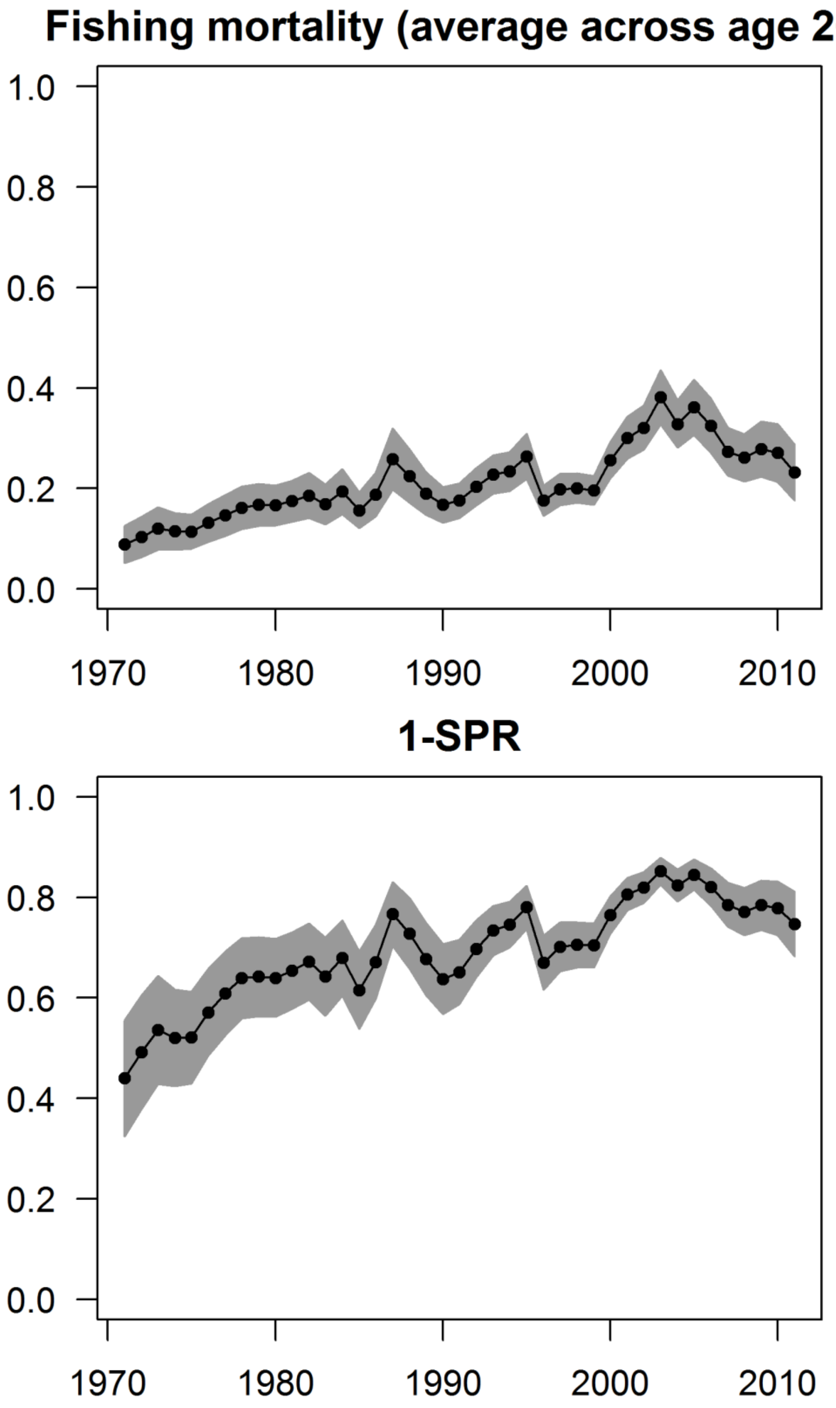


Figure 5.8. Time series of estimated age-0 recruitment (1,000 number) and recruitment deviations of blue marlin in the Pacific. The solid circles represent the maximum likelihood estimates of each quantity and the gray areas indicate the estimated 95% confidence intervals around the quantity. Since recruitment timing occurs in season 2, there is one annual estimate of recruitment.



Fishing mortality (average across age 2+)

1-SPR

Figure 5.9. Time series of estimated fishing mortality (average *F* across age 2 and older) and fishing intensity in terms of female spawning potential ratio (1-*SPR*) of blue marlin in the Pacific. The solid circles represent the maximum likelihood estimates of each quantity and the gray areas indicate the estimated 95% confidence intervals around the quantity.

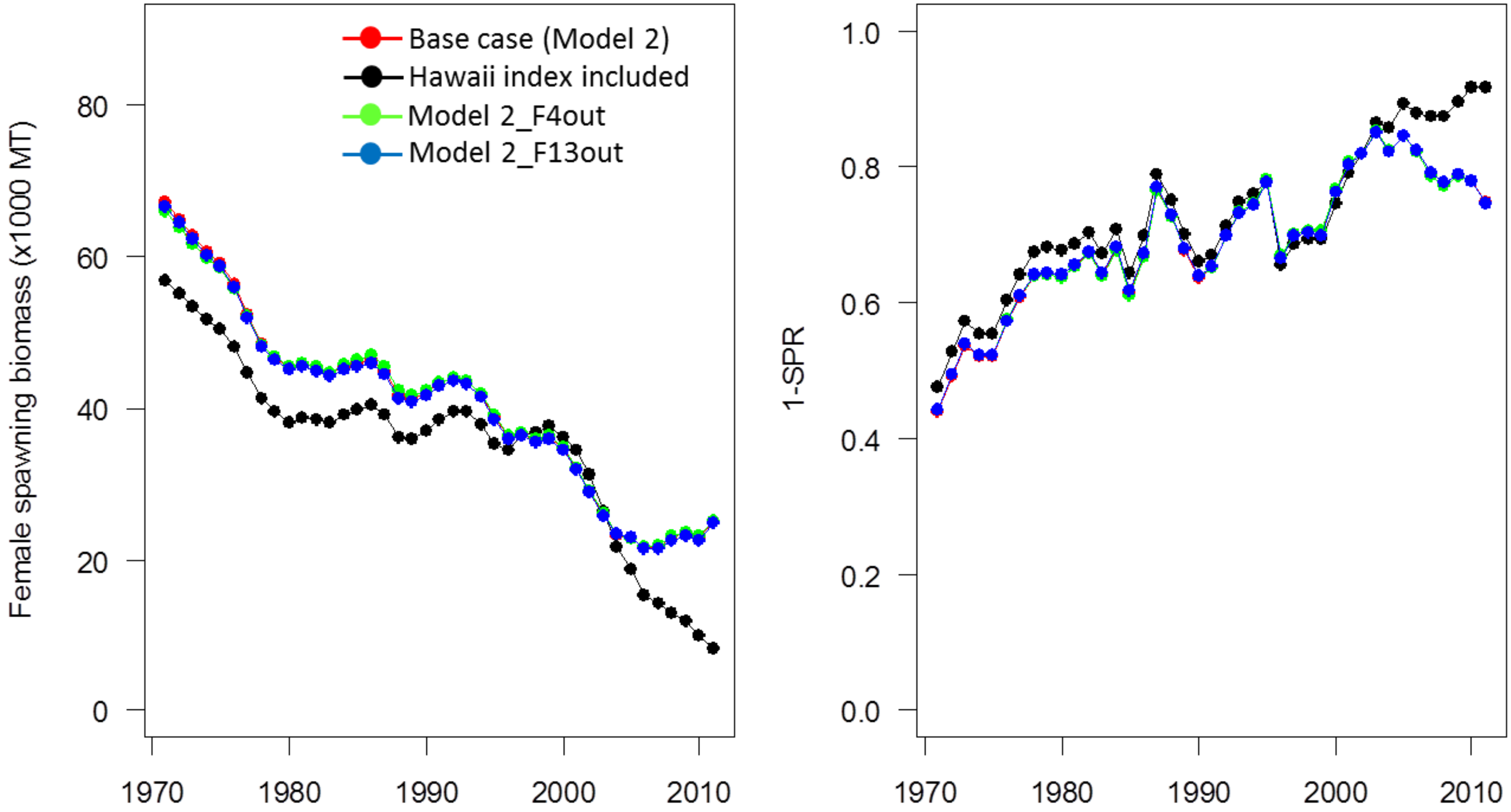


Figure 5.10. Sensitivity analysis for the choice of data series for the base case model, where left panel shows trajectory of female spawning biomass and right panel shows fishing intensity in term of spawning potential ratio (1-*SPR*).

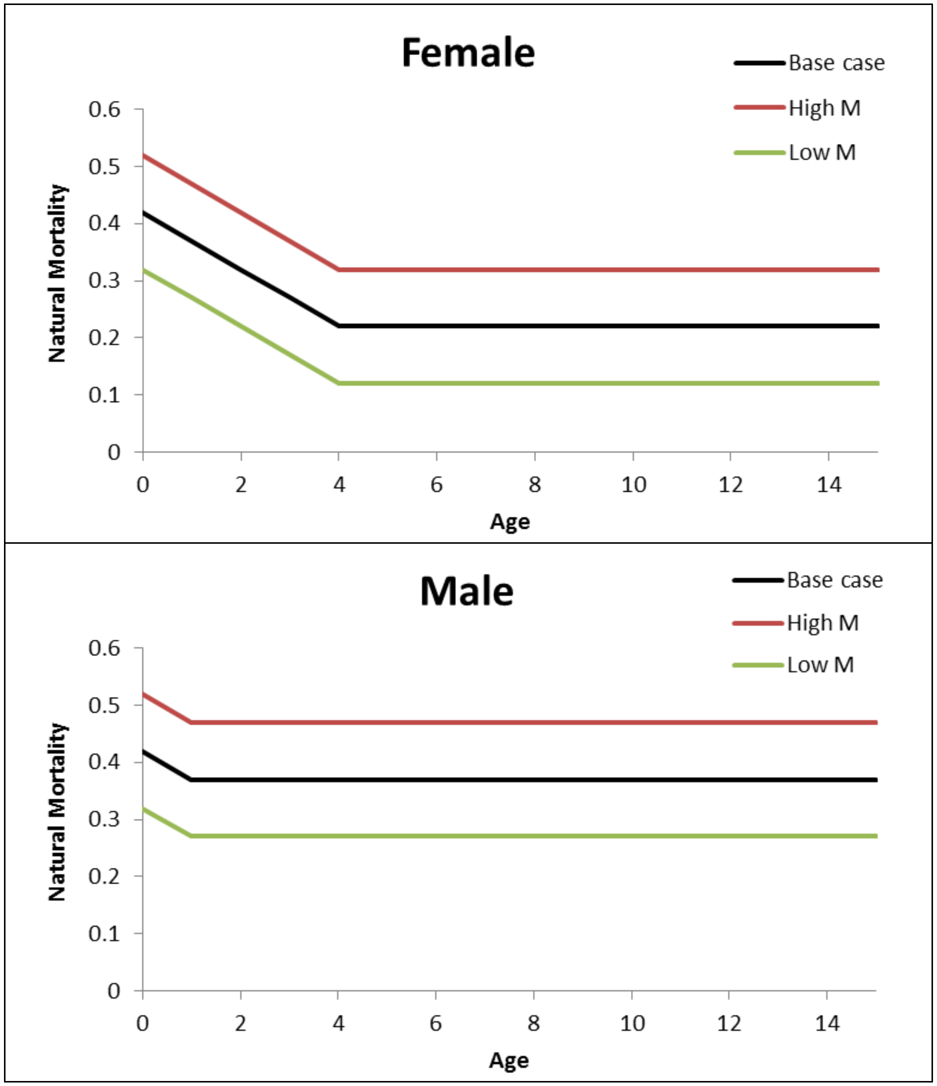


Figure 5.11.a. Sensitivity analyses for alternative natural mortality schedules for females and males, high adult *M* at 0.32 year^{-1} for female and o.47 for male and low adult *M* at 0.12 year^{-1} for female and 0.27 for male.

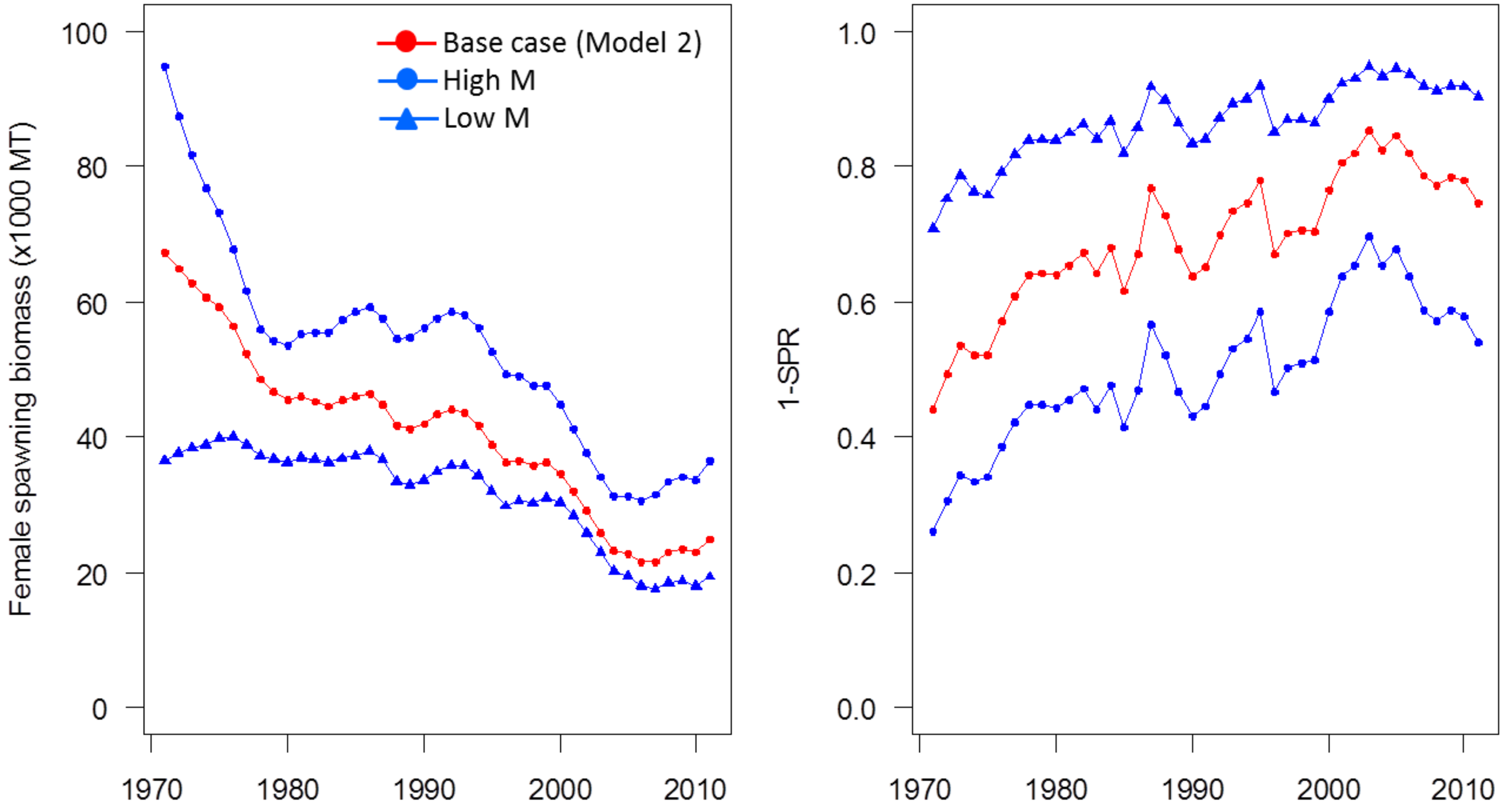


Figure 5.11.b. Sensitivity analyses for alternative natural mortality schedules for females and males, high adult *M* at 0.32 year^{-1} for female and 0.47 for male and low adult *M* at 0.12 year^{-1} for female and 0.27 for male. Left panel shows trajectory of female spawning biomass and right panel shows fishing intensity in term of spawning potential ratio (1-*SPR*).

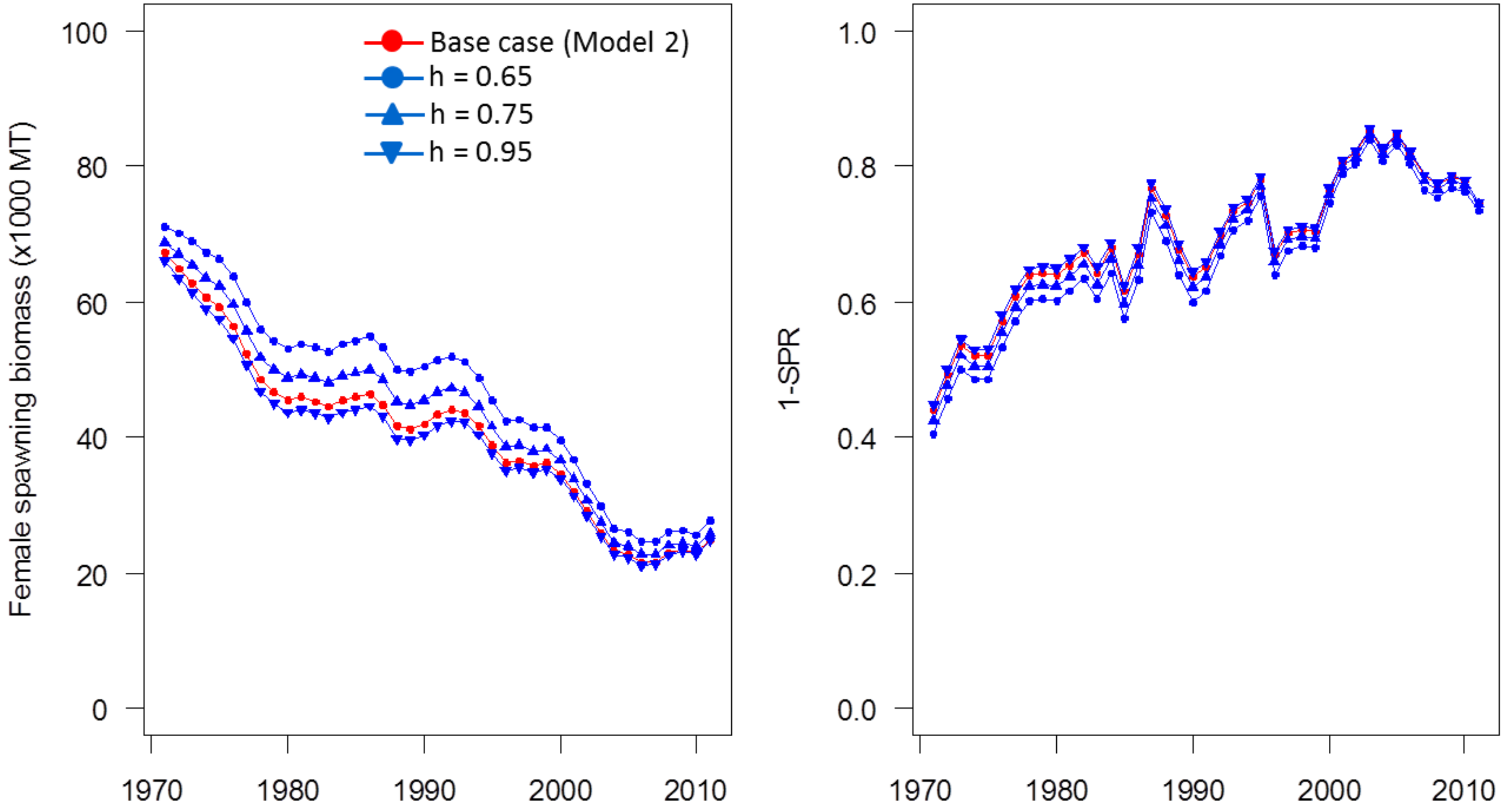


Figure 5.12. Sensitivity analyses for alternative stock-recruitment steepness values (*h*=0.65, 0.75, and 0.95), where left panel shows trajectory of female spawning biomass and right panel shows fishing intensity in term of spawning potential ratio (1-*SPR*).

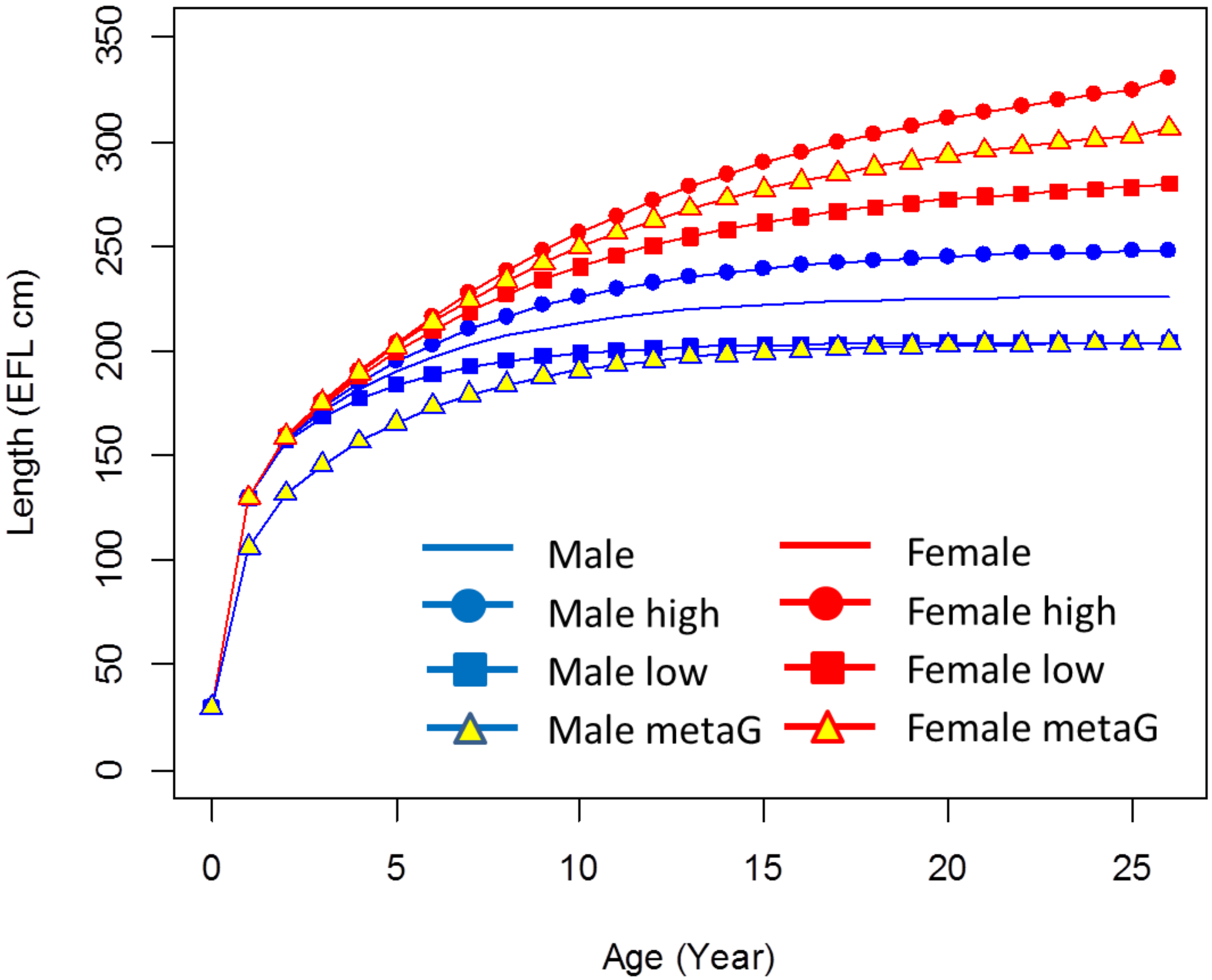


Figure 5.13.a. Sensitivity analyses for alternative growth curves for females and males.

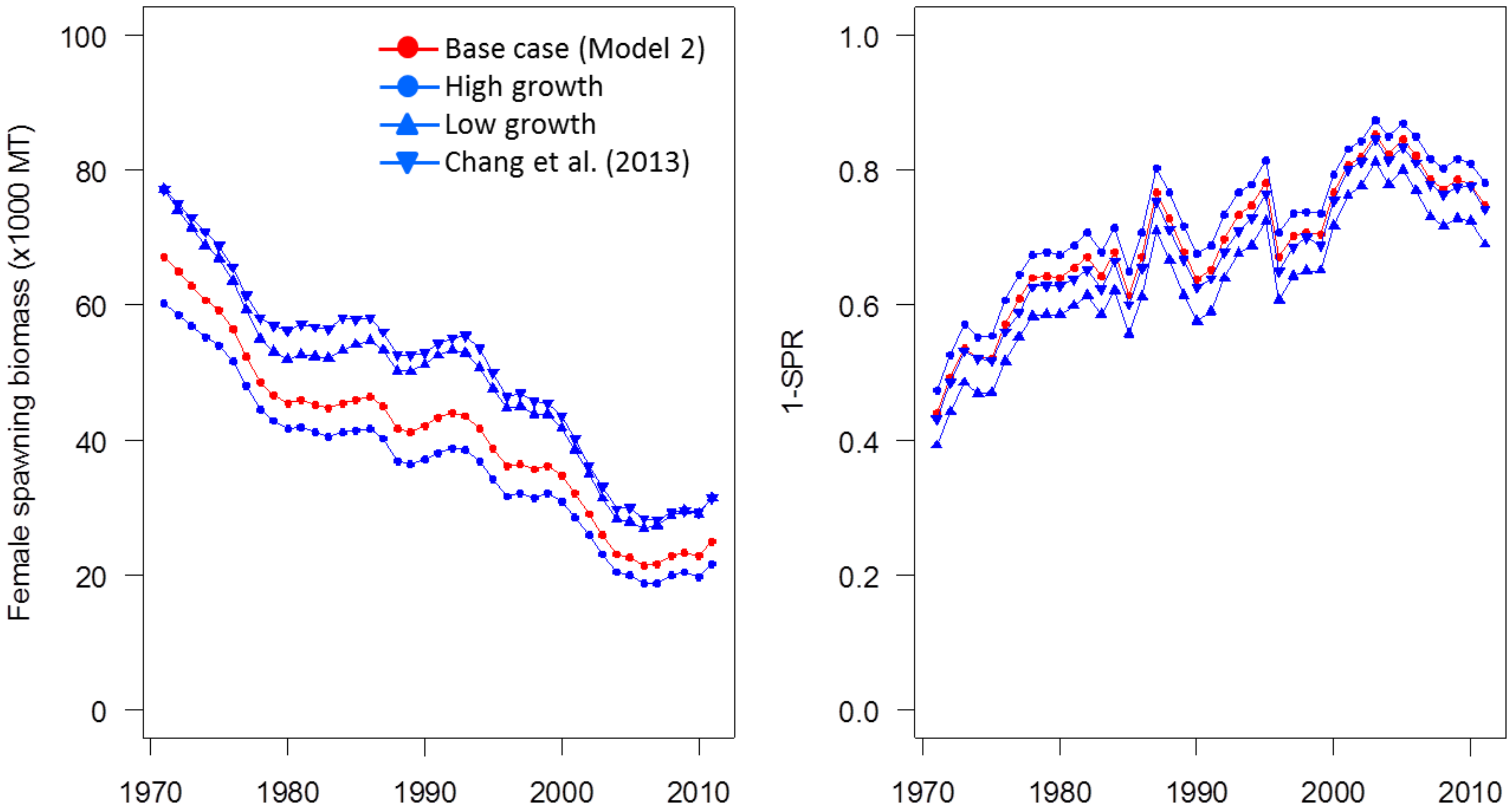


Figure 5.13.b. Sensitivity analyses for alternative growth curves for females and males, where left panel shows trajectory of female spawning biomass and right panel shows fishing intensity in term of spawning potential ratio (1-*SPR*).

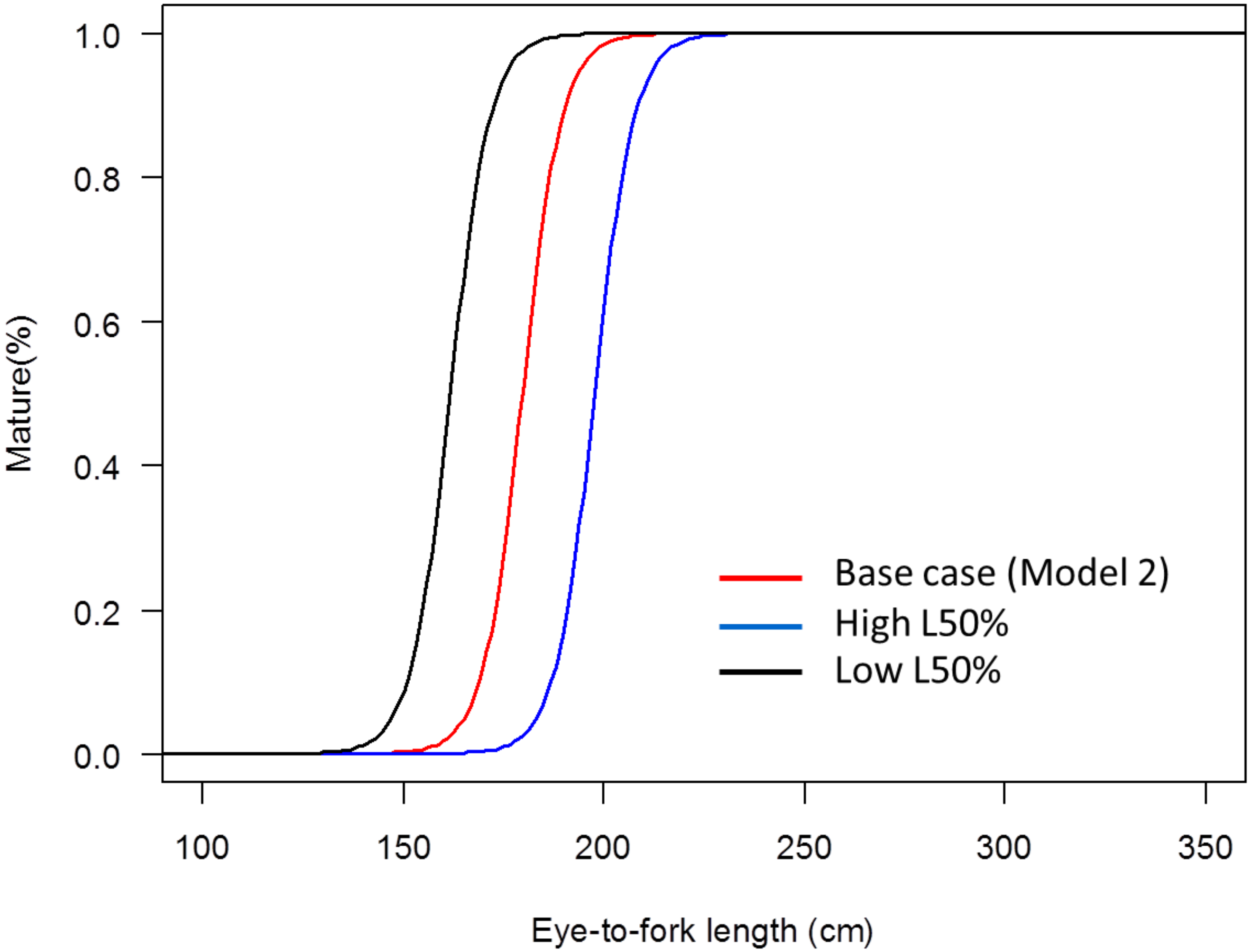


Figure 5.14.a. Sensitivity analyses for alternative maturity schedules for female blue marlin, high size-at-50-percent maturity at 197.736 cm and low size-at-50-percent maturity at 161.784 cm.

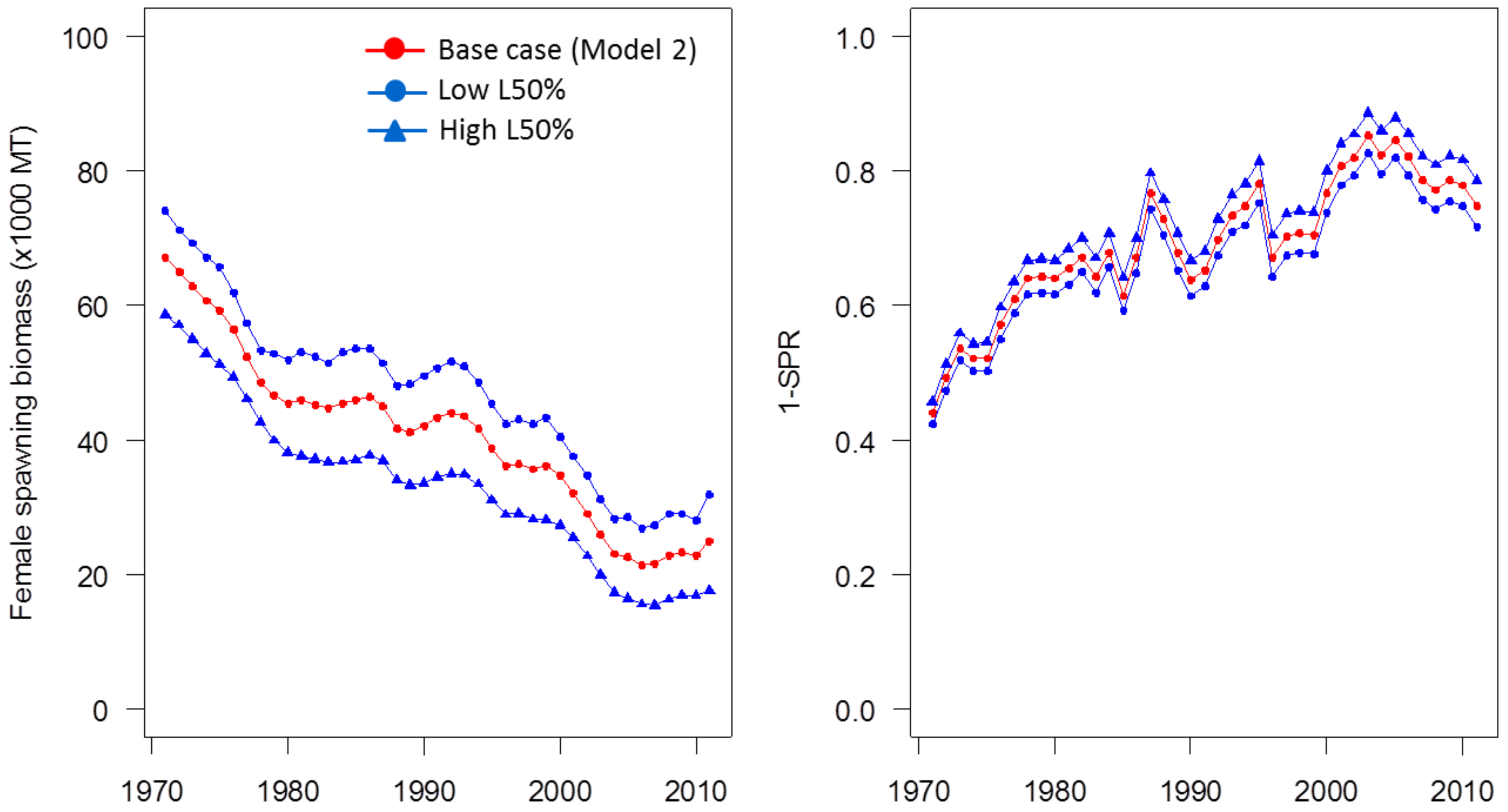


Figure 5.14.b. Sensitivity analyses for alternative maturity schedules for female blue marlin, where left panel shows trajectory of female spawning biomass and right panel shows fishing intensity in term of spawning potential ratio (1-*SPR*).

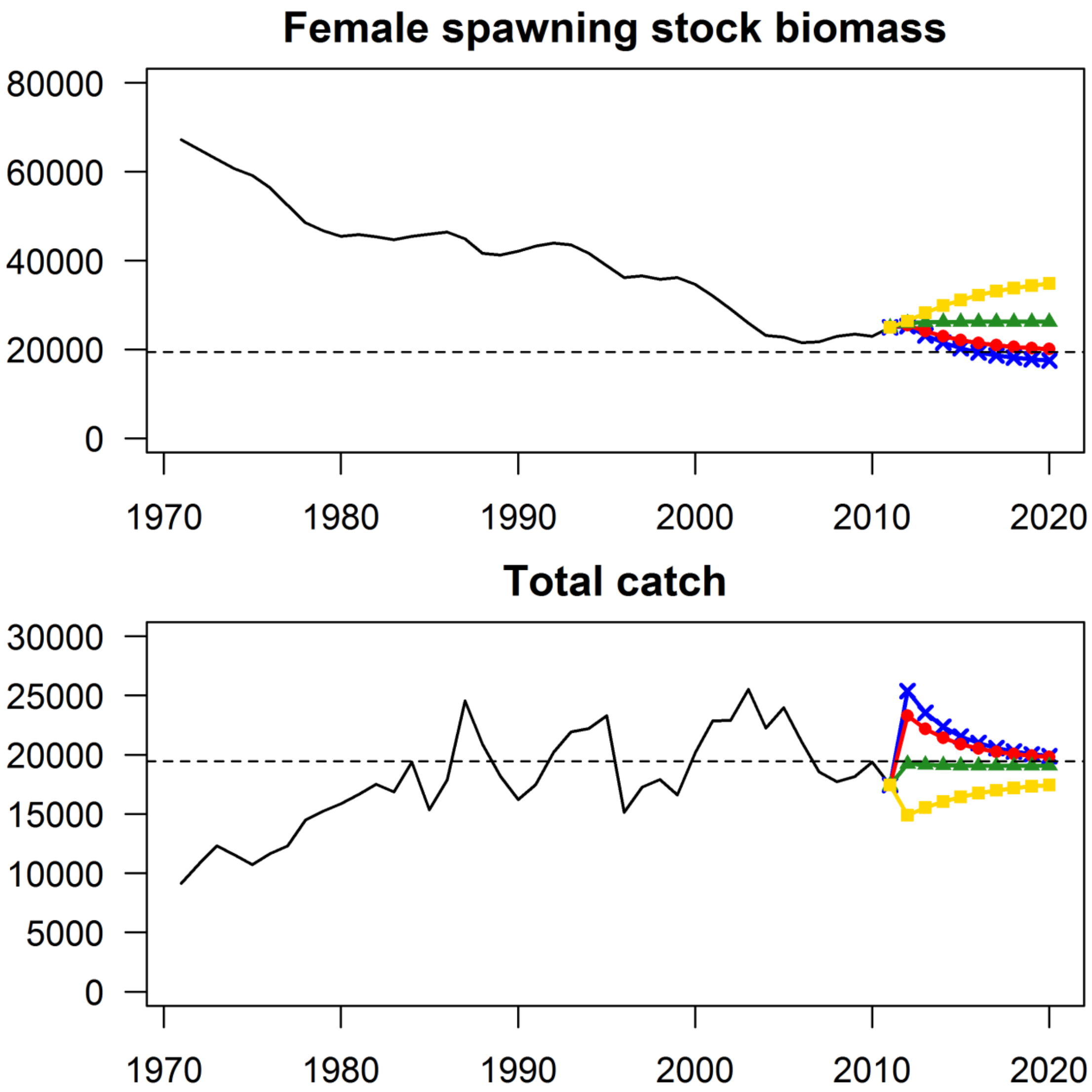


Figure 5.15. Historic and projected trajectories of female spawning biomass (SSB) and total catch from the Pacific blue marlin base case model. The solid black line shows the maximum likelihood estimates, and the estimates after 2012 indicate the prediction if fishing intensity ($F_{X\%}$) continue at (1) an average fishing intensity during 2003-2005 ($F_{2003-2005} = F_{16\%}$) indicated by blue line with cross symbols, (2) fishing intensity at MSY (F_{MSY} =$F_{18\%}$) indicated by red line with circles, (3) fishing intensity during 2009-2011 ($F_{2009-2011} = F_{23\%}$) indicated by green line with triangles, and (4) fishing intensity at $F_{30\%}$ indicated by yellow line with squares. The dashed horizontal lines show the associated MSY levels.

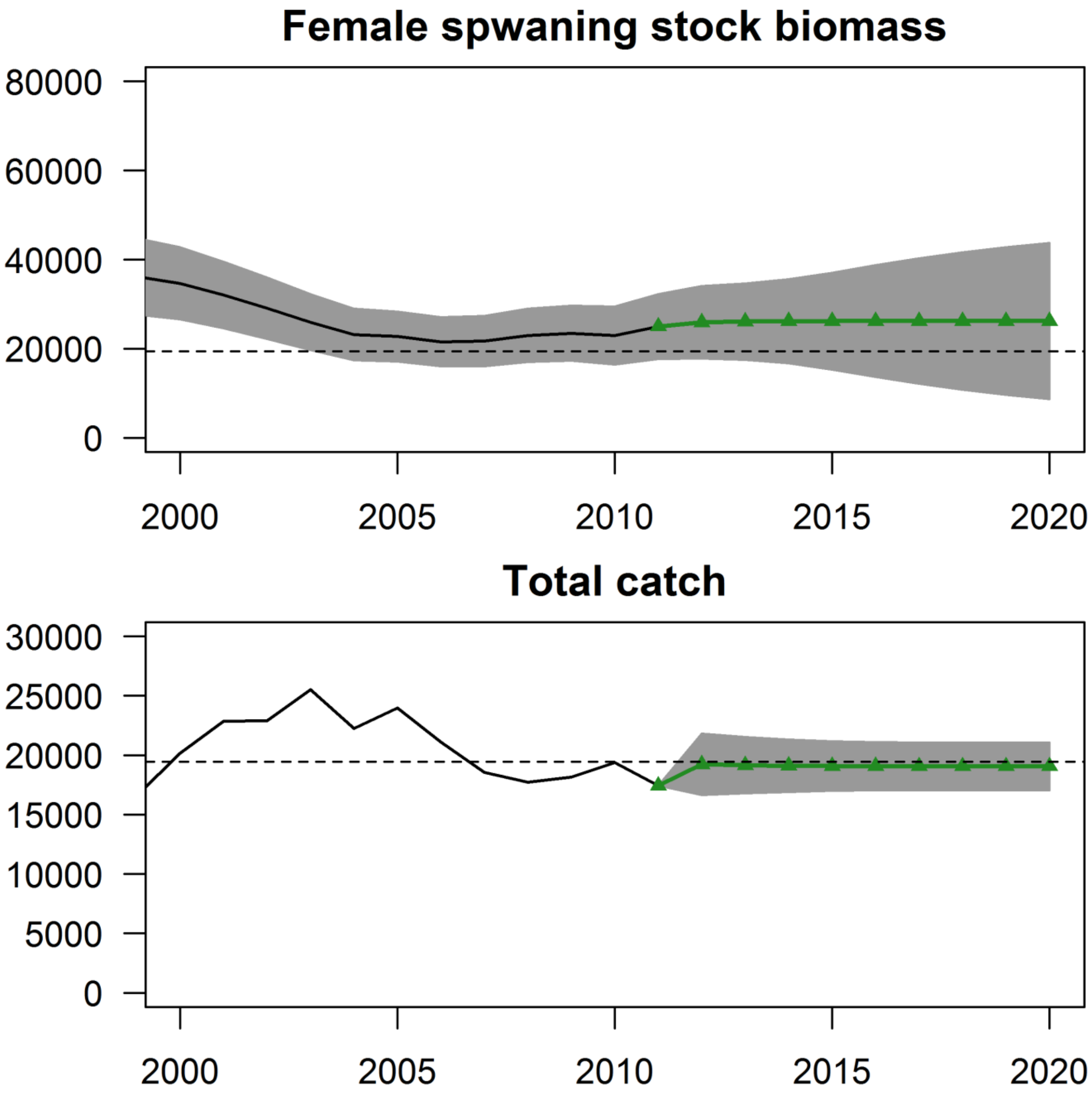


Figure 5.16. Historic and projected trajectory of female spawning biomass (SSB) and total catch from the Pacific blue marlin base case model. The solid black line illustrates the maximum likelihood estimates, and the estimates after 2012 indicate the prediction if fishing intensity ($F_{X\%}$) continue at the average of that observed during 2009-2011 indicated by green line with triangles, where the gray areas indicate the estimated 95% confidence intervals around the quantity. The dashed horizontal lines identifie the associated MSY levels.

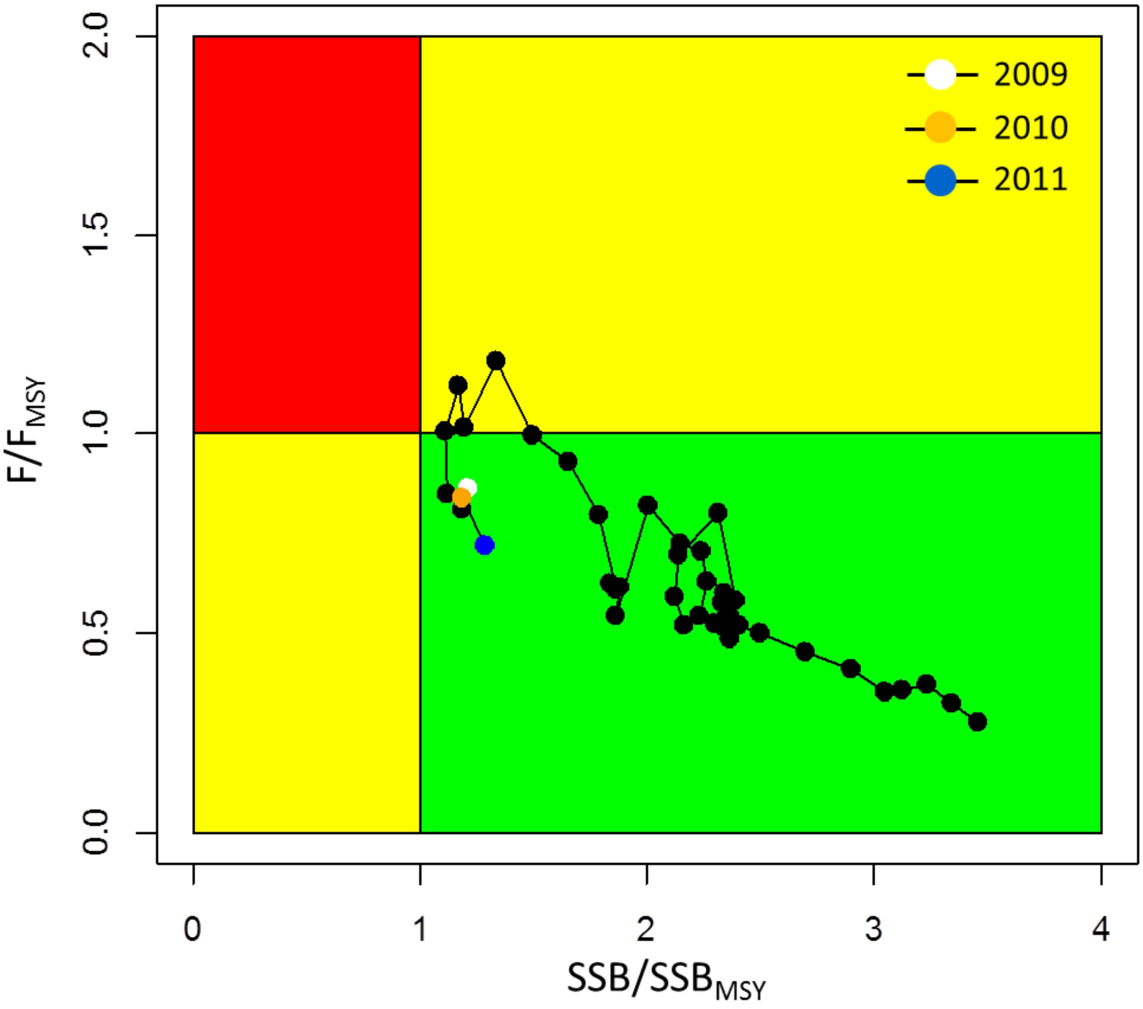


Figure 6.1. Kobe plot of the trends in estimates of relative fishing mortality (average of age 2+) and female spawning stock biomass of Pacific blue marlin (*Makaira nigricans*) during 1971-2011.

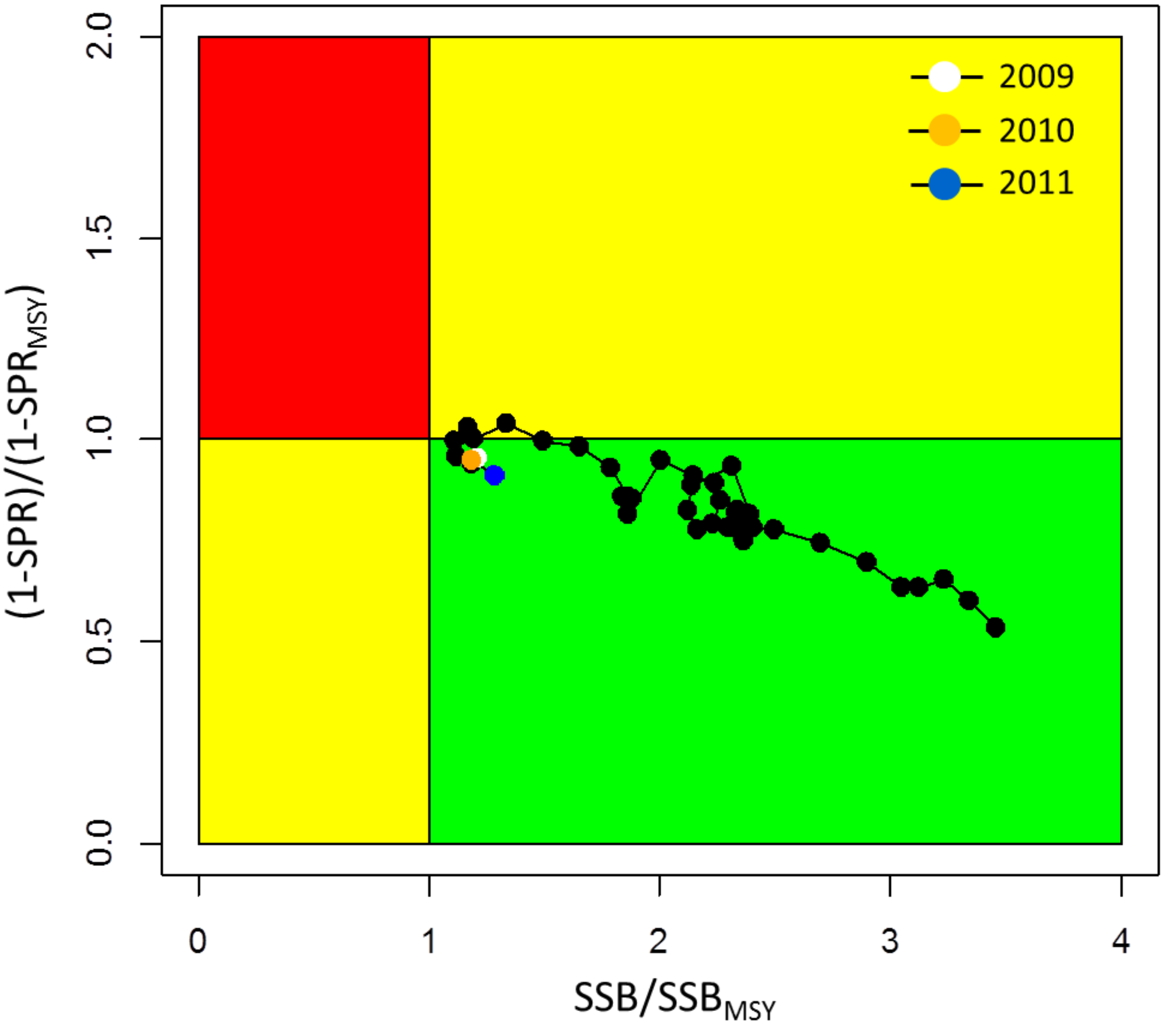


Figure 6.2. Kobe plot of the trends in estimates of relative fishing intensity and female spawning stock biomass of Pacific blue marlin (*Makaira nigricans*) during 1971-2011.

Appendix A

SS3 starter file used in the Pacific blue marlin assessment for the base case.

```
BUM_dat.ss
BUM_ctl.ss
0 # 0=use init values in control file; 1=use ss2.par
1 # run display detail (0,1,2)
1 # detailed age-structured reports in REPORT.SSO (0,1)
0 # write detailed checkup.sso file (0,1)
0 # write parm values to ParmTrace.sso (0=no,1=good,active; 2=good,all;
3=every_iter,all_parms; 4=every,active)
0 # write to cumreport.sso (0=no,1=like&timeseries; 2=add survey fits)
0 # Include prior_like for non-estimated parameters (0,1)
1 # Use Soft Boundaries to aid convergence (0,1) (recommended)
2 # Number of datafiles to produce: 1st is input, 2nd is estimates, 3rd and higher are bootstrap
100 # Turn off estimation for parameters entering after this phase
10 # MCMC burn interval
2 # MCMC thin interval
0 # jitter initial parm value by this fraction
-1 # min yr for sdreport outputs (-1 for styr)
-2 # max yr for sdreport outputs (-1 for endyr; -2 for endyr+Nforecastyrs)
0 # N individual STD years
# vector of year values
1e-004 # final convergence criteria (e.g. 1.0e-04)
0 # retrospective year relative to end year (e.g. -4)
1 # min age for calc of summary biomass
1 # Depletion basis:  denom is: 0=skip; 1=rel X*B0; 2=rel X*Bmsy; 3=rel X*B_styr
1 # Fraction (X) for Depletion denominator (e.g. 0.4)
4 # (1-SPR)_reporting:  0=skip; 1=(1-SPR)/(1-SPR_tgt); 2=(1-SPR)/(1-SPR_MSY); 3=(1-
SPR)/(1-SPR_Btarget); 4=rawSPR
4 # F_report_units: 0=skip; 1=exploitation(Bio); 2=exploitation(Num); 3=sum(Frates); 4=true F
for range of ages
2 26 #_min and max age over which average F will be calculated with F_reporting=4
0 # F_report_basis: 0=raw; 1=rel Fspr; 2=rel Fmsy ; 3=rel Fbtgt
999 # check value for end of file
```

Appendix A

SS3 control file used in the Pacific blue marlin assessment for the base case.

```
#V3.24f
#_data_and_control_files: BUM_dat.ss // BUM_ctl.ss
#_SS-V3.24f-safe-Win64;_08/03/2012;_Stock_Synthesis_by_Richard_Methot_(NOAA)_using_ADMB_11
1  #_N_Growth_Patterns
1 #_N_Morphs_Within_GrowthPattern
#_Cond 1 #_Morph_between/within_stdev_ratio (no read if N_morphs=1)
#_Cond  1 #vector_Morphdist_(-1_in_first_val_gives_normal_approx)
#
1 #  number of recruitment assignments (overrides GP*area*seas parameter values)
0 # recruitment interaction requested
#GP seas area for each recruitment assignment
 1 2 1
#
#_Cond 0 # N_movement_definitions goes here if N_areas > 1
#_Cond 1.0 # first age that moves (real age at begin of season, not integer) also cond on
do_migration>0
#_Cond 1 1 1 2 4 10 # example move definition for seas=1, morph=1, source=1 dest=2, age1=4,
age2=10
#
1 #_Nblock_Patterns
 1 #_blocks_per_pattern
# begin and end years of blocks
 2003 2011
#
0.5 #_fracfemale
1 #_natM_type:_0=1Parm; 1=N_breakpoints;_2=Lorenzen;_3=agespecific;_4=agespec_withseasinterpolate
3 #_N_breakpoints
 0 1 4 # age(real) at M breakpoints
1 # GrowthModel: 1=vonBert with L1&L2; 2=Richards with L1&L2; 3=age_speciific_K; 4=not
implemented
1 #_Growth_Age_for_L1
26 #_Growth_Age_for_L2 (999 to use as Linf)
0 #_SD_add_to_LAA (set to 0.1 for SS2 V1.x compatibility)
0 #_CV_Growth_Pattern:  0 CV=f(LAA); 1 CV=F(A); 2 SD=F(LAA); 3 SD=F(A); 4 logSD=F(A)
1 #_maturity_option:  1=length logistic; 2=age logistic; 3=read age-maturity matrix by
growth_pattern; 4=read age-fecundity; 5=read fec and wt from wtatage.ss
#_placeholder for empirical age-maturity by growth pattern
2 #_First_Mature_Age
1 #_fecundity option:(1)eggs=Wt*(a+b*Wt);(2)eggs=a*L^b;(3)eggs=a*Wt^b; (4)eggs=a+b*L;
(5)eggs=a+b*W
0 #_hermaphroditism option:  0=none; 1=age-specific fxn
1 #_parameter_offset_approach (1=none, 2= M, G, CV_G as offset from female-GP1, 3=like SS2 V1.x)
1 #_env/block/dev_adjust_method (1=standard; 2=logistic transform keeps in base parm bounds;
3=standard w/ no bound check)
#
#_growth_parms
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block
Block_Fxn
 0 2 0.42 0.42 -1 99 -3 0 0 0 0 0 0 0 # NatM_p_1_Fem_GP_1
 0 2 0.37 0.37 -1 99 -3 0 0 0 0 0 0 0 # NatM_p_2_Fem_GP_1
 0 2 0.22 0.22 -1 99 -3 0 0 0 0 0 0 0 # NatM_p_3_Fem_GP_1
 50 200 144 144 -1 99 -4 0 0 0 0 0 0 0 # L_at_Amin_Fem_GP_1
 100 400 304.178 304.178 -1 99 -2 0 0 0 0 0 0 0 # L_at_Amax_Fem_GP_1
 0.05 0.25 0.107 0.107 -1 99 -4 0 0 0 0 0 0 0 # VonBert_K_Fem_GP_1
 0.01 0.5 0.14 0.14 -1 99 -3 0 0 0 0 0 0 0 # CV_young_Fem_GP_1
 0.01 0.5 0.15 0.1 -1 99 -3 0 0 0 0 0 0 0 # CV_old_Fem_GP_1
 0 2 0.42 0.42 -1 99 -3 0 0 0 0 0 0 0 # NatM_p_1_Mal_GP_1
 0 2 0.37 0.37 -1 99 -3 0 0 0 0 0 0 0 # NatM_p_2_Mal_GP_1
 0 2 0.37 0.37 -1 99 -3 0 0 0 0 0 0 0 # NatM_p_3_Mal_GP_1
 50 200 144 144 -1 99 -4 0 0 0 0 0 0 0 # L_at_Amin_Mal_GP_1
 100 400 226 226 -1 99 -2 0 0 0 0 0 0 0 # L_at_Amax_Mal_GP_1
 0.05 0.25 0.211 0.211 -1 99 -4 0 0 0 0 0 0 0 # VonBert_K_Mal_GP_1
 0.01 0.5 0.14 0.14 -1 99 -3 0 0 0 0 0 0 0 # CV_young_Mal_GP_1
 0.01 0.5 0.1 0.1 -1 99 -3 0 0 0 0 0 0 0 # CV_old_Mal_GP_1
 0 3 1.844e-005 1.844e-005 -1 99 -3 0 0 0 0 0 0 0 # Wtlen_1_Fem
```

```
 0 3 2.956 2.956 -1 99 -3 0 0 0 0 0 0 0 # Wtlen_2_Fem
 1 400 179.76 179.76 -1 99 -3 0 0 0 0 0 0 0 # Mat50%_Fem
 -3 3 -0.2039 -0.2039 -1 99 -3 0 0 0 0 0 0 0 # Mat_slope_Fem
 0 3 1 1 -1 99 -3 0 0 0 0 0 0 0 # Eggs/kg_inter_Fem
 0 3 0 0 -1 99 -3 0 0 0 0 0 0 0 # Eggs/kg_slope_wt_Fem
 0 3 1.37e-005 1.37e-005 -1 99 -3 0 0 0 0 0 0 0 # Wtlen_1_Mal
 0 3 2.975 2.975 -1 99 -3 0 0 0 0 0 0 0 # Wtlen_2_Mal
 -4 4 0 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_GP_1
 -4 4 0 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Area_1
 -4 4 -4 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Seas_1
 -4 4 -4 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Seas_2
 -4 4 -4 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Seas_3
 -4 4 -4 0 -1 99 -3 0 0 0 0 0 0 0 # RecrDist_Seas_4
 -4 4 1 1 -1 99 -3 0 0 0 0 0.5 0 0 # CohortGrowDev
#
#_Cond 0  #custom_MG-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-environ parameters
#
#_Cond 0  #custom_MG-block_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no MG-block parameters
#_Cond No MG parm trends
#
#_seasonal_effects_on_biology_parms
 0 0 0 0 0 0 0 0 0 0 #_femwtlen1,femwtlen2,mat1,mat2,fec1,fec2,Malewtlen1,malewtlen2,L1,K
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no seasonal MG parameters
#
#_Cond -4 #_MGparm_Dev_Phase
#
#_Spawner-Recruitment
3 #_SR_function: 2=Ricker; 3=std_B-H; 4=SCAA; 5=Hockey; 6=B-H_flattop; 7=survival_3Parm
#_LO HI INIT PRIOR PR_type SD PHASE
 3 12 6.86278 9.3 -1 99 1 # SR_LN(R0)
 0.2 1 0.87 0.87 -1 99 -4 # SR_BH_steep
 0 2 0.32 0.6 -1 99 -3 # SR_sigmaR
 -5 5 0 0 -1 1 -3 # SR_envlink
 -5 5 0 0 -1 99 -1 # SR_R1_offset
 0 0 0 0 -1 99 -1 # SR_autocorr
0 #_SR_env_link
0 #_SR_env_target_0=none;1=devs;_2=R0;_3=steepness
1 #do_recdev:  0=none; 1=devvector; 2=simple deviations
1966 # first year of main recr_devs; early devs can preceed this era
2010 # last year of main recr_devs; forecast devs start in following year
2 #_recdev phase
1 # (0/1) to read 13 advanced options
 0 #_recdev_early_start (0=none; neg value makes relative to recdev_start)
 -4 #_recdev_early_phase
 0 #_forecast_recruitment phase (incl. late recr) (0 value resets to maxphase+1)
 1 #_lambda for Fcast_recr_like occurring before endyr+1
 1966 #_last_early_yr_nobias_adj_in_MPD
 1971 #_first_yr_fullbias_adj_in_MPD
 2010 #_last_yr_fullbias_adj_in_MPD
 2011 #_first_recent_yr_nobias_adj_in_MPD
 0.65 #_max_bias_adj_in_MPD (-1 to override ramp and set biasadj=1.0 for all estimated recdevs)
 0 #_period of cycles in recruitment (N parms read below)
 -5 #min rec_dev
 5 #max rec_dev
 0 #_read_recdevs
#_end of advanced SR options
#
#_placeholder for full parameter lines for recruitment cycles
# read specified recr devs
#_Yr Input_value
#
# all recruitment deviations
#DisplayOnly -0.0152864 # Main_InitAge_5
#DisplayOnly -0.0803682 # Main_InitAge_4
#DisplayOnly -0.192542 # Main_InitAge_3
#DisplayOnly -0.333628 # Main_InitAge_2
#DisplayOnly -0.37464 # Main_InitAge_1
#DisplayOnly -0.0521844 # Main_RecrDev_1971
#DisplayOnly -0.0992991 # Main_RecrDev_1972
```

```
#DisplayOnly -0.106969 # Main_RecrDev_1973
#DisplayOnly -0.556312 # Main_RecrDev_1974
#DisplayOnly -0.395194 # Main_RecrDev_1975
#DisplayOnly -0.342585 # Main_RecrDev_1976
#DisplayOnly 0.153852 # Main_RecrDev_1977
#DisplayOnly 0.0481587 # Main_RecrDev_1978
#DisplayOnly 0.205223 # Main_RecrDev_1979
#DisplayOnly -0.00269224 # Main_RecrDev_1980
#DisplayOnly 0.0541754 # Main_RecrDev_1981
#DisplayOnly 0.297936 # Main_RecrDev_1982
#DisplayOnly 0.149277 # Main_RecrDev_1983
#DisplayOnly -0.00417386 # Main_RecrDev_1984
#DisplayOnly -0.0263364 # Main_RecrDev_1985
#DisplayOnly 0.199051 # Main_RecrDev_1986
#DisplayOnly 0.202066 # Main_RecrDev_1987
#DisplayOnly 0.204933 # Main_RecrDev_1988
#DisplayOnly 0.104812 # Main_RecrDev_1989
#DisplayOnly 0.177247 # Main_RecrDev_1990
#DisplayOnly 0.138738 # Main_RecrDev_1991
#DisplayOnly 0.0989114 # Main_RecrDev_1992
#DisplayOnly 0.0539628 # Main_RecrDev_1993
#DisplayOnly -0.0544591 # Main_RecrDev_1994
#DisplayOnly 0.0456687 # Main_RecrDev_1995
#DisplayOnly 0.00397931 # Main_RecrDev_1996
#DisplayOnly 0.165626 # Main_RecrDev_1997
#DisplayOnly -0.371254 # Main_RecrDev_1998
#DisplayOnly -0.0134027 # Main_RecrDev_1999
#DisplayOnly 0.0616686 # Main_RecrDev_2000
#DisplayOnly -0.0233525 # Main_RecrDev_2001
#DisplayOnly 0.0682848 # Main_RecrDev_2002
#DisplayOnly 0.245532 # Main_RecrDev_2003
#DisplayOnly -0.0027985 # Main_RecrDev_2004
#DisplayOnly 0.152874 # Main_RecrDev_2005
#DisplayOnly 0.134548 # Main_RecrDev_2006
#DisplayOnly -0.0795457 # Main_RecrDev_2007
#DisplayOnly -0.13129 # Main_RecrDev_2008
#DisplayOnly 0.40023 # Main_RecrDev_2009
#DisplayOnly -0.10844 # Main_RecrDev_2010
#
#Fishing Mortality info
0.5 # F ballpark for tuning early phases
-1960 # F ballpark year (neg value to disable)
3 # F_Method:  1=Pope; 2=instan. F; 3=hybrid (hybrid is recommended)
4 # max F or harvest rate, depends on F_Method
# no additional F input needed for Fmethod 1
# if Fmethod=2; read overall start F value; overall phase; N detailed inputs to read
# if Fmethod=3; read N iterations for tuning for Fmethod 3
5  # N iterations for tuning F in hybrid method (recommend 3 to 7)
#
#_initial_F_parms
#_LO HI INIT PRIOR PR_type SD PHASE
 0 3 0.721221 0 -1 99 1 # InitF_1JPNEarlyLL
 0 1 0 0 -1 99 -1 # InitF_2JPNLateLL
 0 1 0 0 -1 99 -1 # InitF_3JPNCLL
 0 1 0 0 -1 99 -1 # InitF_4JPNDRIFT
 0 1 0 0 -1 99 -1 # InitF_5JPNBait
 0 1 0 0 -1 99 -1 # InitF_6JPNOth
 0 1 0 0 -1 99 -1 # InitF_7HWLL
 0 1 0 0 -1 99 -1 # InitF_8ASLL
 0 1 0 0 -1 99 -1 # InitF_9HWOth
 0 1 0 0 -1 99 -1 # InitF_10TWNLL
 0 1 0 0 -1 99 -1 # InitF_11TWNOth
 0 1 0 0 -1 99 -1 # InitF_12OthLL
 0 1 0 0 -1 99 -1 # InitF_13PYFLL
 0 1 0 0 -1 99 -1 # InitF_14EPOPS
 0 1 0 0 -1 99 -1 # InitF_15WCPFCPS
 0 1 0 0 -1 99 -1 # InitF_16EPOOth
#
#_Q_setup
 # Q_type options:  <0=mirror, 0=float_nobiasadj, 1=float_biasadj, 2=parm_nobiasadj,
3=parm_w_random_dev, 4=parm_w_randwalk, 5=mean_unbiased_float_assign_to_parm
```

```
#_for_env-var:_enter_index_of_the_env-var_to_be_linked
#_Den-dep  env-var  extra_se  Q_type
 0 0 0 0 # 1 JPNEarlyLL
 0 0 0 0 # 2 JPNLateLL
 0 0 0 0 # 3 JPNCLL
 0 0 0 0 # 4 JPNDRIFT
 0 0 0 0 # 5 JPNBait
 0 0 0 0 # 6 JPNOth
 0 0 0 0 # 7 HWLL
 0 0 0 0 # 8 ASLL
 0 0 0 0 # 9 HWOth
 0 0 0 0 # 10 TWNLL
 0 0 0 0 # 11 TWNOth
 0 0 0 0 # 12 OthLL
 0 0 0 0 # 13 PYFLL
 0 0 0 0 # 14 EPOPS
 0 0 0 0 # 15 WCPFCPS
 0 0 0 0 # 16 EPOOth
 0 0 0 0 # 17 S1_JPNEarlyLL
 0 0 0 0 # 18 S2_JPNLateLL
 0 0 0 0 # 19 S3_HWLL
 0 0 0 0 # 20 S4_TWNLL
 0 0 0 0 # 21 S5_TWNLL
 0 0 0 0 # 22 S6_TWNLL
#
#_Cond 0 #_If q has random component, then 0=read one parm for each fleet with random q; 1=read a
parm for each year of index
#_Q_parms(if_any)
#
#_size_selex_types
#discard_options:_0=none;_1=define_retention;_2=retention&mortality;_3=all_discarded_dead
#_Pattern Discard Male Special
 27 0 0 4 # 1 JPNEarlyLL
 24 0 0 0 # 2 JPNLateLL
 5 0 0 2 # 3 JPNCLL
 24 0 0 0 # 4 JPNDRIFT
 5 0 0 4 # 5 JPNBait
 5 0 0 2 # 6 JPNOth
 27 0 0 3 # 7 HWLL
 5 0 0 7 # 8 ASLL
 5 0 0 7 # 9 HWOth
 24 0 0 0 # 10 TWNLL
 5 0 0 10 # 11 TWNOth
 24 0 0 0 # 12 OthLL
 24 0 0 0 # 13 PYFLL
 24 0 0 0 # 14 EPOPS
 5 0 0 14 # 15 WCPFCPS
 5 0 0 14 # 16 EPOOth
 5 0 0 1 # 17 S1_JPNEarlyLL
 5 0 0 2 # 18 S2_JPNLateLL
 5 0 0 7 # 19 S3_HWLL
 5 0 0 10 # 20 S4_TWNLL
 5 0 0 10 # 21 S5_TWNLL
 5 0 0 10 # 22 S6_TWNLL
#
#_age_selex_types
#_Pattern ___ Male Special
 11 0 0 0 # 1 JPNEarlyLL
 11 0 0 0 # 2 JPNLateLL
 11 0 0 0 # 3 JPNCLL
 11 0 0 0 # 4 JPNDRIFT
 11 0 0 0 # 5 JPNBait
 11 0 0 0 # 6 JPNOth
 11 0 0 0 # 7 HWLL
 11 0 0 0 # 8 ASLL
 11 0 0 0 # 9 HWOth
 11 0 0 0 # 10 TWNLL
 11 0 0 0 # 11 TWNOth
 11 0 0 0 # 12 OthLL
 11 0 0 0 # 13 PYFLL
 11 0 0 0 # 14 EPOPS
```

```
 11 0 0 0 # 15 WCPFCPS
 11 0 0 0 # 16 EPOOth
 11 0 0 0 # 17 S1_JPNEarlyLL
 11 0 0 0 # 18 S2_JPNLateLL
 11 0 0 0 # 19 S3_HWLL
 11 0 0 0 # 20 S4_TWNLL
 11 0 0 0 # 21 S5_TWNLL
 11 0 0 0 # 22 S6_TWNLL
#_LO HI INIT PRIOR PR_type SD PHASE env-var use_dev dev_minyr dev_maxyr dev_stddev Block
Block_Fxn
 -2 2 0 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Code_JPNEarlyLL_1
 -5 5 0.0801475 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_GradLo_JPNEarlyLL_1
 -5 2 -0.233817 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_GradHi_JPNEarlyLL_1
 80 100 80 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Knot_1_JPNEarlyLL_1
 100 155 145 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Knot_2_JPNEarlyLL_1
 150 200 190 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Knot_3_JPNEarlyLL_1
 300 320 320 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Knot_4_JPNEarlyLL_1
 -5 3 -2.58954 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_Val_1_JPNEarlyLL_1
 -5 4 3.58794 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_Val_2_JPNEarlyLL_1
 -5 4 3.02191 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Val_3_JPNEarlyLL_1
 -5 3 -4.8389 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_Val_4_JPNEarlyLL_1
 100 300 160.25 66 -1 99 3 0 0 0 0 0 0 0 # SizeSel_2P_1_JPNLateLL
 -19 12 -0.784161 -3 -1 99 3 0 0 0 0 0 0 0 # SizeSel_2P_2_JPNLateLL
 -10 12 6.31431 4 -1 99 3 0 0 0 0 0 0 0 # SizeSel_2P_3_JPNLateLL
 -5 19 9.27944 5 -1 99 3 0 0 0 0 0 0 0 # SizeSel_2P_4_JPNLateLL
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_2P_5_JPNLateLL
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_2P_6_JPNLateLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_3P_1_JPNCLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_3P_2_JPNCLL
 80 300 229.271 66 -1 99 3 0 0 0 0 0 0 0 # SizeSel_4P_1_JPNDRIFT
 -19 12 -12.3996 -3 -1 99 3 0 0 0 0 0 0 0 # SizeSel_4P_2_JPNDRIFT
 -5 12 6.4492 4 -1 99 3 0 0 0 0 0 0 0 # SizeSel_4P_3_JPNDRIFT
 -5 12 5.87563 5 -1 99 3 0 0 0 0 0 0 0 # SizeSel_4P_4_JPNDRIFT
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_4P_5_JPNDRIFT
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_4P_6_JPNDRIFT
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_5P_1_JPNBait
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_5P_2_JPNBait
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_6P_1_JPNOth
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_6P_2_JPNOth
 -2 2 0 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Code_HWLL_7
 -5 5 0.0652704 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_GradLo_HWLL_7
 -5 2 0 0.0911842 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_GradHi_HWLL_7
 80 100 80 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Knot_1_HWLL_7
 100 200 160 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Knot_2_HWLL_7
 150 300 200 0 -1 99 -4 0 0 0 0 0 0 0 # SizeSpline_Knot_3_HWLL_7
 -5 3 -3.57915 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_Val_1_HWLL_7
 -5 4 1.64224 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_Val_2_HWLL_7
 -5 3 0.783337 0 -1 99 4 0 0 0 0 0 0 0 # SizeSpline_Val_3_HWLL_7
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_8P_1_ASLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_8P_2_ASLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_9P_1_HWOth
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_9P_2_HWOth
 100 300 174.626 66 -1 99 3 0 0 0 0 0 0 0 # SizeSel_10P_1_TWNLL
 -19 12 -11.8299 -3 -1 99 3 0 0 0 0 0 0 0 # SizeSel_10P_2_TWNLL
 -5 12 6.98128 4 -1 99 3 0 0 0 0 0 0 0 # SizeSel_10P_3_TWNLL
 -5 12 8.59924 5 -1 99 3 0 0 0 0 0 0 0 # SizeSel_10P_4_TWNLL
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_10P_5_TWNLL
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_10P_6_TWNLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_11P_1_TWNOth
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_11P_2_TWNOth
 100 300 172.626 66 -1 99 3 0 0 0 0 0 0 0 # SizeSel_12P_1_OthLL
 -19 12 -10.8452 -3 -1 99 3 0 0 0 0 0 0 0 # SizeSel_12P_2_OthLL
 -5 12 6.48935 4 -1 99 3 0 0 0 0 0 0 0 # SizeSel_12P_3_OthLL
 -5 15 10.0865 5 -1 99 3 0 0 0 0 0 0 0 # SizeSel_12P_4_OthLL
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_12P_5_OthLL
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_12P_6_OthLL
 80 322 92.8713 66 -1 99 3 0 0 0 0 0 1 2 # SizeSel_13P_1_PYFLL
 -19 12 -12.8637 -3 -1 99 3 0 0 0 0 0 1 2 # SizeSel_13P_2_PYFLL
 -10 12 -4.55127 4 -1 99 3 0 0 0 0 0 1 2 # SizeSel_13P_3_PYFLL
 -10 15 5.48146 5 -1 99 3 0 0 0 0 0 1 2 # SizeSel_13P_4_PYFLL
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_13P_5_PYFLL
```

```
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_13P_6_PYFLL
 100 300 227.018 66 -1 99 3 0 0 0 0 0 0 0 # SizeSel_14P_1_EPOPS
 -19 12 -11.8585 -3 -1 99 3 0 0 0 0 0 0 0 # SizeSel_14P_2_EPOPS
 -5 12 7.25479 4 -1 99 3 0 0 0 0 0 0 0 # SizeSel_14P_3_EPOPS
 -5 12 8.42283 5 -1 99 3 0 0 0 0 0 0 0 # SizeSel_14P_4_EPOPS
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_14P_5_EPOPS
 -999 -999 -999 -5 -1 99 -2 0 0 0 0 0 0 0 # SizeSel_14P_6_EPOPS
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_15P_1_WCPFCPS
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_15P_2_WCPFCPS
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_16P_1_EPOOth
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_16P_2_EPOOth
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_17P_1_S1_JPNEarlyLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_17P_2_S1_JPNEarlyLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_18P_1_S2_JPNLateLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_18P_2_S2_JPNLateLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_19P_1_S3_HWLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_19P_2_S3_HWLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_20P_1_S4_TWNLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_20P_2_S4_TWNLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_21P_1_S5_TWNLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_21P_2_S5_TWNLL
 -1 10 -1 -1 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_22P_1_S6_TWNLL
 -61 61 -61 -61 -1 99 -4 0 0 0 0 0 0 0 # SizeSel_22P_2_S6_TWNLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_1P_1_JPNEarlyLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_1P_2_JPNEarlyLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_2P_1_JPNLateLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_2P_2_JPNLateLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_3P_1_JPNCLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_3P_2_JPNCLL
 0 26 1 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_4P_1_JPNDRIFT
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_4P_2_JPNDRIFT
 0 26 1 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_5P_1_JPNBait
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_5P_2_JPNBait
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_6P_1_JPNOth
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_6P_2_JPNOth
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_7P_1_HWLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_7P_2_HWLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_8P_1_ASLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_8P_2_ASLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_9P_1_HWOth
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_9P_2_HWOth
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_10P_1_TWNLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_10P_2_TWNLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_11P_1_TWNOth
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_11P_2_TWNOth
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_12P_1_OthLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_12P_2_OthLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_13P_1_PYFLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_13P_2_PYFLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_14P_1_EPOPS
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_14P_2_EPOPS
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_15P_1_WCPFCPS
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_15P_2_WCPFCPS
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_16P_1_EPOOth
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_16P_2_EPOOth
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_17P_1_S1_JPNEarlyLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_17P_2_S1_JPNEarlyLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_18P_1_S2_JPNLateLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_18P_2_S2_JPNLateLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_19P_1_S3_HWLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_19P_2_S3_HWLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_20P_1_S4_TWNLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_20P_2_S4_TWNLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_21P_1_S5_TWNLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_21P_2_S5_TWNLL
 0 26 0 1 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_22P_1_S6_TWNLL
 0 26 26 80 -1 99 -4 0 0 0 0 0 0 0 # AgeSel_22P_2_S6_TWNLL
#_Cond 0 #_custom_sel-env_setup (0/1)
#_Cond -2 2 0 0 -1 99 -2 #_placeholder when no enviro fxns
1 #_custom_sel-blk_setup (0/1)
 80 322 181.842 66 -1 99 3 # SizeSel_13P_1_PYFLL_BLK1repl_2003
```

```
 -19 12 2.96656 -3 -1 99 3 # SizeSel_13P_2_PYFLL_BLK1repl_2003
 -10 17 6.87238 4 -1 99 3 # SizeSel_13P_3_PYFLL_BLK1repl_2003
 -10 15 1.40744 5 -1 99 3 # SizeSel_13P_4_PYFLL_BLK1repl_2003
#_Cond No selex parm trends
#_Cond -4 # placeholder for selparm_Dev_Phase
1 #_env/block/dev_adjust_method (1=standard; 2=logistic trans to keep in base parm bounds;
3=standard w/ no bound check)
#
# Tag loss and Tag reporting parameters go next
0  # TG_custom:  0=no read; 1=read if tags exist
#_Cond -6 6 1 1 2 0.01 -4 0 0 0 0 0 0 0  #_placeholder if no parameters
#
1 #_Variance_adjustments_to_input_values
#_fleet: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0.113 0.123 0.072 0 0 0 #_add_to_survey_CV
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 #_add_to_discard_stddev
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 #_add_to_bodywt_CV
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 #_mult_by_lencomp_N
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 #_mult_by_agecomp_N
  1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 #_mult_by_size-at-age_N
#
6 #_maxlambdaphase
1 #_sd_offset
#
16 # number of changes to make to default Lambdas (default value is 1.0)
# Like_comp codes:  1=surv; 2=disc; 3=mnwt; 4=length; 5=age; 6=SizeFreq; 7=sizeage; 8=catch;
# 9=init_equ_catch; 10=recrdev; 11=parm_prior; 12=parm_dev; 13=CrashPen; 14=Morphcomp; 15=Tag-
comp; 16=Tag-negbin
#like_comp fleet/survey  phase  value  sizefreq_method
 9 1 1 0 1
 4 1 1 1 1
 4 2 1 1 1
 4 7 1 1 1
 4 10 1 1 1
 4 14 1 1 1
 6 4 1 1 2
 6 12 1 1 1
 6 13 1 1 1
 1 17 1 1 1
 1 18 1 1 1
 1 19 1 0 1
 1 20 1 1 1
 1 21 1 1 1
 1 22 1 1 1
 11 1 1 0 1
#
# lambdas (for info only; columns are phases)
#  0 0 0 0 0 0 #_CPUE/survey:_1
#  0 0 0 0 0 0 #_CPUE/survey:_2
#  0 0 0 0 0 0 #_CPUE/survey:_3
#  0 0 0 0 0 0 #_CPUE/survey:_4
#  0 0 0 0 0 0 #_CPUE/survey:_5
#  0 0 0 0 0 0 #_CPUE/survey:_6
#  0 0 0 0 0 0 #_CPUE/survey:_7
#  0 0 0 0 0 0 #_CPUE/survey:_8
#  0 0 0 0 0 0 #_CPUE/survey:_9
#  0 0 0 0 0 0 #_CPUE/survey:_10
#  0 0 0 0 0 0 #_CPUE/survey:_11
#  0 0 0 0 0 0 #_CPUE/survey:_12
#  0 0 0 0 0 0 #_CPUE/survey:_13
#  0 0 0 0 0 0 #_CPUE/survey:_14
#  0 0 0 0 0 0 #_CPUE/survey:_15
#  0 0 0 0 0 0 #_CPUE/survey:_16
#  1 1 1 1 1 1 #_CPUE/survey:_17
#  1 1 1 1 1 1 #_CPUE/survey:_18
#  0 0 0 0 0 0 #_CPUE/survey:_19
#  1 1 1 1 1 1 #_CPUE/survey:_20
#  1 1 1 1 1 1 #_CPUE/survey:_21
#  1 1 1 1 1 1 #_CPUE/survey:_22
#  1 1 1 1 1 1 #_lencomp:_1
#  1 1 1 1 1 1 #_lencomp:_2
```

```
#  0 0 0 0 0 0 #_lencomp:_3
#  0 0 0 0 0 0 #_lencomp:_4
#  0 0 0 0 0 0 #_lencomp:_5
#  0 0 0 0 0 0 #_lencomp:_6
#  1 1 1 1 1 1 #_lencomp:_7
#  0 0 0 0 0 0 #_lencomp:_8
#  0 0 0 0 0 0 #_lencomp:_9
#  1 1 1 1 1 1 #_lencomp:_10
#  0 0 0 0 0 0 #_lencomp:_11
#  0 0 0 0 0 0 #_lencomp:_12
#  0 0 0 0 0 0 #_lencomp:_13
#  1 1 1 1 1 1 #_lencomp:_14
#  0 0 0 0 0 0 #_lencomp:_15
#  0 0 0 0 0 0 #_lencomp:_16
#  0 0 0 0 0 0 #_lencomp:_17
#  0 0 0 0 0 0 #_lencomp:_18
#  0 0 0 0 0 0 #_lencomp:_19
#  0 0 0 0 0 0 #_lencomp:_20
#  0 0 0 0 0 0 #_lencomp:_21
#  0 0 0 0 0 0 #_lencomp:_22
#  1 1 1 1 1 1 #_sizefreq:_1
#  1 1 1 1 1 1 #_sizefreq:_2
#  1 1 1 1 1 1 #_sizefreq:_3
#  0 0 0 0 0 0 #_init_equ_catch
#  1 1 1 1 1 1 #_recruitments
#  0 0 0 0 0 0 #_parameter-priors
#  1 1 1 1 1 1 #_parameter-dev-vectors
#  1 1 1 1 1 1 #_crashPenLambda
0 # (0/1) read specs for more stddev reporting
 # 0 1 -1 5 1 5 1 -1 5 # placeholder for selex type, len/age, year, N selex bins, Growth pattern, N growth ages, NatAge_area(-1 for all), NatAge_yr, N Natages
 # placeholder for vector of selex bins to be reported
 # placeholder for vector of growth ages to be reported
 # placeholder for vector of NatAges ages to be reported
999
```

Appendix B

SS3 forecast file used in the Pacific blue marlin assessment for the base case. Exampled model was based on expectation of the spawner-recruit relationship using current (2009-2011) harvest rate (constant $F_{23\%}$).

```
#V3.24f
#C  generic forecast file
# for all year entries except rebuilder; enter either: actual year, -999 for styr, 0 for endyr,
neg number for rel. endyr
1 # Benchmarks: 0=skip; 1=calc F_spr,F_btgt,F_msy
2 # MSY: 1= set to F(SPR); 2=calc F(MSY); 3=set to F(Btgt); 4=set to F(endyr)
0.2 # SPR target (e.g. 0.40)
0.2 # Biomass target (e.g. 0.40)
#_Bmark_years: beg_bio, end_bio, beg_selex, end_selex, beg_relF, end_relF (enter actual year, or
values of 0 or -integer to be rel. endyr)
 0 0 0 0 0 0
#  2011 2011 2011 2011 2011 2011 # after processing
1 #Bmark_relF_Basis: 1 = use year range; 2 = set relF same as forecast below
#
4 # Forecast: 0=none; 1=F(SPR); 2=F(MSY) 3=F(Btgt); 4=Ave F (uses first-last relF yrs); 5=input
annual F scalar
12 # N forecast years
1 # F scalar (only used for Do_Forecast==5)
#_Fcast_years:  beg_selex, end_selex, beg_relF, end_relF  (enter actual year, or values of 0 or -
integer to be rel. endyr)
 2009 2011 2009 2011
#  2009 2011 2009 2011 # after processing
1 # Control rule method (1=catch=f(SSB) west coast; 2=F=f(SSB) )
0.011 # Control rule Biomass level for constant F (as frac of Bzero, e.g. 0.40); (Must be > the
no F level below)
0.01 # Control rule Biomass level for no F (as frac of Bzero, e.g. 0.10)
1 # Control rule target as fraction of Flimit (e.g. 0.75)
3 #_N forecast loops (1=OFL only; 2=ABC; 3=get F from forecast ABC catch with allocations
applied)
3 #_First forecast loop with stochastic recruitment
0 #_Forecast loop control #3 (reserved for future bells&whistles)
0 #_Forecast loop control #4 (reserved for future bells&whistles)
0 #_Forecast loop control #5 (reserved for future bells&whistles)
2050  #FirstYear for caps and allocations (should be after years with fixed inputs)
0.05 # stddev of log(realized catch/target catch) in forecast (set value>0.0 to cause active
impl_error)
0 # Do West Coast gfish rebuilder output (0/1)
1999 # Rebuilder:  first year catch could have been set to zero (Ydecl)(-1 to set to 1999)
2012 # Rebuilder:  year for current age structure (Yinit) (-1 to set to endyear+1)
1 # fleet relative F:  1=use first-last alloc year; 2=read seas(row) x fleet(col) below
# Note that fleet allocation is used directly as average F if Do_Forecast=4
2 # basis for fcast catch tuning and for fcast catch caps and allocation  (2=deadbio;
3=retainbio; 5=deadnum; 6=retainnum)
# Conditional input if relative F choice = 2
# Fleet relative F:  rows are seasons, columns are fleets
#_Fleet:  JPNEarlyLL JPNLateLL JPNCLL JPNDRIFT JPNBait JPNOth HWLL ASLL HWOth TWNLL TWNOth OthLL
PYFLL EPOPS WCPFCPS EPOOth
#  0 0.0268661 0.0127764 0.0041179 0.0102423 0.000351887 0.00300929 0.00261207 0.00264376
0.0182666 0.068624 0.0778065 0.00293446 0.00315989 0.020135 0.00352963
#  0 0.0217177 0.0117594 0.00403827 0.0100455 0.000326285 0.00770952 0.00289037 0.0024713
0.0167228 0.0627754 0.0712057 0.0027036 0.00490002 0.0193306 0.00338985
#  0 0.018181 0.0123973 0.00400282 0.00995918 0.000344156 0.00864478 0.00237183 0.00268037
0.0176073 0.0660799 0.074164 0.00279383 0.00539414 0.0193174 0.00339003
#  0 0.0194314 0.0131274 0.0039805 0.00990746 0.000364498 0.00457062 0.00273465 0.00287971
0.0186242 0.0698819 0.0779877 0.00291169 0.00436975 0.0194258 0.00341242
# max totalcatch by fleet (-1 to have no max) must enter value for each fleet
 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
# max totalcatch by area (-1 to have no max); must enter value for each fleet
 -1
# fleet assignment to allocation group (enter group ID# for each fleet, 0 for not included in an
alloc group)
```

```
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
#_Conditional on >1 allocation group
# allocation fraction for each of: 0 allocation groups
# no allocation groups
0 # Number of forecast catch levels to input (else calc catch from forecast F)
2 # basis for input Fcast catch:  2=dead catch; 3=retained catch; 99=input Hrate(F) (units are
from fleetunits; note new codes in SSV3.20)
# Input fixed catch values
#Year Seas Fleet Catch(or_F)

#
999 # verify end of input
```