# ANNEX 13

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# STOCK ASSESSMENT OF PACIFIC BLUEFIN TUNA IN THE PACIFIC OCEAN IN 2022

**July 2022**

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## TABLE OF CONTENTS

## EXECUTIVE SUMMARY

### 1. Stock Identification and Distribution

Pacific bluefin tuna (*Thunnus orientalis*) has a single Pacific-wide stock managed by both the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC). Although found throughout the North Pacific Ocean, spawning grounds are recognized only in the western North Pacific Ocean (WPO). A portion of each cohort makes trans-Pacific migrations from the WPO to the eastern North Pacific Ocean (EPO), spending up to several years of its juvenile life stage in the EPO before returning to the WPO.

### 2. Catch History

While there are few Pacific bluefin tuna (PBF) catch records prior to 1952, PBF landings records are available dating back to 1804 from coastal Japan and to the early 1900s for U.S. fisheries operating in the EPO. Based on these landing records, PBF catch is estimated to be high from 1929 to 1940, with a peak catch of approximately 47,635 t (36,217 t in the WPO and 11,418 t in the EPO) in 1935; thereafter catches of PBF dropped precipitously due to World War II. PBF catches increased significantly in 1949 as Japanese fishing activities expanded across the North Pacific Ocean. By 1952, a more consistent catch reporting process was adopted by most fishing nations and estimated annual catches of PBF fluctuated widely from 1952 to 2020 (Figure 1). During this period reported catches peaked at 40,383 t in 1956 and reached a low of 8,653 t in 1990. The reported catch in 2019 and 2020 were 11,583 t and 13,825 t, respectively, including non-member countries of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC). Management measures were implemented by Regional Fisheries Management Organizations (RFMOs) beginning in 2011 (WCPFC in 2011 and IATTC in 2012) and became stricter in 2015. While a suite of fishing gears have been used to catch PBF, the majority of the catch is currently made by purse seine fisheries (Figure 2). Catch of PBF has been predominantly composed of juvenile PBF (age 0-2) throughout the assessment period. The catch of age 0 PBF has increased significantly since the early 1990s but declined as the total catch in weight declined since the mid-2010s Data and Assessment due to stricter control of juvenile catch (Figures 1 and 3).

Population dynamics were estimated using a fully integrated age-structured model (Stock Synthesis (SS) v3.30) fitted to catch (retained and discarded), size-composition, and catch-per-unit of effort (CPUE) based abundance index data from 1952 to 2020 fishing years (FY; from July to June of the following year), provided by Members of the ISC, Pacific Bluefin Tuna Working Group (PBFWG) and non-ISC countries obtained through the official statistics of the WCPFC. Life history parameters included a length-at-age relationship from otolith-derived ages and natural mortality estimates from a tag-recapture study and empirical-life history methods. The assessment model is a single-area model and assumes "areas-as-fleets" fishery selectivity. The 2022 base-case model maintained most of the model structure and settings from the previous benchmark assessment in 2020.

A total of 25 fleets were defined for use in the stock assessment model based on country/gear/season/region stratification until the end of the 2020 FY (June 2021). Quarterly observations of catch and size compositions, when available, were used as inputs to the model to describe the removal processes. Annual estimates of standardized CPUE from the Japanese distant water, off-shore and coastal longline, the Taiwanese longline, and the Japanese troll fleets were used as measures of the relative abundance of the population. The CPUE data from Japanese longline (adult index) in 2020 and Japanese troll (recruitment index) after 2016 were not included in the model as these observations may be biased due to the additional management measures implemented in Japan. The assessment model was fitted to the input 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.

After implementing minor improvements and refinements, the PBFWG found that the 2022 base-case model is consistent with the 2020 assessment results, that it fits the data well and the results are internally consistent among most of the data sources. Based on the model diagnostics, it was concluded that the model captures the production function of PBF well, thus its estimated biomass scale is reliable and the model has good predictability. Based on these observations, the PBFWG concluded that the 2022 assessment model reliably represents the population dynamics and is the best available scientific information for the PBF stock.

The base-case model results (Figure 4), reported by fishing year (FY; July 1-June 30) unless otherwise specified, show that: (1) spawning stock biomass (SSB) fluctuated throughout the assessment period (1952-2020); (2) the SSB steadily declined from 1996 to 2010; (3) the SSB has increased since 2011 resulting in the 2020 SSB being back to the 1996 level; (4) total biomass after 2011 continued to increase with an increase in young fish, creating the 2nd highest biomass peak in the assessed history in 2020; (5) fishing mortality ($F_{\%SPR}$), which declined to a level producing about 1% of SPR[1] in 2004-2009, returned to a level producing 30.7% of SPR in 2018-2020; and (6) SSB in 2020 was 10.2% of $SSB_{F=0}$, an increase from the 5.6% of $SSB_{F=0}$ estimated for 2018 in the 2020 assessment (2018 was the last year of the 2020 assessment). Based on the model diagnostics, the estimated biomass trend for the last 40 years is considered robust although SSB prior to the 1980s is uncertain due to data limitations. The SSB in 2020 was estimated to be around 65,464 t (Table 1 and Figure 4), which is a 30,000 t increase from 2018 according to the base-case model. An increase of young fish (0-2 years old) biomass was observed in 2016-2020 (Figure 5), likely resulting from low fishing mortality on those fish (Figure 6) and is expected to accelerate the recovery of SSB in the future even further.

Figure 7 depicts the historical impacts of the harvest by fleet on the PBF stock, showing the estimated biomass when fishing mortality from the respective fleets is zero. The impact of the EPO fisheries group was large before the mid-1980s, decreasing significantly thereafter. From the mid-1980s to the late 1990s, the WPO coastal fisheries group has had the greatest impact on the PBF stock. Since the introduction of the WPO purse seine fishery group targeting small fish (ages 0-1), the impact of this group has rapidly increased, and the impact in 2020 was greater than any of the other fishery groups. The WPO longline fisheries group has had a limited effect on the stock throughout the analysis period because the impact of a fishery on a stock depends on both the number and size of the fish caught by each fleet; i.e., catching a high number of smaller juvenile fish can have a greater impact on future spawning stock biomass than catching the same

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[1] SPR (spawning potential ratio) is the ratio of the cumulative spawning biomass that an average recruit is expected to produce over its lifetime when the stock is fished at the current fishing level to the cumulative spawning biomass that could be produced by an average recruit over its lifetime if the stock was unfished. $F_{\%SPR}$: F that produces % of the spawning potential ratio (i.e., 1-%SPR).

weight of larger mature fish. In 2020, the estimated cumulative impact proportion between WPO and EPO fisheries is about 83% and 17%, respectively. There is greater uncertainty associated with the dead discards than other fishery impacts because the impact of discarding is not based on observed data (unseen catches in Figure 7).

Historical recruitment estimates have fluctuated since 1952 without an apparent trend (Figure 4). Currently, stock projections assume that future recruitment will fluctuate around the historical (1952-2019 FY) average recruitment level after the initial rebuilding target is reached. No significant autocorrelation was found in recruitment estimates, supporting the use in the projections of recruitment sampled at random from the historical time series. In addition, now that SSB has recovered to be larger than the historical median, the PBFWG considers that the assumption that future recruitment will fluctuate within the historical range is reasonable. The recruitment index based on the Japanese troll CPUE has proven to be an informative indicator of recruitment in PBF assessments. However, the present assessment does not use the recruitment index for the recent period (2017-2020) due to a possible change in catchability caused by a change in fishing operations following management intervention as well as operational changes Due to a lack of data to inform trends in recent recruitment, the mean recruitment estimates for 2017-2020 are primarily estimated by the stock-recruitment relationship and are more uncertain than for other years. If recruitment in this period is below average, then the projections would be more pessimistic, while the impact on the current status would be minimal as those cohorts have not grown to contribute to the SSB. The PBFWG, therefore, investigated the projection results based on a model which includes the recruitment monitoring survey CPUE index for the recent period, which are slightly more pessimistic for recruitment in the terminal years of the assessment than the average recruitment. This analysis provided slightly more pessimistic results as compared to those using the base-case model, but the estimated effects on SSB are not sufficient to necessitate modification of the present management advice based on the base-case model. Note that the PBFWG decided not to include the recruitment monitoring index in the base case assessment as, due to its short duration (2017-2020), the PBFWG was unable to assess its reliability and consistency with other data sources in the model.

Estimated age-specific fishing mortalities (F) on the stock during the periods of 2011-2013 and 2018-2020 compared with 2002-2004 estimates (the reference period for the WCPFC Conservation and Management Measure) are presented in Figure 6. A substantial decrease in estimated F is observed in ages 0-2 in 2018-2020 FY relative to the previous years.

## 3. Biological Reference Points

The WCPFC and IATTC have adopted an initial rebuilding target (the median SSB estimated for the period from 1952 to 2014) and a second rebuilding target (20%$SSB_0$ under average recruitment) but did not implement any fishing mortality reference level. The 2022 assessment estimated the initial rebuilding biomass target ($SSB_{MED1952-2014}$) to be 6.3%$SSB_0$ and the corresponding fishing mortality expressed as SPR of $F_{6.3\%SPR}$. The Kobe plot shows that the point estimate of the $SSB_{2020}$ was 10.2%$SSB_0$ (i.e., SSB was approximately 50% of 20%$SSB_0$) and that the recent (2018-2020) fishing mortality corresponds to $F_{30.7\%SPR}$, reaching the historical lowest level (Table 1 and Figure 8). Although no reference points have been adopted to evaluate the status of PBF, an evaluation of stock status against some common reference points shows that the stock is overfished relative to the biomass-based limit reference points adopted for other species in WCPFC (20%$SSB_0$), but that the 2018-2020 fishing mortality was lower than the F corresponding to that reference point (20%SPR) (($1\text{-}SPR_{2018\text{-}2020}$)/($1\text{-}SPR_{20\%}$)=0.87 in Table 2. The PBFWG also investigated the impact of the alternative model incorporating the recruitment monitoring index on the estimation of stock status. This model estimated SSB to be 10.7%$SSB_0$ in 2020 and $F_{27.9\%SPR}$ in 2018-2020. Biomass and SPR estimates from this model do not differ substantively from the base-case model.

## 4. Projections

The PBFWG conducted projections based on the base-case model under several harvest scenarios and time schedules as requested by the RFMOs. The results are shown in Tables 3-5 and Figure 9. Under all examined scenarios the second rebuilding target of WCPFC and IATTC, rebuilding to 20%$SSB_0$ by the 2029 fishing year (FY) (10 years after reaching the initial rebuilding target) with at least 60% probability, is reached, and the risk of SSB falling below the historical lowest observed SSB at least once in 10 years is negligible. Also, amongst the projection scenarios assessed, Scenario 5 (the conversion of small fish quota to large fish quota at the current conversion factor of 1.47) achieved the second highest SSB when the second rebuilding target was met and after 10 years relative to the old CMM, Scenario 10 (Table 4). The Kobe chart of the projection results shows that PBF SSB will recover to the 2nd rebuilding target due to reduced fishing mortality (Figure 10). In scenarios 6-9 where future impact ratios between WPO and EPO are specified by the RFMOs, the recovery probability or impact ratio was approximated during the search for the appropriate increase levels. More specifically, those scenarios were tuned to achieve the 2nd rebuilding target (10 years after achieving the initial rebuilding target) with 60% probability, and as a result, the catch increases are much more aggressive than other scenarios.

The PBFWG evaluated projection results of sensitivity models with lower mortality, larger asymptotic length in the von Bertalanffy growth function, lower steepness, or the recent recruitment monitoring index fit. Though projection results from these lower productivity models are more pessimistic than those from the base-case model, the PBFWG concluded that the current advice is robust to these alternative model assumptions.

The projection results assume that the CMMs are fully implemented and are based on certain biological and other assumptions. For example, these future projection results do not contain assumptions about discard mortality. Although the impact of discards on SSB is small compared to other fisheries (Figure 7), discards should be considered in future harvest scenarios. Given the uncertainty in future recruitment and the influence of recruitment on stock biomass as well as the impact of changes in fishing operations due to the management, monitoring recruitment and SSB should continue.

A future Kobe chart and impacts by fleets estimated from projections under the current management scheme are provided in Figures 10 and 11, respectively. Because the projections include catch limits, fishing mortality ($F_{x\%SPR}$) is expected to decline, i.e., SPR will increase, as biomass increases. The same information for all harvest scenarios are provided in the main body of the assessment report.

## 5. Stock Status

PBF spawning stock biomass (SSB) has gradually increased in the last 10 years, and the rate of increase is accelerating. These biomass increases coincide with a decline in fishing mortality, particularly for fish aged 0 to 3, over the last decade. The latest (2020) SSB is estimated to be 10.2% of $SSB_0$. The following information on the status of the Pacific bluefin tuna stock is provided:

1. No biomass-based limit or target reference points have been adopted for PBF, but the PBF stock is overfished relative to the potential biomass-based reference points ($20\%SSB_0$) adopted for other tuna species by the IATTC and WCPFC. On the other hand, SSB reached its initial rebuilding target ($SSB_{MED} = 6.3\%SSB_0$) in 2019, 5 years earlier than originally anticipated by the RFMOs.

2. No fishing mortality-based reference points have been adopted for PBF by the IATTC and WCPFC. The recent (2018-2020) $F_{\%SPR}$ is estimated to produce a fishing intensity of 30.7%SPR and is below the level corresponding to overfishing for many F-based reference points proposed for tuna species (Table 2), including $SPR_{20\%}$.

## 6. Conservation Information

After the steady decline in SSB from 1996 to the historically low level in 2010, the PBF stock has started recovering, and recovery has been more rapid in recent years, consistent with the implementation of stringent management measures. The 2020 SSB was above the initial rebuilding target but remains below the second rebuilding target adopted by the WCPFC and IATTC. However, stock recovery is occurring at a faster rate than anticipated by managers when the Harvest Strategy to foster rebuilding (WCPFC HS 2017-02) was implemented in 2014. The fishing mortality ($F_{\%SPR}$) in 2018-2020 has been reduced to a level producing 30.7%SPR, the lowest observed in the time series.

Based on these findings, the following information on the conservation of the Pacific bluefin tuna stock is provided:

1. The PBF stock is recovering from the historically low biomass in 2010 and has exceeded the initial rebuilding target ($SSB_{MED1952-2014}$) five years earlier than expected. The rate of recovery is increasing and under all projection scenarios evaluated, it is very likely the second rebuilding target ($20\%SSB_0$ with 60% probability) will be achieved (probabilities > 90%) by 2029. The risk of SSB falling below the historical lowest observed SSB at least once in 10 years is negligible.

2. The projection results show that increases in catches are possible without affecting the attainment of the second rebuilding objective. Increases in catch should consider both the rebuilding rate and the distribution of catch between small and large fish.

3. The projection results assume that the CMMs are fully implemented and are based on certain biological and other assumptions. For example, these future projection results do not contain assumptions about discard mortality. Although the impact of discards on SSB is small compared to other fisheries, discards should be considered in future harvest scenarios.

4. Given the uncertainty in future recruitment and the influence of recruitment on stock biomass as well as the impact of changes in fishing operations due to the management, monitoring recruitment and SSB should continue and research on a recruitment index for the stock assessment should be pursued.

5. The results of projections from sensitivity models with lower productivity assumptions show that this conservation information is robust to uncertainty in stock productivity.

**Table 1.** Total biomass, spawning stock biomass, recruitment, spawning potential ratio, and depletion ratio (SSB/$SSB_{F=0}$) of Pacific bluefin tuna (*Thunnus orientalis*) estimated by the base-case model, 1952-2020 FY.

| Year | Total Biomass (t) | Spawning Stock Biomass (t) | Recruitment (1,000 fish) | Spawning Potential Ratio | Depletion Ratio |
|---|---|---|---|---|---|
| 1952 | 134,789 | 103,359 | 14,008 | 11.6% | 16.1% |
| 1953 | 136,421 | 97,912 | 20,617 | 12.9% | 15.2% |
| 1954 | 146,892 | 88,019 | 34,911 | 7.9% | 13.7% |
| 1955 | 156,701 | 75,353 | 13,343 | 11.4% | 11.7% |
| 1956 | 176,167 | 67,818 | 33,476 | 15.8% | 10.5% |
| 1957 | 193,973 | 77,053 | 11,635 | 10.8% | 12.0% |
| 1958 | 202,415 | 100,943 | 3,203 | 19.5% | 15.7% |
| 1959 | 209,868 | 136,650 | 7,709 | 23.9% | 21.2% |
| 1960 | 202,700 | 144,704 | 7,554 | 17.3% | 22.5% |
| 1961 | 194,047 | 156,534 | 23,235 | 3.4% | 24.3% |
| 1962 | 177,257 | 141,792 | 10,774 | 10.9% | 22.0% |
| 1963 | 166,291 | 120,933 | 27,842 | 6.6% | 18.8% |
| 1964 | 154,459 | 106,314 | 5,689 | 7.5% | 16.5% |
| 1965 | 142,916 | 93,572 | 10,955 | 3.0% | 14.5% |
| 1966 | 120,164 | 89,589 | 8,556 | 0.1% | 13.9% |
| 1967 | 105,483 | 83,751 | 10,951 | 1.1% | 13.0% |
| 1968 | 91,650 | 77,872 | 14,356 | 1.4% | 12.1% |
| 1969 | 80,731 | 64,561 | 6,450 | 8.6% | 10.0% |
| 1970 | 74,490 | 54,181 | 7,182 | 2.9% | 8.4% |
| 1971 | 66,467 | 47,017 | 12,407 | 1.3% | 7.3% |
| 1972 | 64,098 | 40,725 | 22,890 | 0.3% | 6.3% |
| 1973 | 62,899 | 35,510 | 11,251 | 5.6% | 5.5% |
| 1974 | 65,165 | 28,711 | 13,983 | 6.3% | 4.5% |
| 1975 | 65,978 | 26,420 | 11,223 | 8.9% | 4.1% |
| 1976 | 65,030 | 29,152 | 8,071 | 3.1% | 4.5% |
| 1977 | 74,864 | 35,066 | 25,589 | 3.7% | 5.4% |
| 1978 | 76,566 | 32,974 | 14,317 | 5.0% | 5.1% |
| 1979 | 73,608 | 27,866 | 12,876 | 8.2% | 4.3% |
| 1980 | 72,844 | 29,713 | 6,554 | 6.2% | 4.6% |
| 1981 | 57,749 | 27,591 | 13,360 | 0.3% | 4.3% |
| 1982 | 40,714 | 24,235 | 6,454 | 0.0% | 3.8% |
| 1983 | 33,472 | 14,773 | 10,090 | 6.0% | 2.3% |
| 1984 | 37,662 | 12,895 | 9,063 | 5.3% | 2.0% |
| 1985 | 39,805 | 12,957 | 9,654 | 2.7% | 2.0% |
| 1986 | 34,473 | 15,316 | 7,939 | 1.1% | 2.4% |
| 1987 | 32,080 | 14,105 | 5,980 | 8.2% | 2.2% |
| 1988 | 38,238 | 15,059 | 9,483 | 11.0% | 2.3% |
| 1989 | 42,074 | 14,888 | 4,291 | 14.6% | 2.3% |
| 1990 | 57,971 | 18,994 | 17,436 | 18.4% | 3.0% |
| 1991 | 69,431 | 25,290 | 10,617 | 9.8% | 3.9% |
| 1992 | 76,142 | 32,456 | 3,968 | 14.7% | 5.0% |
| 1993 | 83,395 | 43,890 | 4,430 | 16.8% | 6.8% |
| 1994 | 97,472 | 50,177 | 29,319 | 13.5% | 7.8% |
| 1995 | 93,999 | 62,246 | 16,012 | 5.2% | 9.7% |
| 1996 | 96,300 | 61,563 | 17,964 | 8.8% | 9.6% |
| 1997 | 90,121 | 56,179 | 11,082 | 6.0% | 8.7% |
| 1998 | 95,748 | 55,612 | 16,075 | 4.2% | 8.6% |
| 1999 | 91,805 | 51,374 | 22,755 | 3.4% | 8.0% |
| 2000 | 76,307 | 48,461 | 14,385 | 1.7% | 7.5% |
| 2001 | 77,426 | 46,059 | 17,302 | 9.5% | 7.2% |
| 2002 | 75,311 | 43,899 | 13,541 | 5.7% | 6.8% |
| 2003 | 67,904 | 43,152 | 7,157 | 2.3% | 6.7% |
| 2004 | 65,640 | 35,881 | 27,746 | 1.4% | 5.6% |
| 2005 | 55,074 | 29,159 | 15,118 | 0.7% | 4.5% |
| 2006 | 43,314 | 23,294 | 13,540 | 1.1% | 3.6% |
| 2007 | 42,659 | 18,424 | 22,227 | 0.5% | 2.9% |
| 2008 | 38,290 | 13,716 | 21,072 | 0.6% | 2.1% |
| 2009 | 33,985 | 10,195 | 8,277 | 1.2% | 1.6% |
| 2010 | 36,969 | 9,761 | 17,952 | 2.4% | 1.5% |
| 2011 | 38,817 | 11,183 | 13,526 | 4.9% | 1.7% |
| 2012 | 42,482 | 13,902 | 7,169 | 8.2% | 2.2% |
| 2013 | 52,764 | 16,313 | 13,169 | 5.7% | 2.5% |
| 2014 | 53,075 | 19,185 | 3,641 | 11.1% | 3.0% |
| 2015 | 59,220 | 23,640 | 8,653 | 12.5% | 3.7% |
| 2016 | 69,494 | 30,516 | 16,690 | 12.8% | 4.7% |
| 2017 | 82,681 | 32,538 | 10,895 | 21.9% | 5.1% |
| 2018 | 103,849 | 35,741 | 11,145 | 28.3% | 5.6% |
| 2019 | 129,972 | 45,173 | 11,843 | 28.8% | 7.0% |
| 2020 | 156,517 | 65,464 | 11,316 | 35.1% | 10.2% |
| Median(1952-2020) | 74,864 | 35,881 | 11,635 | 6.2% | 5.6% |
| Average(1952-2020) | 89,353 | 49,845 | 13,390 | 8.3% | 7.7% |

**Table 2.** Ratios of the estimated fishing mortalities (Fs and 1-SPRs for 2002-04, 2011-13, and 2018-2020) relative to potential fishing mortality-based reference points, terminal year SSB (t) for each reference period, and depletion ratio **($SSB/SSB_{F=0}$)** for the terminal year of the reference period for Pacific bluefin tuna (*Thunnus orientalis*) from the base-case model**.** $F_{max}$: Fishing mortality (F) that maximizes equilibrium yield per recruit (Y/R). $F_{0.1}$: F at which the slope of the Y/R curve is 10% of the value at its origin. $F_{med}$: F corresponding to the inverse of the median of the observed R/SSB ratio. $F_{xx\%SPR}$: F that produces a given % of the unfished spawning potential (biomass) under equilibrium conditions.

| Reference Period | | | | (1-SPR)/(1-$SPR_{xx\%}$) | | | | Estimated SSB for terminal year of each period (ton) | Depletion rate for terminal year of each period (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Fmax | F0.1 | Fmed | $SPR_{10\%}$ | $SPR_{20\%}$ | $SPR_{30\%}$ | $SPR_{40\%}$ | | |
| 2002-2004 | 1.96 | 2.89 | 1.16 | 1.08 | 1.21 | 1.38 | 1.61 | 35,881 | 5.6% |
| 2011-2013 | 1.54 | 2.27 | 0.87 | 1.04 | 1.17 | 1.34 | 1.56 | 16,313 | 2.5% |
| 2018-2020 | 0.75 | 1.14 | 0.33 | 0.77 | 0.87 | 0.99 | 1.15 | 65,464 | 10.2% |

**Table 3.** Future projection scenarios for Pacific bluefin tuna (*Thunnus orientalis*).

| | Harvesting scenarios | | | | | | |
|---|---|---|---|---|---|---|---|
| Reference No | Catch upper limit increments from status quo | | | Catch limit in the projection | | | Note |
| | WCPO | | EPO | WCPO | | EPO | |
| | Small | Large | Commercial | Small | Large | Commercial | |
| 1 | New CMM | | | 4,475 | 7,860 | 3,995 | NC request (paragraph 1; New CMM)<br>WCPFC CMM 2021-02, IATTC Resolution C-21-05 |
| 2 | New CMM | +500 tons | +500 tons | 4,475 | 8,360 | 4,495 | NC request (Paragraph 1, Appendix table 1st line) |
| 3 | 10% increase on the New CMM | | | 4,948 | 8,621 | 4,395 | NC request (Paragraph 1, Appendix table 2nd line) |
| 4 | 20% increase on the New CMM | | | 5,420 | 9,382 | 4,794 | NC request (Paragraph 1, Appendix table 3rd line) |
| 5 | -580 tons | +853 tons | New CMM | 3,895 | 8,713 | 3,995 | NC request (paragraph 3; conversion factor scenario). Transferring 10% (JPN) and 25% (KOR) of small fish catch quota to their largefish catch quota with the defined conversion factor (1.47). |
| 6 | +30% | +30% | +190% | 5,893 | 10,143 | 11,586 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 75:25. Additional quota is assigned proportionally for the WPO fisheries and independently for the EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them.) |
| 7 | New CMM | +130% | +190% | 4,475 | 17,752 | 11,586 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 75:25. Additional quota is assigned only for the WPO large fish fisheries and EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them) |
| 8 | +60% | +60% | +90% | 7,310 | 12,425 | 7,591 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 80:20. Additional quota is assigned proportionally for the WPO fisheries and independently for the EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them.) |
| 9 | New CMM | +230% | +90% | 4,475 | 25,362 | 7,591 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 80:20. Additional quota is assigned only for the WPO large fish fisheries and EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them) |
| 10 | Old CMM (50% of 2002-04 average level) | Old CMM (2002-04 average level) | Old CMM | 4,475 | 6,841 | 3,300 | Old CMM |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 catch for all fisheries |

* The Reference number of the Scenario is different from those given by the IATTC-WCPFC NC Joint WG meeting.

* Fishing mortality for scenario 1 is specified as the average level of age-specific fishing mortality during 2002-2004, which is the reference years in the WCPFC. Higher levels of the fishing mortality are specified for other scenarios to fulfill their quota in those projections.

* The Japanese unilateral measure (transferring 250 mt of catch upper limit from that for small PBF to that for large PBF during 2020-2034) is reflected in the projections.

**Table 4.** Future projection scenarios for Pacific bluefin tuna (*Thunnus orientalis*) and their results on the base-case model. 2nd rebuilding target is 20%$SSB_{F=0}$. $SSB_{loss}$ is the lowest SSB observed.

| Reference No | Harvesting scenarios | | | | Peformance indicators | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | WCPO | | EPO | | The fishing year expected to achive the 2nd rebuilding target with >60% probability | Risk to breach $SSB_{loss}$ at least once by 2030 | Probability of achiving the 2nd rebuilding target at 10 years after achieving initial rebuilding target [2029] | Median SSB at 10 years after achieving initial rebuilding target [2029] | Median SSB at 2034 | Fishery impact ratio of WPO fishery at 10 years after achieving the initial rebuilding target [2029] | Fishery impact ratio of EPO fishery at 10 years after achieving the initial rebuilding target [2029] |
| | Small | Large | Small | Large | | | | | | | |
| 1 | New CMM | | | | 2023 | 0% | 98.8% | 262,795 | 307,336 | 81.1% | 18.9% |
| 2 | New CMM | 500 tons increase on the New CMM | 500 tons increase on the New CMM | | 2023 | 0% | 98.2% | 256,170 | 298,867 | 80.3% | 19.7% |
| 3 | 10% increase on the New CMM | | | | 2023 | 0% | 96.9% | 245,333 | 280,687 | 82.3% | 17.7% |
| 4 | 20% increase on the New CMM | | | | 2023 | 0% | 94.0% | 227,183 | 253,598 | 83.4% | 16.6% |
| 5 | -580 tons | +853 tons | New CMM | | 2023 | 0% | 99.3% | 269,289 | 319,863 | 80.2% | 19.8% |
| 6 | +30% | +30% | +190% | | 2023 | 0% | 64.1% | 154,417 | 150,121 | 75.5% | 24.5% |
| 7 | New CMM | +130% | +190% | | 2029 | 0% | 60.0% | 147,931 | 157,963 | 75.2% | 24.8% |
| 8 | +60% | +60% | +90% | | 2023 | 0% | 61.3% | 147,275 | 135,698 | 80.6% | 19.4% |
| 9 | New CMM | +230% | +90% | | 2030 | 0% | 58.6% | 145,058 | 160,473 | 78.3% | 21.7% |
| 10 | Old CMM (50% of 2002-04 average level) | Old CMM (2002-04 average level) | Old CMM | | 2023 | 0% | 99.4% | 272,845 | 320,885 | 82.1% | 17.9% |
| 11 | 0 | 0 | 0 | | 2022 | 0% | 100.0% | 478,465 | 578,729 | 83.0% | 17.0% |

* The numbering of Scenarios is different from those given by the IATTC-WCPFC NC Joint WG meeting and the same as Table 3.

* Recruitment is resampled from historical values.

**Table 5.** Expected yield for Pacific bluefin tuna (*Thunnus orientalis*) under various harvesting scenarios based on the base-case model.

| Reference No | Harvesting scenarios | | | | | | Future expected catch | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Catch upper limit increments from status quo | | | Catch upper limit in the projection | | | 2024 | | | | 2034 | | | |
| | WCPO | | EPO | WCPO | | EPO | WCPO | | EPO | | WCPO | | EPO | |
| | Small | Large | Commercial | Small | Large | Commercial | Small | Large | Commercial | Sport | Small | Large | Commercial | Sport |
| 1 | New CMM | | | 4,475 | 7,860 | 3,995 | 4,496 | 7,884 | 4,008 | 1,228 | 4,497 | 7,922 | 4,012 | 1,540 |
| 2 | New CMM | 500 tons increase on the New CMM | 500 tons increase on the New CMM | 4,475 | 8,360 | 4,495 | 4,496 | 8,366 | 4,506 | 1,216 | 4,496 | 8,419 | 4,510 | 1,513 |
| 3 | 10% increase on the New CMM | | | 4,948 | 8,621 | 4,395 | 4,965 | 8,610 | 4,404 | 1,189 | 4,965 | 8,674 | 4,407 | 1,430 |
| 4 | 20% increase on the New CMM | | | 5,420 | 9,382 | 4,794 | 5,434 | 9,307 | 4,801 | 1,150 | 5,435 | 9,413 | 4,802 | 1,318 |
| 5 | -580 tons | +853 tons | New CMM | 3,895 | 8,713 | 3,995 | 3,916 | 8,749 | 4,009 | 1,250 | 3,917 | 8,787 | 4,013 | 1,616 |
| 6 | +30% | +30% | +190% | 5,893 | 10,143 | 11,586 | 5,892 | 10,181 | 11,521 | 996 | 5,889 | 10,018 | 11,247 | 924 |
| 7 | New CMM | +130% | +190% | 4,475 | 17,752 | 11,586 | 4,492 | 17,733 | 11,552 | 1,012 | 4,491 | 17,144 | 11,486 | 1,079 |
| 8 | +60% | +60% | +90% | 7,310 | 12,425 | 7,591 | 7,240 | 12,502 | 7,594 | 979 | 7,211 | 12,073 | 7,512 | 841 |
| 9 | New CMM | +230% | +90% | 4,475 | 25,362 | 7,591 | 4,494 | 23,864 | 7,601 | 1,030 | 4,493 | 24,055 | 7,597 | 1,160 |
| 10 | Old CMM (50% of 2002-04 average level) | Old CMM (2002-04 average level) | Old CMM | 4,475 | 6,841 | 3,300 | 4,497 | 6,866 | 3,317 | 1,243 | 4,497 | 6,888 | 3,319 | 1,580 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

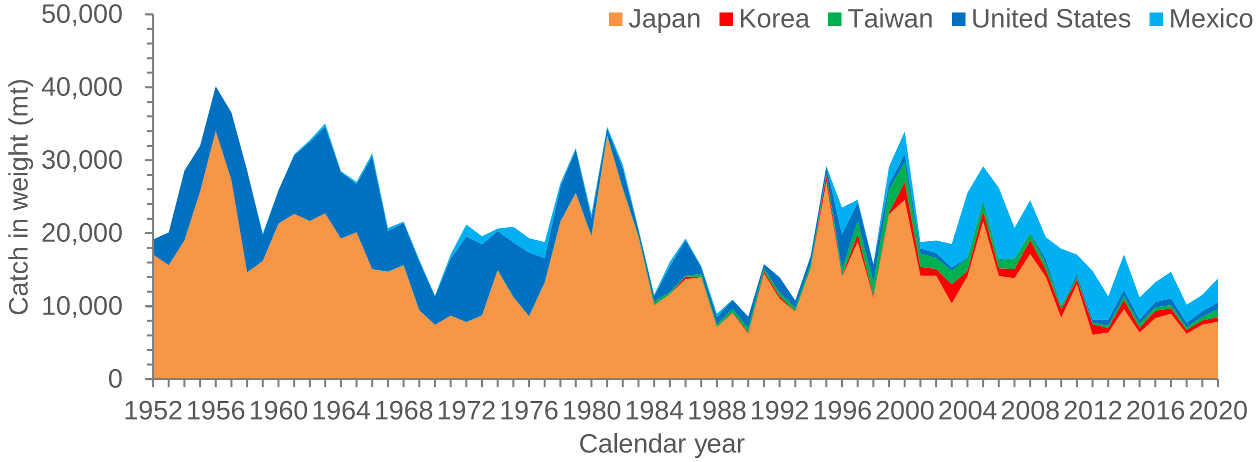

**Figure 1.** Annual catch (ton) of Pacific bluefin tuna (*Thunnus orientalis*) by ISC member countries from 1952 through 2020 (calendar year) based on ISC official statistics.

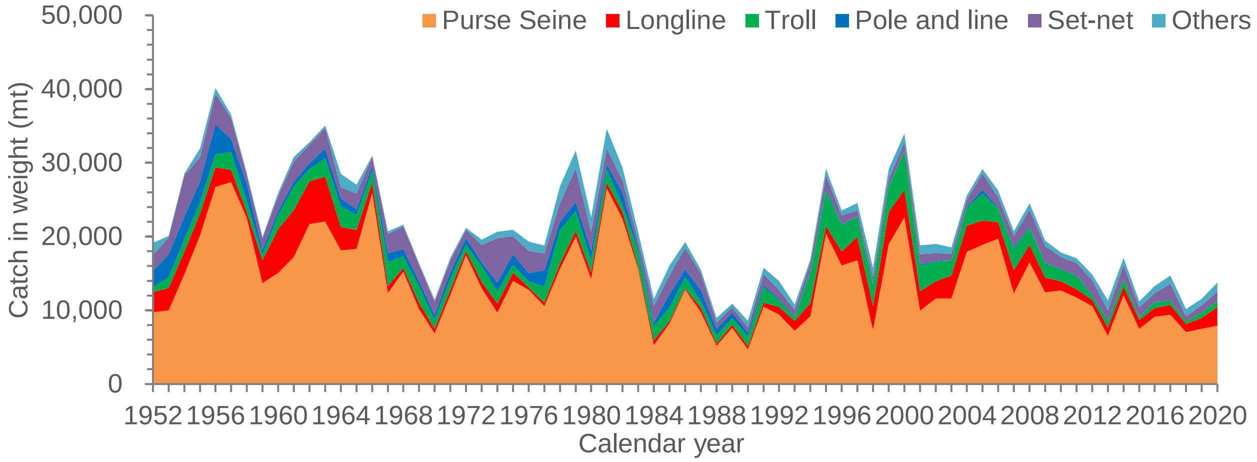

**Figure 2.** Annual catch (ton) of Pacific bluefin tuna (*Thunnus orientalis*) by gear type by ISC member countries from 1952 through 2020 (calendar year) based on ISC official statistics.

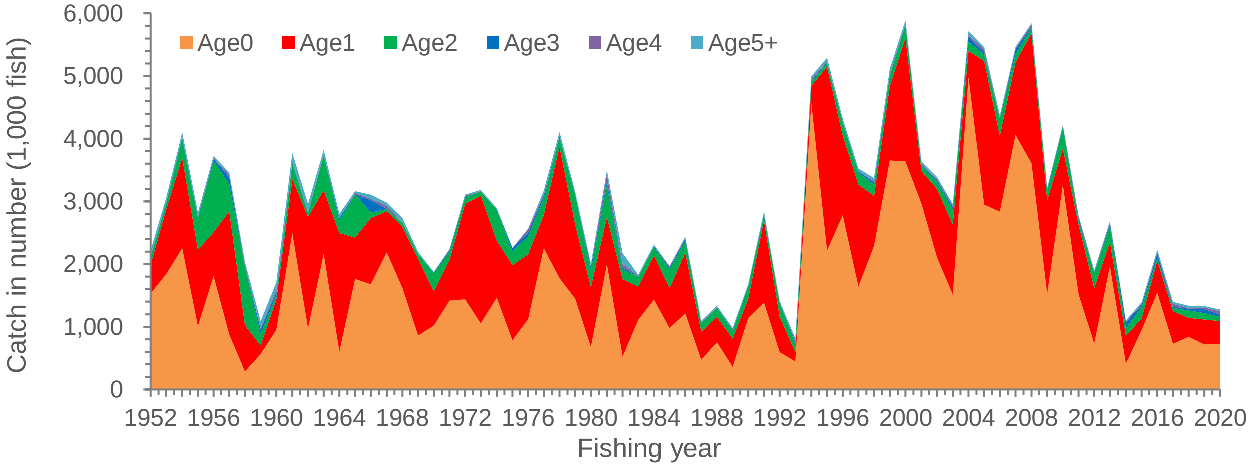

**Figure 3.** Estimated annual catch-at-age (number of fish) of Pacific bluefin tuna (*Thunnus orientalis*) by fishing year by the base-case model (1952-2020).

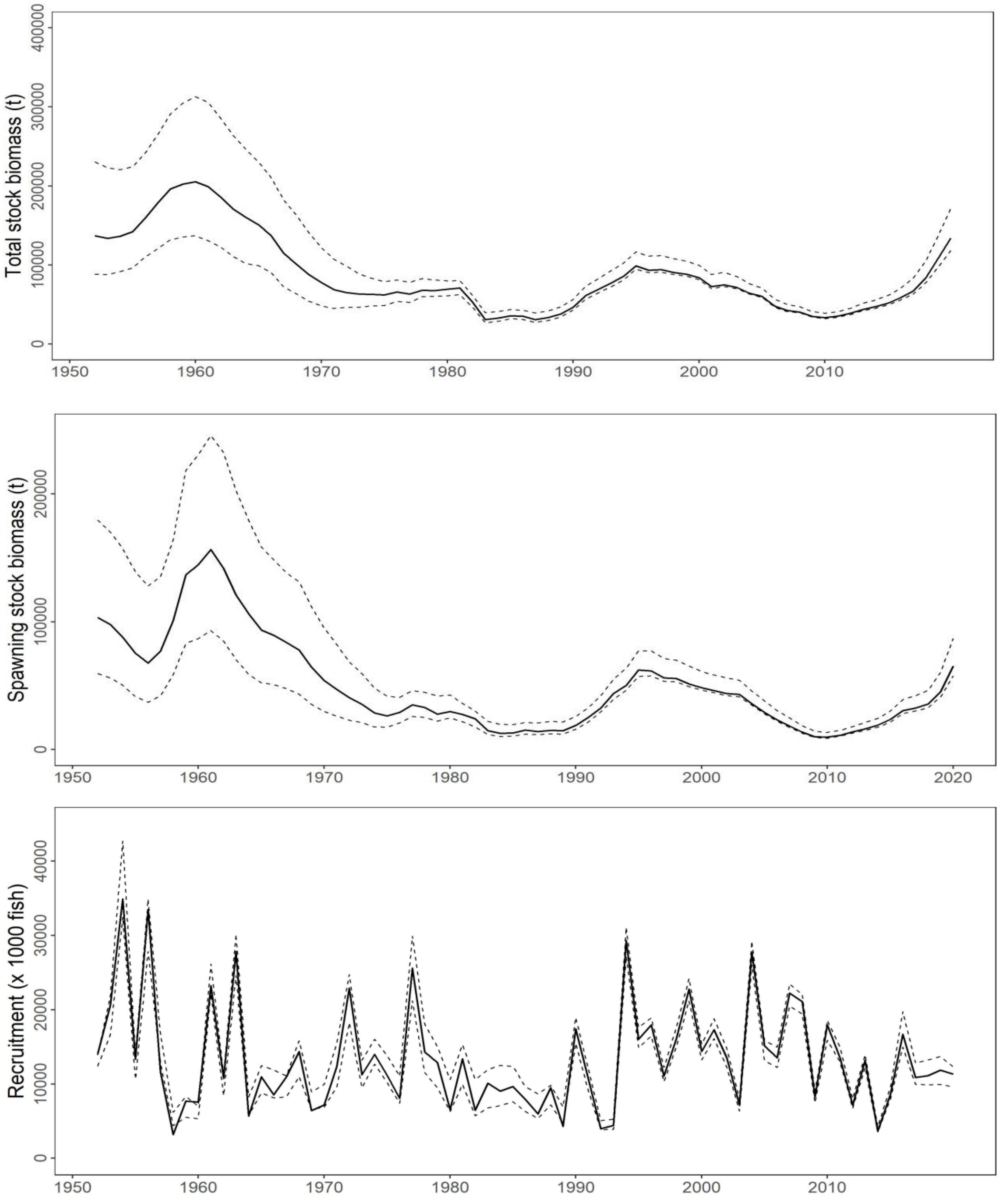

**Figure 4.** Maximum likelihood estimates of total stock biomass (top), spawning stock biomass (middle), and recruitment (bottom) of Pacific bluefin tuna (*Thunnus orientalis*) (1952-2020) estimated from the base-case model. The solid line represents the point estimates and dashed lines delineate the 90% confidence interval by bootstrapping. Note that the bootstrap confidence interval may not capture the full uncertainty around the recruitment estimates for 2017-2020.

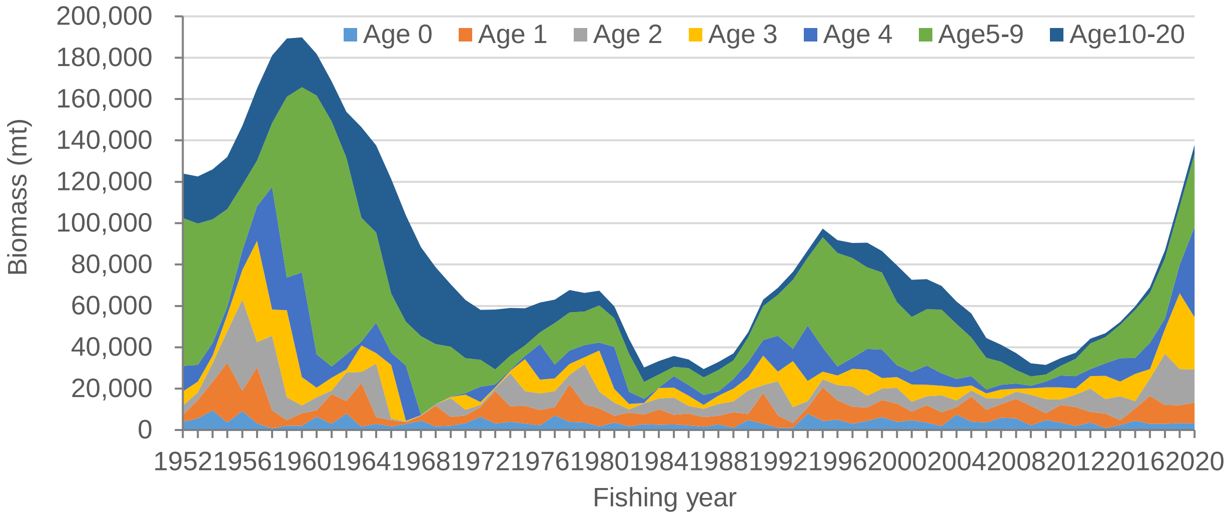

**Figure 5.** Total biomass (tonnes) by age of Pacific bluefin tuna (*Thunnus orientalis*) estimated from the base-case model (1952-2020). Note that the recruitment estimates for 2017-2020 may be more uncertain than in other years.

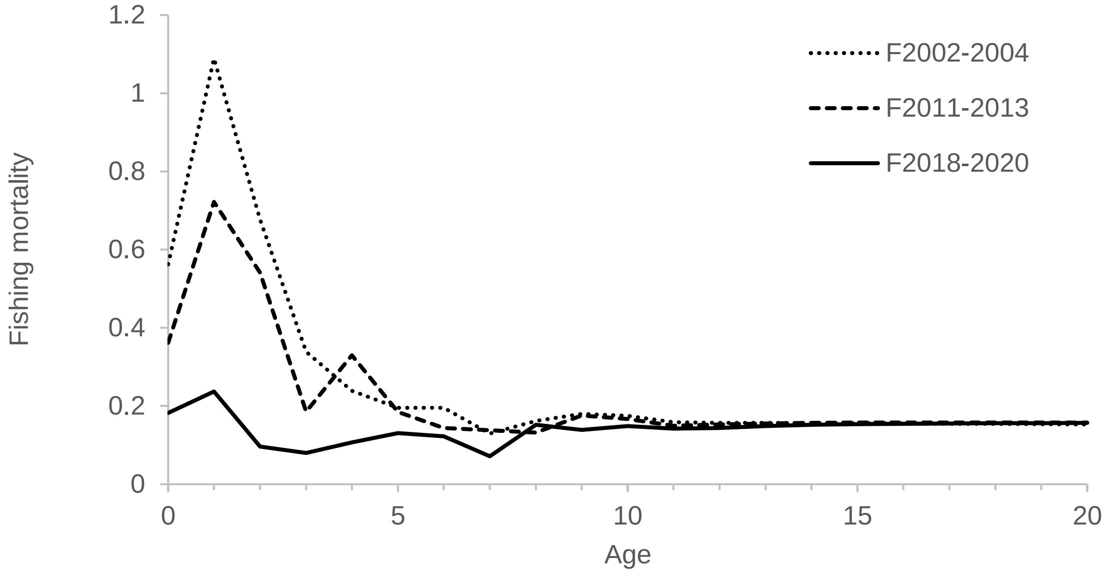

**Figure 6.** Geometric means of annual age-specific fishing mortalities (F) of Pacific bluefin tuna (*Thunnus orientalis*) for 2002-2004 (dotted line), 2011-2013 (broken line), and 2018-2020 (solid line).

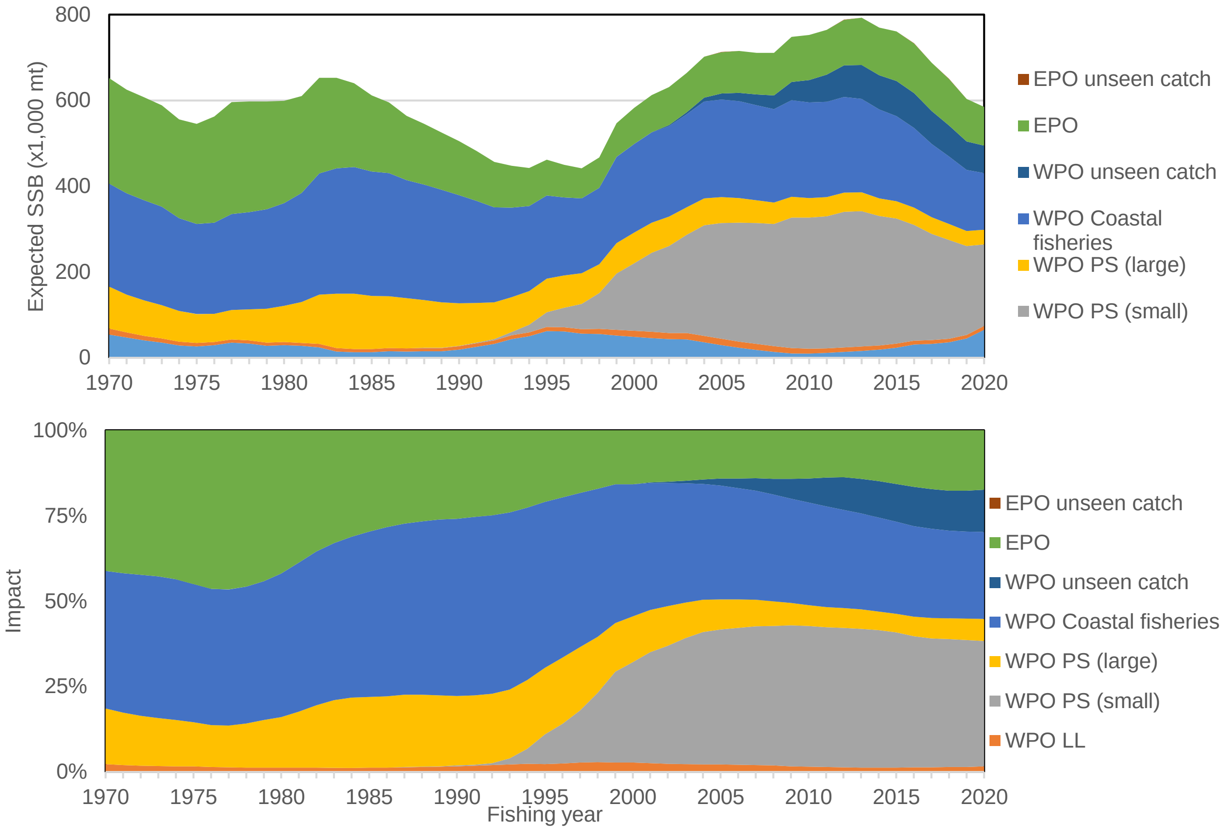

**Figure 7.** The trajectory of the spawning stock biomass of a simulated population of Pacific bluefin tuna (*Thunnus orientalis*) when zero fishing mortality is assumed, estimated by the base-case model. (top: absolute SSB, bottom: relative SSB). In 2020, the estimated cumulative impact proportion between WPO and EPO fisheries is about 83% and 17%, respectively. Fisheries group definition; WPO longline fisheries: F1, F12, F17, F23. WPO purse seine fisheries for small fish: F2, F3, F18, F20. WPO purse seine fisheries for large fish: F4, F5. WPO coastal fisheries: F6-11, F16, F19. EPO fisheries: F13, F14, F15, F24. WPO unaccounted fisheries: F21, 22. EPO unaccounted fisheries: F25. For exact fleet definitions, please see the 2022 PBF stock assessment report.

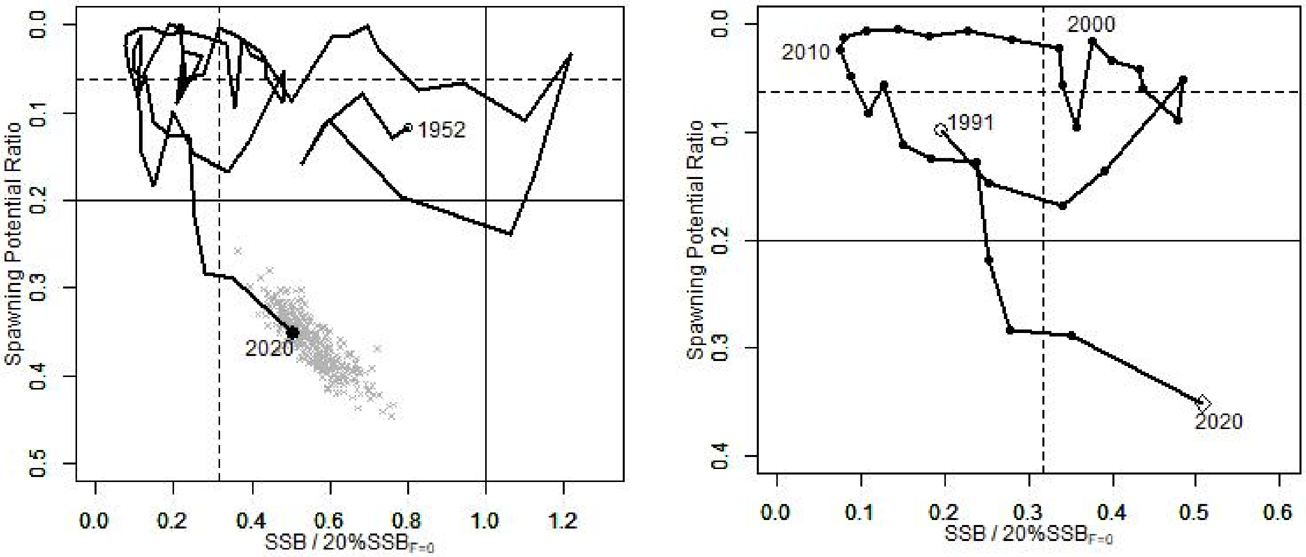

**Figure 8.** Kobe plots for Pacific bluefin tuna (*Thunnus orientalis*) estimated from the base-case model. The X-axis shows the annual SSB relative to 20%$SSB_{F=0}$ and the Y-axis shows the spawning potential ratio (SPR) as a measure of fishing mortality. Vertical and horizontal solid lines in the left figure show 20%$SSB_{F=0}$ (which corresponds to the second biomass rebuilding target) and the corresponding fishing mortality that produces SPR, respectively. Vertical and horizontal broken lines in both figures show the initial biomass rebuilding target ($SSB_{MED}$ = 6.3%$SSB_{F=0}$) and the corresponding fishing mortality that produces SPR, respectively. $SSB_{MED}$ is calculated as the median of estimated SSB in 1952-2014. The left figure shows the historical trajectory, where the open circle indicates the first year of the assessment (1952), the solid circle indicates the last year of the assessment (2020), and grey crosses indicate the uncertainty of estimates in 2020 using bootstrapping. The right figure shows the trajectory of the last 30 years.

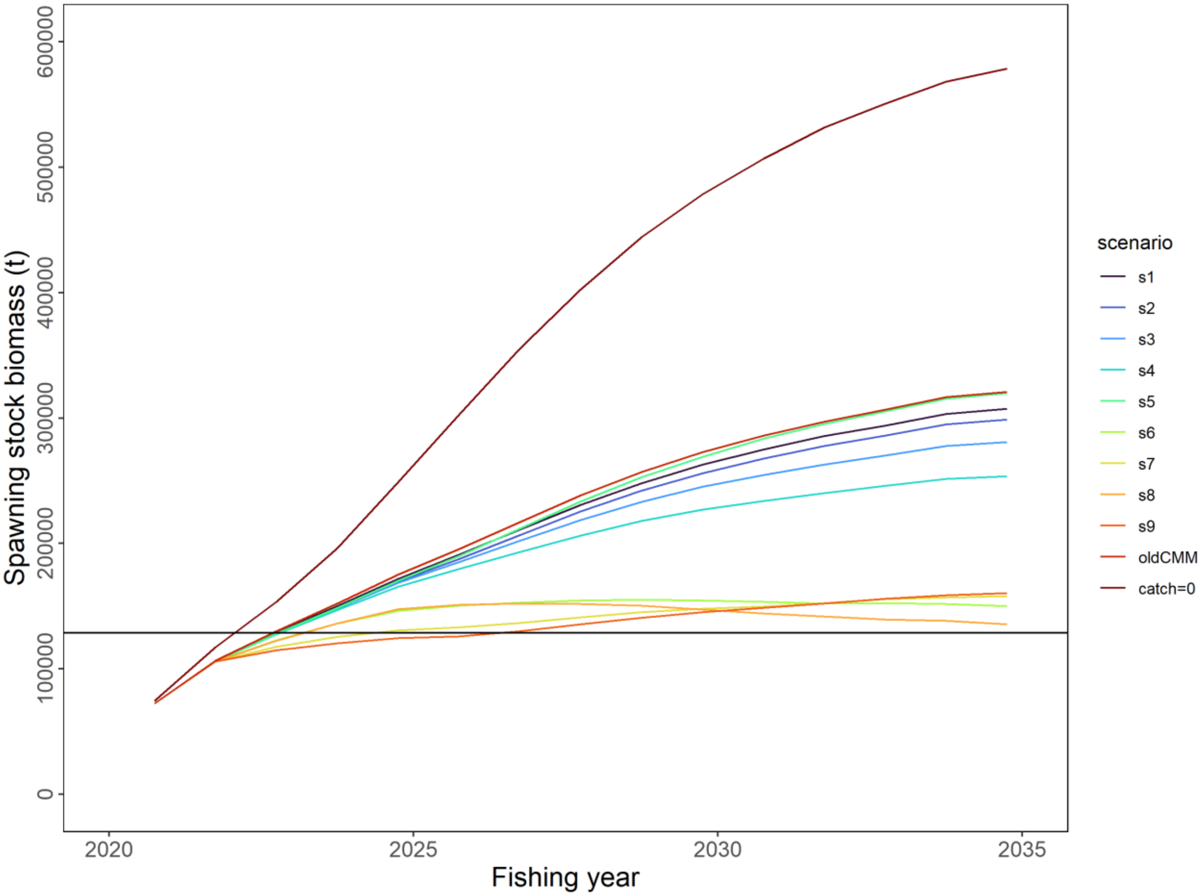

**Figure 9**. Comparisons of various projected median SSB for all harvest scenarios examined for Pacific bluefin tuna (*Thunnus orientalis*) obtained from projection results. The black horizontal solid line shows the second rebuilding target for this species (20%$SSB_{F=0}$).

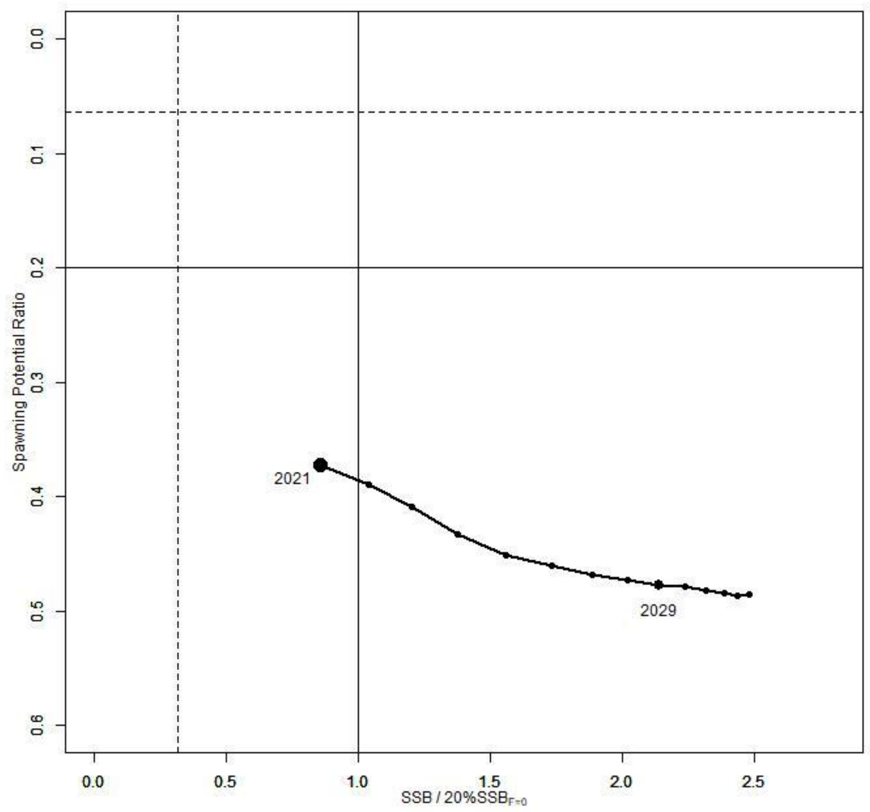

**Figure 10**. "Future Kobe Plot" based on the median estimates of SSB and SPR from the projections for Pacific bluefin tuna (*Thunnus orientalis*) from Scenario 1 from Table 3. The X-axis shows the annual SSB relative to 20%SSB$_{F=0}$ and the Y-axis shows the spawning potential ratio (SPR) as a measure of fishing mortality. Vertical and horizontal solid lines in the figure show 20%SSB$_{F=0}$ (which corresponds to the second biomass rebuilding target) and the corresponding fishing mortality that produces SPR, respectively. Vertical and horizontal broken lines in both figures show the initial biomass rebuilding target (SSB$_{MED}$ = 6.3%SSB$_{F=0}$) and the corresponding fishing mortality that produces SPR, respectively. SSB$_{MED}$ is calculated as the median of estimated SSB in 1952-2014.

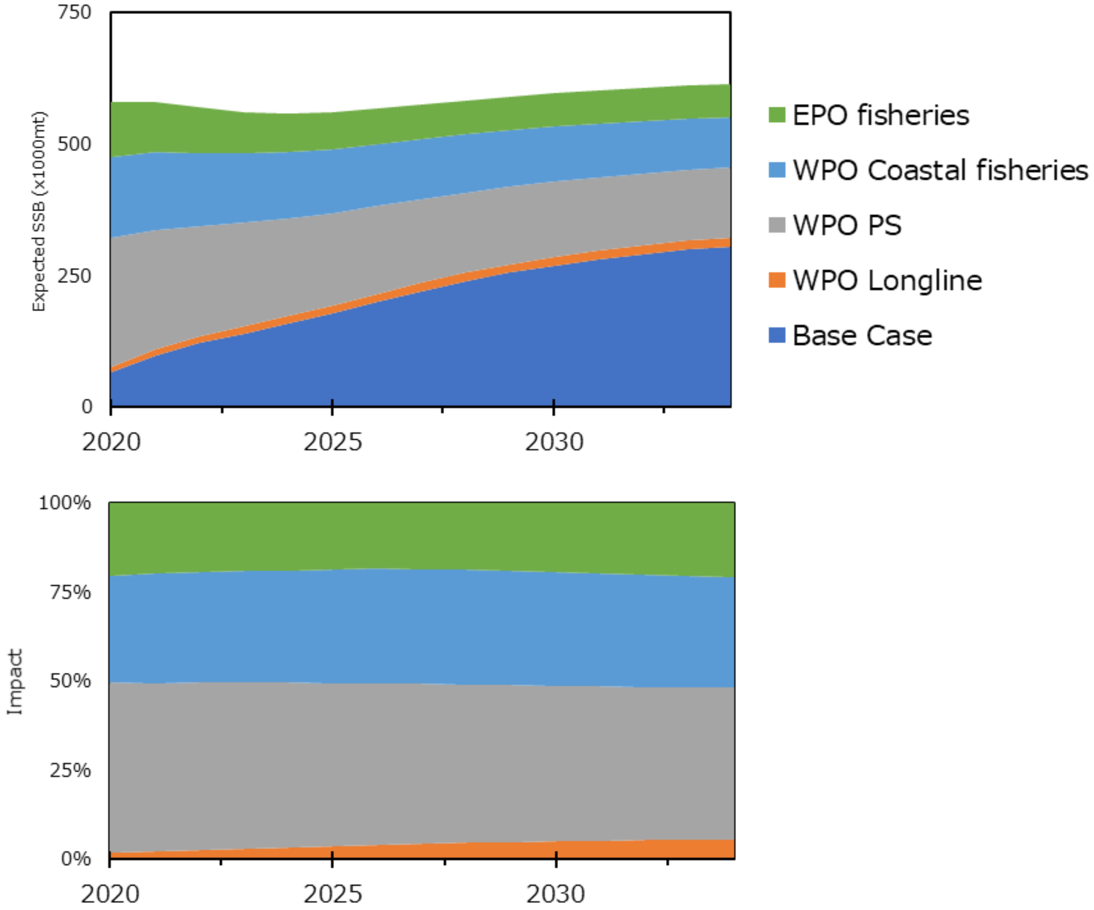

**Figure 11**. “Future impact plot” from projection results for Pacific bluefin tuna (*Thunnus orientalis*) from Scenario 1 of Table 3. The top figure shows absolute biomass and the bottom figure shows relative impacts. The impact is calculated based on the expected increase of SSB in the absence of the respective group of fisheries.

# 1. INTRODUCTION

Pacific bluefin tuna (*Thunnus orientalis*) (PBF) is a highly migratory species of great economic importance found primarily in the North Pacific Ocean. The PBF Working Group (PBFWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) established in 1996 has been tasked with conducting regular stock assessments to assemble fishery statistics and biological information, estimate population parameters, summarize stock status, and develop conservation information. The results are submitted to two Pacific tuna regional fisheries management organizations (RFMOs), the Western Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC), for review and used as the basis of management actions (the Conservation and Management Measures (CMMs) of WCPFC and IATTC resolutions).

The PBFWG completed the last benchmark stock assessment in 2020 using fishery data from 1952 (Fishing Year, FY) through 2018 FY (ISC 2020). The 2020 stock assessment concluded that (1) the 2018 (FY) spawning stock biomass (4.5%$SSB_{F=0}$) is below the two biomass rebuilding targets adopted by the WCPFC and IATTC, while the 2016-18 (FY) fishing intensity (spawning potential ratio, SPR) is below a level corresponding to the initial rebuilding target, and (2) the management measures by the WCPFC (CMM 2018-02) and IATTC (Resolution C-18-01) under the low recruitment scenario resulted in an estimated 100% probability of achieving the initial biomass rebuilding target by 2024, and an estimated 99% probability of achieving the second biomass rebuilding target by 2034.

The 2020 benchmark assessment model was developed and tested using a suite of diagnostics. All diagnostic results did not indicate a misspecified assessment model (ISC 2020). Furthermore, hindcasting diagnostic suggested that the 2020 model predicted future biomass well (Lee and Piner 2021). For the 2022 update assessment, the PBFWG applied the similar structures of the population dynamics model using Stock Synthesis (Methot and Wetzel 2013) and observation model constructed in the 2020 assessment and updated the input data to the most recent year if available. The PBFWG made progress in the update assessment on the issues identified in the 2020 assessment model. For example, research on the new recruitment index (Fujioka et al. 2021), finding a selectivity change in the CPUE index and developing an improved CPUE calculation using an additional data filtering (Tsukahara et al. 2021), elucidating the cause of the bias between the point estimate SSB by the base case model and the median SSB of the models by the bootstrapping replicators (Lee et al. 2021), and developing a more flexible assessment model regarding the model convergence against the alternative assumptions about the productivity of the stock (Fukuda 2021, see section 7). These advances were incorporated into the 2022 assessment base case model or a sensitivity analysis.

The 2022 update assessment of Pacific bluefin tuna was conducted during 08-18 March 2022. This report summarizes the assessment results using newly available seasonal fishery data (i.e., catch, discards, size composition data) and annual abundance index through the 2021 calendar year.

In this report, “year” denotes the fishing year in the model unless otherwise specified. Relationships among calendar year, fishing year, and year class are shown in Table 1-1. A fishing year starts on the 1st of July and ends on the 30th of June of the following year. The 1st of July is assumed to be the date of birth (recruitment) for PBF in the model. For example, the 2020 fishing year corresponds to the period from the 1st of July, 2020, to the 30th of June, 2021.

## 2. BACKGROUND ON BIOLOGY AND FISHERIES

### 2.1. Biology

#### *2.1.1. Stock Structure*

Bluefin tunas in the Pacific and Atlantic Oceans were once considered a single species (*Thunnus thynnus*) with two subspecies (*Thunnus thynnus orientalis* and *Thunnus thynnus thynnus*, respectively), but are now recognized as separate species (*Thunnus orientalis* and *Thunnus thynnus*, respectively) based on genetic information and morphometric studies (Collette 1999). This taxonomy is adopted by the relevant tuna RFMOs, the Food and Agriculture Organization of the United Nations (FAO), and ISC.

The major spawning areas of PBF are found in the western North Pacific Ocean (WPO): one is in waters between the Ryukyu Islands in Japan and the east of Taiwan, another one is in the southern portion of the Sea of Japan (Schaefer 2001), and the other possible one is around Kuroshio-Oyashio transition area in the coastal area of northeastern Japan (Ohshimo et al. 2018, Tanaka et al. 2020) (Figure 2-1). The natal origins of adult PBFs caught either in the waters around the Ryukyu Islands or in the Japan Sea were from both spawning grounds (Uematsu et al. 2018). Elemental analysis of otoliths indicated that adult PBF caught in the waters around Taiwan were also originated from both spawning grounds (Rooker et al. 2021). Age-1 PBFs caught in eastern Pacific Ocean (EPO) were also originated from both spawning grounds using the trace elements in otoliths (Wells et al. 2020). These findings suggest that PBFs comprise a single stock because no significant difference of natal origin between two spawning grounds. Genetics and tagging information (e.g., Bayliff 1994, Tseng and Smith 2012) suggesting a single stock for PBFs. Nakatsuka (2020) reviewed available genetics and reproductive information, otolith and vertebrae data, and fishery data concluded that no information exclusively pointed to the existence of multiple stocks. Therefore, a single stock is used in the PBF assessment within ISC and accepted by the RFMOs (WCPFC and IATTC).

#### *2.1.2. Reproduction*

PBFs are iteroparous spawners, i.e., they spawn more than once in their lifetime. Spawning occurs in the limited areas and seasons: from April to July in the waters around the Ryukyu Islands and off eastern Taiwan and from July to August in the Sea of Japan based on histological studies on PBF gonads (Yonemori 1989, Ashida et al. 2015, Okochi et al. 2016, Ashida et al. 2021, Ashida et al. 2022) and distribution of PBF larvae (Yabe et al. 1966). The recent histological study showed that 80% of the fish ca. 30 kg (corresponding to the 3 years old about age 2.75 in the assessment model) caught in the Sea of Japan from June to August were mature (Tanaka 2006, Okochi et al. 2016). Almost all the fish caught in the waters of the Ryukyu Islands and eastern Taiwan were above 60 kg (> 150 cm fork length (FL)) (Chen et al. 2006, Ashida et al. 2015). These fish were at least 5 years old (age 4.75 in the model) and were all mature. In addition, active spawning females (Ohshimo et al. 2018) and larvae (Tanaka et al. 2020) were recently found in Kuroshio-Oyashio transition area (Figure 2-1). Consider the velocity of

Kuroshio current, the presence of spawning females and these larvae indicates another possible spawning ground from May to August. However, it remains to be verified if these PBF larvae can recruit to the stock.

Although the large PBF were also found in the EPO, in particular recent some years at the Southern California, a recent study which evaluate PBF ovaries of 36 individuals (125-188 cm body length) showed no evidence of active spawning in the EPO (Dewar et al., 2022).

### *2.1.3. Distribution and Movements*

PBFs are mainly distributed in subtropical and temperate latitudes between 20º N and 50°N but are occasionally found in tropical waters and in the southern hemisphere (Figure 2-2).

The movements of PBFs are among the best documented of any highly migratory species despite large inter-annual variations of movement (numbers of migrants, the timing of migration, and migration routes). Mature adults in the WPO generally migrate north to feeding grounds after spawning, although a small proportion of fish move to south or eastwards (Itoh 2006). Ages 0-1 fish hatched in the waters around the Ryukyu Islands and eastern Taiwan migrate north with Kuroshio Current in the summer as they grow, whereas age-0 fish hatched in the Sea of Japan migrates along with the Japanese and Korean coasts (Inagake et al. 2001, Itoh et al. 2003). Depending on ocean conditions, an unknown portion of immature ages 1-3 fish in the WPO makes a seasonal clockwise eastward migration across the North Pacific Ocean (stable isotope in muscle tissues: Tawa et al. 2017, Madigan et al. 2017), spending up to several years as juveniles in the EPO before returning to the WPO (Inagake et al. 2001). The mechanism of eastward trans-Pacific migration is hypothesized due to the limitation of food sources in the WPO and the favorite oceanographic condition (Polovina 1996). While PBFs are in the EPO, the juveniles make seasonal north-south migrations along the west coast of North America (Kitagawa et al. 2007, Boustany et al. 2010). In the spring, PBFs reside in the waters off the southern coast of Baja California, and as the waters warm up in summer, PBFs move northwest into southern California bight. By fall, PBFs are found in the waters off central and northern California. After spending 3-4 years in EPO, PBFs move westward presumably for purposes of spawning as no spawning ground has been observed outside of WPO. This westward migration was observed from December to March as PBFs begin their migration along the coast of California (Boustany et al. 2010). The large interannual and seasonal variation of the trans-Pacific movement made it implausible to quantify the migration rates.

### *2.1.4. Growth*

Age of PBF has been determined using hard tissues such as vertebral ring counts (Aikawa and Kato 1938), scale ring counts (Yukinawa and Yabuta 1967), tag-recapture (Bayliff et al. 1991), and otoliths (daily increments: Foreman 1996; annual rings: Shimose et al. 2008, 2009, Shimose and Takeuchi 2012). A standardized technique for age determination of PBF based on the otolith samples was then developed among the ISC members at the Pacific Bluefin and North Pacific Albacore Tuna Age Determination Workshop in 2014 (Shimose and Ishihara 2015). This was the first large-scale age determination study for PBF. The annuli rings of otolith samples caught by the troll, purse seine, set-net, handline, and longline fisheries landed at Japan and Taiwan between 1992 and 2014 and the daily increments of otolith samples caught by the troll and setnet fisheries in the west coast of Japan between 2011 and 2014 were examined. In addition to analyzing the number of opaque zones in otolith, post-bomb radiocarbon dating was used to validate age estimation, and the estimated ages were consistent between post-bomb radiocarbon dating and otolith thin sections (Ishihara et al. 2017).

Fukuda et al. (2015b), then, estimated growth curves by integrating these annuli data for 1,782 fish (70.5-271 cm in folk length [FL] corresponding to 1-28 years old) and daily increment data for 228 fish (18.6-60.1 cm in FL corresponding to 51-453 days old after hatching). Their analyses indicated that a simple von-Bertalanffy growth function (VBGF; von Bertalanffy 1938) applied to fish aged 0-28 could not fit length at age 0 well due to seasonal patterns in age-0 growth (PBFs grow rapidly from July to December but then hardly grow during winter) (Fukuda et al. 2015a).

These paired age-length data were then used in two ways to estimate growth curves. First, a traditional estimation method treated the paired age-length data obtained from annuli and daily rings data as random at age, and the fitting procedure was optimized outside the integrated assessment model. Second, a length-conditional method used the same age-length data but treated them as random at length (conditional age-at-length (CAAL) data). CAAL data were incorporated into the integrated stock assessment models to simultaneously estimate growth parameters with underlying population dynamics (Piner et al. 2016, Lee et al. 2019). Fukuda et al. (2016) explored several growth patterns using both traditional estimation method (a simple VBGF, a two-stanzas growth model, a two growth patterns model representing different birth date) and length-conditional method (a seasonal growth model) in the earlier integrated model runs and found that the simple VBGF model and the seasonal growth model fit the length compositions better than the other growth models. The seasonal growth model, however, heavily relied on the CAAL data to estimate growth. Since these CAAL data were not representative of the age structure of the population mainly due to the combination of the un-modeled age-based movement and possible sampling bias, including these CAAL data in the integrated model can cause bias and imprecision in estimates of not only growth but also population dynamics (Lee et al. 2019). The PBFWG decided to use a simple VBGF estimated by Fukuda et al. (2015a) and externally calculate the variance of length at age using the length compositions and CAAL data (ISC 2016a). Any misfit of length compositions was further addressed by adding modeling processes in the selectivity section 4.3.2.

The variances of length composition data for all fisheries were reviewed during the 2016 stock assessment workshop meeting (ISC 2016a). The estimated variance of length composition data generally stabilizes after fish mature suggesting that the coefficient of variation (CV) of length at age decreases from age 0 to 3 and steadies from age 3 and above. The possible causes of the higher variance of length at young ages could be from seasonal growth, different birth dates, different growth patterns among years, etc. and the actual variance could be the result of a mix of many factors. This CV of CAAL data was estimated using the length-conditional method developed in Lee et al. (2019).

The growth curve assumed in this assessment was generally consistent with the previous studies (Shimose et al. 2009, Shimose and Takeuchi 2012, Shimose and Ishihara 2015, Fukuda et al. 2015a); grows rapidly to age 5 (approximately 160 cm FL), after which slows down (Figure 2-3). At age 12, the fish reach 226 cm FL, corresponding to 90% of the maximum FL of this species.

Fish larger than 250 cm FL are primarily older than age 20, indicating that the potential lifespan of this species is at least 20 years. Fish larger than 300 cm FL are rarely found in commercial catches.

The length-weight relationship of PBF based on the von Bertalanffy growth curve used in this stock assessment is shown in Table 2-1 and Figure 2-4.

### *2.1.5. Natural Mortality*

Natural mortality coefficients (*M*) is one of the most difficult parameters to be reliably estimated in the stock assessment model based on the simulation studies (Lee et al. 2011, Lee et al. 2012). The ad-hoc approaches based on the tagging analyses, life-history and information from similar species were used. *M* was assumed to be age-specific: high at a young age, decrease as fish grow, and constant afterwards (Figure 2-5).

Natural mortality for age-0 fish was based on results obtained from PBF conventional tagging studies (Takeuchi and Takahashi 2006, Iwata et al. 2012a, Iwata et al. 2014). In the absence of direct estimates of *M* beyond age 0, natural mortality for age-1 fish was based on length-adjusted *M* estimated from conventional tagging studies on southern bluefin tuna (Polacheck et al. 1997, ISC 2009). This adjustment incorporated the difference of life-history between PBF and southern bluefin tuna. A constant natural mortality coefficient was further derived from the median value obtained across a suite of empirical and life-history based methods to represent age 2 and older fish (Aires-da-Silva et al. 2008, ISC 2009). Whitlock et al. (2012) estimated *M* for age 2 and older PBF based on tagging data released from EPO, where the young fish (1-5 years old) occur. The major criticism to use *M* estimated from Whitlock et al (2012) is that the estimate doesn’t represent the whole population due to the incomplete tagging samples (solely in EPO). This stock assessment used the same *M* schedule as the previous stock assessments. See section 4.2.5 for the actual model setting for the *M* values.

## 2.2. Review of Fishery and RFMOs’ management

The main fisheries from each fishing nation and the RFMOs’ management measures are summarized in this section, whereas the fleet structures and associated data used in the stock assessment are summarized in section 3.3 (fishery definitions).

While there were few PBF catch records prior to 1952, some PBF landings records are available dating back to 1804 from coastal Japan and to the early 1900s for U.S. fisheries operating in the EPO. The catch of PBF was estimated to be high from 1929 to 1940, with a peak catch of approximately 47,635 t (36,217 t in the WPO and 11,418 t in the EPO) in 1935; thereafter catches of PBF dropped precipitously due to World War II. PBF catches increased significantly in 1949 as Japanese fishing activities expanded across the North Pacific Ocean (Muto et al. 2008).

By 1952, a more consistent catch reporting process was adopted by most fishing nations. Estimates indicate that annual catches of PBF by ISC member countries fluctuated widely from 1952-2020 (Figure 2-6). Five countries mainly harvest PBF, but Japan catches the majority, followed by Mexico, the USA, Chinese Taipei, and Korea. Catches in tropical waters and in the southern hemisphere has been small and sporadic, although the catch in the southern hemisphere in 2020 was historic high, which is around 50 tons (WCPFC, 2021). During this period, reported catches peaked at 40,383 t in 1956 and 34,612 t in 1981, reached the low amount at 8,653 t in 1990, increased to 33,946 t in 2000, and then declined after 2005. While a suite of fishing gears catch PBF, most of the catch is from purse seine fisheries (Figure 2-7).

The trend of the total catch is associated with RFMOs' management. In 2011, WCPFC started the conservation and management measure to regulate the catches for small PBF (<30 kg in body weight) in its convention area (WCPFC CMM 2010-04). The catch limit was further reduced for 2014 (WCPFC CMM 2013-09) and 2015 (WCPFC CMM 2014-04) to maintain the catch for small PBF less than 50% of the 2002-2004 average level and the catch for large PBF (>30 kg in body weight) less than the 2002-2004 average level. In the IATTC area, the conservation and management measure to regulate the catches for all range in size of PBF in its convention area (IATTC resolution C-12-09) was started in 2012. The catch limit was also further reduced for 2015 and 2016 (IATTC resolution C-14-06). The current measure (IATTC resolution C-18-01) limited total commercial catch for 2019 and 2020, combined, less than 6,200 tons. In 2022, catch limits for large fish in both areas were increased, corresponding to the stock recovery.

The major active PBF fisheries in Japan are longlines, purse seines, trolling, and set nets. Other gear types such as pole-and-line, drift net, and hand-line used to take a considerable amount of catches. The fishing grounds for the currently active fisheries are generally in coastal or nearshore waters, ranging from Hokkaido to the Ryukyu Islands. The distant-water longline fisheries also catch PBF, but their catch is small compared to other active fisheries. Overall, total annual catches by Japanese fisheries have fluctuated between a maximum of 34,000 t in 1956 and a minimum of 6,000 t in 1990 (calendar year). More details of Japanese fisheries taking PBF can be referred to Yamada (2007) and section 3 (longline fishery: Section 3.5.3; purse seine fishery: Section 3.5.4, 3.5.7, 3.5.8, 3.6.3, 3.6.4, and 3.6.5).

In the United States of America (U.S.), two major active PBF fisheries (purse seine and recreational fisheries) catch PBF off the west coast of North America. The U.S. purse seine fishery used to catch a large amount of PBF for canning in the waters off Baja California until Mexico established its Exclusive Economic Zone (EEZ) in 1976 and excluded U.S. purse seine vessels. After 1983, the U.S. purse seine fishery only caught PBFs opportunistically (Aires-da-Silva et al. 2007). Currently, the vast majority of PBF catch in the U.S. is from recreational fisheries in U.S. and Mexican waters (Heberer and Lee 2019).

The Mexican purse seine fishery was developed rapidly after Mexico established its EEZ and is the most important large pelagic fishery in Mexico. This fishery is monitored by an at-sea observer program with 100% coverage, captains' logbooks and Vessel Monitoring Systems (VMS), and recently stereoscopic cameras (Dreyfus and Aires-da-Silva 2015, Dreyfus 2018). Most of the purse seine sets target yellowfin tuna (the dominant species in the catch) in tropical waters; PBFs are caught near Baja California for farming. The Mexican PBF catch history recorded three large annual catches (above 7,000 t) in the years 2004, 2006, and 2010.

In Korea, PBF are mostly caught by the offshore large purse seine fishery (OLPS), but there is some smalls amount of catches reported by the coastal fisheries in recent years. The catch of the OLPS fishery was below 500 t until the mid-1990s, increased with a peak of 2,601 t in 2003, and then has fluctuated from 600 t to 1,900 t. In 2018, the catch of the OLPS fishery was 523 t. The main fishing ground of the OLPS fishery is off Jeju Island, but the vessels occasionally operate in the Yellow Sea and the East Sea (Yoon et al. 2014, Lee et al. 2018).

The amount of PBFs caught by the Taiwanese fisheries (small-scale longline, purse seine, large-scale pelagic driftnet, set net, offshore and coastal gillnet, and bottom longline fisheries) was small (<300 t) between the 1960s and the early 1980s. After 1984, the total landings increased gradually to over 300 t mostly due to the small-scale longline vessels (<100 gross registered tonnage (GRT)) targeting spawners for the sashimi market from April to June. The highest observed catch was 3,000 t in 1999, and then catch declined rapidly to less than 1,000 t in 2008 and to the lowest level of about 200 t in 2012. The catch then slightly increased to around 500 t in 2018, and showed significant increase to more than 1,000 t in 2019-2020.

## 3. STOCK ASSESSMENT INPUT DATA

### 3.1. Spatial Stratification

PBFs are distributed across the North Pacific Ocean and considered to be a single stock (Nakatsuka 2019). Juvenile PBFs move between the western Pacific Ocean (WPO) and the eastern Pacific Ocean (EPO) (Itoh et al. 2003, Boustany et al. 2010), before returning to the WPO to spawn. Because of the lack of direct information on movement rates, a true spatial model has not been used for assessment purposes. Instead, this and previous assessments have been assumed an instantaneously mixed population and incorporated regional selection patterns to implicitly model space (“areas-as-fleets approach”, Waterhouse et al. 2014). The areas-as-fleets approach used by the PBFWG was evaluated in a simulation study, suggesting that although the use of alternative model processes is not as effective as a true spatially explicit model, management quantities can be well estimated when fishery selection is properly set up to account for both availability (spatial patterns) and contact gear selectivity (Lee et al. 2017). A spatially explicit model continues to be an area for future research.

### 3.2. Temporal Stratification

In the stock assessment for PBF, a “fishing year” is defined as July 1st through June 30th of the following calendar year. Thus, the 2018 fishing year corresponds to 1st July 2018 to 30th June 2019. Unless otherwise indicated, the term “year” in this report refers to the fishing year. The time period modeled in the assessment of PBF is 1952-2020, with catch and size composition data compiled quarterly as follows;

**Season 1**: July-September,
**Season 2**: October-December,
**Season 3**: January-March, and
**Season 4**: April-June.

Recruitment is assumed to occur at the beginning of “fishing month 1” (July in calendar month) in the assessment model. Relationships between calendar year, fishing year, and year class are shown in Table 1-1.

### 3.3. Fishery definition

A total of 25 fisheries were defined for the stock assessment of PBF based on stratification of country, gear type, season, area, and size of fish caught (Table 3-1) after PBFWG data preparatory meeting (ISC 2021b). Representative fisheries for each Fleet are as follows;

**Fleet 1**: Japanese longline fisheries (JP LL) for all seasons for 1952-1992, and for season 4 for 1993-2016,
**Fleet 2**: Japanese small pelagic fish purse seine fishery in the East China Sea (JP SPPS) for seasons 1, 3, and 4,
**Fleet 3**: Korean offshore large scale purse seine fishery (KR OLPS),
**Fleet 4**: Japanese tuna purse seine fishery in the Sea of Japan (JP TPSJS),
**Fleet 5**: Japanese tuna purse seine fishery off the Pacific coast of Japan (JP TPS PO),
**Fleet 6**: Japanese troll fishery (JP Troll) for seasons 2-4,
**Fleet 7**: Japanese pole and line fishery (JP PL),
**Fleet 8-10**: Japanese set-net fisheries (JP SetNet),
**Fleet 11**: Japanese other fisheries (JP Others), mainly small-scale fisheries in the Tsugaru Strait,
**Fleet 12**: Taiwanese longline fishery (TW LL) in southern fishing ground,
**Fleet 13**: EPO commercial purse seine fishery (U.S. dominant) for 1952-2001 (U.S. COMM),
**Fleet 14**: EPO commercial purse seine fishery (Mexico dominant) after 2002 (MX COMM),
**Fleet 15**: EPO sports fishery (EPO SP) after 2014,
**Fleet 16**: Japanese troll fishery for farming (JP Troll for Penning),
**Fleet 17**: Taiwanese longline fishery (TW LL) in northern fishing ground,
**Fleet 18**: Japanese small pelagic fish purse seine fishery in the East China Sea (JP SPPS) for season 2,
**Fleet 19**: Japanese troll fishery (JP Troll) for season 1,
**Fleet 20**: Japanese small pelagic fish purse seine fishery in the East China Sea (JP SPPS) for farming,
**Fleet 21**: Unaccounted mortality fisheries (in weight) in WPO,
**Fleet 22**: Unaccounted mortality fisheries (in number) in WPO,
**Fleet 23**: Japanese longline fisheries (JP LL) for seasons 1-3 for 1993-2016 and all seasons for 2017-2020,
**Fleet 24**: Eastern Pacific Ocean sports fishery (EPO SP) for 1952-2013,
**Fleet 25**: Unaccounted mortality fisheries (in number) in EPO.

Some gear/areas fisheries with only a minimal amount of PBF catch were included in the fleet with similar size compositions, fishing ground, and seasons. The decision for which fleet to include the catch was based on expert opinion regarding composition similarity. For example, reported small catch by Korea (by trawl, set-net, and troll fisheries) is included in Fleet 3. Taiwanese purse seine catch was included in Fleet 4, the driftnet catch of both Japan and Taiwan were included in Season 1 of Fleet 7, and the other Taiwanese catches were included in Season 4 of Fleet 7. Japanese miscellaneous catches for Season 1-3 and Season 4 were included in Japanese set-net fleets, Fleet 8 and 9, respectively. The other Japanese catch (by trawl and other small longline other than those from the Tsugaru Strait) were included in Fleet 11. Non ISC members' catch after 2014 (i.e., by New Zealand, Australia, etc.) is included in Fleet 12.

## 3.4. Catch and discard data

### *3.4.1. Catch data*

Although fisheries catching PBF have operated since at least the beginning of the 20th century in the EPO (Bayliff 1991) and for several centuries in the WPO (Ito 1961), the detailed fishery statistics prior to 1952—especially from the WPO—were not available. Therefore, 1952 is used as the starting year of the stock assessments, because a more consistent catch reporting process was adopted, and the catch-and-effort data from Japanese longline fleet were available from that year onward.

Throughout the assessment period, total annual catch fluctuated widely, with the historical maximum and minimum total catches of any calendar year are 40,383 t in 1956 and 8,653 t in 1990, respectively (Table 3-2, Figure 2-6). Annual catches have averaged about 14,000 t in the last decade (in 2011-2020 calendar years). The majority of PBF have been taken by the purse seine fisheries: Japanese tuna purse seine fishery operating off the Pacific coast of Japan (Fleet 5), U.S. purse seine fishery (Fleet 13) with a large portion of the catch until the 1990s, Japanese small pelagic fish purse seine fishery operating in the East China Sea (Fleet 2 and Fleet 18), Japanese tuna purse seine fishery in the Sea of Japan (Fleet 4), Korean Offshore large scale purse seine fishery (Fleet 3), and Mexican purse seine fishery (Fleet 14) (Figure 3-2 (a)).

For the assessment model, catches were compiled for each fleet quarterly (Table 3-3). For some fisheries, quarterly catches for the early period were estimated using recent quarterly catch proportions applied to annual catch data. Examples include Fleets 8 and 9 before 1994 (Kai 2007a), Fleet 5 before 1971 (Takeuchi 2007), etc.. For most fleets, recent quarterly catches were directly derived from logbook or landing statistics. Other fleets primarily operate in only one season such as Fleet 11 which includes small-scaled Japanese fisheries (e.g., trawl, small longline, etc.), and their annual total catch was placed in Season 2. The catches by Fleet 10 were aggregated and placed in Season 2. Catch data for stock assessment were expressed in tones for all fleets except for Fleet 15, 16, 20, 22, and 25 where quarterly catches were expressed in thousands of fish (Figure 3-2 (b)). For the 2022 assessment, the quarterly catch data were updated up to Season 4 of fishing year 2020 (2021 calendar year Quarter 2). Some corrections were made in the terminal year of the previous assessment (2018 FY). Fishery data in the terminal year of the assessment are often from the provisional statistics, so those corrections would occur when the data source was finalized as the official statistics.

### *3.4.2. Unaccounted mortality*

It is recognized that impactful management measures may have altered fishery practices in the most recent years. The PBFWG agreed that the base-case of this assessment should include "unaccounted mortality" (ISC 2019). In this stock assessment, we define "unaccounted mortality" as fishery caused kills that do not show up in landings data. This can include predation of sportfishing catches in addition to discard mortalities. Japan (Nakatsuka and Fukuda 2020), Korea (Lee et al. 2020a), and the U.S. (Piner et al. 2020) provided discard information in response to PBFWG recommendation. Mexico suggested there is no discard or post-release mortality reported from the IATTC/AIDCP onboard observers with a 100% coverage rate. Taiwan also suggested there is no sign of releasing PBF from their fishery while there is a sufficient margin in their fishing quota.

Fleet 21 (unaccounted mortality fisheries from WPO, 2017-2020) includes estimated dead discards from Japan fisheries (setnet, purse seine, longline, and troll, etc.) and Korea purse seine fisheries in the unit of weight, whereas Fleet 22 (Unaccounted mortality fisheries in WPO, 1998-2020) and Fleet 25 (Unaccounted mortality fisheries in EPO, 1999-2020) include estimated dead discards from Japan fisheries for penning (troll and small pelagic purse seine) and from U.S. sport fisheries, respectively, in the unit of number.

Japanese discard mortality was estimated as 5% of reported catch for all Japanese fisheries since 2017 when the release of PBF considered having become significant (Nakatsuka and Fukuda 2020). Korean discard amount was estimated in the same manner (Lee et al. 2020a). For the U.S. recreational fishery, catches, releases (discards), and predation events of hooked fish are recorded in California Commercial Passenger Fishing Vessels logbooks. An estimate of release mortality and subsequent discard mortality numbers were developed for this fleet. A random-effect inverse variance meta-analysis estimated the mortality rate (6%) (Piner et al. 2020). To reflect the uncertainty of these removals, the CV for these unaccounted mortality fleets were given at the high value (0.3) (ISC 2020).

## 3.5. Abundance Indices

### *3.5.1. Overview*

CPUE-based abundance indices which were discussed in ISC PBFWG are listed in Table 3-4. These series were derived from fishery-specific catch and effort data which were standardized with appropriate statistical methods (Figure 3-3 and Table 3-5). In the previous assessment, the PBFWG used four longline CPUE series as the adult abundance indices (S1, S2, S3, and S5), and a Japanese troll index (S4; 1980-2016, and 2018) as the recruitment index for the base-case model (ISC 2020). The S1, S2, and S3 indices (Japanese coastal, offshore, and distant-water longlines, respectively) temporally covered the recent period (1993-), early period (1952-1973), and middle period (1974-1992), respectively. For the current assessment, S1 index was updated, but the 2020 FY data point was not included in the CPUE standardization model because of the suggested possible change in the catchability of that fishery due to the change in the fishing practice to comply with new fishery regulation scheme introduced in 2020 FY for the Japanese longline fishery (Tsukahara et al., 2022). Also, 2017-2020 data points of the S4 index (Japanese troll fishery) were not included in the likelihood function of the assessment model due to the change in the fishing practice to comply the fishing regulation for this fishery (Nishikawa et al., 2021). S5 index (Taiwanese longline fishery) is another terminal adult abundance index, and this was updated to the most recent year (2002-2020). For this assessment, a recruitment index based on the Japanese recruitment monitoring survey was developed, and this was used for the sensitivity analysis of the assessment model to seek the impact of inclusion of this index to the calculation of the management quantity.

The input coefficients of variation (CV) of abundance indices were set at 0.2 for all indices, years, and seasons, when the CV statistically estimated by the standardization model was less than 0.2. If the CV estimated by the standardization model was more than 0.2, the actual CV value was used to represent the sampling variability for the observation. This is the same approach used in the previous assessment (ISC 2020b).

### *3.5.2. Japanese Longline CPUE indices (S1, S2, & S3)*

Japanese longline CPUE indices are derived from logbook data. A total of 3 indices are developed from this longline information; one for the coastal (before 1993) and two for the offshore and distant water fisheries (after 1993). The offshore and distant-water longline CPUE indices have to be split up into two time-series; 1952-1973 (S2; Fujioka et al. 2012b) and 1974-1992 (S3; Yokawa 2008), because of the change in operational pattern and available dataset (i.e., hooks-per-basket).

For this assessment, the coastal longline CPUE for recent period was reviewed and it was found that the fish size caught by this fishery became smaller since 2017 than those in the previous years. A possible reason for this change might be an influx of the new (young) abundant cohort to the fishing ground (change in the availability) or change in the fishery operation such as the area or season (change in the selectivity) or mixed effect of those. Although it was not clear whether there is the selectivity change or availability change, to maintain the size selectivity of the index constant over time, an additional data filtering method to exclude small sized fish was introduced (Tsukahara et al., 2022).

In addition, drastic drops of catch and nominal CPUE for this fishery in the main fishing season (April to June) of 2021 calendar year (2020 FY) were observed, even though this fishery have been increased their catch for recent several years within their allocation. Those were considered as the effect of the new fishery management for PBF stock through the individual quota scheme, which was introduced in 2020 for the Japanese coastal longline fishery (Tsukahara et al., 2022). To avoid the probable impact of a change in catchability due to the new management scheme to the CPUE time series, which cannot be standardized by the CPUE standardization process, the data in 2020 were excluded from the standardization for this assessment. The Japanese longline index time series from 1993 to 2019 was included in the negative loglikelihood function for this stock assessment.

### *3.5.3. Japanese Troll CPUE index (S4, S12)*

Catch-and-effort data for the coastal troll fisheries targeting age-0 PBF in Nagasaki prefectures have been collected from five fishing ports. The troll fishery in Nagasaki prefecture dominates Japanese troll catch, and the fishery can fish age-0 PBF from both spawning grounds (Ryukyu Islands and the Sea of Japan) because of the geographical location of the fishing ground (Ichinokawa et al. 2012). The units of effort in the catch-and-effort data are the cumulative daily number of unloading troll vessels, nearly equivalent to the total number of trolling trips because most troll vessels make one-day trips. The effort data only recorded information that at least one PBF was caught: zero-catch data was unavailable. Therefore, a log-normal model was applied for the standardization of the CPUE (S5).

For this assessment, Nishikawa et al. (2021) critically reviewed the data used for this CPUE calculation as well as the operational information of fishery, and suggested that this index might be negatively biased after 2016 due to the changes in fishery operation (increasing of the live release at sea) responding to a new management measures (e.g. minimum size limitation and substantial IQ management) introduced in 2017. Thus, the data points of S4 index after FY2016 were not included in this assessment.

As a possible alternative index to inform recruitment trend for the period without the recruitment index (2017-2020), the real-time recruitment monitoring survey index was submitted to the WG (Fujioka et al., 2021). The WG agreed to include this new index (S12) for the sensitivity analysis of the assessment and projections (See 4.5.7 and 5.5.1) but not to use in the base-case model as its validity cannot be evaluated against other available data in the model.

### *3.5.4. Taiwanese Longline CPUE indices for southern area (S5-S9)*

An adult index of relative abundance was developed from Taiwanese longline fishing operations. The fishing ground of the Taiwanese longline fleet can be separated into southern and northern areas. The southern area has been considered as the main fishing ground for this fleet. The CPUE used in this assessment (S5 index) was based on the operations in the southern area and standardized by GLMM (Chang et al. 2021) (S5: 2003-2020) and was developed using the following process; (1) Estimating PBF catch in the number of fish from landing weight for 2003 based on an MCMC simulation, (2) Deriving fishing days for 2007-2009 from vessel monitoring system (VMS) data and voyage data recorder (VDR), (3) Deriving fishing days for 2003-2006 from vessels trip information based on linear relationships between fishing days and at-sea days for a trip, by vessel size and fishing port, during 2007-2020, and (4) Estimating and standardizing the CPUE (catch number per fishing days) for 2003-2020 (Chang et al., 2018, Chang et al. 2021).

In addition to this index, four indices were also developed but not included in the likelihood function. These alternative indices include an index for the north area from the non-spatial model for 2003-2020 (S9) and three indices for the north, south, or combined areas from the spatio-temporal model for 2006-2020 data (S6-S8). These indices are being evaluated for potential use in future stock assessments.

## 3.6. Size composition data

### *3.6.1. Overview*

Quarterly size composition data (length or weight) for PBF from 1952 to 2020 were compiled for the stock assessment. All length data (fork length (FL)) were measured to the nearest centimeter (cm), whereas weight data were measured to the nearest kilogram (kg). In the assessment model, the length data bins of 2, 4, and 6 cm width were used for 16-58, 58-110, and 110-290 cm FL fish, respectively. Composition data in weight were binned in a range of bin sizes (0, 1, 2, 5, 10, 16, 24, 32, 42, 53, 65, 77, 89, 101, 114, 126, 138, 150, 161, 172, 182, 193, 202, 211, 220, 228, 236, 243, and 273 kg). This bin strategy attempted to create two bins for each age between 0 and 15 (Fujioka et al. 2012a). The lower boundary of each length or weight bin was used to define the bin.

For this assessment, the size composition data for Fleets 7, 16, 21, 22, and 24 were not included in the negative log-likelihood function of the model in the manner consistent with the previous assessment (ISC 2020b). Within the rest of the fleets, the size compositions for Fleets 10-11 were combined to simplify the assessment model (Table 3-6). Length composition data were updated for this assessment for Fleets 2-6, 12, 14, 15, 17-20, and 23, while the composition data of the rest of fleets were not updated. Fleet 16 was assumed to catch only age-0 fish, thus their size composition was not required. Figure 3-5 shows the quarterly size compositions of each fleet.

The sources of input sample sizes for the size composition data were summarized in Table 3-6. Depending on the corresponding fisheries and available data, the sample size was based on four different criteria; “Number of fish measured”, “Number of landing wells sampled”, “Number of the total month of wells sampled by port”, and “Number of haul wells sampled”.

### *3.6.2. Japanese Longline (Fleets 1 and 23)*

Length-composition data for PBF from the Japanese longline fishery (Fleet 1 and 23) are available for the periods of 1952-1968 and 1994-2020 (Figure 3-5). Until the 1960s, the data were collected mainly from the Tsukiji market. Since the 1990s, sampling and market data have been collected at the major PBF unloading ports (e.g., Okinawa, Miyazaki, and Wakayama prefectures). Length measurements were relatively sparse from 1969 to 1993 and there are concerns about their representativeness and so those data are not included in the assessment. Length compositions for 1952-1968 were estimated based on the aggregated catch and length measurement data by year, month, and area (5x5 degree cells). Using this stratification, length composition was raised by catch in the number of fish (Mizuno et al. 2012).

Since 1993, the length compositions were estimated based on the quarterly landing amount and length measurement in each prefecture. Using quarter and prefecture strata, length composition was raised by landing weight (Ohashi and Tsukahara 2019). Among those data, it was indicated that smaller fish were taken in the fishing season 3 relative to fishing season 4 in principle. Therefore, the fishery was separated into two fleets by seasons as in seasons 1-3 (Fleet 23) and in season 4 (Fleet 1) (ISC 2019).

The composition data from the JLL in season 4 after 1993 (Fleet 1) were used to estimate the selectivity of JLL fishery and JLL index for recent time series (S1 index). Because of the importance to estimate the selectivity of the index, a data filtering method, which was applied for the index standardization model (Tsukahara et al., 2021), was also applied to the composition data to sift out the observed fish smaller than 152 cm from the composition data of Fleet 1 for 1993-2016. Also, the recent size composition data (2017-2020) from JLL in season 4 showed many observations of small sized fish (Tsukahara et al., 2021). Although it is unclear whether those observations were a sign of the selectivity change (i.e. operating in more eastern area, where is not used for the CPUE calculation, to get a small fish) or availability change (i.e. influx of the newly available abundant young cohort to the fishery), the catch time series and size composition data for the all seasons during 2017-2020 were assigned as of Fleet 23, which generally caught smaller sized fish than Fleet 1. More work will be needed to understand the potential effects of recent management measures on the stability of the model process linking to this and other data.

### *3.6.3. Japanese small pelagic fish purse seines in the East China Sea (Fleets 2, 18, and 20)*

Length composition data for PBF from the Japanese small pelagic fish purse seine in the East

China Sea are derived from port sampling program at the major landing ports (Fukuoka and Matsuura ports) (Kumegai et al. 2015), as well as the measurements using a stereo-scopic camera for farming operation (Fukuda and Nakatsuka, 2019).

The composition data from the port sampling data are separated into two fleets by season (Fleet 2 and 18) because catch in the fishing season 2 (fleet 18) took both age 0 and 1 fish, whereas Fleet 2 (Season 1, 3, and 4) took mainly age 0 fish in season 4. In the assessment data set, Fleet 2 (Seasons 1, 3, and 4) has composition data available for 2002-2019, whereas Fleet 18 (Season 2) has data for 2003-2012, 2014, and 2016-2020. In the assessment, the data in Seasons 3-4 of 2014 for Fleet 2 were not used because there seems to be large uncertainty when measuring the data due to the changes in the landing procedures in the ports.

The farming operation by the Japanese small pelagic fish purse seine fishery, where the catch data in number are available, was assigned as Fleet 20 and the size composition data from 2016 to 2020 are available.

### *3.6.4. Korean offshore large purse seine (Fleet 3)*

From the 2020 assessment, length-composition data from the Korean offshore large purse seine were disaggregated and treated as an independent fleet (Fleet 3). The composition data are available for 2003-2020 through the size sampling at port by the scientists or observers as well as the measurement at the laboratory by scientists (Lim et al. 2021).

### *3.6.5. Japanese purse seines in the Sea of Japan (Fleet 4)*

Length-composition data for PBF from the Japanese purse seine fleet in the Sea of Japan (Fleet 4) have been collected by port samplers in Sakai-minato and available since 1987, except for 1990 when there was no catch (Figure 3-5). Size measurements have been high coverage, and most of the landings were sampled. This fleet catches mainly PBF older than age 3 (Fukuda et al. 2012).

### *3.6.6. Japanese purse seines off the Pacific coast of Japan (Fleet 5)*

Size composition data for PBF from Japanese purse seiners operating off the Pacific coast of Japan were collected at Tukiji market and several unloading ports in the Tohoku region between the 1950s and 1993. Since 1994, length and weight composition data have been collected at Shiogama and Ishinomaki ports (Abe et al. 2012).

Although the length measurements from this fishery had been taken since the 1980s, an appropriate method to create the size composition representing the catch has not yet been established for the entire period. Therefore, the length composition for this fleet included in the past assessments had been limited to 1995-2006 (Figure 3-5). The size composition data for those years were highly variable (from 50 cm to very large), and it was recognized the need for further research especially focusing on the smaller fish.

Since 2014 fishing year, catch by this fleet was increased than the years before, and the size of fish was composed by the fish larger than 120 cm, whereas this fleet had caught small fish such as the 50 cm fish in 2000’s. For those recent catches, the port sampling program was strengthened, and the composition data became available for 2014-2020 (Fukuda 2019).

### *3.6.7. Japanese Troll and Pole-and-Line (Fleet 6, 7, and 19)*

Length-composition data for the Japanese troll fisheries (Fleet 6 and 19) were estimated as follows: 1) Fish length was measured at the main unloading ports, 2) The measurement data was aggregated by “area” and “month” as the minimum spatial and temporal strata, and 3) These aggregated data were raised by catch in the number of fish in the corresponding strata (Fukuda et al. 2015). Based on this procedure, the quarterly length-composition data were estimated for the period of 1994-2020 and fitted in the assessment model unless more than 20% of catch did not have corresponding size data. According to this criterion, the length composition data for some quarters were not included in the assessment model.

The Fleets 6 and 7 tend to operate in the same area and catch similar-sized fish (primarily age-0 fish). Thus, the size selectivity information of Fleet 6 has been shared by Fleet 7 in the assessment model because of the relatively poor size sampling of Fleet 7 (Figure 3-5).

### *3.6.8. Japanese set-net and other fisheries (Fleets 8 to 11)*

Size measurement data for PBF from Japanese set-net fisheries have been collected since 1993. The catch-at-size data were estimated based on the multi-stratified raising method using the catch weight. Excessive estimation was avoided by introducing broad size category stratum (i.e., Small/Medium/Large) and limiting over-strata calculation (Hiraoka et al. 2018). Due to the complexity of the dataset, the set-net fishery was divided into 3 fleets: Fleet 8 is ine the Seasons 1, 2, and 3 in all prefectures except for Hokkaido and Aomori, Fleet 9 is in Season 4 from the same areas, and Fleet 10 is all-season fishery in Hokkaido and Aomori (ISC 2015b). For Fleets 8 and 9, length-composition data are available. The data showed that the catch-at-size data were highly variable from year to year, and quarter and quarter, probably because of the influence of the environmental conditions and migration (Kai 2007a). Size compositions for PBF from the set-net fishery in Hokkaido and Aomori prefectures (Fleet 10) are the weight measurements (Sakai et al. 2015). Fleet 11 also has weight composition data, which includes hand line and small-scaled longline fisheries in the Tsugaru Strait and its adjacent waters (Nishikawa et al. 2015). The weight composition data for Fleet 11 were combined to Fleet 10.

Likely due to the COVID-19 pandemic and other reasons such as an opportunistic fishery unloading due to the domestic management to protect small (young) fish, the data sampling in FY 2019-2020 for those coastal fisheries was sparser than the past period (Nishikawa et al., 2022). Accordingly, the composition data for those years were not included in this assessment.

### *3.6.9. Taiwanese longline (Fleet 12 and 17)*

Length-composition data for PBF from the Taiwanese longline fishery (Fleets 12 and 17) were based on the market landing information and port sampling. Since 2010, additional information has been available from the catch documentation scheme (CDS) program, which can provide more size samples with better quality (Chang et al. 2015). The Taiwanese longline fishery was separated into two fleets by fishing area; Fleet 12 for the southern area and Fleet 17 for the northern area. For this assessment, the length composition data for both fleets were updated. The southern area has been the main fishing ground for Taiwanese longliners, and their data period was longer than that of the northern area (Fleet 12: 1992-2020, Fleet 17: 2009-2020).

### *3.6.10. EPO commercial purse seine fisheries (U.S. dominant) for 1952-2001 (Fleet 13) and (Mexico dominant) after 2002 (Fleet 14)*

Length-composition data for PBF from EPO purse seine fishery are collected by port samplers from IATTC and national/municipal at-sea observers and sampling programs (Bayliff 1993, Aires-da-Silva and Dreyfus 2012). Fleet 13 is the U.S. dominant EPO purse seine fishery for 1952-2001, and its length composition data from 1952 to 1982 are used to estimate the selectivity pattern for the stock assessment (ISC 2015b). Fleet 14 is the Mexico dominant EPO purse seine fishery (2001 onwards), and its length composition data from 2005 to 2020 are used to estimate the selectivity pattern. Since 2013, size composition data are measured by stereoscopic cameras from the largest farming company (Dreyfus and Aires-da-Silva 2015). For this assessment, the length composition data for 2019-2020 were updated (Dreyfus 2021).

### *3.6.11. U.S. recreational fisheries (Fleets 15 and 24)*

Size composition data for PBF from the U.S. recreational fishery had been collected by IATTC staff from 1993 to 2011 (Hoyle 2006). Since 2014, NOAA took over the sampling program (Heberer and Lee 2019), and size composition data are measured by port samplers. From the 2020 assessment, the U.S. recreational fishery was separated into two fleets: Fleet 24 in 1952-2013 when the IATTC conducted the sampling and Fleet 15 in 2014 onwards when the NOAA conducted the sampling. There was no information about how the size sampling program operated prior to 2012, thus the PBFWG has agreed that the size composition data before 2012 are not used. Selectivity for Fleet 24 was assumed to be similar to that for Fleet 15.

Due to COVID-19 pandemic, the port sampling program by the SWFSC NOAA discontinued (Lee, 2021). As an alternative, another on-board sampling program by the Sportfishing Association of California (SAC), although it was a lower coverage than the port sampling by NOAA, was suggested for the size data during 2019-2020. This showed that despite the variability in the both of SAC data and NOAA data, either each data seems to provide more appropriate information on the catch-at-age than borrowing the information from the EPO commercial fleet or borrowing the information from the most recent data in the same fleet. Then, for 2022 stock assessment, the WG agreed to use the data on-board sampling program by SAC in 2019 and 2020 FY to inform the size of removals by the U.S. recreational fishery (ISC 2021b).

### *3.6.12. Japanese troll fishery for farming (Fleet 16)*

For the stock assessment, the troll fishery for farming is assumed to target only age-0 fish (ISC 2015a) since there are no size compositions available.

### *3.6.13. Unobserved mortality fleets (Fleets 21, 22, and 25)*

Unobserved mortality related to the possible post-release mortality of discards were included as removals. The unobserved mortality was separated into three separate fleets. Because there is no available data to represent the size distribution of unobserved fish, the size selectivity for these fleets was assumed to be similar to the associated fisheries (Section 4.3.2).

# 4. MODEL DESCRIPTION

## 4.1. Stock Synthesis

An annual time-step length-based, age-structured, forward-simulation population model, fit to seasonal data (expectations generated quarterly), was used to assess the status of PBF. The model was implemented using Stock Synthesis (SS) Version 3.30.14 (Methot and Wetzel 2013). SS is a stock assessment model that estimates the population dynamics using a variety of fishery-dependent, fishery-independent, and biological information. Although it was initially developed for coastal pelagic fishes (sardine and anchovy), it has become a standard tool for tunas and other highly migratory species in the Atlantic, Indian, and Pacific Oceans (IOTC 2016, IATTC 2017). The structure of the model allows for both maximum likelihood and Bayesian estimation processes with full integration across parameter space using a Monte Carlo Markov Chain algorithm. This assessment uses the maximum likelihood estimation (MLE) to estimate parameters and uses normal approximation or bootstrapping to estimate parameter uncertainty. SS is comprised of three subcomponents: (1) a systems dynamics subcomponent that recreates estimates of the numbers/biomass at age using estimates or pre-specified values of movement, natural mortality, growth, fecundity, and spawner-recruitment relationship, etc., (2) an observational subcomponent that relates observed (measured) quantities such as CPUE or proportion at length/age to the population dynamics through estimates of catchability or selectivity, and (3) a statistical subcomponent that uses likelihoods to quantify the fits of the observations to the recreated population.

## 4.2. Biological and Demographic Assumptions

### *4.2.1. Sex Specificity*

This assessment assumes that there is no difference in sexual dimorphism. Studies have found that the sex ratio between females and males is not statistically different from 1:1 (Chen et al. 2006, Shimose and Takeuchi 2012). Males are generally larger than females after they reach sexually mature (Maguire and Hurlbut 1984, Shimose et al. 2009, Shimose and Takeuchi 2012). Shimose and Takeuchi (2012) and Takeuchi (2012) further estimated sex-specific growth for PBF However, samples of paired age-length data by sex are often skewed. Given the lack of records of sex in the fishery data, a single-sex population was assumed for this assessment.

### *4.2.2. Growth*

A sex-combined length-at-age relationship was externally estimated from paired age-length otolith samples (annual rings: Shimose et al. 2009, Shimose and Takeuchi 2012, Shimose and Ishihara 2015; annual and daily rings: Fukuda et al. 2015b) described in the section 2.1.4. This relationship was then re-parameterized to the von Bertalanffy growth equation used in SS **(**Figure 2-3**)** and adjusted for the birth date (1st of July, i.e., the first day of the fishing year),

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

where $L_1$ and $L_2$ are the length (cm) associated with ages (year) near the first ($A_1$) and second ($A_2$) ages, $L_\infty$ is the asymptotic average length-at-age (Francis 1988), and $K$ is the growth coefficient ($y^{-1}$). The growth parameters $K$, $L_1$, and $L_2$ were fixed in the SS model, with $K$ at 0.188 $y^{-1}$ and $L_1$ and $L_2$ at 19.05 cm and 118.57 cm for age 0 and age 3, respectively, based on the length-at-age relationship by Fukuda et al. 2015b. $L_{\infty}$ can be re-parameterized as:

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

$L_{\infty}$ is then calculated as 249.917 cm. The process errors modeled as the coefficients of variation (CVs) were the function of the mean length at age, $CV = f(\text{length-at-age})$. Based on the estimated variances from the length composition data and the conditional age-at-length data, the CV was then fixed at 0.259 and 0.044 for ages 0 and 3, respectively. Linear interpolation between 0-3 was used to generate the process error for intervening ages, and ages 3 and older were assumed to be the same as age 3. The parametrization above results in the traditional von Bertalanffy parameters as follows:

$$L_t = 249.917 \times \left(1 - e^{-0.188\times(t+0.4217)}\right)$$

where

$L_t$ = length at age t;

$L_{\infty}$ = 249.917 cm = theoretical maximum length;

$K$ = 0.188 $y^{-1}$ = growth coefficient or the rate at which $L_{\infty}$ is asymptotically reached; and $t_0$ = -0.4217 (assumed July 1 as birthday, the first day in the fishing year) = theoretical age where length is equal to zero.

### 4.2.3. *Ages Modeled*

Ages from age 0 to the maximum age of 20 were modeled. Age 20 was treated as an accumulator for all older ages (dynamics are simplified in the accumulator age). The maximum age of 20 was set at the age where the number of fish is approximately 0.15% of an unfished cohort remains given the *M* schedule.

### 4.2.4. *Weight-Length Relationship*

A sex-combined weight-length relationship was used to convert fork length ($L$) in cm to weight ($W_L$) in kg (Kai 2007b). The relationship is:

$$W_L = 1.7117 \times 10^{-5} L^{3.0382}$$

where $W_L$ is the weight at length $L$. This weight-length relationship was assumed time-invariant and fixed. (Figure 2-4).

### 4.2.5. *Natural Mortality*

Natural mortality (*M*) was assumed to be age-specific in this assessment. Age-specific *M* estimates for PBF were derived from a meta-analysis of different estimators based on empirical and life history methods to represent juvenile and adult fish (Aires-da-Silva et al. 2008; see Section 2.1.5). The *M* of age 0 fish was estimated from a tagging study, as discussed in detail in Section 2.1.5. Age-specific estimates of *M* were fixed in the SS model as 1.6 $\text{year}^{-1}$ for age 0, 0.386 $\text{year}^{-1}$ for age 1, and 0.25 $\text{year}^{-1}$ for age 2 and older fish.

### 4.2.6. *Recruitment and Reproduction*

PBF spawn throughout spring and summer (April-August) in different areas in the western Pacific Ocean as inferred from egg and larvae collections and examination of female gonads. In the SS model, spawning was assumed to occur at the beginning of April (fishing month 10). Based on Tanaka (2006), age-specific estimates of the proportion of mature fish were fixed in the SS model as 0.2 at age 3, 0.5 at age 4, and 1.0 at age 5 and older fish. PBF ages 0-2 fish were assumed to be immature. Recruitment is assumed to occur in fishing month 1.

A standard Beverton and Holt stock-recruitment relationship (SR) was used in this assessment. The expected recruitment for year $y$ ($R_y$) is a function of spawning biomass ($SSB_y$), an estimated unfished equilibrium spawning biomass ($SSB_0$), a specified steepness parameter ($h$), and an estimated unfished recruitment ($R_0$).

$$R_y = \frac{4hR_0SSB_y}{SSB_0(1-h)+SSB_y(5h-1)}e^{-0.5b_y\sigma_R^2+\tilde{R}_y}$$

$$\tilde{R}_y \sim N(0,\sigma_R^2)$$

Annual recruitment deviations from the SR relationship ($\tilde{R}_y$) were estimated from 1953 to 2020 and assumed to follow a normal distribution with a specified standard deviation $\sigma_R$ in natural log space (Methot and Taylor 2011, Methot and Wetzel 2013). This $\sigma_R$ penalizes recruitment deviated from the spawner-recruitment curve. The central tendency that penalizes the log (recruitment) deviations for deviating from zero was assumed to sum to zero over the estimated period. Estimation of $\sigma_R$ is known to be difficult in the penalized likelihood estimation (Maunder and Deriso 2003), so an iteratively tuning $\sigma_R$ approach was used to match the standard deviation of the estimated recruitment deviations. A couple of repeated model runs were conducted to numerically estimate a value of $\sigma_R$ in SS based on Methot and Taylor 2011, resulting that $\sigma_R$ was set to be 0.6 in the assessment model and was about the variability of deviates estimated by the model. Relatively large $\sigma_R$ allows the model to be less sensitive to our assumptions about the steepness.

A log-bias adjustment pattern fraction ($b$) was applied during the data-poor period (1953-2020) to assure unbiased estimation of mean recruitment. Because the $b$ was calculated in SS, a two-steps procedure was used to apply the estimation of $b$ based on Methot and Taylor 2011. The first model run was to estimate recruitment deviations and variability around these values without adjusting any bias. The $b$ was also calculated in the first model run based on the estimated recruitment deviations and $\sigma_R$, which was 0.9. The assessment model was to apply this estimated $b$ obtained from the first run. The closer to the max value of 1 for $b$ means that data are more informative about recruitment deviations and vice versa because the $b$ is in log space.

The steepness of the stock-recruitment relationship ($h$) was defined as the fraction of recruitment when the spawning stock biomass is 20% of $SSB_0$, relative to $R_0$. Previous studies have indicated that $h$ tends to be poorly estimated due to the lack of information in the data about this parameter (Magnusson and Hilborn 2007, Conn et al. 2010, Lee et al. 2012). Lee et al. (2012) concluded that steepness could be estimable within the stock assessment models when models were correctly specified for relatively low productivity stocks with good contrast in spawning stock biomass. However, the estimate of $h$ may be imprecise and biased for PBF as it is a highly productive species. Independent estimates of steepness that incorporated biological and ecological characteristics of the species (Iwata 2012, Iwata et al. 2012b) reported that mean of $h$ was around 0.999, close to the asymptotic value of 1.0. Therefore, steepness was specified at 0.999 in this assessment. It was noted that these estimates were highly uncertain due to the lack of information on PBF's early life history stages.

### *4.2.7. Stock Structure*

The model assumed a single well-mixed stock for PBF. The assumption of a single stock is supported by the previous tagging and genetic studies (see Section 2.1.1).

### *4.2.8. Movement*

PBF is a highly migratory species, with juveniles known to move widely between the EPO and WPO (Section 2.1.3). In this assessment, PBF stock was assumed to occur in a single, well-mixed area, and spatial dynamics (including regional and seasonal movement rates) were not explicitly modeled. Although the model was not spatially explicit, the collection and pre-processing of data, on which the assessment was based, were fishery specific (i.e., country-gear type) and therefore contained spatial inferences (fleet-as-area approach). This approach estimated fishery-specific time-varying length- and age-based selectivity patterns separately and was shown to be able to approximate the changes in cohorts due to movement and gear selectivity (see Section 4.3.2).

## 4.3. Model Structure

### *4.3.1. Initial Conditions*

When populations are exploited prior to the onset of data collection, stock assessment models must make assumptions about what occurred prior to the start of the dynamic period. Assessment models often make equilibrium assumptions about this pre-dynamic period. These assumptions can make a population in the initial year that is either at an unfished equilibrium, is in equilibrium with an estimated mortality rate influenced by data on historical equilibrium catch, or has estimable age-specific deviations from equilibrium. Two approaches describe the extreme alternatives for dealing with the influence of equilibrium assumptions on the estimated dynamics. The first approach is to start the dynamic model as far back in time as necessary to assume that there was no fishing prior to the dynamic period. Usually, this entails creating a series of hypothetical catches that both extend backward in time and diminish in magnitude with temporal distance from the present. The other approach is to estimate (where possible) parameters defining initial conditions.

Because of the significance (in both time and magnitude) of the historical catch prior to 1952, this assessment used the second method (estimate) to develop non-equilibrium initial conditions that estimated 1) R1 offset, 2) initial fishing mortality rates, and 3) early recruitment deviations. The R1 offset was estimated to reflect the initial equilibrium recruitment relative to R0. This R1 has been estimated in the previous assessments. The equilibrium fishing mortality rates (Fs) were estimated because the initial equilibrium involved not only natural mortality but also fishing mortality. The estimation of the equilibrium Fs can be based on the equilibrium catch, which is the catch taken from a stock for which removals and natural mortality are balanced by stable recruitment and growth. Although this assessment did not fit equilibrium catch (no influence on the total likelihood function for deviating from assumed equilibrium catch), equilibrium Fs were freely estimated. Equilibrium Fs were estimated for the Japanese longline fleets (Fleet 1) and Japanese set-net fleets for seasons 1-3 (Fleet 8) because they represented fleets that took large and small fish, respectively. Ten-year recruitment deviations prior to the start of the dynamic period were estimated to adjust the equilibrium initial age composition before starting the dynamic to be a non-equilibrium initial age composition. The model first applied the R1 offset and initial equilibrium Fs level to an equilibrium age composition to obtain a preliminary number-at-age. Then it applied the recruitment deviations for the specified number of younger ages (information came from the size compositions for early years in the assessment) in this number-at-age. Since the number of estimated ages in the initial age composition is less than the maximum age, the older ages retained their equilibrium levels. Because the older ages in the initial age compositions will have less information, the bias adjustment was set to be zero.

### *4.3.2. Selectivity*

#### *Selectivity assumptions for Fishery fleet*

Selectivity is the observation model process that links composition data to underlying population dynamics. For non-spatial models, this observation model combines contact selectivity of the gear and population availability to the gear. The former is defined as the probability that the gear catches a fish of a given size/age, and the latter is the probability that a fish of a given size/age is spatially available to the gear. In the case of PBF, variable trans-Pacific movement rates of juvenile fish cause temporal variability in the availability component of selectivity for those fisheries catching migratory juveniles. Therefore, in addition to estimating length-based gear selectivity, time-varying age-based selectivity was estimated to approximate the time-varying age-based movement rate. The use of time-varying selection results in better fits to the composition data compared to the time-invariant selection model, which had adverse consequences on fits to other prioritized data (ISC 2014, ISC 2016b).

We also used a combination of model processes (time-varying length- and age-based selectivity) and data weightings to ensure goodness of fits to size composition for the fleets that caught high numbers of fish since 1990 when data were abundant (Table 4-1). In general, fleets with large catches of migratory ages, good quality of size composition data, and no CPUE index were modeled with time-varying selection (Lee et al. 2015). Fleets taking mostly age-0 fish or adults were treated as time-invariant unless fishing patterns changed and blocks of time-invariant selection were used (e.g., Fleet 1). Fleets with small catches or poor size composition data were either aggregated with similar fleets or given low weights. Details are given below.

Fishery-specific selectivity was estimated by fitting length composition data for each fleet except Fleets 7, 11, 20, 21, 22, 24, and 25, whose selectivity patterns were borrowed from other fleets based on the similarity of the size of fish caught (Table 4-1). The size composition data for Fleet 11 were combined with Fleet 10, whereas the size composition data for Fleets 7, 16, and 24 were not used to estimate its selectivity due to poor quality of sampling, limited observations, or/and unclear sampling scheme. The size composition data for the discard fleets (Fleets 21, 22, and 25) were not available, but it was assumed that their selectivity pattern was similar to that of the retained catch. The selectivity for Fleet 16 was assumed to be 100% selected at only age 0.

Fleets with CPUE index (Fleets 1, 6, and 12) were modeled as time-invariant (within blocks of time as appropriate) length-based selection patterns to account for the gear selectivity. Due to the nature of their size compositions (non-migratory ages caught by these fleets (either age-0 fish or spawners) resulting in a single well-behaved mode), functional forms of logistic or double normal curves were used for the CPUE fleets. The choice of asymptotic (logistic curves) or dome-shaped (double normal curves) selection pattern was based on the assumption that at least one of the fleets sampled from the entire population above a specific size (asymptotic selectivity pattern) to stabilize parameter estimation. This assumption was evaluated in the previous study and it was indicated that the Taiwanese longline fleet (Fleet 12) consistently produced the best fitting model when an asymptotic selection was used (Piner 2012). This assumption along with the observed sizes and life history parameters set an upper bound to population size. This asymptotic assumption was later removed in the sensitivity analysis (see Section 5.5.5). Selection patterns were assumed to be dome-shaped (double normal curves) for Fleets 1 and 6.

Fleets without CPUE were categorized into fleets taking fish of non-migratory ages (age-0 fish or spawners for Fleets 2, 17, 19, and 23) and fleets taking fish of migratory ages (ages 1-5 for Fleets 3, 4, 5, 8, 9, 10, 13, 14, 15, and 18). Selectivity for non-CPUE fleets taking fish of non-migratory ages was modeled as time-invariant length-based selection patterns to account for the gear contact, assuming that availability was temporally constant. Due to the nature of their size compositions with a single well-behaved mode, functional forms of double normal curves were estimated. As for non-CPUE fleets taking fish of migratory ages, both length- and age-based selectivity patterns were estimated (Lee et al. 2015). Selection is then a product of the age- and length-based selection patterns. The pattern for the length-based selection was time-invariant asymptotic or dome-shaped, while the age-based selection estimated separate parameters for each age and was time-varying for migratory ages. However, the three EPO fleets (Fleets 13, 14, and 15) were modeled with time-varying length-based selection due to the possible difference in growth between EPO and WPO. Because of the large number of parameters involved, fleets without a significant catch (Fleets 8 and 9) did not include the time-varying age-based component.

#### ***Selectivity for abundance index***

Selectivity for relative abundance indices were assumed to be the same as the fishery from which each respective index was derived. Size selectivity for the S1, S2 and S3 indices, which were CPUE based index from Japanese longline fishery, were assumed to be the same as the fleet 1 Japanese longline fisheries. Size selectivity of S4 and S12, which were the CPUE based index from Japanese troll fishery and recruitment monitoring survey, were assumed to be the same as the fleet 6, which is the Japanese troll fishery in fishery season 2-4. Size selectivity of the S5 index, which was the CPUE based index from Taiwanese longline fishery, was assumed to be the same as the Fleet 12 Taiwanese longline fishery operating in the southern fishing ground.

### *4.3.3. Catchability*

Catchability (q) was estimated assuming that each index of abundance is proportional to the vulnerable biomass/numbers with a scaling factor of q that was assumed to be constant over time. Vulnerable biomass/numbers depend on the fleet-specific selection pattern and underlying population numbers-at-age.

## 4.4. Likelihood Components

### *4.4.1. Observation error structure*

The statistical model estimates best-fit model parameters by minimizing a negative log-likelihood value that consists of likelihoods for data and prior information components. The likelihood components consisted of catch, CPUE indices, size compositions, and a recruitment penalty. The observed total catch data assumed a lognormal error distribution. An unacceptably poor fit to catch was defined as models that did not remove >99% of the total observed catch from any fishery. Fishery CPUE and recruitment deviations were fit assuming a lognormal error structure. Size composition data assumed a multinomial error structure.

### *4.4.2. Weighting of the Data*

Three types of weighting were used in the assessment model: (1) weighting length compositions (via effective sample size), (2) weighting catch, and (3) CPUE data.
Weights given to catch data were S.E.=0.1 (in log space) for all fleets, which is relatively precise for catches, except for unaccounted mortality fleets (S.E.=0.3). Weights given to the CPUE observations were assumed to be CV=0.2 across years and fleet unless the standardization model produced larger uncertainty. In that case, a larger CV estimated from the standardization was used. The weights given to fleet-specific quarterly composition data via effective sample size were based on an ad-hoc method. Sample sizes were low (<15 effective sample sizes) based on the number of well-measured samplings from the number of hauls or daily/monthly landings (Table 4-1) except for the longline fleets. For longline fleets, because only the number of fish measured are available (the number of trips or landings measured were not available), the sample size was scaled relative to the average sample size and standard deviation of the sample size of all other fisheries based on the number of fish sampled.

## 4.5. Model Diagnostics

Multiple diagnostic tests were used to detect misspecification of the observation model (i.e., the model processes relating the population dynamics model to data) and system dynamics model (i.e., the population dynamics) (Maunder and Piner 2015).

### *4.5.1. Age Structured Production Model*

Following the proposal by Maunder and Piner (2015), the Age Structured Production Model (ASPM) diagnostics were performed to evaluate if the information content of data about absolute abundance (i.e., the catch and indices data could provide the information about the population scale given the model processes and selectivity specified) and assess whether the system dynamics model is correctly specified (Carvalho et al. 2017). The ASPM was developed by simplifying the base-case model. The deterministic ASPM retained the fleet structure (number of fleets) of the base-case model. However, three main changes were 1) elimination of the fitting to composition data (now only included catch by fleet and the Japanese longline and Taiwanese longline fisheries CPUE, S1 to S3, and S5, as contributing to the total likelihood function), removal of estimation of annual recruitment variation, and specification of selectivity patterns for each fleet to those estimated in the base-case model. Because the annual recruitment deviates were not estimated in the ASPM, recruitment follows the stock-recruitment curve. The ASPM

only estimates the global scaling parameters, such as the log of unfished recruitment (Log$R_0$) and equilibrium fishing mortality rate (Initial F). The criterion for a satisfactory ASPM is when the model's prediction of abundance matches the patterns observed by the longline CPUE series. The performance test was a visual examination focusing on predictions of the long-term (decadal) trends. The most robust evidence for good ASPM performance would be matching periods of both increasing and declining abundance (two-way trip).
After determining if the ASPM performed well, the reliability of the age-0 CPUE index (Japanese troll index, S4) using an ASPM with annual recruitment deviations specified at those estimated in the base-case model (ASPM-R). The ASPM-R has the addition of temporal recruitment variation that exactly matched the age-0 troll index. If the ASPM-R improves fits of the adult indices, this is evidence that the age-0 troll index is consistent with the other data sources in the model and provides good information on recruitment variability.

#### *4.5.2. Residual analyses*

Residual analyses are commonly used to detect the misspecification of the observation model. A visual examination between observed and predicted values was first applied to ensure that the fit was good. To further determine the goodness-of-fit, the root-mean-square error (RMSE) was used for the CPUE data, and the ratio of inputted sample weights to model estimates of the weights was used for the size composition data. Residual plots evaluated trends in residuals and the magnitude of the residuals. Inputted weights above model estimates of the weight to that data source were considered diagnostic of lack of fit.

#### *4.5.3. $R_0$ likelihood component profiling analyses*

Negative log-likelihoods of various data components across a profiled population scale estimate of log($R_0$) were used to evaluate which data sources were providing information on the global scale (Lee et al. 2014). Data components with a large amount of information on the population scale will show significant degradation in fit as the population scale was changed from the best estimate. A model with a global scale estimated that was consistent with the information provided by the primary tuning indices would be considered a positive diagnostic.

#### *4.5.4. Retrospective analysis*

A retrospective analysis was performed on the base-case model via the subsequent removal of the terminal year of data. The underlying assumption is that the estimates of historical abundance from the base-case model that uses all the data are more accurate than the estimates of abundance from the retrospective models that ignore recent data. Therefore, this analysis shows the possible bias of model predictions. A 10-year retrospective analysis was conducted for temporal trends in spawning biomass, and the Mohn's rho statistic (Mohn 1999, Hurtado-Ferro et al. 2014) was calculated to quantify the severity of retrospective patterns. In other words, a larger absolute Mohn's rho indicates an obvious consistent pattern of change in the peeled models relative to the base-case model.

#### *4.5.5. Hindcasting*

Hindcasting was used to assess the prediction quality of the base-case model (Kell et al. 2016). The underlying assumption is that the assessment model that worked well in the past and predicted the past well indicates that the assessment model has a good prediction skill. We first retrospected 10-years of stock dynamics (i.e., peeling off 10-years of data sources) and made a 10-years past prediction using the full dynamic base-case model and age-structured production model. We chose the 10-years because the rebuilding measure for PBF uses the 10-years timeline. This work can be thought of as if we conducted the assessment ten years ago using data only up to that year and forecast forward with the catches by fleets as did occur in the next ten years, could we have predicted what happened to the stock?

#### *4.5.6. Convergence Criteria*

A model was not considered converged unless the hessian was positive definite. Convergence to a global minimum was further examined by randomly perturbing the starting values of all parameters by 10%, and randomly changing the ordering of phases of global parameters used in the optimization of likelihood components prior to refitting the model. These analyses were conducted as a quality control procedure to ensure that the model was not converging on a local minimum.

#### *4.5.7. Sensitivity analysis*

The effect of different assumptions of the system dynamics model and observation model were examined via sensitivity analysis. Two groups of models were conducted, and several sensitivity runs for each group were performed. The first group of models addressed the observation model using full time-series data (1952-2020), and the second group of models addressed the system dynamics model process using short time-series data (1983-2020). The short time-series model used similar parameterization to the base-case model. The differences are 1) estimating one initial equilibrium fishing mortality for Japanese set-net (initial F) and 2) using the size composition data of Fleet 13 (EPO commercial fishery) in 1983 in the likelihood function of the model to estimate the selectivity of that fishery during 1983-2001.

In each sensitivity run, an assumption of the model was changed, and the model was re-run to examine effects on derived quantities. Sensitivity runs are the followings:

1. Base-case model using full time-series data (addressed observation model)
    a. Different data-weighting of size composition data
    b. Doubled amount of unseen catch
    c. No asymptotic selectivity
    d. Fit the recruitment monitoring index after 2016
2. Model using short time-series data (addressed system dynamics model)
    a. Lower steepness
    b. High and low length at age 3
    c. High and low natural mortality for age 2 and older

### 4.6. Projections and Biological Reference Points

#### *4.6.1. Projections*

Projections were conducted outside the integrated model using forecasting software assuming age-structured population dynamics with a quarterly time step in a forward direction, based on the results of the stock assessment model using SS3 (Ichinokawa 2012, Akita et al. 2015, 2016, Nakayama et al. 2018). This software provides stochastic projection, including parameter and observation uncertainty of bootstrap replicates in SS, followed by stochastic simulations. The base-case model replicates were created using the same error structure as the base-case model and then fit in the base-case model using SS. In the projections reported in this report, the projection SSB estimates are the medians of the 6,000 individual SSB calculated for each 300 bootstrap replicates, followed by 20 stochastic simulations.

Future recruitment is randomly resampled from the recruitment estimates by each base-case model replicates. As for the second rebuilding period starting in 2020 (from the next year of the stock achieving the initial rebuilding target with the 60% of its probability), future recruitment was randomly resampled from historical recruitment for 1952-2019. This future recruitment assumption is consistent with the guidance for projections from the Joint WCPFC NC-IATTC WG meeting and adopted by WCPFC (Harvest Strategy 2017-02) and was confirmed with little autocorrelation of the historical recruitment.

Several alternative harvest scenarios of a setting catch limit, which included the requested scenarios by the WCPFC NC 17 to the ISC (WCPFC NC 17, Attachment F), were shown in Table 4-2. Scenario 1 approximates the conservation and management measures which are currently in force in the WCPFC convention area (WCPFC CMM2021-02) and IATTC convention area (IATTC Resolution C21-05). For the EPO commercial fishery, since the IATTC Resolution apply only a catch limit, constant catch limit of 3,995 tons with high F level as that in 2002-2004 are assumed in this future projection to consume all the quota. For the WPO fishery, the maximum F level is assumed as 2002-2004 average level as the approximation of the effort control prescribed in the WCPFC CMM.

Scenarios from 2 to 4 were based on the request from the WCPFC NC 17 to investigate the effects of the less conservative management measures which depict possible increases in catch limit in specified amounts or fractions from the currently specified limit (WCPFC NC 17, Attachment F). Scenario 5 was also based on the request from the WCPFC NC17 that analyze the impacts of a transfer of 10% for Japan and 25% for Korea of small fish (PBF of less than 30 kg of its body weight) limit to large fish (PBF of 30 kg and larger) limit using a conversion factor of 0.68:1 for the small and large fish catch limits.

Scenarios 6-9 were based on another request from the WCPFC 17 that explore the future catch amount to satisfy the second rebuilding objective by 10 years after reaching the initial rebuilding target, with achieving a specified future fishery impact on SSB of approximately 75%/80% from WCPO fisheries and 25%/20% from EPO fisheries. Under the harvest scenarios 6-9, the proportion of historically accumulated WCPO v.s. EPO impact was gradually changed to achieve the specified ratio of the fishery impact in 10 years after achieving rebuilding target. Thus, the impact proportion is dynamic and may change further in a longer term if the same harvest scenario continues beyond the target year. In addition to the above-mentioned scenarios, a future population dynamics that approximates the previous CMM (WCPFC CMM 2020-02 and IATTC Resolution C20-02), which had introduced during 2015-2021 (scenario 10), and a scenario with zero removals (no fishery) was also examined (scenario 11).

As the performance measures of each harvesting scenarios, PBFWG provided the expected year to achieve the second rebuilding target with 60% of probability, the probability achieving the second rebuilding target at ten years after achieving the initial rebuilding target, the probability of SSB being below the historical lowest at any time of projection period, the median SSB at ten years after achieving the initial rebuilding target and 2034, ratio of the future expected fishery impact between the WCPO and the EPO in ten years after achieving the initial rebuilding target, and the expected future catch at certain years.

Scenario 1 projection was further conducted from the model including the new recruitment monitoring index as robustness test. Sensitivity analyses of the projections to model assumptions (natural mortality, steepness, and growth) were also conducted using short time-series data.

### *4.6.2. Biological Reference Points*

The WCPFC has adopted the initial rebuilding target (the median SSB estimated for the period 1952 through 2014) and the second rebuilding target (20%SSBF=0 under average recruitment) by their CMM prepared by the joint WCPFC-NC and IATTC working group. Although biological reference points have not been formally adopted, the rebuilding targets (within specified time periods) could be considered consistent with interim biomass-based reference points, and the probabilities of achieving those targets consistent with interim fishing mortality reference points. In addition to these interim reference points, two commonly used biological-based reference points were calculated: (1) equilibrium depletion (terminal SSB/unfished SSB from the base-case model) was used to characterize current stock status, and (2) spawning potential ratio (SPR) was used to characterize current fishing intensity. Here, SPR is the cumulative spawning biomass that an average recruit is expected to produce over its lifetime when the stock is fished at the current intensity, divided by the cumulative spawning biomass that could be produced by a recruit over its lifetime when unfished. As it was considered inadvisable to compare the fishing mortality from different years when selectivity changes substantially, it was suggested to use the spawning potential ratio to be the measure of fishing intensity. Those reference points were calculated for the terminal year of the 2022 assessment (2020 FY), the initial and second rebuilding targets, and some historical years.

# 5. STOCK ASSESSMENT MODELLING RESULTS

## 5.1. Model Convergence

All estimated parameters in the base-case model were within the boundaries, and the final gradient of the model was 0.0012. The model hessian was positive-definite, and the variance-covariance matrix could be estimated. Based on the results from the 114 model runs with the random perturbations of initial values, there was some evidence for local minimums around the best fitting model. Most runs that stopped prior to reaching the best observed negative log-likelihood were similar to the base case model. The best-fitting model was chosen as the base-case model. The PBFWG considered it to have likely converged to a global minimum as there was no evidence of further improvements in the total likelihood (Figure 5-1).

## 5.2. Model Diagnostics

### *5.2.1. Age structured production model (ASPM) diagnostics*

The ASPM model generally fits well the abundance indices for the adult PBF such as S1 (Japanese longline late period) and S5 (Taiwanese longline south), without invoking process variation in recruitment (Figure 5-2 (a)). This result indicated that the model processes contributing to productivity (growth, natural mortality, and recruitment) and selectivity (fleet-specific time-varying selectivity) and the catch time series reasonably explain the effects of fishing that lead to changes in adult fish indices. This production model effect alone can provide information on the population scale (unfished stock size). Because the base-case model prioritized the indices, the ASPM and base-case models estimated similar levels of the population scale. However, there is a difference in the estimated biomass during the assessment period (Figure 5-3). This result confirms that composition data are not the primary drivers of the estimated scale in dynamics.

An ASPM with annual recruitment deviations specified at those estimated in the base-case model (ASPM-R) improved the model fits to both Japanese longline and Taiwanese longline indices (Figure 5-2 (b)). The estimated scale and trends of the population by the ASPM-R were also closer to the full model (base-case model) than those of ASPM (Figure 5-3). Those results indicate that the information provided by the recruitment index (S4) are consistent with those of the other data sources and likely provide good information on recruitment variability.

### *5.2.2. Likelihood Profiles on fixed log-scale Unfished Recruitment (log R0)*

Results of the profile of total and component likelihoods over a range of fixed log(R0) for the base-case model are shown in Figure 5-4. Relative likelihood values on the y-axis represent the degradation in model fit for each component (negative log-likelihood for each profile run minus the minimum component negative log-likelihood across profiles). A relative likelihood value = 0 indicates the best fit of the log(R0) value for that data component. All likelihood components showed best fits at very similar values of log(R0). Recruitment (penalty of the deviations) fit best at 9.575, all combined CPUEs at 9.525, and all combined size composition at 9.50. The estimate of log (R0) for the base-case model was 9.52517 (Figure 5-4 (A)).

Both size compositions and CPUE components showed informative gradients (convex function in the negative log-likelihood context) on both of low and high sides of the log(R0). Catch data is treated as a likelihood component in this model; however, the gradient for the catch component was not informative about log(R0). The recruitment component is strongly influenced on the low side of the log(R0), which is reasonable as greater recruitment variability is expected as the mean level of recruitment is specified as lower. We note that the likelihood comes from contributions of time series of recruitment deviations and not the penalty applied to the difference between the log of recruitment in initial equilibrium regime and log of R0. It is also worth noting that the observed variability of recruitment deviations is slightly lower than the assumed recruitment variability (fixed $\sigma R = 0.6$).

Composition data from the fleets with abundance indices (Japanese longline (Fleet 1), Japanese Troll (Fleet 6), and Taiwanese longline in the south fishing ground (Fleet 12)) had the most impact on the log(R0) profile (Figure 5-4 (b)). The composition data from the rest of the fleets were less important to the log(R0) estimation. This is expected as fleets without indices were fit using time-varying selectivity, which reduced their direct influence on the global scale.

Most of the abundance indices showed a gradual slope of relative likelihoods around a log(R0) value of 9.5, indicating consistent estimates of population scale. However, the abundance index for S1 (Japanese longline) indicated a gradual improvement in relative likelihood as log(R0) decreased (Figure 5-4 (C)).

Given the complexity of the biology and fleet structure, the PBFWG considers the base-case model to have the desirable property of being internally consistent regarding population scale. Furthermore, the unwanted influence of composition data on the population scale has been reasonably well handled, as demonstrated by relative likelihood values for composition component < 2 units base model estimate of log(R0).

### *5.2.3. Goodness-of-fit to Abundance Indices*

Predicted and observed abundance indices (section 3.5.2) by fishery for the base-case model are shown in Figure 5-5. The fits were generally within 95% CI for all the observed abundance indices. In particular, the base-case model fits very well with the S2, S3 (Japanese longline for the early and middle periods), and S4 (Japanese troll) indices. The root mean-squared-error (RMSE) between observed and predicted abundance indices for these indices were close to or less than 0.2, which was the input CVs for these indices.

The model also moderately fits the S1 and S5 indices (Japanese longline for the late period and Taiwanese longline CPUEs with 0.30 and 0.25 of RMSEs, respectively). Therefore, the PBFWG considered the data and model structure to provide a good prediction of recent changes in population abundance.

### *5.2.4. Goodness-of-fit to Size compositions*

The base-case model fits the size modes in data (aggregated by fishery and season well (Figure 5-6 and Table 5-1). The average effective sample sizes (effNs, an estimate of the model expected precision) are larger than the average input sample sizes for all fleets, indicating more precision in the assessment model for those data than was assumed.

Residuals in Fleet 1 during 1993-2016 were substantially decreased from the previous assessment because the observed fish smaller than 152 cm were excluded (Nishikawa et al. 2022). Removing these data was to ensure the selectivity was stable for the Japan longline CPUE standardization model (Tsukahara et al. 2022). Although the exclusion of these data ignored the catch for those small fish that have occurred, it was also confirmed that the amount of such catch was not substantial (Tsukahara et al. 2022). The PBFWG noted this as a subject for future research (see section 7).

The current base-case model, which incorporated detailed gear-specific selectivity and spatial and temporal (seasonal) variation of availability, could replicate the observed size composition data for all the fleets.

### *5.2.5. Retrospective Analysis*

The retrospective analysis showed a slight underestimation of terminal SSB for the past 10 years. In particular, excluding 2019-2020 FY data likely made the 2016-2018 SSB much lower than the full data series model. This retrospective pattern might result from the retrospective period covering several inflection points in SSB, such as introducing the catch upper limit, tightening the allowable catch, and the strong cohort in 2016 entering the longline fisheries. It should be noted that the trend of the SSB is basically informed by two abundance indices from the Japanese and Taiwanese longline fleets, which confirmed its consistency with the catch by the ASPM diagnostics. Those indices showed a rapid recovery trend of the stock, and the full data model could fit those data well. The retrospective analysis did not indicate an over- or under-estimating recruitment for the past 10 terminal years except for the past 3 years when the reliable age-0 index was not available (Figure 5-8).

The PBFWG concluded that the retrospective analysis did not indicate significant model misspecification.

### *5.2.6. Hindcasting*

A 10-year hindcasting model, which was fitted to the observation data up to 2010, using the age-structured production model (ASPM) could predict the past 10 years (from 2011 to 2020) trend of the abundance indices from the Japanese and Taiwanese longline CPUEs with good contrast (Fig. 5-9). We can make such good predictions because the PBF assessment uses a production function (made up of growth, natural mortality, and the spawner-recruitment function) that can accurately describe the average effects on abundance of catches at age over a range of stock sizes.

On the other hand, a 10-year hindcasting model using the full dynamics model slightly over-predicted the past 10 years' trend of the abundance indices, although the indices (prior to 2011) fit better than those in the ASPM (Fig. 5-10). Compared with the ASPM, the full dynamics model includes the size composition data and the recruitment variability to estimate the age structure precisely. There is a possibility that those data/assumptions might cause the over-prediction trend of the full dynamics model for short-term projections. It should be noted that the average recruitments for the past 10-years estimated by the base case model were lower than that of the expected recruitments (10% lower). Higher recruitment for the forecasting 10 years period in conjunction with the catch at age calculated based on a terminal year selectivity of the assessment period could be a cause for the gap in the full dynamics model fit to the indices between the assessment period and forecasting period.

Though further exploration is necessary for the difference in the predictability between the ASPM and full model, it was concluded that the PBF assessment model which peeled off the past 10-years data could predict the recovery of the stock which suggested by the recent abundance indices.

## 5.3. Model Parameter Estimates

### *5.3.1. Recruitment Deviations*

A Beverton-Holt relationship based on a steepness value of h=0.999 was used for the base-case model, and stock and recruitment plots are presented in Figure 5-11. The estimated recruitment deviations were relatively precise after 1990, indicating that data well informed these estimates. The recent four years (2017-2020) of the recruitment deviations showed larger uncertainty because of reduced information on those four-year classes due to the lack of information from the recruitment index. The variability of recruitment deviations (σR) in the base case ([1953-2020] σR = 0.52) is close but slightly lower than assumed recruitment variability (σR = 0.6). As these values are close, the estimated population scale and recruitment would not be substantially affected by the recruitment penalty.

### *5.3.2. Selectivity*

The estimated selectivity curves by each fleet for the base-case model are shown in Figures 5-12 and 5-13. Both length-based and age-based selections were estimated for Fleets 2, 3, 4, 5, 6, 8, 9, 10, 15, and 18. The length-based selections were estimated as asymptotic or dome-shaped, while the age-based selections were estimated for each age. Temporal variations in the age-based selectivity were captured for Fleets 3, 4, 5, 10, and 18. For the rest of the fleets with estimated length-based selectivity (Fleets 1, 13, 14, 17, and 19), dome-shaped patterns were estimated except for Fleet 12 with the asymptotic pattern. Among these fisheries, temporal variations were captured for Fleets 1, 13, 14, and 15. A combination of length and age selections is used to approximate the gear-specific contact selectivity and the spatial and temporal (seasonal) variation in availability, respectively. This modeling approach is mainly responsible for the increased number of parameters estimated since the 2016 assessment. In total, 366 selectivity parameters were estimated in the base-case model.

In general, the length- or age-based selectivity of all fleets allowing time-varying selection indicated gradual/distinct change of selection pattern from catching small (young) fish to large (old) fish (Figures 5-12 and 5-13). In particular, the larger (older) fish have been more available in recent years for Fleets 3, 5, 10, 14, and 15.

## 5.4. Stock Assessment Results

### *5.4.1. Total and Spawning Stock Biomass*

The base-case model produced estimated dynamics consistent with the previous assessment over the years both covered. Point estimates of total stock biomass from the base-case model showed long-term fluctuation (Table 5-2 and Figure 5-14), ranging from about 33,000 t in 1983 to about 210,000 t in 1959. Estimated total stock biomass showed a gradual increase since 2009. Particularly in the recent 5 years, there has been an increase of young fish (0-2 years old), creating its second-highest biomass peak in the assessed history in 2020 (Figure 5-15).

Spawning stock biomass (SSB) estimates also exhibited long-term fluctuation, consistent with that of total stock biomass (Figure 5-14). Estimates of SSB at the beginning of quarter 4 (April-June) in the first five years (1952-1956) of the assessment period averaged approximately 86,000 t (Table 5-2). The highest SSB of about 157,000 t occurred in 1961, while the lowest SSB of about 10,000 t occurred in 2010. In the 1990s, SSB reached its second-highest level of about 62,000 t in 1995 and declined until 2010. The SSB has increased since 2011, resulting in the 2020 SSB jumping back to the 1996 level. These changes in total and spawning stock biomass coincide with a decline in fishing mortality over the last decade.

The quadratic approximation to the likelihood function at the global minimum, using the hessian matrix, indicated that the CV of SSB estimates was about 16% on average for 1980-2020 and 16% for 2020. The average CV for 1952-1979 was about 39%, resulting from limited data in the early years.

The unfished SSB ($SSB_0$) was estimated by extrapolating the estimated stock recruit relationship under the equilibrium assumptions of about 644,000 t ($R_0$ = 13.7 million fish). The depletion ratios ($SSB/SSB_0$) of the assessment period ranged from 1.5% to 24.3%. The 1995, 2010, and 2020 SSB corresponded 9.7%, 1.5%, and 10.2% of the $SSB_0$, respectively.

### *5.4.2. Recruitment*

Recruitment estimates (age-0 fish on July 1st) fluctuated widely without an apparent trend and were almost identical to the 2020 assessment. Recent strong cohorts occurred in 2004 (27.7 million fish), 2007 (22.2 million), and 2008 (21.0 million), and moderately good cohorts occurred in 2005 (15.1 million), 2010 (18.0 million), and 2016 (16.7 million) (Table 5-2 and Figure 5-14). The average estimated recruitment was approximately 13.4 million fish for the entire stock assessment period (1952-2020). The 2009, 2012, 2014, and 2015 recruitments were relatively low (8.2, 7.2, 3.6, and 8.6 million fish, respectively), and the average recruitment level for the last 10 years (2011-2020; 10.8 million fish) has been below the historical average level.

Recruitment estimates were also less precise at the start of assessment period until the 1970’s (average CV = 24%, maximum CV = 44%) and became moderately precise from 1980 to 1993 (average CV = 21%, maximum CV = 35%) when CPUE-based recruitment index from the Japanese troll fishery became available. From 1994 to 2016, recruitment estimates improved their precision (average CV = 8%) due to the comprehensive size data collection for Japanese fisheries that began in 1994. The recruitment estimates for the past four years (2017-2020) were not precise due to the lack of the recruitment indices (average CV =32.5%).

### *5.4.3. Catch at Age*

The catch number of PBF at each age was estimated internally in the stock assessment model based on the growth assumption, observed catch, and selectivity. Because there was a big difference in the amount of composition information available before and after 1994 (Figure 3-1), there is greater uncertainty in the estimated catch number at age before the early 1990s.

PBF catches have been predominately composed of juveniles (ages 0-2) (Figure 5-16) throughout the assessment period. Historically, the estimated number of fish caught showed a fluctuation ranging from a low of one million fish in 1959 to a high of about 4 million fish in 1978 during the 1950s to the early 1990s (Figure 5-16). Because the catch of age-0 PBF has increased significantly from the early 1990s to the 2000s, the estimated number of fish caught were fluctuated around 4 million on average.

After the management measures by the RFMOs (WCPFC in 2011 and IATTC in 2012), catch in the number of fish decreased to less than 2 million fish on average. The recent management measures strengthened since 2015 calendar year (i.e., WCPFC CMM 2019-02, IATTC Resolution C-18-01), have maintained the catch in the number of fish at about 1.5 million fish on average. The catch of age 0 PBF, which has the largest fishery impact on the future biomass, has also decreased significantly since the mid-2010s as the total catch in weight declined due to stricter control of juvenile catch in both the EPO and the WCPO.

### *5.4.4. Fishing Mortality at Age*

Historically, fishing mortality rates (F) for ages 0-2 have been higher than those for age 3 and older fish (Table 5-3). However, the F for those ages declined since 2016, resulting in the F at ages 0-2 being to a similar level of Fs at age 3 and older. The geometric mean F at age 1 during 1995-2010 was 1.24, while F at ages 0, 2, and 3 were 0.54, 0.62, and 0.21, respectively. The F at age 4 and older during the same period was 0.16. When the management measures by the RFMOs were introduced in 2011, fishing mortality for ages 0-2 decreased (Figure 5-17). When the management measures were strengthened in 2015, a further substantial decrease of F was observed in ages 0-2.

### *5.4.5. Fishery Impact*

The cumulative impact of the different fishery groups on the SSB were evaluated by simulating the population dynamics while removing each fishery using the base-case model (Wang et al. 2009). Figure 5-18 showed (a) historical fishery impact on the SSB of PBF and (b) ratio of fishery impact within each fishery group.

Historically, the WPO coastal fisheries group has had the greatest impact on the PBF stock. However, since the early 1990s, the WPO purse seine fishery group targeting small fish (ages 0-1) has had a greater impact. The effect of this group in 2018 was greater than any of the other fishery groups. The impact of the EPO fisheries group was large before the mid-1980s, decreasing significantly after that. The WPO longline fisheries group has had a limited effect on the stock throughout the analysis period. This is because the impact of a fishery on a stock depends on both the number and size of the fish caught by each fleet; i.e., catching a high number of smaller juvenile fish can have a greater impact on future spawning stock biomass than catching the same weight of larger mature fish. The impact of discards is more uncertain than other impacts as it is not based on observed data.

### *5.4.6. Biological Reference Points*

The base case results show that the point estimate of the $SSB_{2020}/SSB_{F=0}$ was 10.2%. As shown in the Kobe plot (Figure 5-19), there has been a continuous recovery in SSB and a declining trend in fishing mortality (SPR). SSB reached the initial rebuilding target (the median of SSB point estimates during 1952-2014; 6.3%$SSB_0$) in 2019, and the fishing mortality declined in the most recent years (2018-2020) below $F_{30\%SPR}$, which is a lower rate than most of commonly used F-based reference points except $F_{0.1}$ and $F_{40\%SPR}$ (Table 5-3).

Currently, a rebuilding measure for this species, which includes two recovery targets and a pre-agreed HCR with a specific catch limit, is in force (WCPFC HS 2017-02). The conservation advice based on the stock status for this species has been considered relative to the biological reference point estimations for given past years and to some indicators associated with the future stock status, such as the probability of achieving the rebuilding target at given year (ISC 2018; IATTC SAC09-15 rev2, 2018).

Note that a comparison of the recent fishing mortality against fishing mortality-based reference points may be confusing when the stock is subject to rebuilding measures, including catch upper limits.

## 5.5. Sensitivity Analysis

### *5.5.1. Sensitivity runs using full time-series data*

#### *Different data-weighting of size composition data*

Because of many fleets with composition data, data weighting is an important issue. A sensitivity run was conducted using an alternative weighting, which down-weighted the size composition data of Fleets 13 (EPO commercial fishery in the early period) and 20 (Japanese Purse seine for farming fishery). Those fleets were chosen because they had a lower harmonic mean value of the estimated effective sample sizes than the inputted sample sizes. The fits to the abundance indices were slightly better in the down weighting model than in the base-case model (1 unit of negative log-likelihood by aggregated for all indices). Also, there was no sign of improvement in the fit to the size composition data. Overall, the alternative weighting model did not substantially affect the estimated spawning biomass or recruitment (Figure 5-20). The PBFWG concluded that the base-case results were not sensitive to the alternative assumption of relative data weighting and thus used the same method with the 2020 assessment. The PBFWG recommends that continued research into data weighting should be conducted.

#### *Increased amount of unseen catch*

Recent management measures may have created discard issues for some fleets. Although data on discard is limited, the base-case model assumed discard levels for some fleets (see section 3.6.13). These assumed amounts are not well known; thus, a sensitivity run was conducted assuming discard was double the assumed value. Model results were nearly identical to the base case, with the model able to predict the catches in the discard fleet (Figure 5-21). This result was expected because discarding issues are only in recent years. The PBFWG concluded that uncertainty in the discard level is not critical for this assessment but could influence in future assessments.

#### *No asymptotic selectivity*

Taiwanese longline operating in the south fishing ground (Fleet 12) is the only fleet assumed an asymptotic length-based selectivity in the base-case model. This fleet does catch the largest fish, but forcing an asymptotic selectivity is a strong model assumption. A sensitivity run was conducted, allowing for a dome-shaped length-based selectivity for the Fleet 12. This sensitivity model estimated a selection pattern that has about 60% selections for the fish larger than 250 cm, with a slightly larger SSB size than the base case (Figures 5-22 and 5-23). The model could also converge without this strong structural assumption (asymptotic selectivity). The PBFWG considered that the base-case model is not sensitive to and does not require an asymptotic selection pattern, likely because of the strong production function effects in the model.

***Fit the recruitment monitoring index after 2016***

In the past assessments, the recruitment index based on the Japanese troll CPUE had been a good indicator of the recruitment trend (ISC 2020). However, continuity was lost for this index because of the catchability change by introduction of the new fishery management scheme after 2016 (e.g., individual quota) (Nishikawa et al. 2021). The recruitment monitoring survey index was developed as an alternative source of information regarding the recruitment trend in recent years (Fujioka 2021). However, because it was challenging to evaluate the performance or consistency of this short time series index (from 2017 to 2020) with other data in the model, the base-case model was developed without this new recruitment index.

A sensitivity run was conducted that included the recruitment monitoring survey index. The model including this index estimated lower recruitment in 2019-2020 than the base-case model, although it did not affect the estimated SSB (Figure 5-24). Since the terminal recruitment estimates can affect the important management quantities, such as the F-based reference points and the short-term projection results, those quantities were also examined and compared with the base case. The alternative model incorporating the recruitment monitoring index estimated fishing mortality to be F27.9%SPR in 2018-2020, which does not differ substantively from the base-case model (F30.7%SPR) (Table 5-4). The WG concluded that the inclusion/exclusion of the new recruitment index does not influence critically to the management quantities estimated by the base case model.

### 5.5.2. Sensitivity runs using short time-series data

***Lower steepness***

In several past assessments, the base-case model convergence was sensitive to changes in the assumed level of steepness. Small changes in the specified steepness level had resulted in a non-positive definite hessian. To develop a more flexible model in terms of the model convergence to the alternative assumptions for steepness and other productivity assumptions, the PBFWG developed the short time-series model (Fukuda 2021, Fukuda et al. 2022). A lower steepness (h= 0.85) than the value used in the base-case model was used in the short time-series model to test the robustness of the management advice based on the base-case model.

The relative SSB at the starting point of the short-term assessment period (1983 FY) was similar to the low steepness run with the base-case model, and both models indicated a recovery of SSB since 2011. However, relative SSB at the terminal year was pessimistic likely due to the lower relative recruitment during the low SSB period (Fig. 5-25).

***High and low length at age 3***

Asymptotic length (or L infinity) assumed in the assessment model was estimated outside the assessment model based on the reasonably good amount of the age at length observation data from otolith analysis (Fukuda et al., 2015). Since this is one of the critical parameters to govern the productivity of the stock, sensitivity runs that assumed either higher or lower (by 5%) length at age 3 parameter, which strongly correlated to the L infinity, were conducted. The higher and lower length at age 3 models showed lower and higher relative SSB than the base-case model, respectively. Those could be considered typical model behavior, as shown in the other tuna stock assessment.

***High and low natural mortality for age 2 and older***

Although the age-specific M used in the assessment is based on empirical evidence, there is still uncertainty in the M value for older fish. Sensitivity runs that assumed either higher or lower (by 20%) for age 2 and older were run. The higher and lower M for age 2+ showed higher and lower relative SSB than the base-case model, respectively. However, those also could be considered as expected behavior of the model.

## 6. FUTURE PROJECTION

The WCPFC and IATTC defined the median SSB from MLE point estimates between 1952 and 2014 as the initial rebuilding target and 20% $SSB_{F=0}$ as the second rebuilding target[2]. The time series of the estimated SSB in the base case assessment model showed that the PBF stock achieved the initial rebuilding target in the 2019 fishing year. PBFWG evaluates rebuilding to the second target from the assessment model's terminal year (2020) using simulation-based projections. The projected SSB estimates are the medians of the 6,000 individual SSB calculated for each 300 bootstrap replicates, followed by 20 stochastic simulations based on the different future recruitment time series. The probability of rebuilding to the second rebuilding target within 10 years after achieving the initial rebuilding target (2029 FY) was calculated based on 6,000 replicates.

Tables 6-1 and 6-2 summarize the results for the future projections for each harvesting scenario and provide the probability of recovery and future expected yields, respectively. All the examined scenarios show that the probability of achieving the second rebuilding target (Table 6-1, Figure 6-1) is above the level prescribed in the WCPFC Harvest Strategy (60% in 10 years after achieving the initial rebuilding target).

Scenario 1 approximates the current management measure indicating that the stock would achieve the second rebuilding targe with a 60% probability by the 2023 FY. This scenario shows a gradual increase of SSB to the level that the 2034 SSB is higher than 40%$SSB_0$ (Figure 6-1). The projection result in scenario 4 indicates that an additional 20% increase in the catch limit would lower the probability of reaching the second target by 5% in 2029 and rebuild to lower biomass by 40 thousand tons in 2034 (Table 6-1 and Figure 6-3). Also, scenario 5 (the conversion of small fish quota to large fish quota at the current conversion factor of 1.47) projects a higher SSB than scenario 1 in 2034.

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[2] The second rebuilding target defined as "20%$SSB_{F=0}$ under average recruitment" by the WCPFC Harvest Strategy is conceptually different from the R0 based (expected recruitment at unfished biomass), which has been done by the PBFWG, although two estimates were close.

In scenarios 6-9, which the RFMOs specify future impact ratios between WPO and EPO, the recovery probability or impact ratio was approximated during the search for the appropriate increase levels. More specifically, those scenarios were tuned to achieve the 2nd rebuilding target (10 years after achieving the initial rebuilding target) with a 60% probability. As a result, the catch increases are much more aggressive than in other scenarios. Those scenarios confirm that measures restricting the catch of small fish are more effective than those on large fish in rebuilding the stock (Table 6-1).

Under the average recruitment condition with zero removals (scenario 11), SSB would achieve the second rebuilding target by the 2022 FY (2023 calendar year) and a twice SSB in 2034 (Table 6-1 and Figure 6-4). This scenario points to the potential productivity of the population. In summary, the stock is rebuilding faster to the second rebuilding target, and future biomass will be higher with stricter catch management measures.

Figure 6-2 displays the expected fishery impact on the projected SSB under the continuation of current management measures (i.e., scenario 1). The impact on all fishery groups would decrease as the stock recovers. The percentage of total fishery impact by each fishery group was generally constant through the projected period, although there were some small changes. Different management measures could have different effects on future impact, particularly when the catch distribution between small and large PBF is changed. See appendix 1 for the fishery impact plots from different harvesting scenarios beyond scenario 1.

The projection results assume that the CMMs are fully implemented and are based on certain biological and other assumptions. For example, these future projection results do not contain assumptions about discard mortality. Although the impact of discards on SSB is small compared to other fisheries, discards should be considered in future harvest scenarios.

## 6.1. Robustness test and sensitivity runs

The projection results based on the model incorporating the recruitment monitoring index (section 5.5.1) were similar to those found on the base-case model under the current management measures (i.e., scenario 1). The inclusion/exclusion of the new recruitment index does not influence the management advice (Table 6-3).

Sensitivity analyses of the projections to model assumptions (natural mortality, steepness, and growth) were also conducted using short time-series data. The projection results based on the low steepness model (section 5.5.2) confirmed that the second rebuilding target (20% $SSB_{F=0}$) would be achieved within the time limit scheduled by the rebuilding plan (10 years after achieving the initial rebuilding target). The projection using the low steepness model also applied the future recruitments as the resampled value from the assessment recruitment time-series (1983-2020), when SSB fluctuated between 1% to 10% of $SSB_0$. This model has a more pessimistic assumption about the future recruitment than an assumption of the future recruitment using the assumed stock-recruitment relationship. Although the pessimistic assumption about the future recruitment was applied, the results suggested the robustness of the stock recovery to the second rebuilding target.

The projection based on the sensitivity model with higher length at age 3 assumption as well as the sensitivity model with an assumption of 20% lower M for age 2 and older fish also showed that the stock achieved the second rebuilding target within the defined period.

Overall, the projections based on sensitivity runs mentioned above examined the effect of different assumptions of the system dynamics model and observation model concluded that those alternative assumptions do not influence the management advice based on the 2022 stock assessment.

## 7. RESOLVED ISSUES AND MAJOR UNRESOLVED OR FUTURE ISSUES

This section highlights the major issues that the PBFWG identified in the previous assessment which are grouped into 1) resolved issues and 2) unable to adequately resolve or anticipate in this assessment. These unresolved issues need to be addressed in future assessments. This list is not meant to be an all-inclusive list.

### 7.1. Resolved issues

#### *7.1.1. Bootstrapping bias*

Stock assessment replicates were simulated using the parametric bootstrapping in SS and then used in the future projections to account for the uncertainty in the assessment terminal year and recruitment estimates. The distribution of the bootstrapped SSBs showed a positive bias compared to the point estimates from the 2020 base-case model since the 1980s. The source of the bias was identified, and this bias was resolved (Lee et al. 2021). The bootstrapped median bias using the new procedure is less than 5%.

#### *7.1.2. The proliferation of fleets, parameters, and model convergence*

The number of countries and fisheries fishing for PBF combined with the spatial disaggregation of the population age groups has resulted in a proliferation of fleets modeled since the 2016 assessment. Matching the length composition data in the assessment model requires estimating both length-based and age-based selection. This has greatly increased the number of parameters estimated. A short time-series model starting in 1983 (Section 4.5.7) limited issues associated with composition misfit in the early years and reduced the number of parameters estimated. This short time-series model also resolved the convergence issue with lower steepness values (Fukuda. 2021). Although this updated assessment did not use the short time-series model as the base-case model, the working group will consider this model as the base-case in future assessments.

#### *7.1.3. Size composition data for key longline indices*

The current assessment relies on two longline fleets' abundance indices to represent annual changes in the abundance of large mature PBF. To limit the impacts of migratory patterns, which potentially change the availability of different size/age groups taken, data analysis has proceeded on seasonal and area subsets of those fleets (see section 3.6.2.). Recent composition data suggested that even with these data analysis considerations, the Japanese longline fleet 1 used to create CPUE data is seeing an influx of new migrants in the observed size compositions and CPUE standardization. The influx of new migrants is smaller in size and may represent newly recruited spawners to this fleet as the population rebuilds, change in how fishermen fished making smaller fish more likely to be caught caused by management, or seasonal migrants that the data preparation as mentioned earlier was attempted to remove. The recent composition data were sub-setting, and smaller sizes of fish were removed from fleet 1 so that the observed CPUE is a reliable indicator of changes in abundance with a consistent selectivity pattern.

## 7.2. Unresolved or future issues

### *7.2.1. Fisheries with a strong modal distribution of length*

Several fisheries with observed length compositions indicated a steep increase in selection on the first few sizes taken. Given the parametric selectivity currently used, parameters associated with describing the ascending limb of selectivity have little information on their values because selectivity is changing rapidly within a single size bin. The working group should explore an alternative model structure or data preparation (e.g., a smaller size bin) to resolve this issue. This issue is somewhat related to issue 7.2.1, as these poorly informed parameters can cause convergence issues.

### *7.2.2. CPUE for key longline indices*

The current assessment relies on two longline fleets' abundance indices to represent annual changes in the abundance of large mature PBF. The catchability of the Japanese longline fleet 1 changed in 2020 due to an Individual Quota (IQ) management starting in 2020. The standardized Japanese longline CPUE index was conducted using data until 2019. In future assessments, the WG may need a new index or rely on CPUE from the Taiwanese longline fleet 12. More work needs to ensure that any new regulations for fleet 12 do not cause the catchability change in fleet 12.

### *7.2.3. Unseen mortality or discards*

Management measures enacted over the last 7 years have resulted in the increasing abundance of juvenile age classes. More restrictive management coupled with the potential for rapid increases in local abundance may result in increased bycatches and following releasing of unwanted sized PBF. The working group attempted to deal with this potential problem with the addition of unseen mortalities, but its magnitude is poorly understood. Depending on the relative magnitude of this unseen fishery mortality, this issue, unless adequately understood, may potentially weaken the strong relationship between observed catches, production function, and the model's ability to predict changes in the abundance of fishes taken in the longline fleets. This 'fishing effect' is the backbone of the current assessment and has allowed for strong model stability and improved its predictions. Measures to either account for this unseen mortality or eliminate it should be explored.

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## 9. TABLE AND FIGURE

**Table 1-1.** Definition of calendar year, fishing year, and year class used in the Pacific bluefin tuna (*Thunnus orientalis*) stock assessment.

| Fishing year | 2018 | | | | | | | | | | | | 2019 | | | | | | | | | | | | 2020 | | | | | | | | | | | | 2021 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Season | Season 1 | | | Season 2 | | | Season 3 | | | Season 4 | | | Season 1 | | | Season 2 | | | Season 3 | | | Season 4 | | | Season 1 | | | Season 2 | | | Season 3 | | | Season 4 | | | Season 1 | | | Season 2 | | |
| Fishing month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 |
| SSB | | | | | | | | | | SSB in 2018 | | | | | | | | | | | | SSB in 2019 | | | | | | | | | | | | SSB in 2020 | | | | | | | | |
| Day of birth in SS | Birthday of 2018 yr class | | | | | | | | | | | | Birthday of 2019 yr class | | | | | | | | | | | | Birthday of 2020 yr class | | | | | | | | | | | | Birthday of 2021 yr class | | | | | |
| Recruitment | Recruitment in 2018 | | | | | | | | | | | | Recruitment in 2019 | | | | | | | | | | | | Recruitment in 2020 | | | | | | | | | | | | Recruitment in 2021 | | | | | |
| Year class | 2018 yr class | | | | | | | | | | | | 2019 yr class | | | | | | | | | | | | 2020 yr class | | | | | | | | | | | | 2021 yr class | | | | | |
| Calender year | 2018 | | | | | | 2019 | | | | | | | | | | | | 2020 | | | | | | | | | | | | 2021 | | | | | | | | | | | |
| Month | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |

**Table 2-1.** Age-length-weight relation at the beginning of fishing year derived from the von Bertalanffy growth curve and length-weight relationship used in the Pacific bluefin tuna (*Thunnus orientalis*) stock assessment.

| Age | Length (cm) | Lt + SD | L t- SD | Weight (kg) |
|---|---|---|---|---|
| 0 | 19.1 | 24.1 | 14.0 | 0.2 |
| 1 | 58.6 | 68.9 | 48.3 | 4.4 |
| 2 | 91.4 | 100.9 | 81.9 | 16.1 |
| 3 | 118.6 | 123.9 | 113.3 | 34.5 |
| 4 | 141.1 | 147.4 | 134.8 | 58.4 |
| 5 | 159.7 | 166.9 | 152.6 | 85.2 |
| 6 | 175.2 | 183.0 | 167.4 | 112.8 |
| 7 | 188.0 | 196.4 | 179.6 | 139.8 |
| 8 | 198.6 | 207.4 | 189.8 | 165.1 |
| 9 | 207.4 | 216.6 | 198.2 | 188.4 |
| 10 | 214.7 | 224.2 | 205.1 | 209.2 |
| 11 | 220.7 | 230.5 | 210.9 | 227.6 |
| 12 | 225.7 | 235.8 | 215.7 | 243.6 |
| 13 | 229.9 | 240.1 | 219.7 | 257.5 |
| 14 | 233.3 | 243.7 | 222.9 | 269.3 |
| 15 | 236.2 | 246.6 | 225.7 | 279.5 |
| 16 | 238.5 | 249.1 | 227.9 | 288.0 |
| 17 | 240.5 | 251.1 | 229.8 | 295.3 |
| 18 | 242.1 | 252.8 | 231.3 | 301.4 |
| 19 | 243.4 | 254.2 | 232.6 | 306.5 |
| 20 | 245.7 | 256.6 | 234.8 | 315.1 |

**Table 3-1.** Definition of fleets in the stock assessment of Pacific bluefin tuna (*Thunnus orientalis*).

| Fleet # | Fleet name | Unit of Catch | Gears included | | | | Abundance index |
|---|---|---|---|---|---|---|---|
| | | | **Representative component** | **Component 2** | **Component 3** | **Component 4** | |
| Fleet 1 | JPLL | Weight | JP Longline (1952-1992) | JP Longline (1993-2016, Season 4) | | | S1, S2, S3 |
| Fleet 2 | JP SPPS (Seas1, 3, 4) | Weight | JP SPPS (Season 1, 3, 4) | | | | |
| Fleet 3 | KROLPS | Weight | KR OLPS | KR Trawl*1 | KR Setnet*1 | KR Troll*1 | S9 |
| Fleet 4 | JPTPSJS | Weight | JP TPSJS | TW PS*2 | | | |
| Fleet 5 | JPTPSPO | Weight | JP TPSPO | | | | |
| Fleet 6 | JPTroll (Seas2-4) | Weight | JP Troll (Season 2-4) | | | | S4, S12 |
| Fleet 7 | JPPL | Weight | JP Pole-and-Line | JP Driftnet*3 | TW Driftnet*3 | TW Others*4 | |
| Fleet 8 | JPSetNet (Seas1-3) | Weight | JP Setnet (Season 1-3) | JP Miscellaneous (Season 1-3) | | | |
| Fleet 9 | JPSetNet (Seas4) | Weight | JP Setnet (Season 4) | JP Miscellaneous (Season 4) | | | |
| Fleet 10 | JPSetNet_HK_AM | Weight | JP Setnet in Hokkaido and Aomori | | | | |
| Fleet 11 | JPOthers | Weight | JP Handline & Tsugaru Longline | JP Trawl | JP OtherLL | | |
| Fleet 12 | TWLL (South) | Weight | TW Longline (South area) | Out of ISC members (NZ, AU, etc.)*5 | | | S5, S6 |
| Fleet 13 | USCOMM (-2001) | Weight | US Commercial Fisheries (PS, Others) | Mex Commercial Fisheries (PS, Others) | | | |
| Fleet 14 | MEXCOMM (2002-) | Weight | Mex Commercial Fisheries (PS, Others) | US Commercial Fisheries (PS, Others) | | | |
| Fleet 15 | EPOSP | Number | US Recreational Fisheries (2014-) | | | | |
| Fleet 16 | JPTroll4Pen | Number | JP Troll for Farming | | | | |
| Fleet 17 | TWLL (North) | Weight | TW Longline (North area) | | | | S7, S8 |
| Fleet 18 | JP SPPS (Seas2) | Weight | JP SPPS (Season 2) | | | | |
| Fleet 19 | JPTroll (Seas1) | Weight | JP Troll (Season 1) | | | | S11 |
| Fleet 20 | JP SPPS Pen | Number | JP SPPS for Farming | | | | |
| Fleet 21 | Unaccounted mortality | Weight | Discard amount for WPO | | | | |
| Fleet 22 | Unaccounted mortality | Number | Discard amount for WPO | | | | |
| Fleet 23 | JPLL (Seas1-3) | Weight | JP Longline(1993-2016, Season 1-3 ) | JP Longline(2017-2020 ) | | | |
| Fleet 24 | EPOSP_early | Number | US Recreational Fisheries (-2013) | | | | |
| Fleet 25 | Unaccounted mortality | Number | Discard amount for EPO | | | | |

*1 Catch for KRean Trawl, KRean Setnet and KRean Troll are **included** in the input data until the 2022 stock assessment.

*2 Annual catches for Taiwanese PS are put into the Season 1 in the input data.

*3 Annual catches for Japanese and Taiwanese Driftnets are put into the Season 1 in the input data.

*4 Annual catches for Japanese and Taiwanese Others are put into the Season 4 in the input data.

*5 Annual catches of out of ISC PBFWG members are put into Season 1 in the input data.

Note: Seasons follow the fishing year.

**Table 3-2.** Pacific bluefin tuna (*Thunnus orientalis*) catches (in metric tons) by fisheries, for calendar year 1952-2020.

| Calendar Year | Japan (JP)[1] | | | | | | Sub Total |
|---|---|---|---|---|---|---|---|
| | Purse Seine | Longline | Troll[2] | Pole and Line | Set Net | Others | |
| 1952 | 7,680 | 2,694 | 667 | 2,198 | 2,145 | 1,700 | 17,084 |
| 1953 | 5,570 | 3,040 | 1,472 | 3,052 | 2,335 | 160 | 15,629 |
| 1954 | 5,366 | 3,088 | 1,656 | 3,044 | 5,579 | 266 | 18,999 |
| 1955 | 14,016 | 2,951 | 1,507 | 2,841 | 3,256 | 1,151 | 25,722 |
| 1956 | 20,979 | 2,672 | 1,763 | 4,060 | 4,170 | 385 | 34,029 |
| 1957 | 18,147 | 1,685 | 2,392 | 1,795 | 2,822 | 414 | 27,255 |
| 1958 | 8,586 | 818 | 1,497 | 2,337 | 1,187 | 215 | 14,640 |
| 1959 | 9,996 | 3,136 | 736 | 586 | 1,575 | 167 | 16,196 |
| 1960 | 10,541 | 5,910 | 1,885 | 600 | 2,032 | 369 | 21,337 |
| 1961 | 9,124 | 6,364 | 3,193 | 662 | 2,710 | 599 | 22,652 |
| 1962 | 10,657 | 5,769 | 1,683 | 747 | 2,545 | 293 | 21,694 |
| 1963 | 9,786 | 6,077 | 2,542 | 1,256 | 2,797 | 294 | 22,752 |
| 1964 | 8,973 | 3,140 | 2,784 | 1,037 | 1,475 | 1,884 | 19,293 |
| 1965 | 11,496 | 2,569 | 1,963 | 831 | 2,121 | 1,106 | 20,086 |
| 1966 | 10,082 | 1,370 | 1,614 | 613 | 1,261 | 129 | 15,069 |
| 1967 | 6,462 | 878 | 3,273 | 1,210 | 2,603 | 302 | 14,728 |
| 1968 | 9,268 | 500 | 1,568 | 983 | 3,058 | 217 | 15,594 |
| 1969 | 3,236 | 878 | 2,219 | 721 | 2,187 | 195 | 9,436 |
| 1970 | 2,907 | 607 | 1,198 | 723 | 1,779 | 224 | 7,438 |
| 1971 | 3,721 | 697 | 1,492 | 938 | 1,555 | 317 | 8,720 |
| 1972 | 4,212 | 512 | 842 | 944 | 1,107 | 197 | 7,814 |
| 1973 | 2,266 | 838 | 2,108 | 526 | 2,351 | 636 | 8,725 |
| 1974 | 4,106 | 1,177 | 1,656 | 1,192 | 6,019 | 754 | 14,904 |
| 1975 | 4,491 | 1,061 | 1,031 | 1,401 | 2,433 | 808 | 11,225 |
| 1976 | 2,148 | 320 | 830 | 1,082 | 2,996 | 1,237 | 8,613 |
| 1977 | 5,110 | 338 | 2,166 | 2,256 | 2,257 | 1,052 | 13,179 |
| 1978 | 10,427 | 648 | 4,517 | 1,154 | 2,546 | 2,276 | 21,568 |
| 1979 | 13,881 | 729 | 2,655 | 1,250 | 4,558 | 2,429 | 25,502 |
| 1980 | 11,327 | 811 | 1,531 | 1,392 | 2,521 | 1,953 | 19,535 |
| 1981 | 25,422 | 590 | 1,777 | 754 | 2,129 | 2,653 | 33,325 |
| 1982 | 19,234 | 718 | 864 | 1,777 | 1,667 | 1,709 | 25,969 |
| 1983 | 14,774 | 217 | 2,028 | 356 | 972 | 1,117 | 19,464 |
| 1984 | 4,433 | 142 | 1,874 | 587 | 2,234 | 868 | 10,138 |
| 1985 | 4,154 | 105 | 1,850 | 1,817 | 2,562 | 1,175 | 11,663 |
| 1986 | 7,412 | 102 | 1,467 | 1,086 | 2,914 | 719 | 13,700 |
| 1987 | 8,653 | 211 | 880 | 1,565 | 2,198 | 445 | 13,952 |
| 1988 | 3,605 | 157 | 1,124 | 907 | 843 | 498 | 7,134 |
| 1989 | 6,190 | 209 | 903 | 754 | 748 | 283 | 9,087 |
| 1990 | 2,989 | 267 | 1,250 | 536 | 716 | 455 | 6,213 |
| 1991 | 9,808 | 218 | 2,069 | 286 | 1,485 | 650 | 14,516 |
| 1992 | 7,162 | 513 | 915 | 166 | 1,208 | 1,081 | 11,045 |
| 1993 | 6,600 | 812 | 546 | 129 | 848 | 365 | 9,300 |
| 1994 | 8,131 | 1,206 | 4,111 | 162 | 1,158 | 398 | 15,166 |
| 1995 | 18,909 | 678 | 4,778 | 270 | 1,859 | 586 | 27,080 |
| 1996 | 7,644 | 901 | 3,640 | 94 | 1,149 | 570 | 13,998 |
| 1997 | 13,152 | 1,300 | 2,740 | 34 | 803 | 811 | 18,840 |
| 1998 | 5,391 | 1,255 | 2,876 | 85 | 874 | 700 | 11,181 |
| 1999 | 16,173 | 1,157 | 3,440 | 35 | 1,097 | 709 | 22,611 |
| 2000 | 16,486 | 953 | 5,217 | 102 | 1,125 | 689 | 24,572 |
| 2001 | 7,620 | 791 | 3,466 | 180 | 1,366 | 782 | 14,205 |
| 2002 | 8,903 | 841 | 2,607 | 99 | 1,100 | 631 | 14,181 |
| 2003 | 5,768 | 1,237 | 2,060 | 44 | 839 | 446 | 10,394 |
| 2004 | 8,257 | 1,847 | 2,445 | 132 | 896 | 514 | 14,091 |
| 2005 | 12,817 | 1,925 | 3,633 | 549 | 2,182 | 548 | 21,654 |
| 2006 | 8,880 | 1,121 | 1,860 | 108 | 1,421 | 777 | 14,167 |
| 2007 | 6,840 | 1,762 | 2,823 | 236 | 1,503 | 657 | 13,821 |
| 2008 | 10,221 | 1,390 | 2,377 | 64 | 2,358 | 770 | 17,180 |
| 2009 | 8,077 | 1,080 | 2,003 | 50 | 2,236 | 575 | 14,021 |
| 2010 | 3,742 | 890 | 1,583 | 83 | 1,603 | 495 | 8,396 |
| 2011 | 8,340 | 837 | 1,820 | 63 | 1,651 | 283 | 12,993 |
| 2012 | 2,462 | 673 | 570 | 113 | 1,932 | 343 | 6,093 |
| 2013 | 2,771 | 784 | 904 | 8 | 1,415 | 529 | 6,411 |
| 2014 | 5,456 | 683 | 1,023 | 5 | 1,907 | 499 | 9,573 |
| 2015 | 3,645 | 648 | 413 | 8 | 1,242 | 431 | 6,386 |
| 2016 | 5,095 | 691 | 778 | 54 | 1,228 | 508 | 8,354 |
| 2017 | 4,540 | 913 | 605 | 49 | 2,221 | 665 | 8,993 |
| 2018 | 4,050 | 700 | 371 | 9 | 645 | 431 | 6,206 |
| 2019 | 4,464 | 1,002 | 720 | + | 941 | 372 | 7,499 |
| 2020[3] | 3,960 | 1,416 | 760 | 1 | 1,234 | 502 | 7,873 |

1 Part of Japanese catch is estimated by the WG from best available source for the stock assessment

2 Japanese troll catch since 1998 includes catch for farming.

3 Catch of most recent year is provisional.

# Table 3-2. Cont.

| Calendar Year | Korea (KR)[4] | | | | | Sub Total | Taiwan (TW) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Purse Seine | Longline | Setnet | Troll | Trawl | | Longline | Set-net | Purse Seine | Gill-net (not specified) | Distant Driftnet | Others | Sub Total |
| 1952 | | | | | | | | | | | | | |
| 1953 | | | | | | | | | | | | | |
| 1954 | | | | | | | | | | | | | |
| 1955 | | | | | | | | | | | | | |
| 1956 | | | | | | | | | | | | | |
| 1957 | | | | | | | | | | | | | |
| 1958 | | | | | | | | | | | | | |
| 1959 | | | | | | | | | | | | | |
| 1960 | | | | | | | | | | | | | |
| 1961 | | | | | | | | | | | | | |
| 1962 | | | | | | | | | | | | | |
| 1963 | | | | | | | | | | | | | |
| 1964 | | | | | | | | | | | | | |
| 1965 | | | | | | | 54 | | | | | | 54 |
| 1966 | | | | | | | - | | | | | | 0 |
| 1967 | | | | | | | 53 | | | | | | 53 |
| 1968 | | | | | | | 33 | | | | | | 33 |
| 1969 | | | | | | | 23 | | | | | | 23 |
| 1970 | | | | | | | - | | | | | | 0 |
| 1971 | | 0 | | | | | 1 | | | | | | 1 |
| 1972 | | 0 | | | | | 14 | | | | | | 14 |
| 1973 | | 0 | | | | | 33 | | | | | | 33 |
| 1974 | | 0 | | | | | 47 | | | | | 15 | 62 |
| 1975 | | 3 | | | | | 61 | | | | | 5 | 66 |
| 1976 | | 5 | | | | | 17 | | | | | 2 | 19 |
| 1977 | | 0 | | | | | 131 | | | | | 2 | 133 |
| 1978 | | 3 | | | | | 66 | | | | | 2 | 68 |
| 1979 | | 0 | | | | | 58 | | | | | - | 58 |
| 1980 | | 0 | | | | | 114 | | | | | 5 | 119 |
| 1981 | | 0 | | | | | 179 | | | | | - | 179 |
| 1982 | 31 | 0 | | | | 31 | 207 | | | | 2 | - | 209 |
| 1983 | 13 | 0 | | | | 13 | 175 | | 9 | | 2 | - | 186 |
| 1984 | 4 | 1 | | | | 5 | 477 | | 5 | | - | 8 | 490 |
| 1985 | 1 | 0 | | | | 1 | 210 | | 80 | | 11 | - | 301 |
| 1986 | 344 | 0 | | | | 344 | 70 | | 16 | | 13 | - | 99 |
| 1987 | 89 | 13 | | | | 102 | 365 | | 21 | | 14 | - | 400 |
| 1988 | 32 | 0 | | | | 32 | 108 | | 197 | | 37 | 25 | 367 |
| 1989 | 71 | 0 | | | | 71 | 205 | | 259 | | 51 | 3 | 518 |
| 1990 | 132 | 0 | | | | 132 | 189 | | 149 | | 299 | 16 | 653 |
| 1991 | 265 | 0 | | | | 265 | 342 | | - | | 107 | 12 | 461 |
| 1992 | 288 | 0 | | | | 288 | 464 | | 73 | | 3 | 5 | 545 |
| 1993 | 40 | 0 | | | | 40 | 471 | | 1 | | | 3 | 475 |
| 1994 | 50 | 0 | | | | 50 | 559 | | | | | - | 559 |
| 1995 | 821 | 0 | | | | 821 | 335 | | | | | 2 | 337 |
| 1996 | 102 | 0 | | | | 102 | 956 | - | - | - | | - | 956 |
| 1997 | 1,054 | 0 | | | | 1,054 | 1,814 | - | - | - | | - | 1,814 |
| 1998 | 188 | 0 | | | | 188 | 1,910 | - | - | - | | - | 1,910 |
| 1999 | 256 | 0 | | | | 256 | 3,089 | - | - | - | | - | 3,089 |
| 2000 | 2,401 | 0 | | | 0 | 2,401 | 2,780 | - | - | 1 | | 1 | 2,782 |
| 2001 | 1,176 | 0 | | | 10 | 1,186 | 1,839 | - | - | 2 | | 2 | 1,843 |
| 2002 | 932 | 0 | | | 1 | 933 | 1,523 | - | - | 3 | | 1 | 1,527 |
| 2003 | 2,601 | 0 | | | 0 | 2,601 | 1,863 | - | - | 10 | | 11 | 1,884 |
| 2004 | 773 | 0 | | | 0 | 773 | 1,714 | - | - | 1 | | 2 | 1,717 |
| 2005 | 1,318 | 0 | | | 9 | 1,327 | 1,368 | 1 | - | - | | 1 | 1,370 |
| 2006 | 1,012 | 0 | | | 3 | 1,015 | 1,149 | 1 | - | - | | - | 1,150 |
| 2007 | 1,281 | 0 | | | 4 | 1,285 | 1,401 | 2 | - | 8 | | - | 1,411 |
| 2008 | 1,866 | 0 | | | 10 | 1,876 | 979 | 1 | - | 1 | | - | 981 |
| 2009 | 936 | 0 | | | 4 | 940 | 877 | 1 | - | 10 | | - | 888 |
| 2010 | 1,196 | 0 | | | 16 | 1,212 | 373 | 29 | - | 7 | | - | 409 |
| 2011 | 670 | 0 | | + | 14 | 684 | 292 | 16 | - | 7 | | 1 | 316 |
| 2012 | 1,421 | 0 | | | 2 | 1,423 | 210 | 2 | - | - | | 2 | 214 |
| 2013 | 604 | - | 1 | + | 0 | 605 | 331 | 2 | - | 1 | | - | 334 |
| 2014 | 1,305 | | 6 | 0 | - | 1,311 | 483 | 38 | - | 4 | | - | 525 |
| 2015 | 676 | | 1 | 0 | | 677 | 552 | 25 | - | 1 | | - | 578 |
| 2016 | 1,024 | | 3 | 0 | 2 | 1,030 | 454 | - | - | + | | - | 454 |
| 2017 | 734 | | 3 | | 6 | 743 | 415 | - | - | - | | + | 415 |
| 2018 | 523 | | 7 | | 5 | 535 | 381 | + | - | 3 | | + | 384 |
| 2019 | 542 | | 36 | | 3 | 581 | 486 | 2 | - | 2 | | 2 | 492 |
| 2020 | 567 | | 35 | | 3 | 605 | 1,148 | 1 | - | + | | 3 | 1,152 |

[4] Catch statistics of Korea derived from Japanese Import statistics for 1982-1999.

## Table 3-2. Cont.

| Calendar Year | United States (US)[5] | | | | | | | | | Mexico (MX) | | | Sub total | Out of ISC members | | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Drift gill-net | Longline | Pole and line | Troll | Hook and Line | Others | Purse seine | Sport | Sub Total | Others | Purse seine | Sub Total | | New Zealand (NZ)[6] | Australia (AU)[7] | |
| 1952 | | | | | | | 2,076 | 2 | 2,078 | - | - | | 2,078 | | | 19,162 |
| 1953 | | | | | | | 4,433 | 48 | 4,481 | - | - | | 4,481 | | | 20,110 |
| 1954 | | | | | | | 9,537 | 11 | 9,548 | - | - | | 9,548 | | | 28,547 |
| 1955 | | | | | | | 6,173 | 93 | 6,266 | - | - | | 6,266 | | | 31,988 |
| 1956 | | | | | | | 5,727 | 388 | 6,115 | - | - | | 6,115 | | | 40,144 |
| 1957 | | | | | | | 9,215 | 73 | 9,288 | - | - | | 9,288 | | | 36,543 |
| 1958 | | | | | | | 13,934 | 10 | 13,944 | - | - | | 13,944 | | | 28,584 |
| 1959 | | | 56 | | | | 3,506 | 13 | 3,575 | 32 | 171 | 203 | 3,778 | | | 19,974 |
| 1960 | | | + | | | | 4,547 | 1 | 4,548 | - | - | | 4,548 | | | 25,885 |
| 1961 | | | 16 | | | | 7,989 | 23 | 8,028 | - | 130 | 130 | 8,158 | | | 30,810 |
| 1962 | | | + | | | | 10,769 | 25 | 10,794 | - | 294 | 294 | 11,088 | | | 32,782 |
| 1963 | | | 28 | | | | 11,832 | 7 | 11,867 | - | 412 | 412 | 12,279 | | | 35,031 |
| 1964 | | | 39 | | | | 9,047 | 7 | 9,093 | - | 131 | 131 | 9,224 | | | 28,517 |
| 1965 | | | 11 | + | | 66 | 6,523 | 1 | 6,601 | - | 289 | 289 | 6,890 | | | 27,030 |
| 1966 | | | 12 | | | | 15,450 | 20 | 15,482 | - | 435 | 435 | 15,917 | | | 30,986 |
| 1967 | | | + | | | | 5,517 | 32 | 5,549 | - | 371 | 371 | 5,920 | | | 20,701 |
| 1968 | | | 8 | | | | 5,773 | 12 | 5,793 | - | 195 | 195 | 5,988 | | | 21,615 |
| 1969 | | | 9 | | | | 6,657 | 15 | 6,681 | - | 260 | 260 | 6,941 | | | 16,400 |
| 1970 | | | + | | | | 3,873 | 19 | 3,892 | - | 92 | 92 | 3,984 | | | 11,422 |
| 1971 | | | + | | | | 7,804 | 8 | 7,812 | - | 555 | 555 | 8,367 | | | 17,088 |
| 1972 | | | 3 | | | 42 | 11,656 | 15 | 11,716 | - | 1,646 | 1,646 | 13,362 | | | 21,190 |
| 1973 | | | 5 | + | | 20 | 9,639 | 54 | 9,718 | - | 1,084 | 1,084 | 10,802 | | | 19,560 |
| 1974 | | | + | + | | 30 | 5,243 | 58 | 5,331 | - | 344 | 344 | 5,675 | | | 20,641 |
| 1975 | | | 83 | | | 1 | 7,353 | 34 | 7,471 | - | 2,145 | 2,145 | 9,616 | | | 20,907 |
| 1976 | | | 22 | + | | 3 | 8,652 | 21 | 8,698 | - | 1,968 | 1,968 | 10,666 | | | 19,298 |
| 1977 | | | 10 | | | 3 | 3,259 | 19 | 3,291 | - | 2,186 | 2,186 | 5,477 | | | 18,789 |
| 1978 | | | 4 | | | 2 | 4,663 | 5 | 4,674 | - | 545 | 545 | 5,219 | | | 26,855 |
| 1979 | | | 5 | | | 1 | 5,889 | 11 | 5,906 | - | 213 | 213 | 6,119 | | | 31,679 |
| 1980 | | | + | | | 24 | 2,327 | 7 | 2,358 | - | 582 | 582 | 2,940 | | | 22,594 |
| 1981 | 4 | | + | 10 | | + | 867 | 9 | 890 | - | 218 | 218 | 1,108 | | | 34,612 |
| 1982 | 9 | | 1 | | | + | 2,639 | 11 | 2,660 | - | 506 | 506 | 3,166 | | | 29,375 |
| 1983 | 31 | | 59 | | | 2 | 629 | 33 | 754 | - | 214 | 214 | 968 | | | 20,631 |
| 1984 | 6 | 1 | 5 | | | 18 | 673 | 49 | 752 | - | 166 | 166 | 918 | | | 11,551 |
| 1985 | 8 | | | | | 20 | 3,320 | 89 | 3,437 | - | 676 | 676 | 4,113 | | | 16,078 |
| 1986 | 16 | | | | | 41 | 4,851 | 12 | 4,920 | - | 189 | 189 | 5,109 | | | 19,252 |
| 1987 | 2 | | | | | 18 | 861 | 34 | 915 | - | 119 | 119 | 1,034 | | | 15,488 |
| 1988 | 4 | | | | | 46 | 923 | 6 | 979 | 1 | 447 | 448 | 1,427 | | | 8,960 |
| 1989 | 3 | | | | | 18 | 1,046 | 112 | 1,179 | - | 57 | 57 | 1,236 | | | 10,912 |
| 1990 | 11 | | | | | 81 | 1,380 | 65 | 1,537 | - | 50 | 50 | 1,587 | | | 8,585 |
| 1991 | 4 | 2 | | | | + | 410 | 92 | 508 | - | 9 | 9 | 517 | 2 | | 15,761 |
| 1992 | 9 | 38 | | | | 14 | 1,928 | 110 | 2,099 | - | 0 | 0 | 2,099 | 0 | | 13,977 |
| 1993 | 32 | 42 | | | | 29 | 580 | 283 | 966 | - | 0 | | 966 | 6 | 0 | 10,787 |
| 1994 | 28 | 30 | | | | 1 | 906 | 86 | 1,051 | 2 | 63 | 65 | 1,116 | 2 | 1 | 16,894 |
| 1995 | 20 | 29 | | | | + | 657 | 245 | 951 | - | 11 | 11 | 962 | 2 | 1 | 29,202 |
| 1996 | 43 | 25 | | 2 | | + | 4,639 | 40 | 4,749 | - | 3,700 | 3,700 | 8,449 | 4 | | 23,509 |
| 1997 | 58 | 26 | | 1 | | 48 | 2,240 | 131 | 2,504 | - | 367 | 367 | 2,871 | 14 | 1 | 24,594 |
| 1998 | 40 | 54 | | 128 | | 59 | 1,771 | 422 | 2,474 | - | 1 | 1 | 2,475 | 20 | 3 | 15,777 |
| 1999 | 22 | 54 | | 20 | | 88 | 184 | 408 | 776 | 35 | 2,369 | 2,404 | 3,180 | 21 | 5 | 29,162 |
| 2000 | 30 | 19 | | 1 | | 11 | 693 | 319 | 1,073 | 99 | 3,019 | 3,118 | 4,191 | 21 | 8 | 33,975 |
| 2001 | 35 | 6 | | 6 | | 1 | 292 | 344 | 684 | - | 863 | 863 | 1,547 | 50 | 7 | 18,838 |
| 2002 | 7 | 2 | | 1 | | 2 | 50 | 613 | 675 | 2 | 1,708 | 1,710 | 2,385 | 55 | 6 | 19,087 |
| 2003 | 14 | 1 | | | | 3 | 22 | 355 | 395 | 43 | 3,211 | 3,254 | 3,649 | 41 | 12 | 18,581 |
| 2004 | 10 | 1 | | | | + | | 50 | 61 | 14 | 8,880 | 8,894 | 8,955 | 67 | 10 | 25,614 |
| 2005 | 5 | 1 | | | | 1 | 201 | 73 | 281 | - | 4,542 | 4,542 | 4,823 | 20 | 13 | 29,207 |
| 2006 | 1 | 1 | | | | + | | 94 | 96 | - | 9,806 | 9,806 | 9,902 | 21 | 5 | 26,260 |
| 2007 | 2 | + | | | | + | 42 | 12 | 56 | - | 4,147 | 4,147 | 4,203 | 13 | 4 | 20,737 |
| 2008 | 1 | + | | | | + | | 63 | 64 | 15 | 4,407 | 4,422 | 4,486 | 14 | 3 | 24,540 |
| 2009 | 3 | 1 | | 0 | | 2 | 410 | 156 | 572 | - | 3,019 | 3,019 | 3,591 | 16 | 3 | 19,459 |
| 2010 | 1 | 0 | | | | 0 | | 88 | 89 | - | 7,746 | 7,746 | 7,835 | 10 | 0 | 17,862 |
| 2011 | 18 | 0 | | 0 | | 100 | | 225 | 343 | 1 | 2,731 | 2,732 | 3,075 | 28 | 1 | 17,097 |
| 2012 | 4 | 0 | | 0 | | 38 | | 400 | 442 | 1 | 6,668 | 6,669 | 7,111 | 13 | 1 | 14,855 |
| 2013 | 7 | 1 | | 0 | | 3 | | 809 | 820 | | 3,154 | 3,154 | 3,974 | 24 | 0 | 11,348 |
| 2014 | 5 | 0 | | + | 2 | - | 401 | 420 | 828 | | 4,862 | 4,862 | 5,690 | 12 | 0 | 17,111 |
| 2015 | 4 | 0 | | | 7 | - | 86 | 400 | 499 | | 3,082 | 3,082 | 3,581 | 16 | 0 | 11,237 |
| 2016 | 9 | 1 | | 0 | 31 | - | 316 | 372 | 728 | | 2,709 | 2,709 | 3,437 | 18 | 0 | 13,293 |
| 2017 | 1 | 1 | | 0 | 18 | - | 466 | 451 | 938 | | 3,643 | 3,643 | 4,581 | 14 | 0 | 14,746 |
| 2018 | 18 | 1 | | - | 31 | 4 | 12 | 513 | 579 | | 2,482 | 2,482 | 3,061 | 20 | 0 | 10,206 |
| 2019 | 10 | 2 | | 1 | 36 | 1 | 226 | 462 | 737 | | 2,249 | 2,249 | 2,986 | | | 11,557 |
| 2020 | 28 | 2 | | - | 87 | 1 | 116 | 651 | 884 | | 3,266 | 3,266 | 4,150 | | | 13,779 |

[5] US in 1952-1958 contains catch from other countries - primarily Mexico. Other includes catches from gillnet, troll, pole-and-line, and longline.

[6] Catches by New Zealand from 1991 to 2006 are derived from the Ministry of Fisheries, Science Group (Compilers) 2006: Report from the Fishery Assessment Plenary, May 2006: stock

[7] Catches by Australia are provided by SPC.

**Table 3-3.** Quarterly catch of Pacific bluefin tuna (*Thunnus orientalis*) by fleet and fishing year for 1952-2020.

| Fishing year | Season | Weight (mt) | | | | | | | | | | | | | | | | | | | Number (1000 fish) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fleet 1 | Fleet 2 | Fleet 3 | Fleet 4 | Fleet 5 | Fleet 6 | Fleet 7 | Fleet 8 | Fleet 9 | Fleet 10 | Fleet 11 | Fleet 12 | Fleet 13 | Fleet 14 | Fleet 17 | Fleet 18 | Fleet 19 | Fleet 21 | Fleet 23 | Fleet 15 | Fleet 16 | Fleet 20 | Fleet 22 | Fleet 24 | Fleet 25 |
| 1952 | 1 | 1073 | 0 | 0 | 0 | 4936 | 0 | 713 | 736 | 0 | 236 | 0 | 0 | 1951 | 0 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1952 | 2 | 132 | 0 | 0 | 0 | 0 | 498 | 505 | 537 | 0 | 170 | 172 | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1952 | 3 | 145 | 0 | 0 | 0 | 0 | 282 | 796 | 503 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1952 | 4 | 1898 | 0 | 0 | 0 | 1990 | 39 | 907 | 0 | 568 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1953 | 1 | 764 | 0 | 0 | 0 | 3580 | 0 | 650 | 371 | 0 | 255 | 0 | 0 | 3843 | 0 | 0 | 0 | 51 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 1953 | 2 | 241 | 0 | 0 | 0 | 0 | 1098 | 706 | 458 | 0 | 186 | 131 | 0 | 590 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1953 | 3 | 263 | 0 | 0 | 0 | 0 | 318 | 609 | 430 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1953 | 4 | 1578 | 0 | 0 | 0 | 1917 | 44 | 815 | 0 | 1427 | 107 | 0 | 0 | 2289 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1954 | 1 | 1096 | 0 | 0 | 0 | 3448 | 0 | 744 | 1109 | 0 | 861 | 0 | 0 | 6845 | 0 | 0 | 0 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1954 | 2 | 178 | 0 | 0 | 0 | 0 | 1236 | 923 | 1032 | 0 | 613 | 219 | 0 | 403 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1954 | 3 | 177 | 0 | 0 | 0 | 0 | 289 | 569 | 612 | 0 | 1 | 0 | 0 | 483 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1954 | 4 | 1310 | 0 | 0 | 0 | 5008 | 40 | 761 | 0 | 1334 | 43 | 0 | 0 | 3131 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1955 | 1 | 1172 | 0 | 0 | 0 | 9008 | 0 | 665 | 788 | 0 | 364 | 0 | 0 | 2467 | 0 | 0 | 0 | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| 1955 | 2 | 311 | 0 | 0 | 0 | 0 | 1125 | 862 | 889 | 0 | 260 | 101 | 0 | 93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1955 | 3 | 124 | 0 | 0 | 0 | 0 | 338 | 813 | 903 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1955 | 4 | 1104 | 0 | 0 | 0 | 7496 | 47 | 1087 | 0 | 1180 | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1956 | 1 | 1521 | 0 | 0 | 0 | 13483 | 0 | 953 | 636 | 0 | 262 | 0 | 0 | 4753 | 0 | 0 | 0 | 62 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 |
| 1956 | 2 | 161 | 0 | 0 | 0 | 0 | 1316 | 1232 | 1134 | 0 | 185 | 192 | 0 | 974 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1956 | 3 | 163 | 0 | 0 | 0 | 0 | 459 | 359 | 506 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1956 | 4 | 905 | 0 | 0 | 0 | 6036 | 64 | 481 | 0 | 935 | 98 | 0 | 0 | 141 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1957 | 1 | 566 | 0 | 0 | 0 | 12111 | 0 | 425 | 558 | 0 | 74 | 0 | 0 | 8779 | 0 | 0 | 0 | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| 1957 | 2 | 98 | 0 | 0 | 0 | 0 | 1785 | 545 | 830 | 0 | 25 | 194 | 0 | 296 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1957 | 3 | 135 | 0 | 0 | 0 | 0 | 287 | 468 | 286 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1957 | 4 | 384 | 0 | 0 | 0 | 3937 | 40 | 626 | 0 | 394 | 14 | 0 | 0 | 2635 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1958 | 1 | 113 | 0 | 0 | 0 | 4650 | 0 | 541 | 189 | 0 | 10 | 0 | 0 | 11188 | 0 | 0 | 0 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1958 | 2 | 211 | 0 | 0 | 0 | 0 | 1117 | 709 | 316 | 0 | 4 | 183 | 0 | 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1958 | 3 | 371 | 0 | 0 | 0 | 0 | 141 | 117 | 365 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1958 | 4 | 1573 | 0 | 0 | 0 | 4431 | 20 | 157 | 0 | 509 | 39 | 0 | 0 | 1278 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1959 | 1 | 841 | 0 | 0 | 0 | 5565 | 0 | 135 | 227 | 0 | 29 | 0 | 0 | 2487 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1959 | 2 | 916 | 0 | 0 | 0 | 0 | 550 | 178 | 408 | 0 | 10 | 153 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1959 | 3 | 642 | 0 | 0 | 0 | 0 | 362 | 120 | 457 | 0 | 0 | 0 | 0 | 103 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1959 | 4 | 4029 | 0 | 0 | 0 | 3475 | 50 | 161 | 0 | 562 | 15 | 0 | 0 | 1492 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1960 | 1 | 706 | 0 | 0 | 0 | 7066 | 0 | 204 | 302 | 0 | 113 | 0 | 0 | 2912 | 0 | 0 | 0 | 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1960 | 2 | 729 | 0 | 0 | 0 | 0 | 1407 | 182 | 504 | 0 | 80 | 302 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1960 | 3 | 781 | 0 | 0 | 0 | 0 | 613 | 133 | 683 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1960 | 4 | 3940 | 0 | 0 | 0 | 3356 | 85 | 177 | 0 | 863 | 16 | 0 | 0 | 1164 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1961 | 1 | 1472 | 0 | 0 | 0 | 5768 | 0 | 170 | 430 | 0 | 12 | 0 | 0 | 6755 | 0 | 0 | 0 | 112 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1961 | 2 | 597 | 0 | 0 | 0 | 0 | 2383 | 201 | 701 | 0 | 4 | 580 | 0 | 217 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1961 | 3 | 800 | 0 | 0 | 0 | 0 | 323 | 149 | 566 | 0 | 1 | 0 | 0 | 108 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1961 | 4 | 4331 | 0 | 0 | 0 | 3981 | 45 | 200 | 0 | 561 | 32 | 0 | 0 | 2376 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1962 | 1 | 593 | 0 | 0 | 0 | 6677 | 0 | 176 | 744 | 0 | 71 | 0 | 0 | 8578 | 0 | 0 | 0 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1962 | 2 | 459 | 0 | 0 | 0 | 0 | 1256 | 227 | 527 | 0 | 43 | 288 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1962 | 3 | 541 | 0 | 0 | 0 | 0 | 488 | 251 | 528 | 0 | 2 | 0 | 0 | 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1962 | 4 | 5130 | 0 | 0 | 0 | 3485 | 68 | 336 | 0 | 702 | 73 | 0 | 0 | 2428 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1963 | 1 | 600 | 0 | 0 | 0 | 6301 | 0 | 305 | 406 | 0 | 240 | 0 | 0 | 9718 | 0 | 0 | 0 | 89 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1963 | 2 | 255 | 0 | 0 | 0 | 0 | 1897 | 381 | 689 | 0 | 158 | 276 | 0 | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1963 | 3 | 313 | 0 | 0 | 0 | 0 | 534 | 208 | 598 | 0 | 1 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1963 | 4 | 2321 | 0 | 0 | 0 | 3175 | 74 | 278 | 0 | 992 | 30 | 0 | 0 | 1768 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1964 | 1 | 360 | 0 | 0 | 0 | 5798 | 0 | 246 | 562 | 0 | 49 | 0 | 0 | 7420 | 0 | 0 | 0 | 97 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1964 | 2 | 260 | 0 | 0 | 0 | 0 | 2078 | 315 | 726 | 0 | 27 | 366 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1964 | 3 | 322 | 0 | 0 | 0 | 0 | 377 | 229 | 518 | 0 | 1 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1964 | 4 | 1945 | 0 | 0 | 0 | 4024 | 52 | 242 | 0 | 857 | 32 | 0 | 54 | 545 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1965 | 1 | 160 | 0 | 0 | 0 | 7471 | 0 | 213 | 711 | 0 | 37 | 0 | 0 | 5400 | 0 | 0 | 0 | 69 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1965 | 2 | 336 | 0 | 0 | 0 | 0 | 1465 | 200 | 690 | 0 | 18 | 313 | 0 | 918 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1965 | 3 | 122 | 0 | 0 | 0 | 0 | 310 | 145 | 299 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1965 | 4 | 862 | 0 | 0 | 0 | 3058 | 43 | 189 | 0 | 382 | 46 | 0 | 0 | 4873 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1966 | 1 | 285 | 0 | 0 | 0 | 7025 | 0 | 188 | 161 | 0 | 57 | 0 | 0 | 11021 | 0 | 0 | 0 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1966 | 2 | 275 | 0 | 0 | 0 | 0 | 1204 | 133 | 291 | 0 | 29 | 81 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1966 | 3 | 218 | 0 | 0 | 0 | 0 | 628 | 285 | 847 | 0 | 2 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1966 | 4 | 387 | 0 | 0 | 0 | 2376 | 87 | 373 | 0 | 570 | 61 | 0 | 53 | 3064 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1967 | 1 | 246 | 0 | 0 | 0 | 4085 | 0 | 330 | 273 | 0 | 84 | 0 | 0 | 2768 | 0 | 0 | 0 | 114 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 1967 | 2 | 73 | 0 | 0 | 0 | 0 | 2443 | 261 | 728 | 0 | 44 | 259 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1967 | 3 | 179 | 0 | 0 | 0 | 0 | 301 | 221 | 631 | 0 | 3 | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1967 | 4 | 140 | 0 | 0 | 0 | 3741 | 42 | 307 | 0 | 819 | 130 | 0 | 33 | 789 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1968 | 1 | 135 | 0 | 0 | 0 | 5527 | 0 | 255 | 456 | 0 | 177 | 0 | 0 | 4812 | 0 | 0 | 0 | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1968 | 2 | 54 | 0 | 0 | 0 | 0 | 1171 | 206 | 755 | 0 | 93 | 206 | 0 | 325 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1968 | 3 | 75 | 0 | 0 | 0 | 0 | 426 | 160 | 375 | 0 | 3 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1968 | 4 | 661 | 0 | 0 | 0 | 1176 | 59 | 197 | 0 | 433 | 141 | 0 | 23 | 1608 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1969 | 1 | 109 | 0 | 0 | 0 | 2061 | 0 | 184 | 294 | 0 | 319 | 0 | 0 | 5258 | 0 | 0 | 0 | 78 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1969 | 2 | 54 | 0 | 0 | 0 | 0 | 1656 | 213 | 426 | 0 | 196 | 160 | 0 | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1969 | 3 | 37 | 0 | 0 | 0 | 0 | 230 | 178 | 232 | 0 | 3 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1969 | 4 | 524 | 0 | 0 | 0 | 1274 | 32 | 204 | 0 | 433 | 140 | 0 | 0 | 1416 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1970 | 1 | 23 | 0 | 0 | 0 | 1633 | 0 | 210 | 282 | 0 | 190 | 0 | 0 | 2534 | 0 | 0 | 0 | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1970 | 2 | 35 | 0 | 0 | 0 | 0 | 894 | 194 | 398 | 0 | 99 | 161 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1970 | 3 | 181 | 0 | 0 | 0 | 0 | 286 | 234 | 163 | 0 | 4 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1970 | 4 | 505 | 0 | 0 | 0 | 2835 | 40 | 269 | 0 | 284 | 171 | 0 | 1 | 4039 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1971 | 1 | 19 | 0 | 0 | 0 | 887 | 0 | 230 | 200 | 0 | 340 | 0 | 0 | 3349 | 0 | 0 | 0 | 52 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1971 | 2 | 43 | 0 | 0 | 0 | 0 | 1114 | 240 | 261 | 0 | 202 | 212 | 0 | 939 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1971 | 3 | 47 | 0 | 0 | 0 | 0 | 162 | 297 | 199 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1971 | 4 | 446 | 0 | 0 | 0 | 2049 | 23 | 78 | 0 | 215 | 111 | 0 | 14 | 2879 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1972 | 1 | 15 | 0 | 0 | 0 | 2163 | 0 | 449 | 127 | 0 | 164 | 0 | 0 | 8861 | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1972 | 2 | 31 | 0 | 0 | 0 | 0 | 629 | 159 | 233 | 0 | 89 | 124 | 0 | 1603 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1972 | 3 | 57 | 0 | 0 | 0 | 0 | 405 | 73 | 485 | 0 | 2 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1972 | 4 | 799 | 0 | 0 | 0 | 464 | 56 | 160 | 0 | 501 | 70 | 0 | 33 | 2043 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1973 | 1 | 21 | 0 | 0 | 0 | 1803 | 0 | 419 | 359 | 0 | 277 | 0 | 0 | 8690 | 0 | 0 | 0 | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| 1973 | 2 | 25 | 0 | 0 | 0 | 0 | 1573 | 183 | 514 | 0 | 186 | 286 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1973 | 3 | 30 | 0 | 0 | 0 | 0 | 318 | 450 | 1313 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1973 | 4 | 1037 | 0 | 0 | 0 | 416 | 44 | 246 | 0 | 1403 | 155 | 0 | 47 | 1227 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1974 | 1 | 105 | 0 | 0 | 0 | 3690 | 0 | 483 | 865 | 0 | 546 | 0 | 0 | 4238 | 0 | 0 | 0 | 58 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| 1974 | 2 | 48 | 0 | 0 | 0 | 0 | 1236 | 363 | 1424 | 0 | 362 | 368 | 0 | 151 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1974 | 3 | 29 | 0 | 0 | 0 | 0 | 198 | 806 | 287 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1974 | 4 | 891 | 0 | 0 | 0 | 3415 | 28 | 132 | 0 | 349 | 73 | 0 | 61 | 3065 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1975 | 1 | 121 | 0 | 0 | 0 | 1077 | 0 | 1096 | 309 | 0 | 605 | 0 | 0 | 5748 | 0 | 0 | 0 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 1975 | 2 | 61 | 0 | 0 | 0 | 0 | 769 | 50 | 378 | 0 | 431 | 132 | 0 | 769 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1975 | 3 | 37 | 0 | 0 | 0 | 0 | 159 | 80 | 231 | 0 | 5 | 0 | 0 | 616 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1975 | 4 | 298 | 0 | 0 | 0 | 1122 | 22 | 271 | 0 | 430 | 240 | 0 | 17 | 2283 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1976 | 1 | 54 | 0 | 0 | 0 | 1026 | 0 | 1300 | 301 | 0 | 818 | 0 | 0 | 7250 | 0 | 0 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1976 | 2 | 15 | 0 | 0 | 0 | 0 | 619 | 518 | 431 | 0 | 540 | 152 | 0 | 497 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1976 | 3 | 69 | 0 | 0 | 0 | 0 | 416 | 169 | 320 | 0 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1976 | 4 | 244 | 0 | 0 | 0 | 4063 | 58 | 1338 | 0 | 411 | 108 | 0 | 131 | 2015 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## **Table 3-3.** Cont.

| Fishing year | Season | Weight (mt) | | | | | | | | | | | | | | | | | | | Number (1000 fish) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fleet 1 | Fleet 2 | Fleet 3 | Fleet 4 | Fleet 5 | Fleet 6 | Fleet 7 | Fleet 8 | Fleet 9 | Fleet 10 | Fleet 11 | Fleet 12 | Fleet 13 | Fleet 14 | Fleet 17 | Fleet 18 | Fleet 19 | Fleet 21 | Fleet 23 | Fleet 15 | Fleet 16 | Fleet 20 | Fleet 22 | Fleet 24 | Fleet 25 |
| 1977 | 1 | 37 | 0 | 0 | 0 | 1047 | 0 | 1258 | 222 | 0 | 485 | 0 | 0 | 3094 | 0 | 0 | 0 | 76 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1977 | 2 | 12 | 0 | 0 | 0 | 0 | 1617 | 377 | 378 | 0 | 331 | 168 | 0 | 348 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1977 | 3 | 58 | 0 | 0 | 0 | 0 | 867 | 51 | 377 | 0 | 2 | 0 | 0 | 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1977 | 4 | 243 | 0 | 0 | 0 | 10346 | 121 | 426 | 0 | 527 | 107 | 0 | 66 | 704 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1978 | 1 | 340 | 0 | 0 | 3 | 78 | 0 | 2329 | 282 | 0 | 441 | 0 | 0 | 4403 | 0 | 0 | 0 | 158 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1978 | 2 | 16 | 0 | 0 | 0 | 0 | 3372 | 380 | 512 | 0 | 298 | 246 | 0 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1978 | 3 | 55 | 0 | 0 | 0 | 0 | 510 | 454 | 733 | 0 | 2 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1978 | 4 | 580 | 0 | 0 | 0 | 11145 | 71 | 211 | 0 | 1011 | 115 | 0 | 58 | 2331 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1979 | 1 | 104 | 0 | 0 | 0 | 2736 | 0 | 1720 | 527 | 0 | 768 | 0 | 0 | 3539 | 0 | 0 | 0 | 93 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1979 | 2 | 24 | 0 | 0 | 0 | 0 | 1982 | 406 | 861 | 0 | 541 | 888 | 0 | 227 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1979 | 3 | 43 | 0 | 0 | 0 | 0 | 294 | 572 | 363 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1979 | 4 | 749 | 0 | 0 | 0 | 6168 | 41 | 195 | 0 | 379 | 140 | 0 | 114 | 1435 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 | 1 | 20 | 0 | 0 | 0 | 5159 | 0 | 1641 | 322 | 0 | 574 | 0 | 0 | 1439 | 0 | 0 | 0 | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1980 | 2 | 41 | 0 | 0 | 0 | 0 | 1143 | 468 | 353 | 0 | 387 | 474 | 0 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 | 3 | 185 | 0 | 0 | 0 | 0 | 283 | 85 | 406 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1980 | 4 | 336 | 0 | 0 | 0 | 6344 | 0 | 115 | 0 | 404 | 54 | 0 | 179 | 356 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1981 | 1 | 56 | 0 | 0 | 1297 | 17781 | 0 | 2382 | 271 | 0 | 352 | 0 | 0 | 742 | 0 | 0 | 0 | 68 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1981 | 2 | 41 | 0 | 0 | 0 | 0 | 1426 | 302 | 393 | 0 | 248 | 523 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1981 | 3 | 63 | 0 | 8 | 0 | 0 | 435 | 336 | 277 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1981 | 4 | 583 | 0 | 12 | 0 | 5410 | 53 | 671 | 0 | 341 | 69 | 0 | 207 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1982 | 1 | 73 | 0 | 6 | 1615 | 12209 | 0 | 1905 | 198 | 0 | 300 | 0 | 0 | 2682 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1982 | 2 | 20 | 0 | 5 | 0 | 0 | 370 | 444 | 277 | 0 | 204 | 132 | 0 | 406 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1982 | 3 | 38 | 0 | 3 | 0 | 0 | 81 | 31 | 189 | 0 | 1 | 0 | 0 | 91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1982 | 4 | 161 | 0 | 5 | 0 | 11951 | 0 | 107 | 0 | 207 | 35 | 0 | 175 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1983 | 1 | 8 | 0 | 3 | 570 | 2262 | 0 | 897 | 143 | 0 | 113 | 0 | 0 | 631 | 0 | 0 | 0 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1983 | 2 | 15 | 0 | 2 | 0 | 0 | 1925 | 131 | 210 | 0 | 74 | 310 | 0 | 125 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1983 | 3 | 41 | 0 | 1 | 0 | 0 | 287 | 33 | 380 | 0 | 3 | 0 | 0 | 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1983 | 4 | 94 | 0 | 2 | 0 | 2448 | 0 | 116 | 0 | 431 | 138 | 0 | 477 | 144 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1984 | 1 | 20 | 0 | 1 | 807 | 1184 | 0 | 588 | 311 | 0 | 343 | 0 | 0 | 563 | 0 | 0 | 0 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 1984 | 2 | 9 | 0 | 1 | 0 | 0 | 1558 | 391 | 413 | 0 | 215 | 336 | 0 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1984 | 3 | 24 | 0 | 0 | 0 | 0 | 538 | 1011 | 265 | 0 | 3 | 0 | 0 | 62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1984 | 4 | 74 | 0 | 0 | 0 | 2897 | 135 | 464 | 0 | 358 | 153 | 0 | 210 | 1572 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1985 | 1 | 8 | 0 | 0 | 448 | 889 | 0 | 961 | 229 | 0 | 714 | 0 | 0 | 1264 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 1985 | 2 | 8 | 0 | 0 | 0 | 0 | 1165 | 120 | 352 | 0 | 488 | 447 | 0 | 1126 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1985 | 3 | 19 | 0 | 84 | 0 | 0 | 224 | 74 | 369 | 0 | 3 | 0 | 0 | 109 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1985 | 4 | 84 | 0 | 130 | 0 | 6340 | 0 | 460 | 0 | 547 | 118 | 0 | 70 | 428 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1986 | 1 | 8 | 0 | 70 | 16 | 1072 | 0 | 668 | 375 | 0 | 564 | 0 | 0 | 3759 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1986 | 2 | 5 | 0 | 60 | 0 | 0 | 1238 | 212 | 553 | 0 | 387 | 403 | 0 | 801 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1986 | 3 | 20 | 0 | 22 | 0 | 0 | 354 | 1089 | 274 | 0 | 2 | 0 | 0 | 93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1986 | 4 | 195 | 0 | 34 | 0 | 4874 | 15 | 132 | 0 | 299 | 89 | 0 | 365 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 1 | 20 | 0 | 18 | 250 | 3550 | 0 | 519 | 193 | 0 | 612 | 0 | 0 | 813 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1987 | 2 | 9 | 0 | 15 | 0 | 0 | 505 | 98 | 297 | 0 | 432 | 187 | 0 | 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1987 | 3 | 19 | 0 | 8 | 0 | 0 | 89 | 146 | 94 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 4 | 123 | 16 | 12 | 0 | 1027 | 0 | 357 | 0 | 113 | 45 | 0 | 108 | 221 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1988 | 1 | 35 | 0 | 7 | 742 | 2010 | 0 | 796 | 87 | 0 | 228 | 0 | 0 | 974 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1988 | 2 | 10 | 0 | 6 | 0 | 0 | 1020 | 42 | 118 | 0 | 157 | 127 | 0 | 227 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1988 | 3 | 27 | 3 | 17 | 0 | 0 | 259 | 68 | 86 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1988 | 4 | 190 | 3 | 27 | 0 | 2134 | 27 | 356 | 0 | 125 | 24 | 0 | 205 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1989 | 1 | 20 | 88 | 15 | 580 | 3623 | 0 | 411 | 81 | 0 | 186 | 0 | 0 | 988 | 0 | 0 | 0 | 88 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 1989 | 2 | 4 | 0 | 12 | 0 | 0 | 529 | 146 | 114 | 0 | 132 | 110 | 0 | 130 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1989 | 3 | 21 | 0 | 32 | 0 | 0 | 166 | 17 | 165 | 0 | 1 | 0 | 0 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1989 | 4 | 280 | 5 | 50 | 0 | 360 | 92 | 213 | 0 | 133 | 26 | 0 | 189 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1990 | 1 | 24 | 32 | 27 | 149 | 2474 | 0 | 830 | 64 | 0 | 90 | 0 | 0 | 1311 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| 1990 | 2 | 10 | 0 | 23 | 0 | 0 | 990 | 47 | 179 | 0 | 60 | 199 | 0 | 194 | 0 | 0 | 118 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1990 | 3 | 16 | 99 | 65 | 0 | 0 | 636 | 30 | 421 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1990 | 4 | 193 | 26 | 100 | 0 | 646 | 161 | 79 | 0 | 288 | 49 | 0 | 342 | 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1991 | 1 | 14 | 182 | 54 | 224 | 3466 | 0 | 429 | 123 | 0 | 146 | 0 | 2 | 334 | 0 | 0 | 0 | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 1991 | 2 | 14 | 0 | 46 | 0 | 0 | 1191 | 103 | 363 | 0 | 95 | 414 | 0 | 5 | 0 | 0 | 5165 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1991 | 3 | 36 | 394 | 71 | 0 | 0 | 274 | 18 | 183 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1991 | 4 | 462 | 2061 | 109 | 0 | 1677 | 0 | 35 | 0 | 332 | 68 | 0 | 464 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 1 | 10 | 255 | 59 | 469 | 2183 | 0 | 944 | 173 | 0 | 116 | 0 | 0 | 1650 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 |
| 1992 | 2 | 20 | 0 | 50 | 0 | 0 | 642 | 65 | 269 | 0 | 66 | 193 | 0 | 328 | 0 | 0 | 198 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 3 | 15 | 582 | 10 | 0 | 0 | 145 | 12 | 102 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 4 | 708 | 751 | 15 | 0 | 1243 | 34 | 38 | 0 | 280 | 27 | 0 | 471 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1993 | 1 | 0 | 99 | 8 | 83 | 3831 | 0 | 204 | 161 | 0 | 32 | 0 | 6 | 525 | 0 | 0 | 0 | 48 | 0 | 62 | 0 | 0 | 0 | 0 | 10 | 0 |
| 1993 | 2 | 0 | 0 | 7 | 0 | 0 | 320 | 36 | 230 | 0 | 16 | 207 | 0 | 113 | 0 | 0 | 12 | 0 | 0 | 37 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1993 | 3 | 0 | 25 | 12 | 0 | 0 | 67 | 0 | 70 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 42 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1993 | 4 | 1085 | 562 | 19 | 0 | 2677 | 15 | 17 | 0 | 481 | 16 | 0 | 559 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 1 | 0 | 14 | 10 | 694 | 3973 | 0 | 206 | 168 | 0 | 36 | 0 | 3 | 967 | 0 | 0 | 0 | 458 | 0 | 77 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1994 | 2 | 0 | 0 | 9 | 0 | 0 | 3570 | 65 | 356 | 0 | 31 | 272 | 0 | 58 | 0 | 0 | 185 | 0 | 0 | 22 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 3 | 0 | 406 | 202 | 0 | 0 | 2475 | 9 | 132 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 4 | 616 | 254 | 309 | 0 | 2040 | 733 | 136 | 0 | 256 | 23 | 0 | 335 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 1 | 0 | 4055 | 168 | 496 | 2798 | 0 | 143 | 243 | 0 | 213 | 0 | 2 | 716 | 0 | 0 | 0 | 440 | 0 | 35 | 0 | 0 | 0 | 0 | 16 | 0 |
| 1995 | 2 | 0 | 0 | 142 | 0 | 0 | 1130 | 94 | 788 | 0 | 205 | 476 | 0 | 0 | 0 | 0 | 8860 | 0 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 3 | 0 | 1355 | 25 | 0 | 0 | 136 | 5 | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 4 | 827 | 140 | 38 | 0 | 3124 | 57 | 1 | 0 | 253 | 16 | 0 | 956 | 757 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 1996 | 1 | 0 | 451 | 21 | 450 | 1967 | 0 | 90 | 129 | 0 | 142 | 0 | 4 | 7652 | 0 | 0 | 0 | 256 | 0 | 25 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1996 | 2 | 0 | 0 | 18 | 0 | 0 | 3191 | 66 | 416 | 0 | 110 | 503 | 0 | 0 | 0 | 0 | 158 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 3 | 0 | 594 | 259 | 0 | 0 | 846 | 1 | 114 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1996 | 4 | 1215 | 1113 | 397 | 0 | 1402 | 550 | 4 | 0 | 199 | 6 | 0 | 1814 | 61 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 1997 | 1 | 0 | 3000 | 215 | 708 | 4027 | 0 | 113 | 165 | 0 | 20 | 0 | 15 | 2638 | 0 | 0 | 0 | 224 | 0 | 27 | 0 | 0 | 0 | 0 | 5 | 0 |
| 1997 | 2 | 0 | 0 | 183 | 0 | 0 | 1120 | 25 | 246 | 0 | 53 | 702 | 0 | 41 | 0 | 0 | 2309 | 0 | 0 | 44 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 3 | 0 | 559 | 46 | 0 | 0 | 605 | 2 | 158 | 0 | 1 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1997 | 4 | 1150 | 518 | 71 | 0 | 13 | 515 | 2 | 0 | 131 | 15 | 0 | 1910 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1998 | 1 | 0 | 549 | 38 | 326 | 2376 | 0 | 108 | 114 | 0 | 29 | 0 | 23 | 2017 | 0 | 0 | 0 | 131 | 0 | 53 | 0 | 23 | 0 | 23 | 21 | 0 |
| 1998 | 2 | 0 | 0 | 33 | 0 | 0 | 1613 | 64 | 359 | 0 | 68 | 609 | 0 | 24 | 0 | 0 | 1049 | 0 | 0 | 46 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1998 | 3 | 0 | 686 | 63 | 0 | 0 | 798 | 10 | 317 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1998 | 4 | 1076 | 986 | 96 | 0 | 5592 | 360 | 2 | 0 | 329 | 32 | 0 | 3089 | 2280 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1999 | 1 | 0 | 2228 | 52 | 579 | 5448 | 0 | 65 | 133 | 0 | 16 | 0 | 26 | 442 | 0 | 0 | 0 | 129 | 0 | 25 | 0 | 107 | 0 | 107 | 35 | 0 |
| 1999 | 2 | 0 | 0 | 44 | 0 | 0 | 2101 | 17 | 391 | 0 | 46 | 482 | 0 | 49 | 0 | 0 | 653 | 0 | 0 | 41 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1999 | 3 | 0 | 651 | 747 | 0 | 0 | 1456 | 1 | 168 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1999 | 4 | 893 | 2380 | 1597 | 0 | 3403 | 770 | 83 | 0 | 164 | 5 | 0 | 2780 | 669 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 |
| 2000 | 1 | 0 | 3214 | 30 | 747 | 4042 | 0 | 66 | 154 | 0 | 87 | 0 | 29 | 3204 | 0 | 0 | 0 | 117 | 0 | 15 | 0 | 191 | 0 | 191 | 13 | 0 |
| 2000 | 2 | 0 | 0 | 27 | 0 | 0 | 2780 | 6 | 475 | 0 | 72 | 638 | 0 | 0 | 0 | 0 | 2048 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 3 | 0 | 898 | 963 | 0 | 0 | 934 | 0 | 358 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2000 | 4 | 749 | 2914 | 179 | 0 | 981 | 464 | 4 | 0 | 189 | 45 | 0 | 1834 | 382 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2001 | 1 | 0 | 409 | 9 | 239 | 1918 | 0 | 167 | 73 | 0 | 174 | 0 | 57 | 821 | 0 | 0 | 0 | 83 | 0 | 13 | 0 | 275 | 0 | 275 | 21 | 0 |
| 2001 | 2 | 0 | 0 | 37 | 0 | 0 | 1847 | 113 | 293 | 0 | 232 | 683 | 0 | 0 | 0 | 0 | 261 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2001 | 3 | 0 | 62 | 160 | 0 | 0 | 988 | 17 | 113 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 76 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2001 | 4 | 671 | 2126 | 175 | 0 | 556 | 697 | 51 | 0 | 117 | 6 | 0 | 1513 | 0 | 275 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

## **Table 3-3.** Cont.

| Fishing year | Season | Weight (mt) | | | | | | | | | | | | | | | | | | | Number (1000 fish) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fleet 1 | Fleet 2 | Fleet 3 | Fleet 4 | Fleet 5 | Fleet 6 | Fleet 7 | Fleet 8 | Fleet 9 | Fleet 10 | Fleet 11 | Fleet 12 | Fleet 13 | Fleet 14 | Fleet 17 | Fleet 18 | Fleet 19 | Fleet 21 | Fleet 23 | Fleet 15 | Fleet 16 | Fleet 20 | Fleet 22 | Fleet 24 | Fleet 25 |
| 2002 | 1 | 0 | 959 | 509 | 599 | 2767 | 0 | 224 | 157 | 0 | 235 | 0 | 61 | 0 | 1497 | 0 | 0 | 37 | 0 | 45 | 0 | 358 | 0 | 358 | 31 | 0 |
| 2002 | 2 | 0 | 0 | 88 | 0 | 0 | 706 | 24 | 231 | 0 | 251 | 409 | 0 | 0 | 0 | 0 | 1835 | 0 | 0 | 56 | 0 | 0 | 0 | 0 | 2 | 0 |
| 2002 | 3 | 0 | 99 | 238 | 0 | 0 | 520 | 11 | 84 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 95 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2002 | 4 | 992 | 1771 | 394 | 0 | 185 | 824 | 34 | 0 | 87 | 54 | 0 | 1832 | 0 | 590 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2003 | 1 | 0 | 783 | 88 | 571 | 200 | 0 | 58 | 96 | 0 | 291 | 0 | 84 | 0 | 2704 | 0 | 0 | 80 | 0 | 78 | 0 | 442 | 0 | 442 | 21 | 0 |
| 2003 | 2 | 0 | 0 | 1881 | 0 | 0 | 416 | 6 | 156 | 0 | 71 | 403 | 0 | 0 | 0 | 0 | 2159 | 0 | 0 | 85 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2003 | 3 | 0 | 38 | 53 | 0 | 0 | 182 | 5 | 109 | 0 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 116 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2003 | 4 | 1380 | 1144 | 556 | 0 | 609 | 54 | 15 | 0 | 266 | 47 | 0 | 1698 | 0 | 3620 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2004 | 1 | 0 | 10 | 59 | 2100 | 2225 | 0 | 114 | 136 | 0 | 81 | 0 | 93 | 0 | 5285 | 0 | 0 | 78 | 0 | 154 | 0 | 526 | 0 | 526 | 3 | 0 |
| 2004 | 2 | 0 | 0 | 105 | 0 | 0 | 1868 | 94 | 186 | 0 | 68 | 421 | 0 | 0 | 0 | 0 | 2131 | 0 | 0 | 205 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 3 | 0 | 586 | 720 | 0 | 0 | 1173 | 164 | 379 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 122 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2004 | 4 | 1602 | 1888 | 264 | 0 | 264 | 906 | 321 | 0 | 572 | 217 | 0 | 1287 | 0 | 1986 | 43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 1 | 0 | 3280 | 222 | 3694 | 77 | 0 | 171 | 414 | 0 | 137 | 0 | 71 | 0 | 2764 | 0 | 0 | 293 | 0 | 106 | 0 | 454 | 0 | 454 | 5 | 0 |
| 2005 | 2 | 0 | 0 | 121 | 0 | 0 | 1034 | 30 | 346 | 0 | 102 | 413 | 0 | 0 | 0 | 0 | 3029 | 0 | 0 | 108 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 3 | 0 | 59 | 220 | 0 | 0 | 513 | 68 | 284 | 0 | 7 | 0 | 0 | 0 | 640 | 0 | 0 | 0 | 0 | 81 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2005 | 4 | 873 | 2412 | 339 | 0 | 940 | 85 | 23 | 0 | 356 | 135 | 0 | 1078 | 0 | 4714 | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| 2006 | 1 | 0 | 252 | 354 | 2012 | 692 | 0 | 315 | 148 | 0 | 328 | 0 | 48 | 0 | 4573 | 0 | 0 | 251 | 0 | 115 | 0 | 633 | 0 | 633 | 2 | 0 |
| 2006 | 2 | 0 | 0 | 102 | 0 | 0 | 695 | 17 | 229 | 0 | 69 | 331 | 0 | 0 | 1 | 0 | 2513 | 0 | 0 | 62 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 3 | 0 | 485 | 376 | 0 | 0 | 228 | 32 | 253 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 61 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2006 | 4 | 1022 | 1059 | 13 | 0 | 479 | 70 | 15 | 0 | 270 | 127 | 0 | 1261 | 0 | 1424 | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 1 | 0 | 363 | 121 | 2123 | 364 | 0 | 238 | 150 | 0 | 381 | 0 | 58 | 0 | 2723 | 4 | 0 | 101 | 0 | 66 | 0 | 876 | 0 | 876 | 1 | 0 |
| 2007 | 2 | 0 | 0 | 776 | 0 | 0 | 1985 | 105 | 314 | 0 | 52 | 1013 | 0 | 0 | 44 | 0 | 1968 | 0 | 0 | 71 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 3 | 0 | 214 | 581 | 0 | 0 | 619 | 12 | 268 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 99 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2007 | 4 | 802 | 1610 | 1003 | 0 | 1 | 220 | 30 | 0 | 844 | 239 | 0 | 784 | 0 | 1794 | 175 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2008 | 1 | 0 | 3007 | 62 | 3028 | 0 | 0 | 287 | 389 | 0 | 186 | 0 | 35 | 0 | 2613 | 2 | 0 | 72 | 0 | 33 | 0 | 607 | 0 | 607 | 10 | 0 |
| 2008 | 2 | 0 | 0 | 230 | 0 | 0 | 1163 | 14 | 455 | 0 | 95 | 797 | 0 | 0 | 1 | 0 | 2361 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2008 | 3 | 0 | 702 | 518 | 0 | 0 | 868 | 1 | 449 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2008 | 4 | 662 | 2177 | 213 | 0 | 1 | 241 | 13 | 0 | 1031 | 276 | 0 | 625 | 0 | 1209 | 186 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2009 | 1 | 0 | 2891 | 97 | 1299 | 828 | 0 | 108 | 180 | 0 | 181 | 0 | 82 | 0 | 2221 | 3 | 0 | 62 | 0 | 26 | 0 | 256 | 0 | 256 | 12 | 0 |
| 2009 | 2 | 0 | 0 | 112 | 0 | 0 | 703 | 43 | 143 | 0 | 106 | 677 | 0 | 0 | 3 | 0 | 181 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2009 | 3 | 0 | 718 | 617 | 0 | 0 | 264 | 0 | 342 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2009 | 4 | 400 | 1390 | 424 | 0 | 35 | 38 | 36 | 0 | 566 | 264 | 0 | 260 | 0 | 2447 | 78 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 2010 | 1 | 0 | 123 | 26 | 1052 | 35 | 0 | 179 | 190 | 0 | 79 | 0 | 45 | 0 | 5300 | 0 | 0 | 20 | 0 | 27 | 0 | 563 | 0 | 563 | 4 | 0 |
| 2010 | 2 | 0 | 0 | 145 | 0 | 0 | 979 | 44 | 237 | 0 | 9 | 693 | 0 | 0 | 1 | 0 | 388 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2010 | 3 | 0 | 67 | 191 | 0 | 0 | 492 | 29 | 374 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2010 | 4 | 372 | 3058 | 429 | 0 | 0 | 298 | 34 | 0 | 380 | 384 | 0 | 197 | 0 | 451 | 76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| 2011 | 1 | 0 | 611 | 21 | 1906 | 320 | 0 | 38 | 158 | 0 | 148 | 0 | 48 | 0 | 2379 | 0 | 0 | 39 | 0 | 49 | 0 | 375 | 0 | 375 | 29 | 0 |
| 2011 | 2 | 0 | 0 | 43 | 0 | 0 | 789 | 22 | 217 | 0 | 36 | 567 | 0 | 0 | 19 | 0 | 2377 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2011 | 3 | 0 | 9 | 163 | 0 | 0 | 242 | 70 | 360 | 0 | 5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2011 | 4 | 189 | 530 | 674 | 0 | 3 | 7 | 45 | 0 | 500 | 151 | 0 | 148 | 0 | 1286 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| 2012 | 1 | 0 | 261 | 559 | 841 | 199 | 0 | 103 | 205 | 0 | 514 | 0 | 26 | 0 | 5421 | 0 | 0 | 2 | 0 | 24 | 0 | 180 | 0 | 180 | 35 | 0 |
| 2012 | 2 | 0 | 0 | 28 | 0 | 0 | 233 | 0 | 176 | 0 | 54 | 644 | 0 | 0 | 3 | 0 | 620 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2012 | 3 | 0 | 9 | 76 | 0 | 0 | 256 | 2 | 273 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2012 | 4 | 237 | 743 | 493 | 0 | 12 | 19 | 6 | 0 | 372 | 170 | 0 | 192 | 0 | 1368 | 123 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| 2013 | 1 | 0 | 10 | 1 | 1729 | 268 | 0 | 81 | 132 | 0 | 204 | 0 | 40 | 0 | 1788 | 0 | 0 | 22 | 0 | 28 | 0 | 264 | 0 | 264 | 57 | 0 |
| 2013 | 2 | 0 | 0 | 35 | 0 | 0 | 477 | 3 | 217 | 0 | 82 | 895 | 0 | 0 | 8 | 0 | 2 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 5 | 0 |
| 2013 | 3 | 0 | 79 | 516 | 0 | 0 | 789 | 0 | 306 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2013 | 4 | 311 | 2459 | 783 | 0 | 0 | 60 | 43 | 0 | 818 | 285 | 0 | 257 | 0 | 4036 | 216 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 2014 | 1 | 0 | 654 | 6 | 2203 | 47 | 0 | 125 | 92 | 0 | 231 | 0 | 21 | 0 | 1228 | 1 | 0 | 40 | 0 | 21 | 25 | 61 | 0 | 61 | 0 | 0 |
| 2014 | 2 | 0 | 0 | 6 | 0 | 0 | 97 | 1 | 107 | 0 | 110 | 679 | 0 | 0 | 2 | 0 | 14 | 0 | 0 | 26 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 3 | 0 | 246 | 607 | 0 | 0 | 60 | 7 | 76 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 39 | 1 | 0 | 0 | 0 | 0 | 0 |
| 2014 | 4 | 191 | 86 | 5 | 0 | 939 | 18 | 12 | 0 | 388 | 261 | 0 | 308 | 0 | 3133 | 237 | 0 | 0 | 0 | 0 | 2 | 0 | 121 | 0 | 0 | 0 |
| 2015 | 1 | 0 | 27 | 0 | 1864 | 0 | 0 | 11 | 88 | 0 | 210 | 0 | 26 | 0 | 43 | 0 | 0 | 19 | 0 | 25 | 25 | 243 | 27 | 243 | 0 | 0 |
| 2015 | 2 | 0 | 0 | 65 | 0 | 0 | 233 | 6 | 77 | 0 | 167 | 808 | 0 | 0 | 3 | 0 | 7 | 0 | 0 | 47 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 3 | 0 | 1 | 981 | 0 | 0 | 153 | 5 | 116 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 72 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2015 | 4 | 217 | 97 | 33 | 0 | 1287 | 82 | 5 | 0 | 199 | 283 | 0 | 237 | 0 | 2716 | 215 | 0 | 0 | 0 | 0 | 2 | 0 | 267 | 0 | 0 | 0 |
| 2016 | 1 | 0 | 463 | 6 | 1772 | 0 | 0 | 8 | 135 | 0 | 183 | 0 | 23 | 0 | 329 | 0 | 0 | 224 | 0 | 83 | 8 | 261 | 1 | 261 | 0 | 0 |
| 2016 | 2 | 0 | 0 | 9 | 0 | 0 | 213 | 52 | 254 | 0 | 62 | 769 | 0 | 0 | 16 | 0 | 805 | 0 | 0 | 20 | 2 | 0 | 0 | 0 | 0 | 0 |
| 2016 | 3 | 0 | 83 | 738 | 0 | 0 | 178 | 31 | 479 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2016 | 4 | 358 | 131 | 0 | 0 | 1620 | 6 | 64 | 0 | 368 | 175 | 0 | 232 | 0 | 3650 | 172 | 0 | 0 | 0 | 0 | 2 | 0 | 219 | 0 | 0 | 0 |
| 2017 | 1 | 0 | 111 | 3 | 1691 | 0 | 0 | 32 | 259 | 0 | 518 | 0 | 30 | 0 | 479 | 1 | 0 | 82 | 0 | 37 | 10 | 164 | 0 | 164 | 0 | 0 |
| 2017 | 2 | 0 | 0 | 2 | 0 | 0 | 299 | 1 | 109 | 0 | 316 | 1038 | 0 | 0 | 0 | 0 | 375 | 0 | 219 | 35 | 5 | 0 | 0 | 0 | 0 | 0 |
| 2017 | 3 | 0 | 11 | 530 | 0 | 0 | 81 | 30 | 148 | 0 | 1 | 0 | 0 | 0 | 418 | 0 | 0 | 0 | 27 | 59 | 1 | 0 | 0 | 0 | 0 | 0 |
| 2017 | 4 | 0 | 81 | 0 | 0 | 1571 | 15 | 28 | 0 | 209 | 36 | 0 | 257 | 0 | 2429 | 115 | 0 | 0 | 171 | 354 | 2 | 0 | 245 | 12 | 0 | 0 |
| 2018 | 1 | 0 | 124 | 0 | 1536 | 0 | 0 | 5 | 98 | 0 | 37 | 0 | 38 | 0 | 40 | 0 | 0 | 42 | 0 | 11 | 7 | 218 | 1 | 218 | 0 | 0 |
| 2018 | 2 | 0 | 0 | 5 | 0 | 0 | 196 | 8 | 110 | 0 | 7 | 533 | 0 | 0 | 17 | 0 | 95 | 0 | 183 | 37 | 5 | 0 | 0 | 0 | 0 | 0 |
| 2018 | 3 | 0 | 8 | 542 | 0 | 0 | 375 | 36 | 312 | 0 | 1 | 0 | 0 | 0 | 2007 | 0 | 0 | 0 | 116 | 195 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2018 | 4 | 0 | 152 | 16 | 0 | 1567 | 51 | 12 | 0 | 233 | 52 | 0 | 284 | 0 | 7 | 194 | 0 | 0 | 1 | 429 | 5 | 0 | 232 | 12 | 0 | 0 |
| 2019 | 1 | 0 | 449 | 10 | 1564 | 0 | 0 | 7 | 101 | 0 | 171 | 0 | 35 | 0 | 248 | 0 | 0 | 39 | 0 | 14 | 10 | 155 | 3 | 155 | 0 | 0 |
| 2019 | 2 | 0 | 0 | 12 | 0 | 0 | 198 | 6 | 76 | 0 | 12 | 647 | 2 | 0 | 12 | 0 | 216 | 0 | 224 | 29 | 3 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 3 | 0 | 9 | 447 | 0 | 0 | 293 | 20 | 433 | 0 | 0 | 0 | 0 | 0 | 3271 | 0 | 0 | 0 | 149 | 126 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2019 | 4 | 0 | 66 | 115 | 0 | 1556 | 108 | 26 | 0 | 260 | 191 | 0 | 683 | 0 | 11 | 462 | 0 | 0 | 6 | 740 | 2 | 0 | 183 | 11 | 0 | 0 |
| 2020 | 1 | 0 | 2 | 32 | 1611 | 0 | 0 | 8 | 146 | 0 | 124 | 0 | 49 | 0 | 165 | 2 | 0 | 55 | 2 | 19 | 27 | 126 | 31 | 126 | 0 | 0 |
| 2020 | 2 | 0 | 0 | 12 | 0 | 0 | 246 | 4 | 147 | 0 | 43 | 907 | 0 | 0 | 47 | 0 | 289 | 0 | 209 | 111 | 7 | 0 | 0 | 0 | 0 | 0 |
| 2020 | 3 | 0 | 4 | 99 | 0 | 0 | 305 | 23 | 799 | 0 | 0 | 0 | 1 | 0 | 3028 | 1 | 0 | 0 | 192 | 124 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2020 | 4 | 0 | 20 | 327 | 0 | 373 | 44 | 16 | 0 | 281 | 175 | 0 | 1019 | 0 | 5 | 451 | 0 | 0 | 16 | 585 | 15 | 0 | 240 | 12 | 0 | 0 |

**Table 3-4 (a).** CPUE based Abundance index used in the base-case stock assessment model for Pacific bluefin tuna (*Thunnus orientalis*).

| CPUE # | Abundance index | Available period (fishing year) | Corresponding fisheries | Corresponding fleet for the selectivity setting | Data quality | Document for reference | Update |
|---|---|---|---|---|---|---|---|
| S1 | Japanese coastal longline CPUE for spawning season. | **1993-2019** | JP Longline | Fleet 1 : JPLL | Standardized by VAST | ISC/22/PBFWG-1/01 | X |
| S2 | Japanese offshore and distant water longliners CPUE | **1952-1973** | JP Longline | Fleet 1 : JPLL | Standardized by lognormal model | ISC/12/PBFWG-1/10 | |
| S3 | Japanese offshore and distant water longliners CPUE | **1974-1992** | JP Longline | Fleet 1 : JPLL | | ISC/08/PBFWG-1/05 | |
| S4 | Japanese troll CPUE in Nagasaki prefecture (Sea of Japan and East China sea) | **1980-2016** | JP Troll | Fleet 6 : JP Troll (Seas 2-4) | Standardized by lognormal model | ISC/20/PBFWG-1/04 | |
| S5 | Taiwanese longline CPUE (South area) | **2002-2020** | TW Longline | Fleet 12 : TWLL (South) | Standardized by GLMM | ISC/21/PBFWG-2/02 | X |

**Table 3-4 (b).** CPUE based Abundance index **NOT** used in the base-case stock assessment model for Pacific bluefin tuna (*Thunnus orientalis*).

| CPUE # | Abundance index | Available period (fishing year) | Corresponding fisheries | Corresponding fleet for the selectivity setting | Data quality | Document for reference | Update |
|---|---|---|---|---|---|---|---|
| S6 | Taiwanese longline geo-stat CPUE (South core area) | **2006-2018** | TW Longline | Fleet 12 : TWLL (South) | Standardized by spatio-temporal GLMM | ISC/20/PBFWG-1/03 | |
| S7 | Taiwanese longline geo-stat CPUE (North core area) | **2006-2018** | TW Longline | Fleet 17 : TWLL (North) | Standardized by spatio-temporal GLMM | ISC/20/PBFWG-1/03 | |
| S8 | Taiwanese longline GLMM CPUE (North whole area) | **2003-2018** | TW Longline | Fleet 17 : TWLL (North) | Standardized by GLMM | ISC/20/PBFWG-1/03 | |
| S10 | Korean Offshore Large scale Purse Seine CPUE | **2004-2018** | KR Purse Seine | Fleet 3: KROLPS | Standardized by GLM | ISC/19/PBFWG-2/13 | |
| S11 | Japanese Recruitment monitoring in the Pacific Ocean | **2011-2018** | JP Troll | Fleet 19: JP Troll (Seas 1) | Standardized by GLMM | ISC/19/PBFWG-2/12 | |
| S12 | Japanese Recruitment monitoring in the East China Sea | **2017-2020** | JP Troll | Fleet 6 : JP Troll (Seas 2-4) | Standardized by VAST | ISC/21/PBFWG-2/03 | X |

**Table 3-5 (a).** Available abundance indices (CPUE) of Pacific bluefin tuna (*Thunnus orientalis*). S1, S2, S3, S4, and S5 were fitted to the base-case model (numbers in bold). Numbers in grey indicate that data points were removed. S1-9 ,11,12 were annual indices.

| Fishing year | JP LL | | | JP Troll | TW LL | | | | JP Troll Monitoring | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | S10 | S11 | S12 |
| 1952 | | 1.32 | | | | | | | | | |
| 1953 | | 1.19 | | | | | | | | | |
| 1954 | | 1.06 | | | | | | | | | |
| 1955 | | 0.80 | | | | | | | | | |
| 1956 | | 0.55 | | | | | | | | | |
| 1957 | | 0.63 | | | | | | | | | |
| 1958 | | 1.52 | | | | | | | | | |
| 1959 | | 2.49 | | | | | | | | | |
| 1960 | | 1.87 | | | | | | | | | |
| 1961 | | 1.83 | | | | | | | | | |
| 1962 | | 1.66 | | | | | | | | | |
| 1963 | | 1.17 | | | | | | | | | |
| 1964 | | 1.21 | | | | | | | | | |
| 1965 | | 0.95 | | | | | | | | | |
| 1966 | | 1.21 | | | | | | | | | |
| 1967 | | 0.59 | | | | | | | | | |
| 1968 | | 0.53 | | | | | | | | | |
| 1969 | | 0.62 | | | | | | | | | |
| 1970 | | 0.44 | | | | | | | | | |
| 1971 | | 0.28 | | | | | | | | | |
| 1972 | | 0.26 | | | | | | | | | |
| 1973 | | 0.18 | | | | | | | | | |
| 1974 | | | 0.52 | | | | | | | | |
| 1975 | | | 0.37 | | | | | | | | |
| 1976 | | | 0.88 | | | | | | | | |
| 1977 | | | 0.95 | | | | | | | | |
| 1978 | | | 1.17 | | | | | | | | |
| 1979 | | | 0.76 | | | | | | | | |
| 1980 | | | 0.99 | 0.67 | | | | | | | |
| 1981 | | | 1.15 | 1.19 | | | | | | | |
| 1982 | | | 0.66 | 0.62 | | | | | | | |
| 1983 | | | 0.39 | 0.92 | | | | | | | |
| 1984 | | | 0.43 | 0.94 | | | | | | | |
| 1985 | | | 0.39 | 0.88 | | | | | | | |
| 1986 | | | 0.45 | 0.99 | | | | | | | |
| 1987 | | | 0.45 | 0.72 | | | | | | | |
| 1988 | | | 0.52 | 0.83 | | | | | | | |
| 1989 | | | 0.79 | 0.65 | | | | | | | |
| 1990 | | | 0.79 | 1.29 | | | | | | | |
| 1991 | | | 1.26 | 1.34 | | | | | | | |
| 1992 | | | 1.36 | 0.59 | | | | | | | |
| 1993 | 2.29 | | | 0.49 | | | | | | | |
| 1994 | 1.67 | | | 2.03 | | | | | | | |
| 1995 | 2.03 | | | 1.11 | | | | | | | |
| 1996 | 2.09 | | | 1.62 | | | | | | | |
| 1997 | 1.93 | | | 0.95 | | | | | | | |
| 1998 | 1.49 | | | 0.84 | | | | | | | |
| 1999 | 1.06 | | | 1.53 | | | | | | | |
| 2000 | 0.77 | | | 1.16 | | | | | | | |
| 2001 | 0.92 | | | 1.16 | | | | | | | |
| 2002 | 1.40 | | | 0.76 | 2.11 | | | | | | |
| 2003 | 1.50 | | | 0.65 | 2.06 | | | | | | |
| 2004 | 1.53 | | | 1.30 | 1.36 | | | 0.92 | | | |
| 2005 | 0.88 | | | 1.44 | 1.57 | | | 1.18 | | | |
| 2006 | 0.96 | | | 0.74 | 1.18 | 2.92 | 0.72 | 0.73 | | | |
| 2007 | 0.60 | | | 1.43 | 0.91 | 1.56 | 1.04 | 1.03 | | | |
| 2008 | 0.35 | | | 1.46 | 0.77 | 0.94 | 1.20 | 1.11 | | | |
| 2009 | 0.22 | | | 1.16 | 0.40 | 0.68 | 0.50 | 0.65 | | | |
| 2010 | 0.18 | | | 1.13 | 0.34 | 0.50 | 0.74 | 0.77 | | | |
| 2011 | 0.14 | | | 0.98 | 0.32 | 0.41 | 0.54 | 0.63 | 0.68 | 1.32 | |
| 2012 | 0.30 | | | 0.50 | 0.33 | 0.47 | 0.75 | 0.76 | 0.67 | 0.64 | |
| 2013 | 0.30 | | | 0.90 | 0.46 | 0.66 | 1.23 | 1.25 | 1.17 | 1.06 | |
| 2014 | 0.38 | | | 0.43 | 0.65 | 0.69 | 1.49 | 1.14 | 0.33 | 0.38 | |
| 2015 | 0.40 | | | 0.50 | 0.67 | 0.84 | 1.57 | 1.48 | 0.60 | 0.63 | |
| 2016 | 0.65 | | | 1.10 | 0.71 | 0.86 | 1.26 | 1.21 | 1.40 | 0.94 | |
| 2017 | 0.66 | | | | 0.79 | 1.25 | 0.71 | 0.73 | 2.02 | 1.65 | 1.60 |
| 2018 | 0.90 | | | | 0.86 | 1.22 | 1.23 | 1.41 | 1.14 | 1.37 | 1.30 |
| 2019 | 1.38 | | | | 1.50 | | | | | | 0.47 |
| 2020 | | | | | 2.01 | | | | | | 0.63 |

**Table 3-5 (b).** Available abundance indices (CPUE) of Pacific bluefin tuna (*Thunnus orientalis*). S10 was quarterly index.

| Fishing Year | Season | S10 |
|---|---|---|
| 2003 | 1 | |
| 2003 | 2 | |
| 2003 | 3 | |
| 2003 | 4 | 1.513 |
| 2004 | 1 | 0.753 |
| 2004 | 2 | 1.078 |
| 2004 | 3 | 2.142 |
| 2004 | 4 | 1.076 |
| 2005 | 1 | 0.698 |
| 2005 | 2 | 0.768 |
| 2005 | 3 | 0.634 |
| 2005 | 4 | 0.752 |
| 2006 | 1 | 0.560 |
| 2006 | 2 | 0.646 |
| 2006 | 3 | 0.677 |
| 2006 | 4 | 0.508 |
| 2007 | 1 | 0.584 |
| 2007 | 2 | 1.114 |
| 2007 | 3 | 1.131 |
| 2007 | 4 | 1.683 |
| 2008 | 1 | 0.453 |
| 2008 | 2 | 0.913 |
| 2008 | 3 | 1.555 |
| 2008 | 4 | 1.241 |
| 2009 | 1 | 0.724 |
| 2009 | 2 | 0.707 |
| 2009 | 3 | 0.748 |
| 2009 | 4 | 0.857 |
| 2010 | 1 | 0.446 |
| 2010 | 2 | 0.582 |
| 2010 | 3 | 0.801 |
| 2010 | 4 | 1.473 |
| 2011 | 1 | 0.344 |
| 2011 | 2 | 0.557 |
| 2011 | 3 | 0.845 |
| 2011 | 4 | 2.336 |
| 2012 | 1 | 1.812 |
| 2012 | 2 | 0.432 |
| 2012 | 3 | 0.560 |
| 2012 | 4 | 3.650 |
| 2013 | 1 | 0.327 |
| 2013 | 2 | 0.653 |
| 2013 | 3 | 1.256 |
| 2013 | 4 | 1.151 |
| 2014 | 1 | |
| 2014 | 2 | |
| 2014 | 3 | 1.075 |
| 2014 | 4 | 0.574 |
| 2015 | 1 | |
| 2015 | 2 | 0.621 |
| 2015 | 3 | 0.940 |
| 2015 | 4 | 0.699 |
| 2016 | 1 | 0.387 |
| 2016 | 2 | 0.340 |
| 2016 | 3 | 1.614 |
| 2016 | 4 | |
| 2017 | 1 | |
| 2017 | 2 | |
| 2017 | 3 | 3.011 |
| 2017 | 4 | |
| 2018 | 1 | |
| 2018 | 2 | |
| 2018 | 3 | |
| 2018 | 4 | |

**Table 3-6.** Characteristics of the size composition data used in the stock assessment for Pacific bluefin tuna (*Thunnus orientalis*).

| Fleet # | Fleet name | Catch-at-size data (Size bin definition) | Size data included | | Available period (Fishing year) | Source of sample size | Update |
|---|---|---|---|---|---|---|---|
| | | | Component 1 | Component 2 | | | |
| Fleet 1 | JPLL | Length bin | JPLL (Season 4) | | 1952-1968, 1993-2016 | Scaled Number of fish measured | X |
| Fleet 2[*1] | JP SPPS (Seas1, 3, 4) | Length bin | JP SPPS (Season 1, 3, 4) | | 2002-2020 | Number of landing well measured | X |
| Fleet 3[*1] | KROLPS | Length bin | KROLPS | | 2010-2020 | | X |
| Fleet 4 | JP TPSJS | Length bin | JP TPSJS | | 1987-1989, 1991-2020 | same velue with the last assessment | X |
| Fleet 5 | JP TPSPO | Length bin | JP TPSPO | | 1995-2006 and 2014-2020 | Number of landing well measured | X |
| Fleet 6 | JP Troll (Seas2-4) | Length bin | JP Troll (Season 2-4) | | 1994-2020 | Total month of well sampled port | X |
| Fleet 7[*2] | JP PL | Length bin | JP Pole-and-Line | | 1994-1996, 1998-2004, 2006-2010 | | |
| Fleet 8 | JP SetNet (Seas1-3) | Length bin | JP Setnet (Season 1-3) | | 1993-2018 | Total month of well sampled port | X |
| Fleet 9 | JP SetNet (Seas4) | Length bin | JP Setnet (Season 4) | | 1993-2018 | Total month of well sampled port | X |
| Fleet 10[*3] | JP SetNet_HK_AM | Weight bin | JP Setnet in Hokkaido and Aomori | JP Handline & Tsugaru Longline | 1994-2018 | Total month of well sampled port | X |
| Fleet 11[*3] | JP Others | Weight bin | JP Handline & Tsugaru Longline | | 1994-2018 | Total month of well sampled port | X |
| Fleet 12 | TWLL (South) | Length bin | TWLL (South area) | | 1992-2020 | Scaled Number of fish measured | X |
| Fleet 13 | USCOMM (-2001) | Length bin | US Commercial Fisheries (PS) | | 1952-1965, 1969-1982 | Number of haul well measured | |
| Fleet 14 | MXCOMM (2002-) | Length bin | MX Commercial Fisheries (PS) | | 2005-2006, 2008-2020 | Number of haul well measured | X |
| Fleet 15[*4] | EPOSP | Length bin | US Recreational Fisheries | | 2014-2020 | | X |
| Fleet 16[*5] | JP Troll4Pen | Age (age-0 only) | | | | | |
| Fleet 17 | TWLL (North) | Length bin | TWLL (North area) | | 2009-2020 | Scaled Number of fish measured | X |
| Fleet 18 | JP SPPS (Seas2) | Length bin | JP SPPS (Season 2) | | 2012-2020 | Number of landing well measured | X |
| Fleet 19 | JP Troll (Seas1) | Length bin | JP Troll (Season 1) | | 1994-2004, 2006-2008, 2011,2012, 2016, 2018 | Total month of well sampled port | X |
| Fleet 20 | JP SPPS for Pen | Length bin | JP SPPS for farming | | 2016-2020 | | X |
| Fleet 23 | JPLL (1993- ,S3) | Length bin | JPLL (1993-2016, Season 3) | JPLL (2017-2020) | 1993-2020 | | X |
| Fleet 24 | EPOSP_early | Length bin | US Recreational Fisheries | | 1993-2003, 2005-06, 2008-11 | | |

*1 Size composition data of Fleet 2 and 3 were combined. A selectivity pattern was estimated and shared by those two fleets.
*2 Size composition data of Fleet 7 was not used in the assessment model. The selectivity pattern estimated for Fleet 6 was mirrored.
*3 Size composition data of Fleet 10 and 11 were combined. A selectivity pattern was estimated and shared by those two fleets.
*4 Size composition data of Fleet 15 was not used in the assessment model. The selectivity pattern estimated for Fleet 13 was mirrored.
*5 Fleet 16 was assumed the age based selectivity to catch only age-0 fish. Thus size composition data was not used in the assessment model.

**Table 4-1.** Fishery-specific selectivity and their attributes used in the base-case stock assessment model for Pacific bluefin tuna (*Thunnus orientalis*).

| Fleet # | Fleet name | Main Ages of fish caught | Priority for size data | Type of size data | Sampling quality | CPUE index | Catch in number | Length-based contact selectivity | Age-based availability | Time-varying process | Time-varying Option |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fleet 1 | JPLL (Seas 4) | Spawners in WPO | High* | Length | Good | Yes | Low | Dome-shaped (double normal) | - | Constant on length-based | - |
| Fleet 2 | JP SPPS (Seas1, 3, 4) for consumption | Age 0 fish in WPO | Medium* | Length | Good | - | High | Dome-shaped (double normal) | Full selection at ages 0-1 | Constant on length-based | - |
| Fleet 3 | KROLPS | Age 0 and Migratory ages (ages 0-4) | Medium** | Length | Fair (opportunistically sampling was conducted for 2004-2009, systematically since 2010) | - | Med | Asymptotic (logistic) | Age-specific (ages 1-4) | Constant on length-based; time-varying on ages 1-2 for 2007-2020 | Deviation |
| Fleet 4 | JP TPSJS | Migratory ages (ages 1-5) | High* | Length | Very Good | - | High | Asymptotic (logistic) | Age-specific (ages 3-9) | Constant on length-based; time-varying on ages 3-7 for 2000-2020 | Deviation |
| Fleet 5 | JPTPSPO | Migratory ages (ages 1-7) | Medium* | Length | Fair to Good (improvement after 2014 by systematic sampling) | - | High | Asymptotic (logistic) | Age-specific (ages 1-10) | Constant on length-based; time-varying on ages 1, 4-7 for 2004-2005, 2011-2014, 2015-2020 | Block |
| Fleet 6 | JPTroll (Season2-4) | Age 0 fish in WPO | High* | Length | Good | Yes | High | Dome-shaped (double normal) | Full selection at ages 0-2 | Constant on length- and age-based | - |
| Fleet 7 | JPPL | Age 0 fish in WPO | Low | Length | Bad | - | Historic | Mirror to Fleet 6 | | | |
| Fleet 8 | JPSetNet (Season1-3) | Migratory ages (ages 1-5) | Low* | Length | Fair | - | Med | Asymptotic (logistic) | Age-specific (ages 1-4) | Constant on length-based; | |
| Fleet 9 | JPSetNet (Season4) | Migratory ages (ages 1-5) | Low* | Length | Fair | - | Low | Asymptotic (logistic) | Age-specific (ages 1-5) | Constant on length-based; | |
| Fleet 10 | JPSetNet_HK_AM | Migratory ages (ages 1-6) | Medium* | Weight | Good | - | Low | Asymptotic (logistic) | Age-specific (ages 1-6) | Constant on length-based; Time varying on ages1, 4-5 for 2004-2005, 2011-2014, 2015-2020) | Block |
| Fleet 11 | JPOthers | Migratory ages (ages 1-5) | Medium** | Weight | Good | - | Low | Mirror to Fleet 10 | | | |
| Fleet 12 | TWLL (South) | Spawners in WPO | High* | Length | Very Good | Yes | Low | Asymptotic (logistic) | - | Constant on length- and age-based | |
| Fleet 13 | USCOMM (-2001) | Migratory ages (ages 1-5) | Medium* | Length | Fair (many samples) | - | High-historic | Dome-shaped (double normal) | - | Time–varying on length-based for 1954-1981 | Block |
| Fleet 14 | MEXCOMM (2002-) | Migratory ages (ages 1-5) | High* | Length | Fair to Good (improvement after 2013 due to the stereo-camera) | - | High | Dome-shaped (double normal) | - | Time–varying on length-based for 2006-2020 | Block |
| Fleet 15 | EPO Sports (2014-) | Migratory ages (ages 1-5) | Low | Length | Fair (Good samples are available after 2014) | - | Low | Dome-shaped (double normal) | Full selection at ages 0-7 | Time–varying on length-based for 2014-2020 | Block |
| Fleet 16 | JPTroll for farming | Age 0 fish in WPO | Low | - | Catch in # of Age-0 fish are available | - | Med | None | Full selection at age 0 | Constant on age-based | - |
| Fleet 17 | TWLL (North) | Spawners in WPO | Low* | Length | Fair | - | Low | Dome-shaped (double normal) | None | Constant on length-based | - |
| Fleet 18 | JPSPPS (Season2) | Migratory ages (ages 1-5) | Medium* | Length | Good | - | High | Dome-shaped (double normal) | Age-specific (age 1) | Constant on length-based; Time–varying on age-based for 2004-2020 | Deviation |
| Fleet 19 | JPTroll (Season1) | Age 0 fish in WPO | Medium* | Length | Good | - | High | Dome-shaped (double normal) | - | Constant on length-based | - |
| Fleet 20 | JPSPPS for farming | Age 0-1 in WPO | Medium* | Length | Good (improvement after 2016 due to the stereo-camera); Catch in # of fish are available | - | Med | Share to Fleet 2 | | | |
| Fleet 21 | Discard in WPO (mt) | Not Available | | | | - | NA | Mirror to Fleet 8 | | | |
| Fleet 22 | Discard in WPO (Num) | Not Available | | | | - | NA | Mirror to Fleet 8 | | | |
| Fleet 23 | JPLL (Seas 1-3) | Migratory ages (ages 1-7) | Medium* | Length | Good | - | Low | Dome-shaped (double normal) | - | Constant on length-based | - |
| Fleet 24 | EPO Sports (-2013) | Migratory ages (ages 1-5) | Low | Length | Fair | - | Low | Mirror to Fleet 14 | | | |
| Fleet 25 | EPO Discard in Num | Migratory ages (ages 1-5) | NA | | | - | Low | Mirror to Fleet 14 | | | |

**Table 4-2.** Harvest scenarios used in the projection for Pacific bluefin tuna (*Thunnus orientalis*).

| Reference No | Harvesting scenarios | | | | | | |
|---|---|---|---|---|---|---|---|
| | Catch upper limit increments from status quo | | | Catch limit in the projection | | | Note |
| | WCPO | | EPO | WCPO | | EPO | |
| | Small | Large | Commercial | Small | Large | Commercial | |
| 1 | New CMM | | | 4,475 | 7,860 | 3,995 | NC request (paragraph 1; New CMM)<br>WCPFC CMM 2021-02, IATTC Resolution C-21-05 |
| 2 | New CMM | +500 tons | +500 tons | 4,475 | 8,360 | 4,495 | NC request (Paragraph 1, Appendix table 1st line) |
| 3 | 10% increase on the New CMM | | | 4,948 | 8,621 | 4,395 | NC request (Paragraph 1, Appendix table 2nd line) |
| 4 | 20% increase on the New CMM | | | 5,420 | 9,382 | 4,794 | NC request (Paragraph 1, Appendix table 3rd line) |
| 5 | -580 tons | +853 tons | New CMM | 3,895 | 8,713 | 3,995 | NC request (paragraph 3; conversion factor scenario). Transferring 10% (JPN) and 25% (KOR) of small fish catch quota to their largefish catch quota with the defined conversion factor (1.47). |
| 6 | +30% | +30% | +190% | 5,893 | 10,143 | 11,586 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 75:25. Additional quota is assigned proportionally for the WPO fisheries and independently for the EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them.) |
| 7 | New CMM | +130% | +190% | 4,475 | 17,752 | 11,586 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 75:25. Additional quota is assigned only for the WPO large fish fisheries and EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them) |
| 8 | +60% | +60% | +90% | 7,310 | 12,425 | 7,591 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 80:20. Additional quota is assigned proportionally for the WPO fisheries and independently for the EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them.) |
| 9 | New CMM | +230% | +90% | 4,475 | 25,362 | 7,591 | NC request (Achieving 2nd rebuilding target at 10 years after achieving initial rebuilding target in 60 % probability. Fishery impact ratio at rebuilding year is 80:20. Additional quota is assigned only for the WPO large fish fisheries and EPO commercial fisheries. The balance of additional quota between the WPO and EPO is adjusted to achieve the given fishery impact ratio between them) |
| 10 | Old CMM (50% of 2002-04 average level) | Old CMM (2002-04 average level) | Old CMM | 4,475 | 6,841 | 3,300 | Old CMM |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 catch for all fisheries |

* The Reference number of the Scenario is different from those given by the IATTC-WCPFC NC Joint WG meeting.

* Fishing mortality for scenario 1 is specified as the average level of age-specific fishing mortality during 2002-2004, which is the reference years in the WCPFC. Higher levels of the fishing mortality are specified for other scenarios to fulfill their quota in those projections.

* The Japanese unilateral measure (transferring 250 mt of catch upper limit from that for small PBF to that for large PBF during 2020-2034) is reflected in the projections.

**Table 5-1**. Mean input variances (input N after variance adjustment), model estimated mean variance (mean *effN*), and harmonic means of the *effN* by composition data component for the base-case model, where effective sample size (effN) is the models estimate of the statistical precision. A higher ratio of mean *effN* to mean input N indicates a better model fit. Number of observations corresponds to the number of quarters in which size composition data were sampled in a fishery.

| Fleet | Number of observations | Mean input N after var adj | Mean *eff*N | Harmonic mean *eff*N |
|---|---|---|---|---|
| 1 | 73 | 8.2 | 50.3 | 26.4 |
| 2 | 42 | 10.5 | 36.2 | 15.4 |
| 3 | 18 | 13.6 | 54.4 | 22.9 |
| 4 | 33 | 10.8 | 28.3 | 14.8 |
| 5 | 18 | 11.0 | 44.7 | 32.9 |
| 6 | 56 | 8.4 | 37.2 | 16.1 |
| 8 | 76 | 6.5 | 18.6 | 12.1 |
| 9 | 26 | 7.0 | 19.8 | 13.2 |
| 10 | 25 | 8.6 | 35.2 | 14.9 |
| 12 | 29 | 10.6 | 113.9 | 36.4 |
| 13 | 50 | 14.5 | 19.1 | 6.3 |
| 14 | 18 | 10.4 | 32.0 | 19.1 |
| 15 | 17 | 12.8 | 22.6 | 15.1 |
| 17 | 12 | 2.8 | 150.0 | 73.0 |
| 18 | 16 | 9.8 | 17.6 | 9.9 |
| 19 | 18 | 6.4 | 25.7 | 10.6 |
| 20 | 5 | 16.2 | 20.8 | 12.5 |
| 23 | 32 | 4.2 | 22.7 | 17.7 |

**Table 5-2.** Time series estimates of total biomass, spawning stock biomass, recruitment and spawning potential ratio from the base-case model for Pacific bluefin tuna (*Thunnus orientalis*).

| Year | Total Biomass (t) | Spawning Stock Biomass (t) | Recruitment (1,000 fish) | Spawning Potential Ratio | Depletion Ratio |
|---|---|---|---|---|---|
| 1952 | 134,789 | 103,359 | 14,008 | 11.6% | 16.1% |
| 1953 | 136,421 | 97,912 | 20,617 | 12.9% | 15.2% |
| 1954 | 146,892 | 88,019 | 34,911 | 7.9% | 13.7% |
| 1955 | 156,701 | 75,353 | 13,343 | 11.4% | 11.7% |
| 1956 | 176,167 | 67,818 | 33,476 | 15.8% | 10.5% |
| 1957 | 193,973 | 77,053 | 11,635 | 10.8% | 12.0% |
| 1958 | 202,415 | 100,943 | 3,203 | 19.5% | 15.7% |
| 1959 | 209,868 | 136,650 | 7,709 | 23.9% | 21.2% |
| 1960 | 202,700 | 144,704 | 7,554 | 17.3% | 22.5% |
| 1961 | 194,047 | 156,534 | 23,235 | 3.4% | 24.3% |
| 1962 | 177,257 | 141,792 | 10,774 | 10.9% | 22.0% |
| 1963 | 166,291 | 120,933 | 27,842 | 6.6% | 18.8% |
| 1964 | 154,459 | 106,314 | 5,689 | 7.5% | 16.5% |
| 1965 | 142,916 | 93,572 | 10,955 | 3.0% | 14.5% |
| 1966 | 120,164 | 89,589 | 8,556 | 0.1% | 13.9% |
| 1967 | 105,483 | 83,751 | 10,951 | 1.1% | 13.0% |
| 1968 | 91,650 | 77,872 | 14,356 | 1.4% | 12.1% |
| 1969 | 80,731 | 64,561 | 6,450 | 8.6% | 10.0% |
| 1970 | 74,490 | 54,181 | 7,182 | 2.9% | 8.4% |
| 1971 | 66,467 | 47,017 | 12,407 | 1.3% | 7.3% |
| 1972 | 64,098 | 40,725 | 22,890 | 0.3% | 6.3% |
| 1973 | 62,899 | 35,510 | 11,251 | 5.6% | 5.5% |
| 1974 | 65,165 | 28,711 | 13,983 | 6.3% | 4.5% |
| 1975 | 65,978 | 26,420 | 11,223 | 8.9% | 4.1% |
| 1976 | 65,030 | 29,152 | 8,071 | 3.1% | 4.5% |
| 1977 | 74,864 | 35,066 | 25,589 | 3.7% | 5.4% |
| 1978 | 76,566 | 32,974 | 14,317 | 5.0% | 5.1% |
| 1979 | 73,608 | 27,866 | 12,876 | 8.2% | 4.3% |
| 1980 | 72,844 | 29,713 | 6,554 | 6.2% | 4.6% |
| 1981 | 57,749 | 27,591 | 13,360 | 0.3% | 4.3% |
| 1982 | 40,714 | 24,235 | 6,454 | 0.0% | 3.8% |
| 1983 | 33,472 | 14,773 | 10,090 | 6.0% | 2.3% |
| 1984 | 37,662 | 12,895 | 9,063 | 5.3% | 2.0% |
| 1985 | 39,805 | 12,957 | 9,654 | 2.7% | 2.0% |
| 1986 | 34,473 | 15,316 | 7,939 | 1.1% | 2.4% |
| 1987 | 32,080 | 14,105 | 5,980 | 8.2% | 2.2% |
| 1988 | 38,238 | 15,059 | 9,483 | 11.0% | 2.3% |
| 1989 | 42,074 | 14,888 | 4,291 | 14.6% | 2.3% |
| 1990 | 57,971 | 18,994 | 17,436 | 18.4% | 3.0% |
| 1991 | 69,431 | 25,290 | 10,617 | 9.8% | 3.9% |
| 1992 | 76,142 | 32,456 | 3,968 | 14.7% | 5.0% |
| 1993 | 83,395 | 43,890 | 4,430 | 16.8% | 6.8% |
| 1994 | 97,472 | 50,177 | 29,319 | 13.5% | 7.8% |
| 1995 | 93,999 | 62,246 | 16,012 | 5.2% | 9.7% |
| 1996 | 96,300 | 61,563 | 17,964 | 8.8% | 9.6% |
| 1997 | 90,121 | 56,179 | 11,082 | 6.0% | 8.7% |
| 1998 | 95,748 | 55,612 | 16,075 | 4.2% | 8.6% |
| 1999 | 91,805 | 51,374 | 22,755 | 3.4% | 8.0% |
| 2000 | 76,307 | 48,461 | 14,385 | 1.7% | 7.5% |
| 2001 | 77,426 | 46,059 | 17,302 | 9.5% | 7.2% |
| 2002 | 75,311 | 43,899 | 13,541 | 5.7% | 6.8% |
| 2003 | 67,904 | 43,152 | 7,157 | 2.3% | 6.7% |
| 2004 | 65,640 | 35,881 | 27,746 | 1.4% | 5.6% |
| 2005 | 55,074 | 29,159 | 15,118 | 0.7% | 4.5% |
| 2006 | 43,314 | 23,294 | 13,540 | 1.1% | 3.6% |
| 2007 | 42,659 | 18,424 | 22,227 | 0.5% | 2.9% |
| 2008 | 38,290 | 13,716 | 21,072 | 0.6% | 2.1% |
| 2009 | 33,985 | 10,195 | 8,277 | 1.2% | 1.6% |
| 2010 | 36,969 | 9,761 | 17,952 | 2.4% | 1.5% |
| 2011 | 38,817 | 11,183 | 13,526 | 4.9% | 1.7% |
| 2012 | 42,482 | 13,902 | 7,169 | 8.2% | 2.2% |
| 2013 | 52,764 | 16,313 | 13,169 | 5.7% | 2.5% |
| 2014 | 53,075 | 19,185 | 3,641 | 11.1% | 3.0% |
| 2015 | 59,220 | 23,640 | 8,653 | 12.5% | 3.7% |
| 2016 | 69,494 | 30,516 | 16,690 | 12.8% | 4.7% |
| 2017 | 82,681 | 32,538 | 10,895 | 21.9% | 5.1% |
| 2018 | 103,849 | 35,741 | 11,145 | 28.3% | 5.6% |
| 2019 | 129,972 | 45,173 | 11,843 | 28.8% | 7.0% |
| 2020 | 156,517 | 65,464 | 11,316 | 35.1% | 10.2% |
| Median(1952-2020) | 74,864 | 35,881 | 11,635 | 6.2% | 5.6% |
| Average(1952-2020) | 89,353 | 49,845 | 13,390 | 8.3% | 7.7% |

**Table 5-3.** Ratios of the estimated fishing mortalities (Fs and 1-SPRs for 2002-04, 2011-13, 2018-20) relative to potential fishing mortality-based reference points, and terminal year SSB (t) for each reference period, and depletion ratios for the terminal year of the reference period for Pacific bluefin tuna (*Thunnus orientalis*) from the base-case model**.** $F_{max}$: Fishing mortality (F) that maximizes equilibrium yield per recruit (Y/R). $F_{0.1}$: F at which the slope of the Y/R curve is 10% of the value at its origin. $F_{med}$: F corresponding to the inverse of the median of the observed R/SSB ratio. $F_{xx\%SPR}$: F that produces given % of the unfished spawning potential (biomass) under equilibrium condition.

| Reference Period | | | | (1-SPR)/(1-SPR$_{xx\%}$) | | | | Estimated SSB for terminal year of each period (ton) | Depletion rate for terminal year of each period (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Fmax | F0.1 | Fmed | SPR$_{10\%}$ | SPR$_{20\%}$ | SPR$_{30\%}$ | SPR$_{40\%}$ | | |
| 2002-2004 | 1.96 | 2.89 | 1.16 | 1.08 | 1.21 | 1.38 | 1.61 | 35,881 | 5.6% |
| 2011-2013 | 1.54 | 2.27 | 0.87 | 1.04 | 1.17 | 1.34 | 1.56 | 16,313 | 2.5% |
| 2018-2020 | 0.75 | 1.14 | 0.33 | 0.77 | 0.87 | 0.99 | 1.15 | 65,464 | 10.2% |

**Table 5-4.** Ratios of the estimated fishing mortalities (Fs and 1-SPRs for 2002-04, 2011-13, 2018-20) relative to potential fishing mortality-based reference points, and terminal year SSB (t) for each reference period, and depletion ratios for the terminal year of the reference period for Pacific bluefin tuna (*Thunnus orientalis*) from the sensitivity analysis including the recruitment index from 2017 to 2020**.** $F_{max}$: Fishing mortality (F) that maximizes equilibrium yield per recruit (Y/R). $F_{0.1}$: F at which the slope of the Y/R curve is 10% of the value at its origin. $F_{med}$: F corresponding to the inverse of the median of the observed R/SSB ratio. $F_{xx\%SPR}$: F that produces given % of the unfished spawning potential (biomass) under equilibrium condition.

| Reference Period | Fmax | F0.1 | Fmed | (1-SPR)/(1-$SPR_{xx\%}$) | | | | Estimated SSB for terminal year of each period (ton) | Depletion rate for terminal year of each period (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $SPR_{10\%}$ | $SPR_{20\%}$ | $SPR_{30\%}$ | $SPR_{40\%}$ | | |
| 2002-2004 | 1.95 | 2.88 | 1.18 | 1.08 | 1.21 | 1.38 | 1.61 | 36,108 | 5.7% |
| 2011-2013 | 1.53 | 2.26 | 0.89 | 1.04 | 1.17 | 1.34 | 1.56 | 16,421 | 2.6% |
| 2018-2020 | 0.81 | 1.23 | 0.37 | 0.80 | 0.90 | 1.03 | 1.20 | 67,929 | 10.7% |

**Table 6-1.** Future projection scenarios for Pacific bluefin tuna (*Thunnus orientalis*) and their probability of achieving various target levels by various time schedules based on the base-case model.

| Reference No | Harvesting scenarios | | | | Peformance indicators | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | WCPO | | EPO | | The fishing year expected to achive the 2nd rebuilding target with >60% probability | Risk to breach $SSB_{loss}$ at least once by 2030 | Probability of achiving the 2nd rebuilding target at 10 years after achieving initial rebuilding target [2029] | Median SSB at 10 years after achieving initial rebuilding target [2029] | Median SSB at 2034 | Fishery impact ratio of WPO fishery at 10 years after achieving the initial rebuilding target [2029] | Fishery impact ratio of EPO fishery at 10 years after achieving the initial rebuilding target [2029] |
| | Small | Large | Small | Large | | | | | | | |
| 1 | New CMM | | | | 2023 | 0% | 98.8% | 262,795 | 307,336 | 81.1% | 18.9% |
| 2 | New CMM | 500 tons increase on the New CMM | 500 tons increase on the New CMM | | 2023 | 0% | 98.2% | 256,170 | 298,867 | 80.3% | 19.7% |
| 3 | 10% increase on the New CMM | | | | 2023 | 0% | 96.9% | 245,333 | 280,687 | 82.3% | 17.7% |
| 4 | 20% increase on the New CMM | | | | 2023 | 0% | 94.0% | 227,183 | 253,598 | 83.4% | 16.6% |
| 5 | -580 tons | +853 tons | New CMM | | 2023 | 0% | 99.3% | 269,289 | 319,863 | 80.2% | 19.8% |
| 6 | +30% | +30% | +190% | | 2023 | 0% | 64.1% | 154,417 | 150,121 | 75.5% | 24.5% |
| 7 | New CMM | +130% | +190% | | 2029 | 0% | 60.0% | 147,931 | 157,963 | 75.2% | 24.8% |
| 8 | +60% | +60% | +90% | | 2023 | 0% | 61.3% | 147,275 | 135,698 | 80.6% | 19.4% |
| 9 | New CMM | +230% | +90% | | 2030 | 0% | 58.6% | 145,058 | 160,473 | 78.3% | 21.7% |
| 10 | Old CMM (50% of 2002-04 average level) | Old CMM (2002-04 average level) | Old CMM | | 2023 | 0% | 99.4% | 272,845 | 320,885 | 82.1% | 17.9% |
| 11 | 0 | 0 | 0 | | 2022 | 0% | 100.0% | 478,465 | 578,729 | 83.0% | 17.0% |

* The numbering of Scenarios is different from those given by the IATTC-WCPFC NC Joint WG meeting and the same as Table 3.

* Recruitment is resampled from historical values.

**Table 6-2.** Expected yield for Pacific bluefin tuna (*Thunnus orientalis*) under various harvesting scenarios based on the base-case model.

| Reference No | Harvesting scenarios | | | | | | Future expected catch | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Catch upper limit increments from status quo | | | Catch upper limit in the projection | | | 2024 | | | | 2034 | | | |
| | WCPO | | EPO | WCPO | | EPO | WCPO | | EPO | | WCPO | | EPO | |
| | Small | Large | Commercial | Small | Large | Commercial | Small | Large | Commercial | Sport | Small | Large | Commercial | Sport |
| 1 | New CMM | | | 4,475 | 7,860 | 3,995 | 4,496 | 7,884 | 4,008 | 1,228 | 4,497 | 7,922 | 4,012 | 1,540 |
| 2 | New CMM | 500 tons increase on the New CMM | 500 tons increase on the New CMM | 4,475 | 8,360 | 4,495 | 4,496 | 8,366 | 4,506 | 1,216 | 4,496 | 8,419 | 4,510 | 1,513 |
| 3 | 10% increase on the New CMM | | | 4,948 | 8,621 | 4,395 | 4,965 | 8,610 | 4,404 | 1,189 | 4,965 | 8,674 | 4,407 | 1,430 |
| 4 | 20% increase on the New CMM | | | 5,420 | 9,382 | 4,794 | 5,434 | 9,307 | 4,801 | 1,150 | 5,435 | 9,413 | 4,802 | 1,318 |
| 5 | -580 tons | +853 tons | New CMM | 3,895 | 8,713 | 3,995 | 3,916 | 8,749 | 4,009 | 1,250 | 3,917 | 8,787 | 4,013 | 1,616 |
| 6 | +30% | +30% | +190% | 5,893 | 10,143 | 11,586 | 5,892 | 10,181 | 11,521 | 996 | 5,889 | 10,018 | 11,247 | 924 |
| 7 | New CMM | +130% | +190% | 4,475 | 17,752 | 11,586 | 4,492 | 17,733 | 11,552 | 1,012 | 4,491 | 17,144 | 11,486 | 1,079 |
| 8 | +60% | +60% | +90% | 7,310 | 12,425 | 7,591 | 7,240 | 12,502 | 7,594 | 979 | 7,211 | 12,073 | 7,512 | 841 |
| 9 | New CMM | +230% | +90% | 4,475 | 25,362 | 7,591 | 4,494 | 23,864 | 7,601 | 1,030 | 4,493 | 24,055 | 7,597 | 1,160 |
| 10 | Old CMM (50% of 2002-04 average level) | Old CMM (2002-04 average level) | Old CMM | 4,475 | 6,841 | 3,300 | 4,497 | 6,866 | 3,317 | 1,243 | 4,497 | 6,888 | 3,319 | 1,580 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 6-3.** Sensitivity analyses of the future projection for Pacific bluefin tuna (*Thunnus orientalis*) and their probability of achieving various target levels by various time schedules based on the sensitivity models.

| Model | Harvesting scenarios | | | | The fishing year expected to achive the 2nd rebuilding target with >60% propability | Risk to breach the initial rebuilding target at 2024 | Probability of achiving the 2nd rebuilding target at 10 years after achieving initial rebuilding target | Median SSB at 10 years after achieving initial rebuilding target | Median SSB at 2034 |
|---|---|---|---|---|---|---|---|---|---|
| | WCPO | | EPO | | | | | | |
| | Small | Large | Small | Large | | | | | |
| BC including alternative recruitment index | Status quo | | | | 2022 | 0.0% | 98.2% | 255,582 | 301,552 |
| short model BC | Status quo | | | | 2023 | 0.0% | 98.0% | 245,252 | 284,571 |
| short model L bigger | Status quo | | | | 2025 | 0.0% | 97.6% | 271,413 | 307,364 |
| short model M lower | Status quo | | | | 2025 | 0.0% | 97.2% | 342,215 | 401,572 |
| short model h 0.85 | Status quo | | | | 2029 | 0.0% | 70.4% | 312,001 | 349,180 |

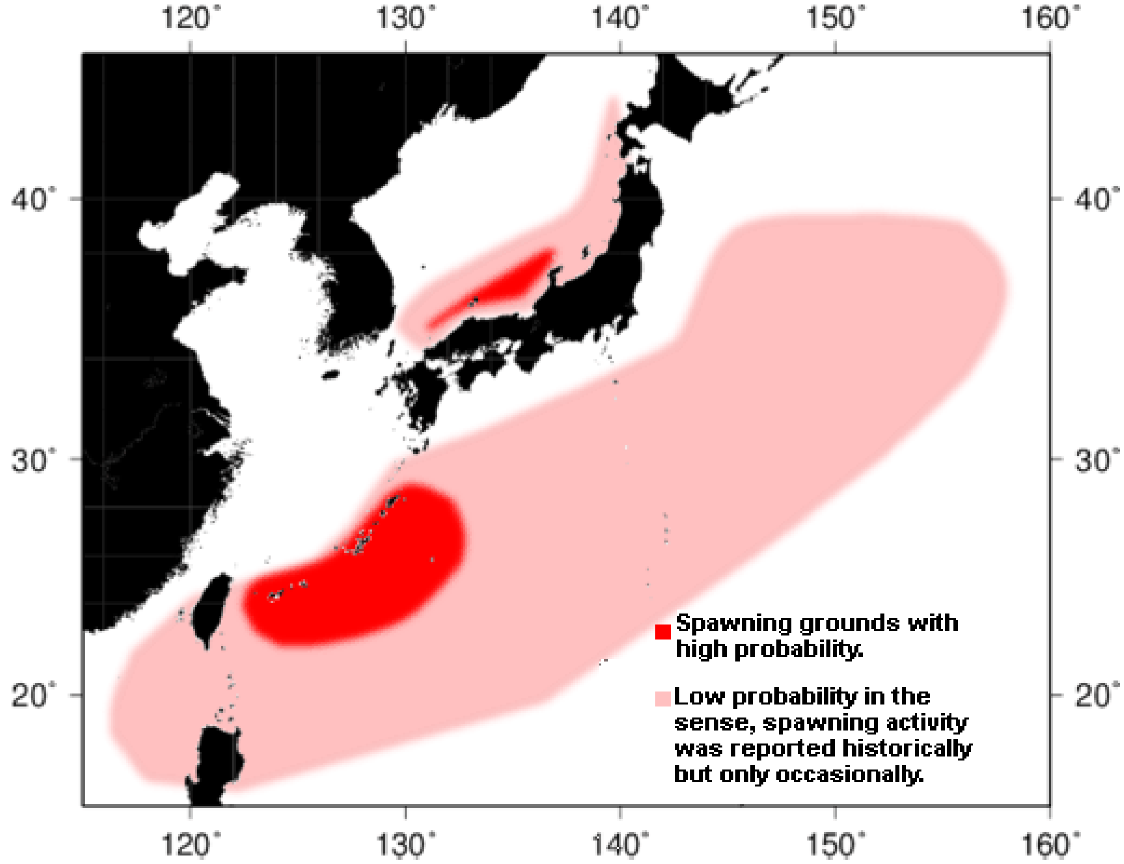


**Figure 2-1.** Generalized spawning grounds for Pacific bluefin tuna (*Thunnus orientalis*). Red areas represent higher probability of spawning.

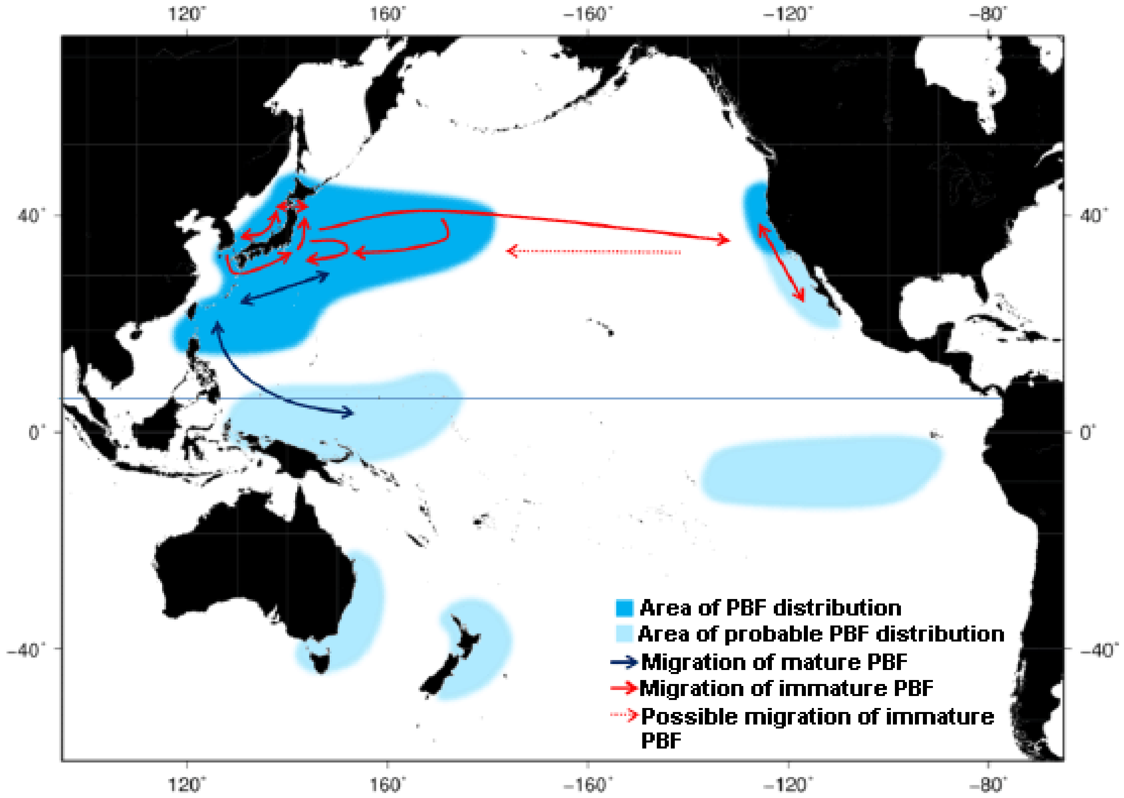


**Figure 2-2.** Generalized distribution of Pacific bluefin tuna (*Thunnus orientalis*). Darker areas indicate the core habitat.

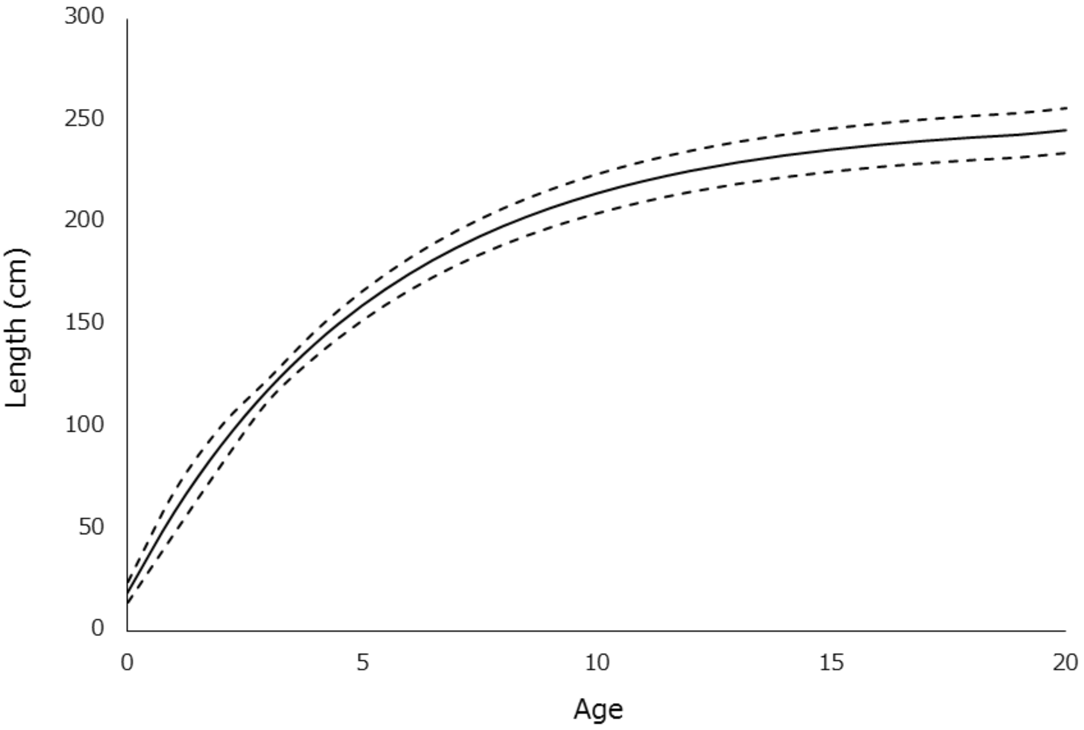


**Figure 2-3.** The von Bertalanffy growth curve for Pacific bluefin tuna (*Thunnus orientalis*) used in this stock assessment. Integer age (0,1,2,3,…) corresponds to the middle of first quarter 1 of each fishing year (i.e., August 15 in the calendar year).

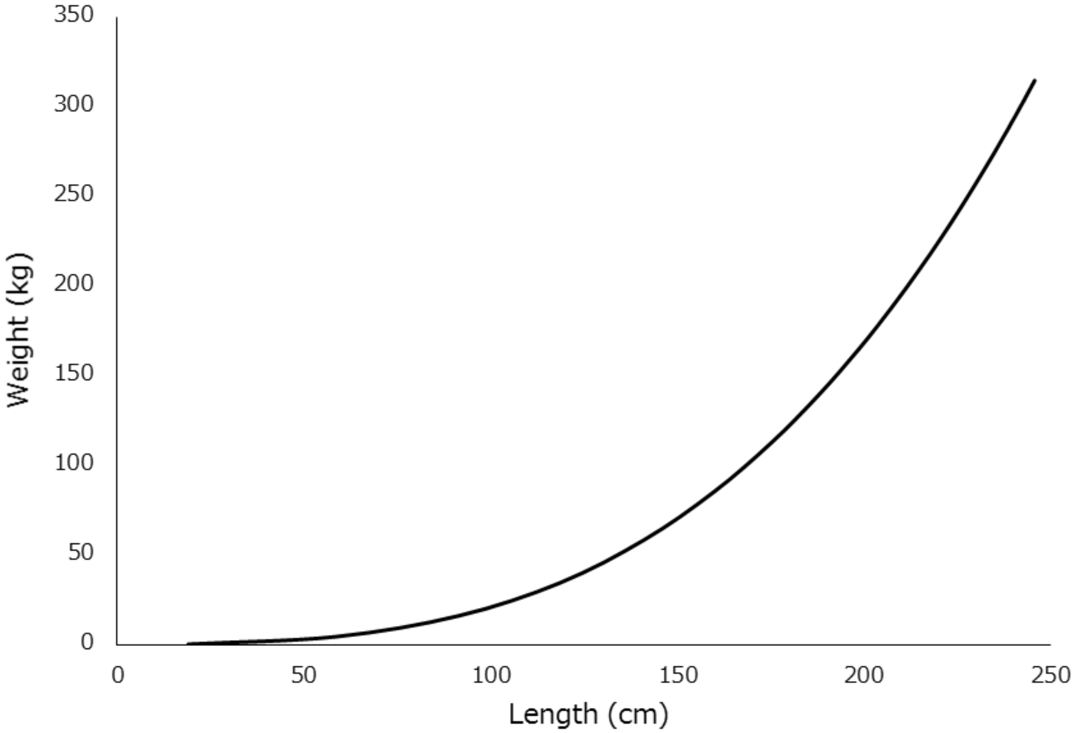


**Figure 2-4.** Length-weight relationship for Pacific bluefin tuna (*Thunnus orientalis*) used in this stock assessment.

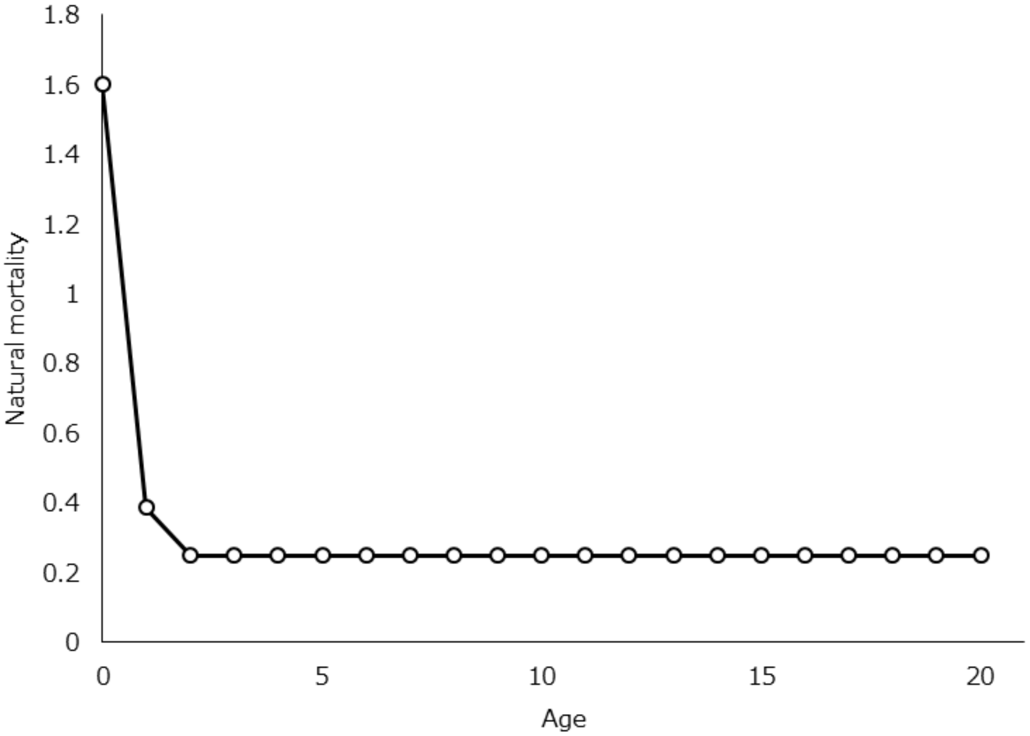


**Figure 2-5.** Assumed natural mortality (*M*) at age of Pacific bluefin tuna (*Thunnus orientalis*) used in this stock assessment.

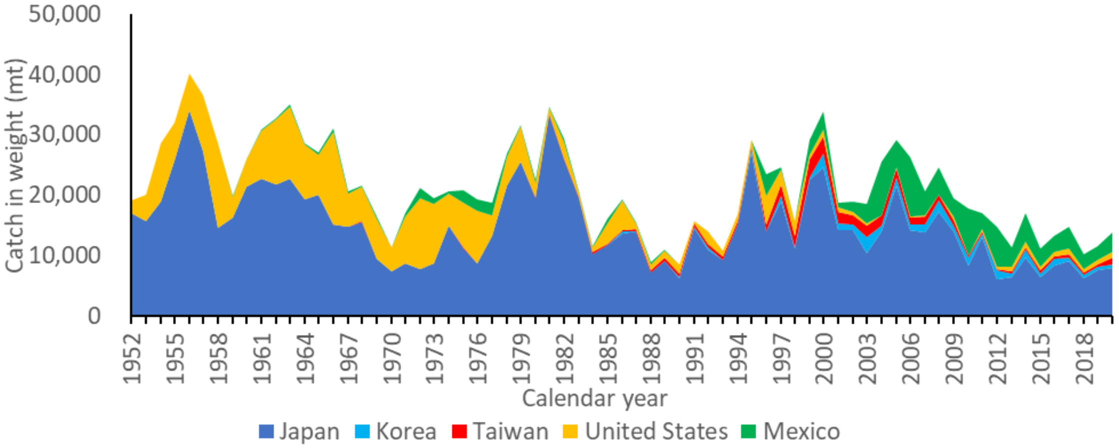


**Figure 2-6.** Annual catch (ton) of Pacific bluefin (*Thunnus orientalis*) tuna by ISC member countries from 1952 through 2020 (calendar year) based on ISC official statistics.

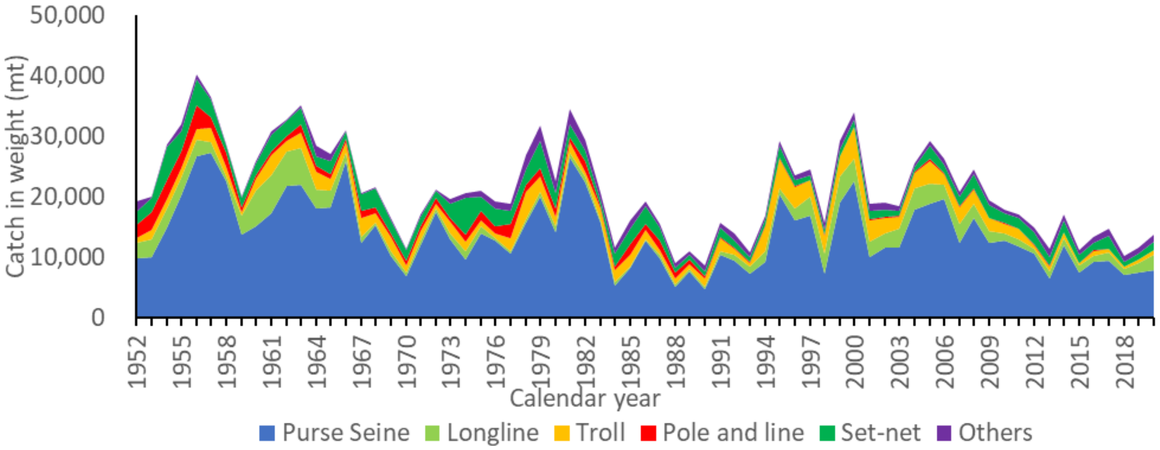


**Figure 2-7.** Annual catch (ton) of Pacific bluefin tuna (*Thunnus orientalis*) by gear type by ISC member countries from 1952 through 2020 (calendar year) based on ISC official statistics.

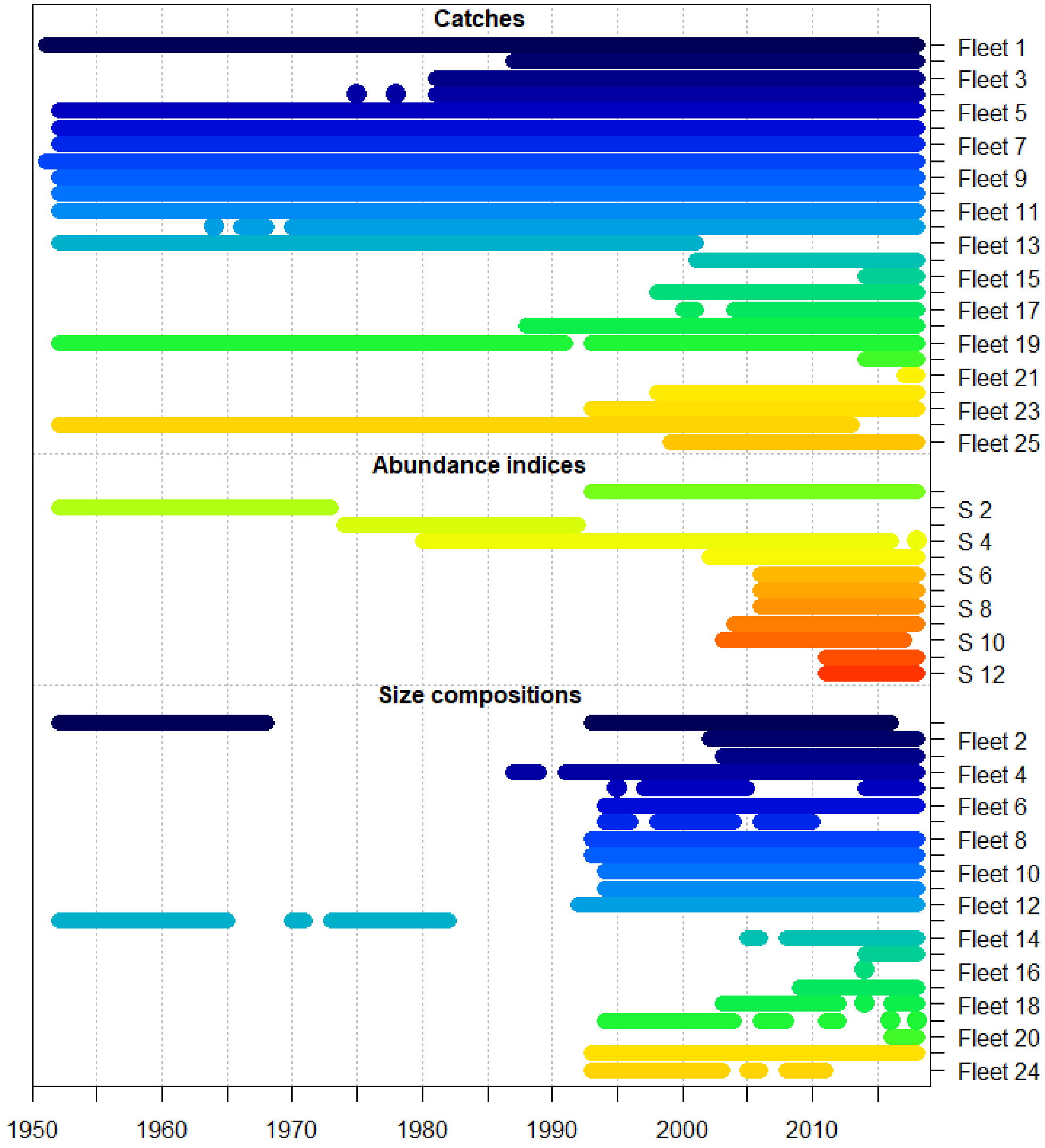


**Figure 3-1.** Data sources and temporal coverage of catch, abundance indices, and size composition data used in the stock assessment of Pacific bluefin tuna (*Thunnus orientalis*).

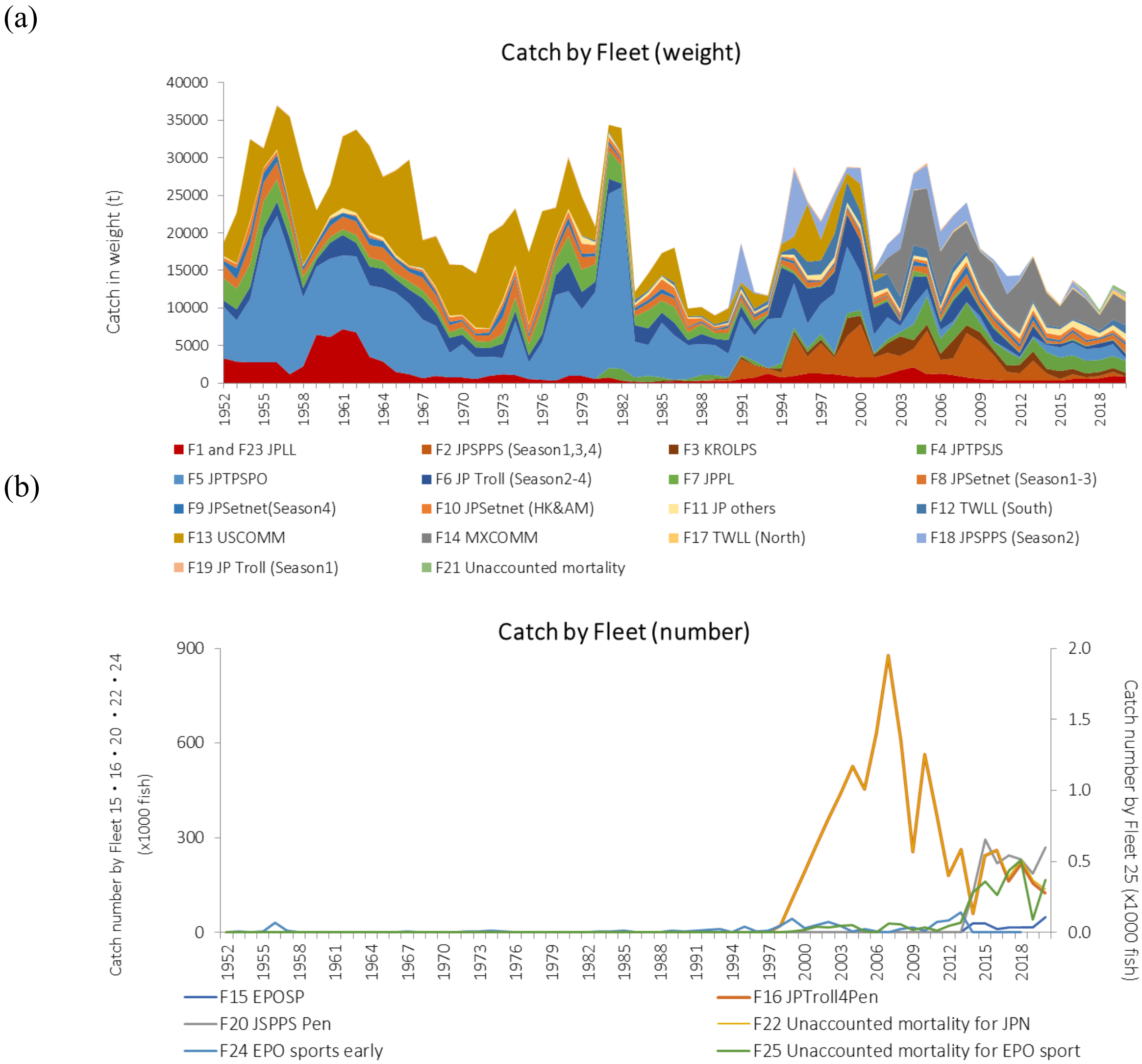


**Figure 3-2.** Historical annual catch of Pacific bluefin tuna (*Thunnus orientalis*) by Fleets 1-14,17-19,21, and 23 (a: upper panel) , by Fleets 15, 16, 20, 22, 24 and 25 (b: lower panel) for fishing year 1952-2020.

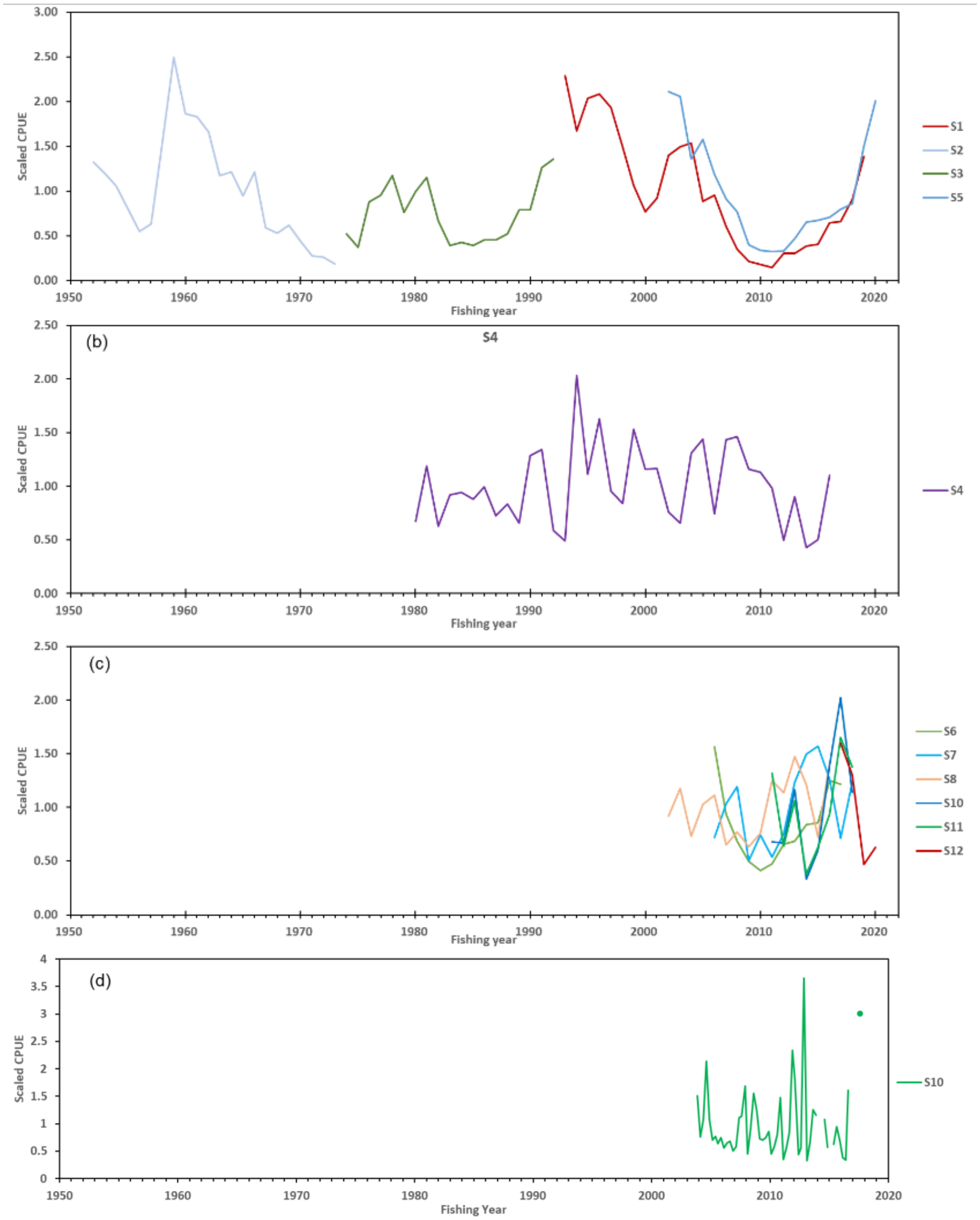


**Figure 3-3.** Abundance indices of Pacific bluefin tuna (*Thunnus orientalis*) submitted to ISC PBFWG. The longline indices of Japanese fisheries (S1, S2, and S3) and Taiwanese fishery in southern area (S5) were used to represent adult abundance (Fig.-(a)), and the index of Japanese troll fishery (S4) will be used as recruitment index (Fig.-(b)). The other indices were not fitted to the assessment model (Fig.-(c) and (d)); e.g. the indices of Taiwanese longline fishery (S6-9), and Japanese troll monitoring (S11, S12) Korean purse seine (S10).

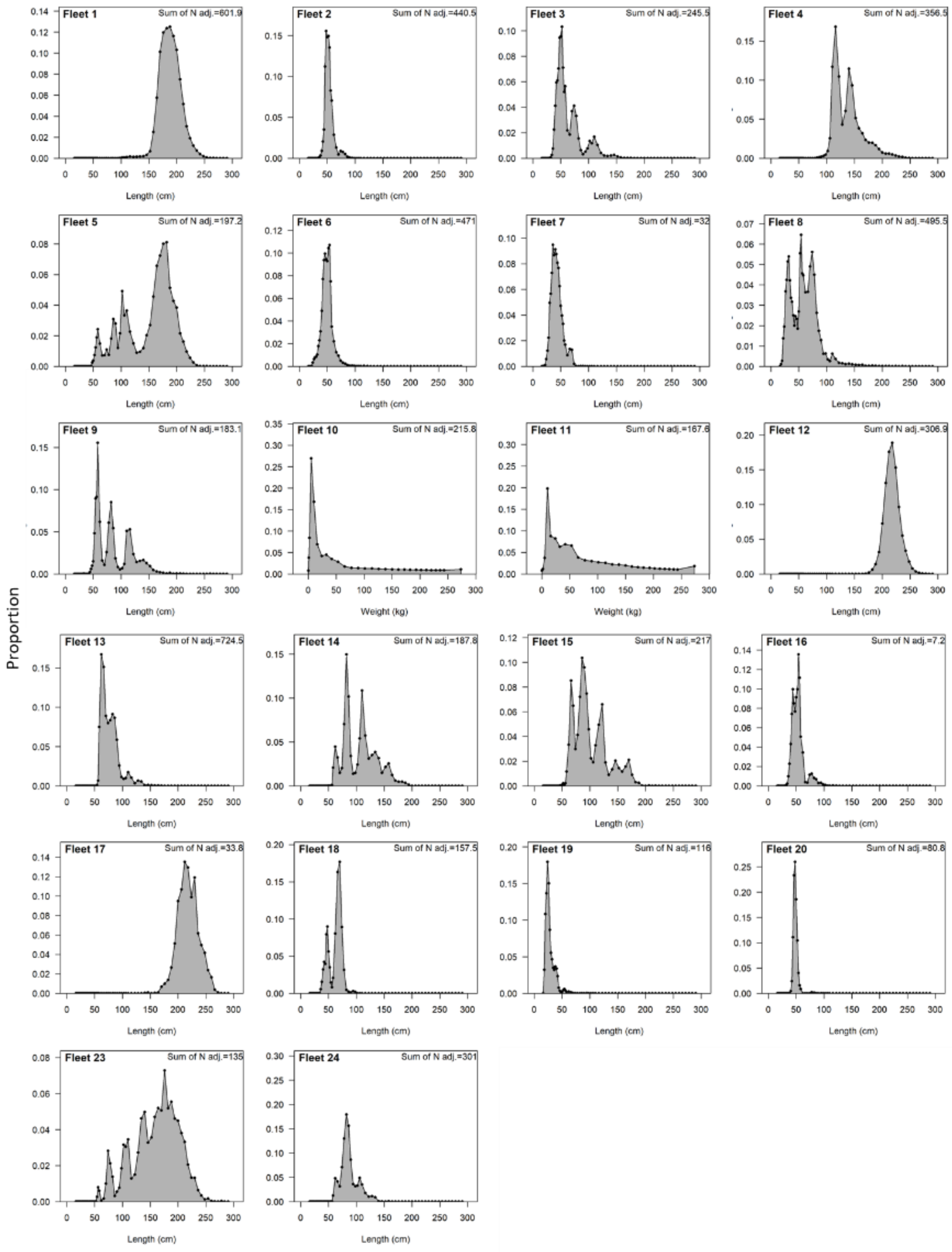


**Figure 3-4.** Aggregated size compositions of Pacific bluefin tuna (*Thunnus orientalis*) for each fleet used in the stock assessment. The data were aggregated across seasons and years. The x-axis is in fork length (cm) for all fleets except for Fleet 10-11 in weight (kg).

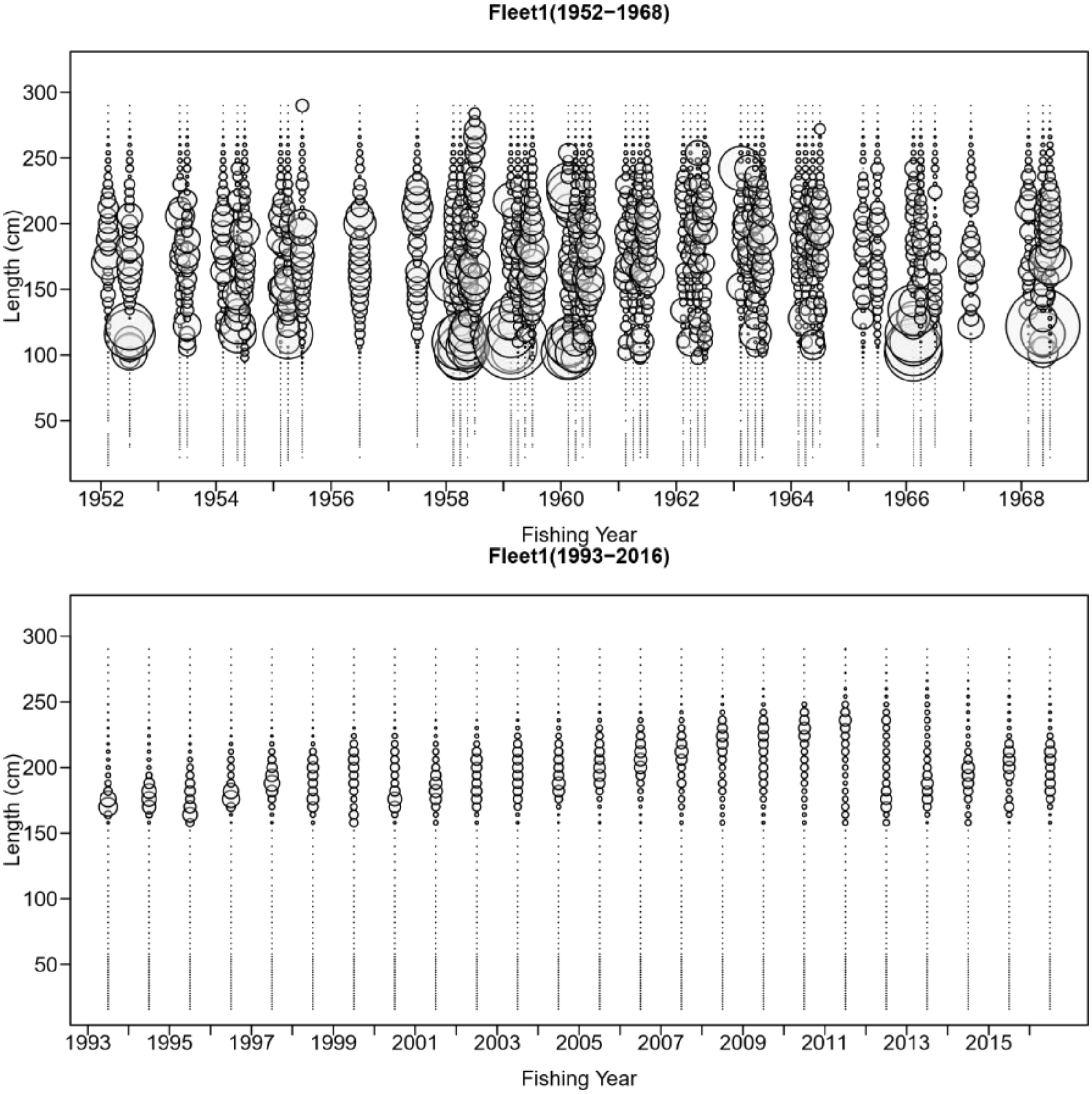


**Figure 3-5.** Size composition data by fleet and season used in the stock assessment model for Pacific bluefin tuna (*Thunnus orientalis*). Larger circles indicate higher proportions of fish.

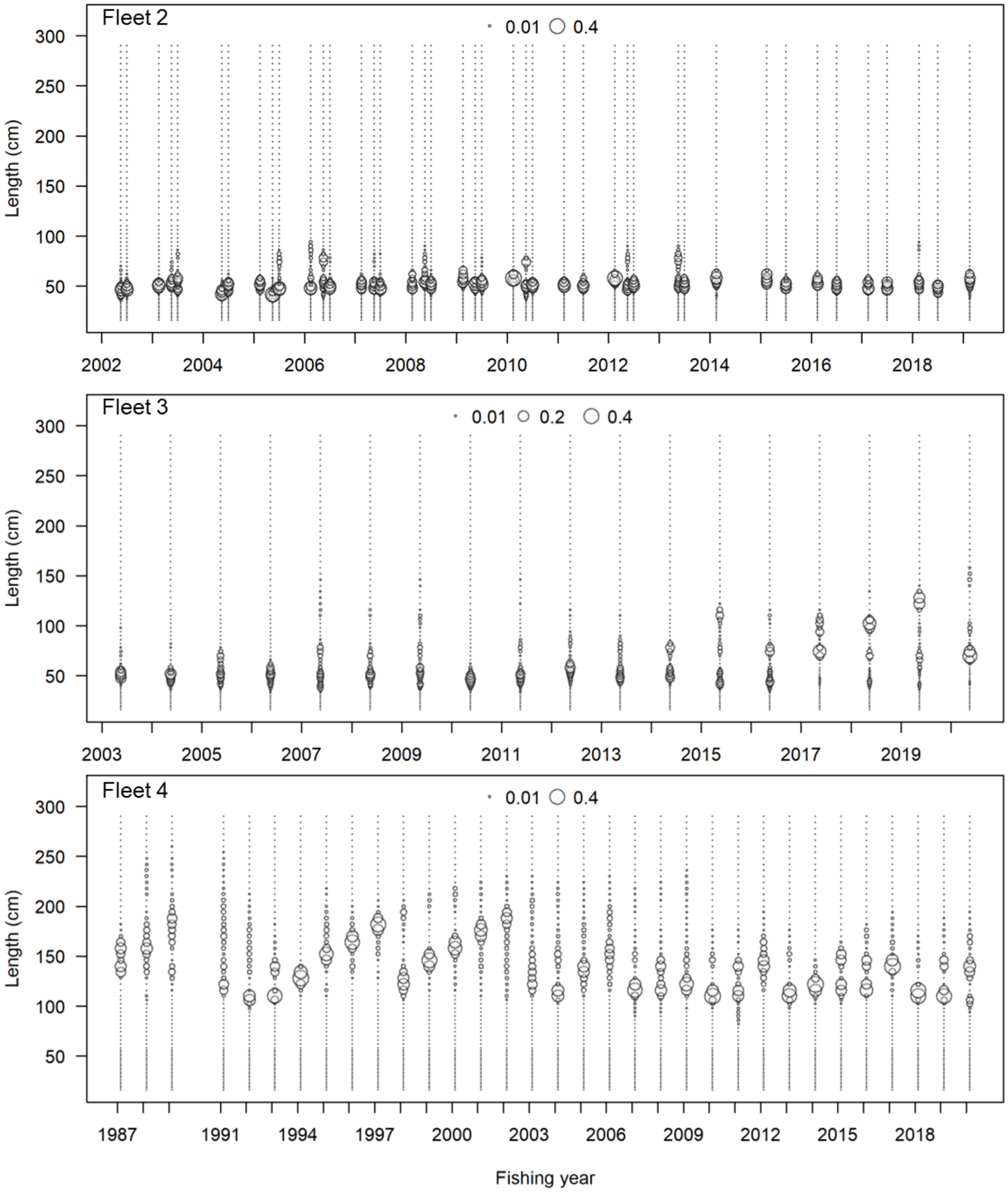


**Figure 3-5.** Cont.

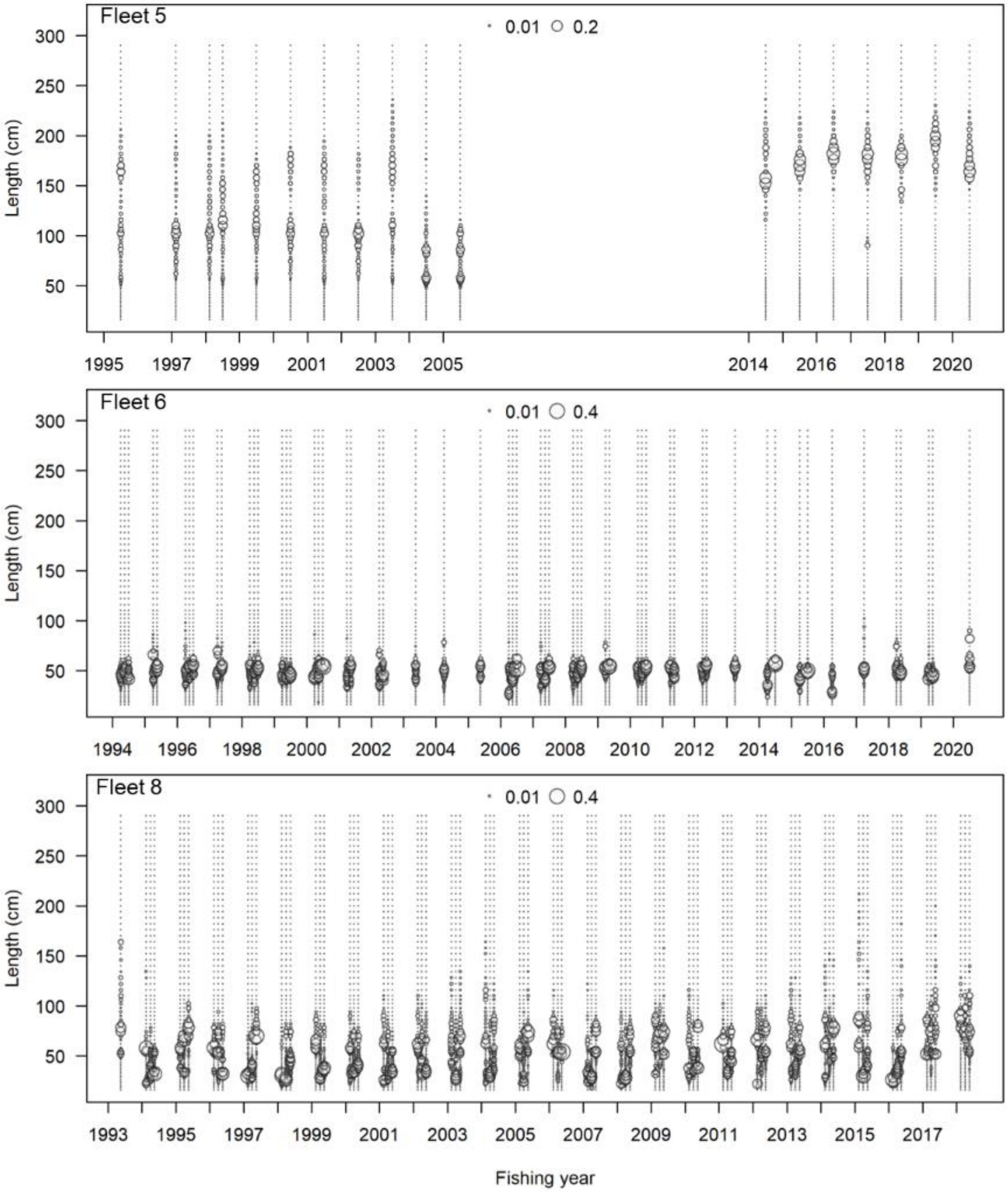


**Figure 3-5.** Cont.

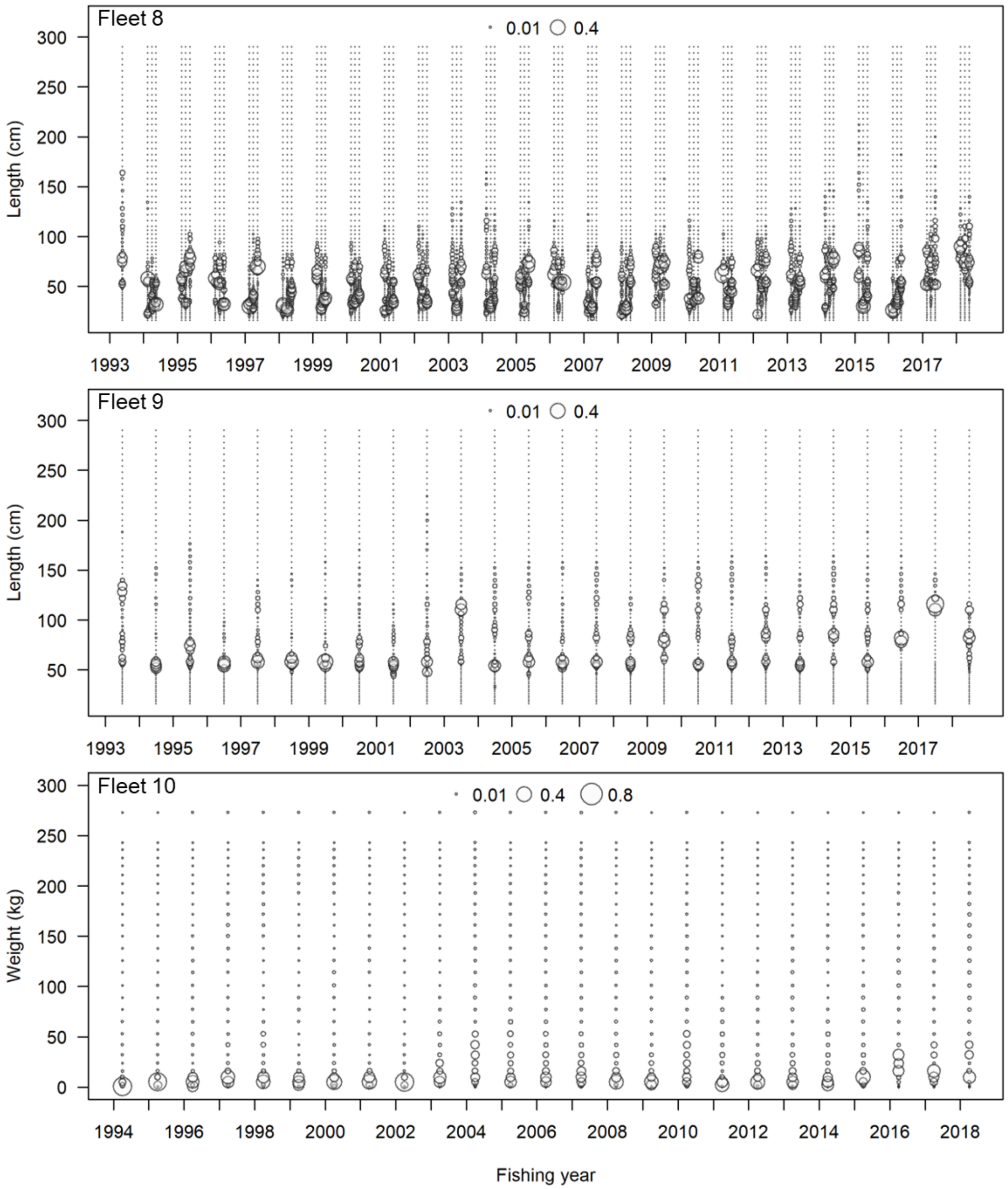


**Figure 3-5.** Cont.

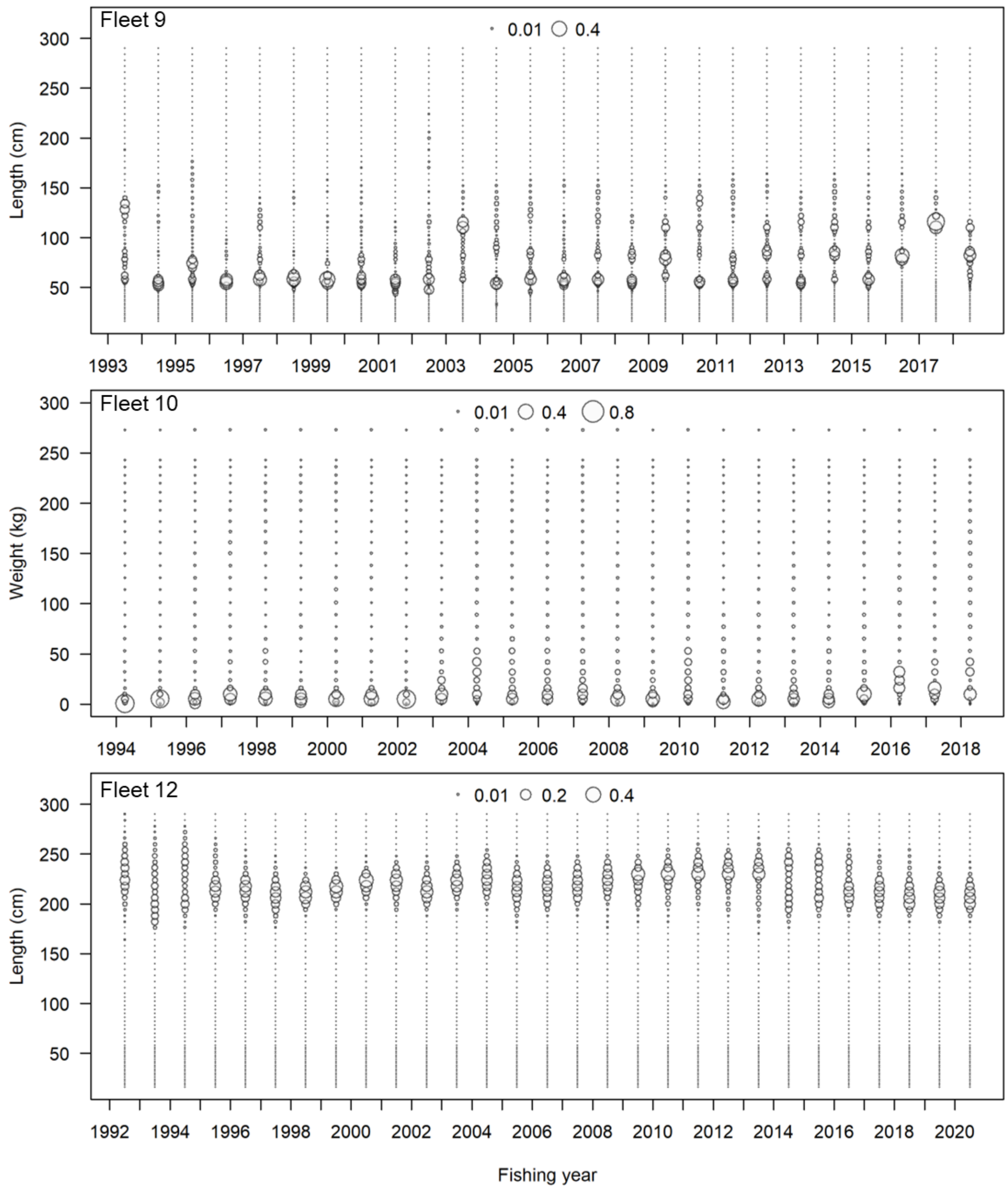


**Figure 3-5.** Cont.

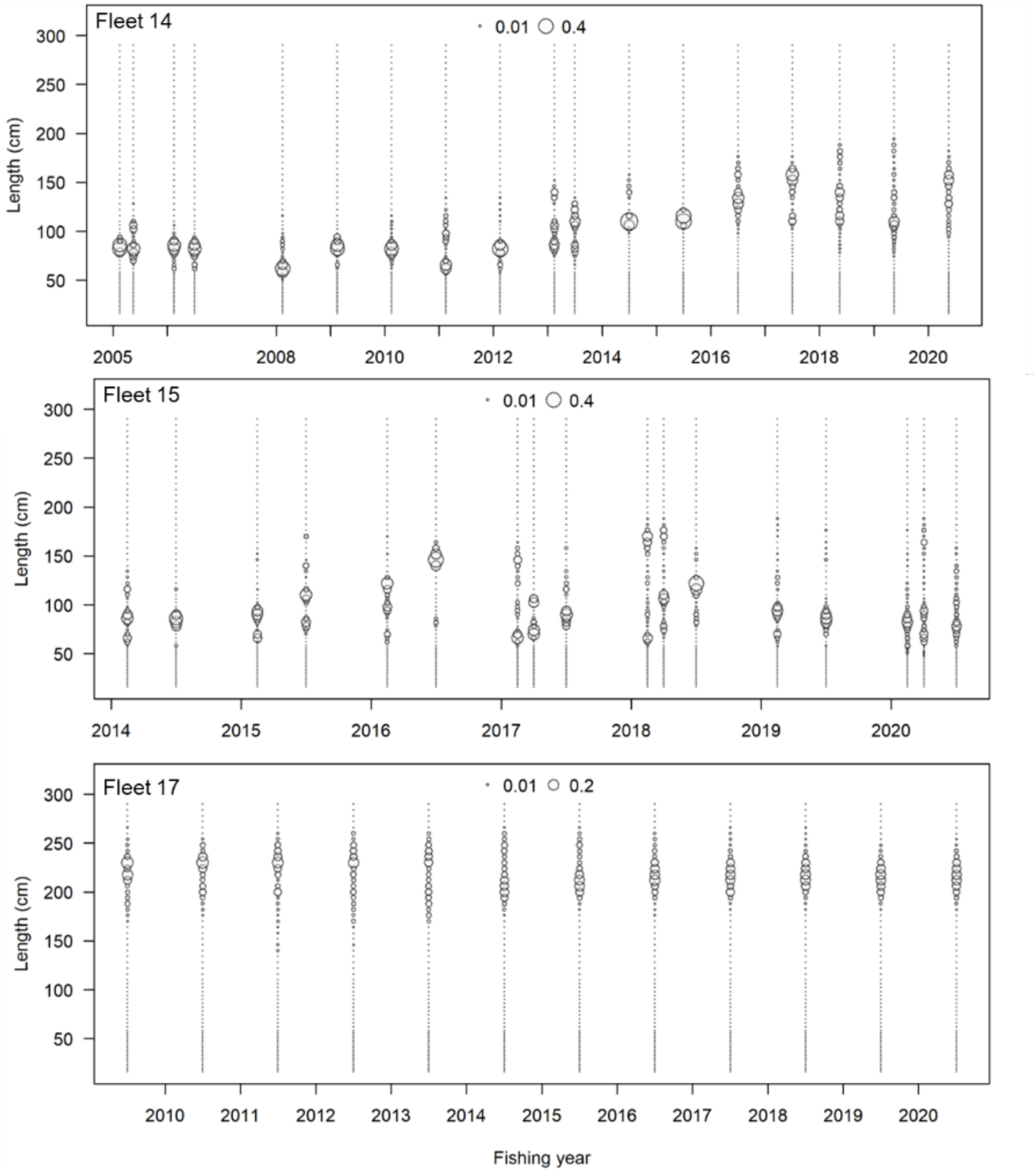


**Figure 3-5.** Cont.

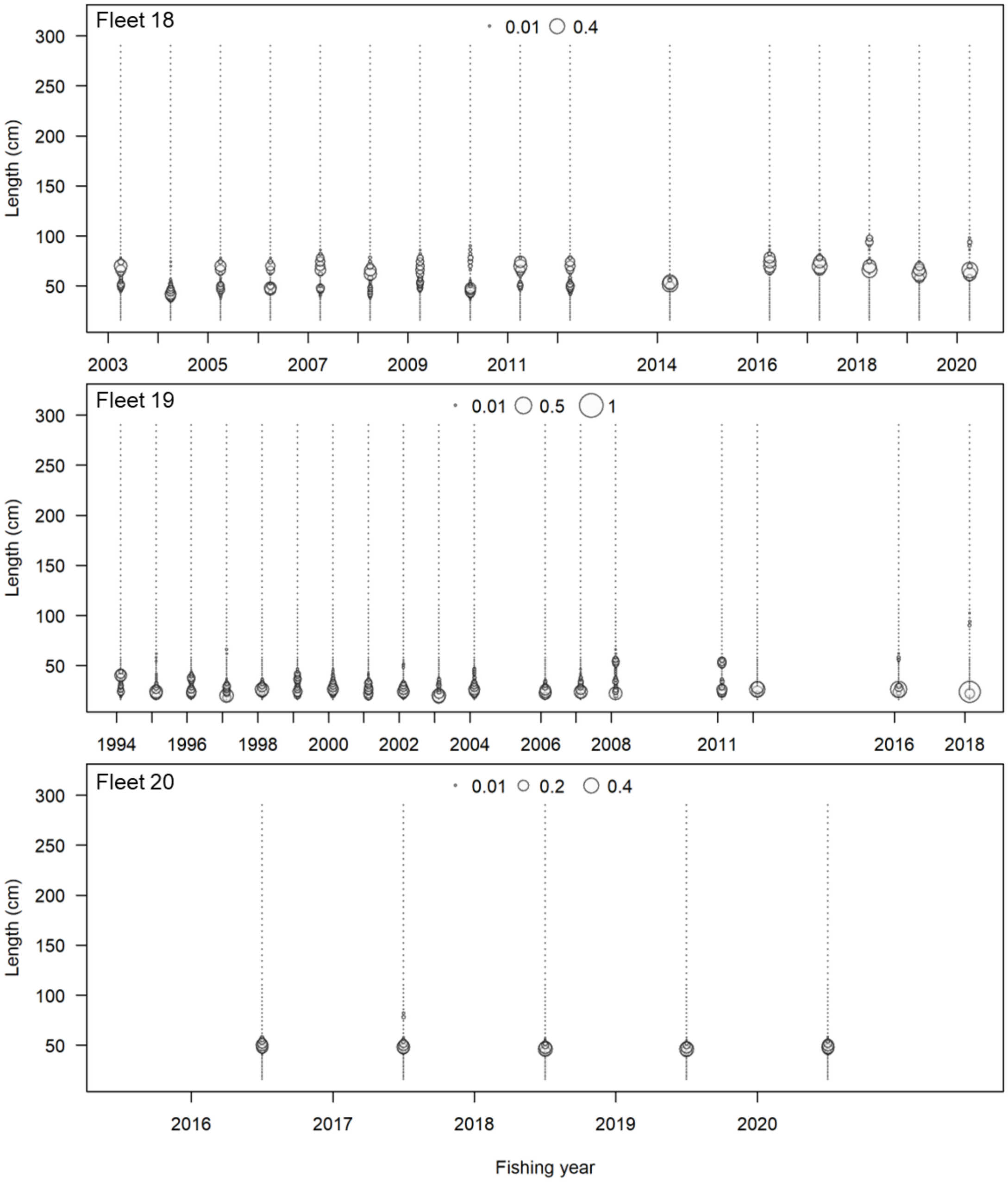


**Figure 3-5.** Cont.

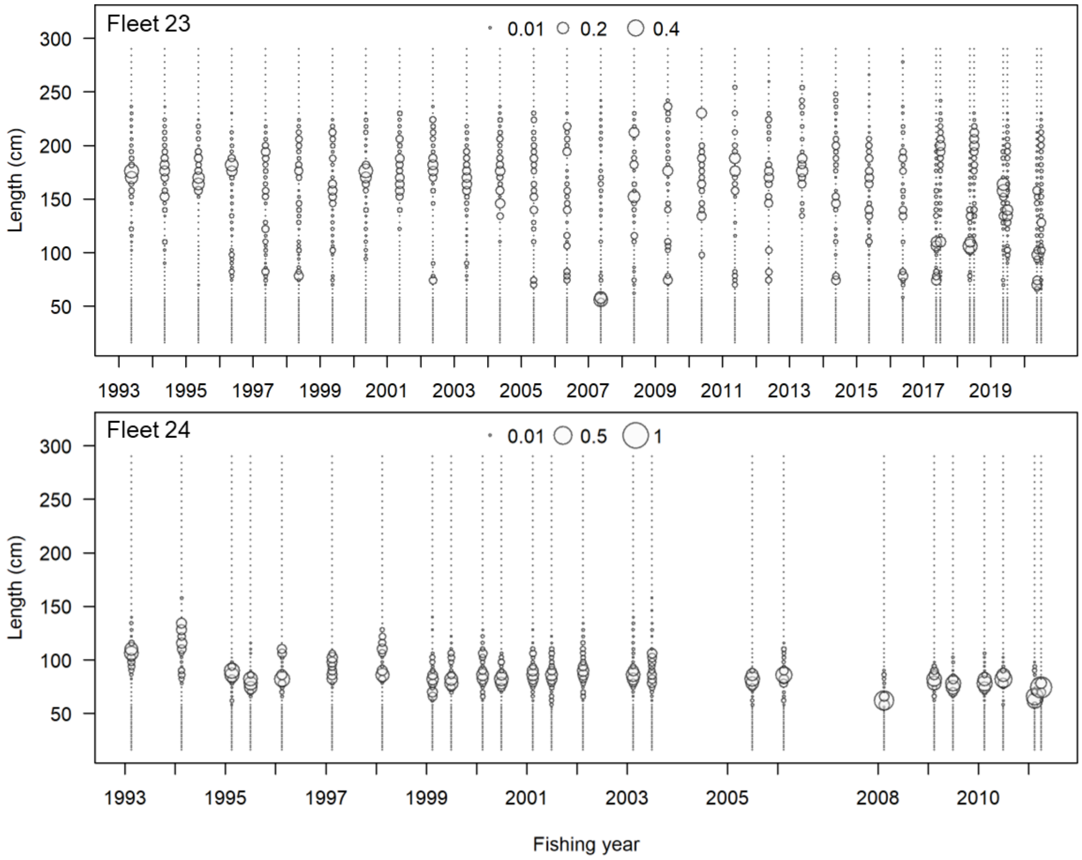


**Figure 3-5.** Cont.

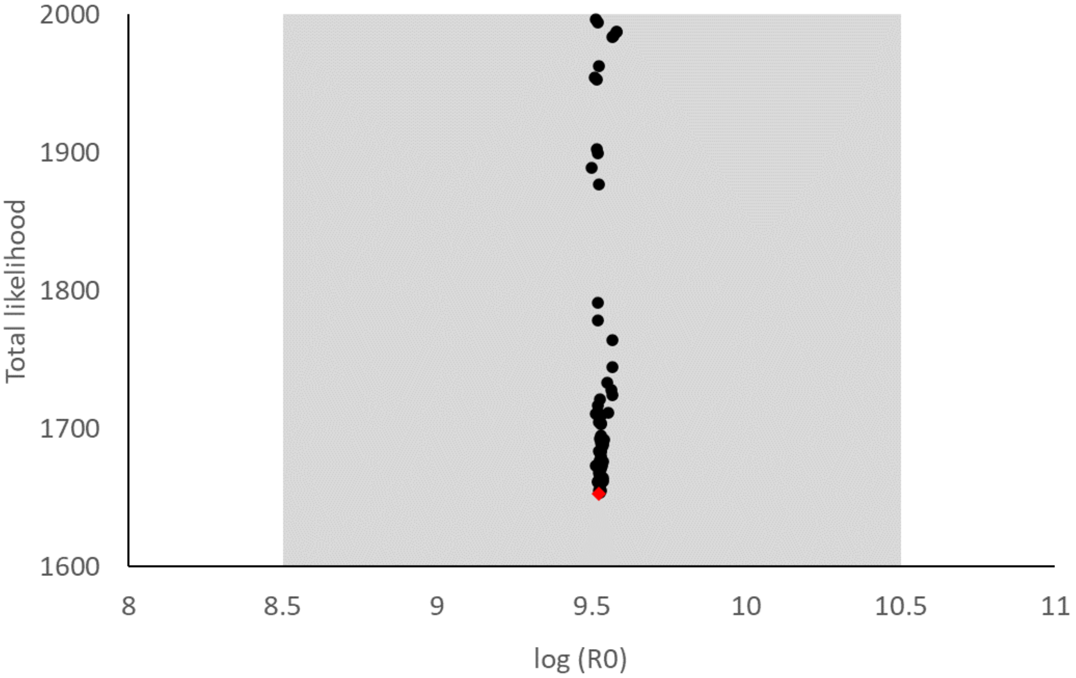


**Figure 5-1.** Effects of random perturbations of initial values on estimated log ($R_0$) and total likelihood by the base-case model for Pacific bluefin tuna (*Thunnus orientalis*). Red circle represents the value of the base-case model. Gray shaded area shows a range of log ($R_0$) in which the model explorations for the starting value of log ($R_0$) were conducted.

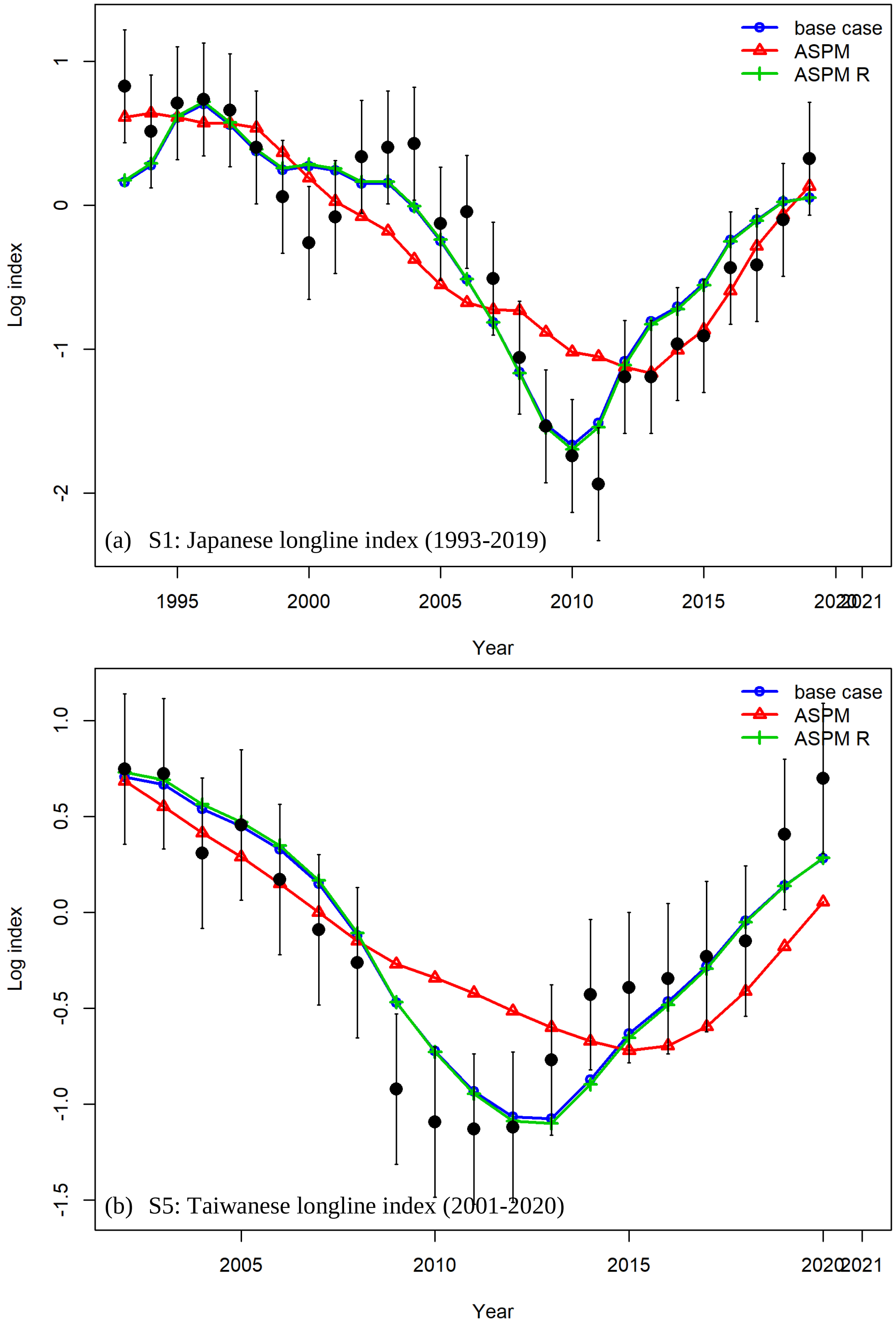


**Figure 5-2**. Comparisons of the (a) Japanese longline index and (b) Taiwanese longline index predicted by the base-case model (blue), age structured production model (ASPM; red) and ASPM with annual recruitment deviations specified at those estimated in the base-case model (ASPM R; right green). Black closed circles with error bars represent the observed abundance indices with 95% CI).

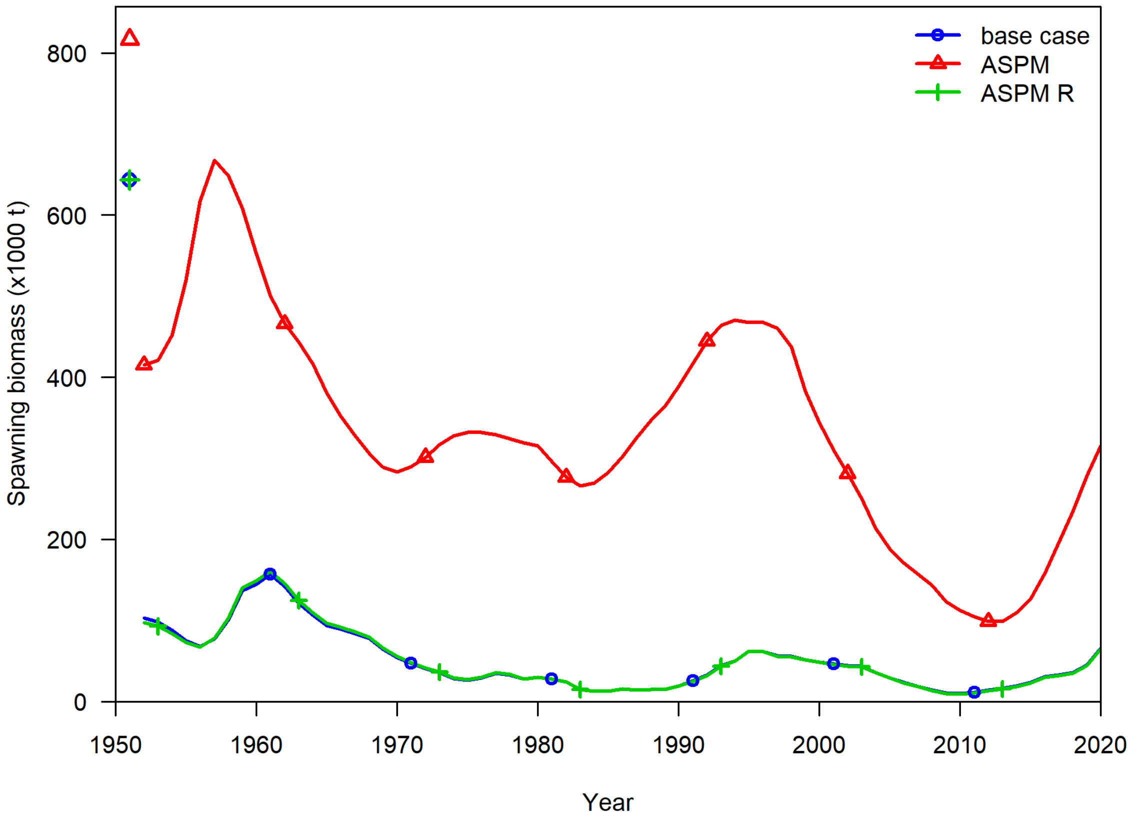


**Figure 5-3**. Unfished spawning stock biomass (open plots with vertical bars) and spawning stock biomass of Pacific bluefin tuna (*Thunnus orientalis*) for the base-case model (blue), age structured production model (ASPM; red) and ASPM with annual recruitment deviations specified at those estimated in the base-case model (ASPM R; right green).

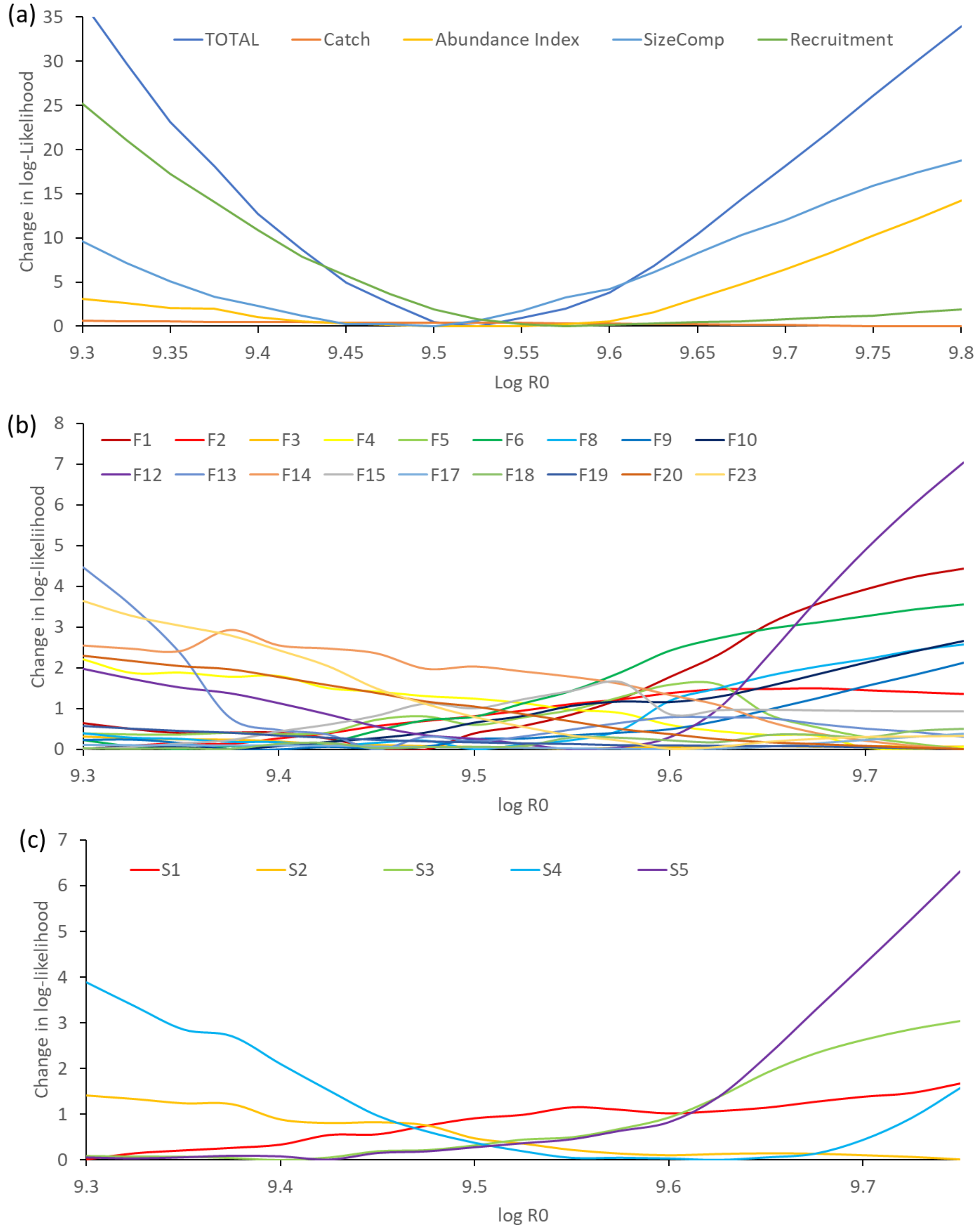


**Figure 5-4.** Profiles of (a) total and component likelihoods (b) likelihood for each size composition component and (c) likelihood for each index component over fixed log($R_0$) for the base-case model of Pacific bluefin tuna (*Thunnus orientalis*).

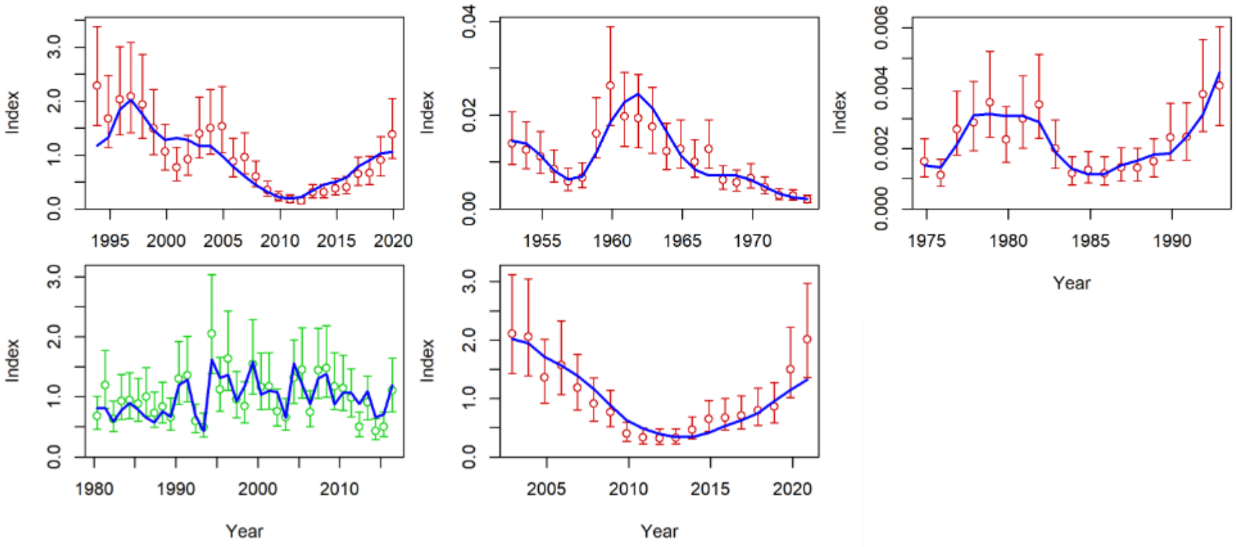


**Figure 5-5.** Predicted (blue lines) and observed (open dots) abundance indices for the base-case model of Pacific bluefin tuna (*Thunnus orientalis*), where vertical lines represent the 95% CI of observations.

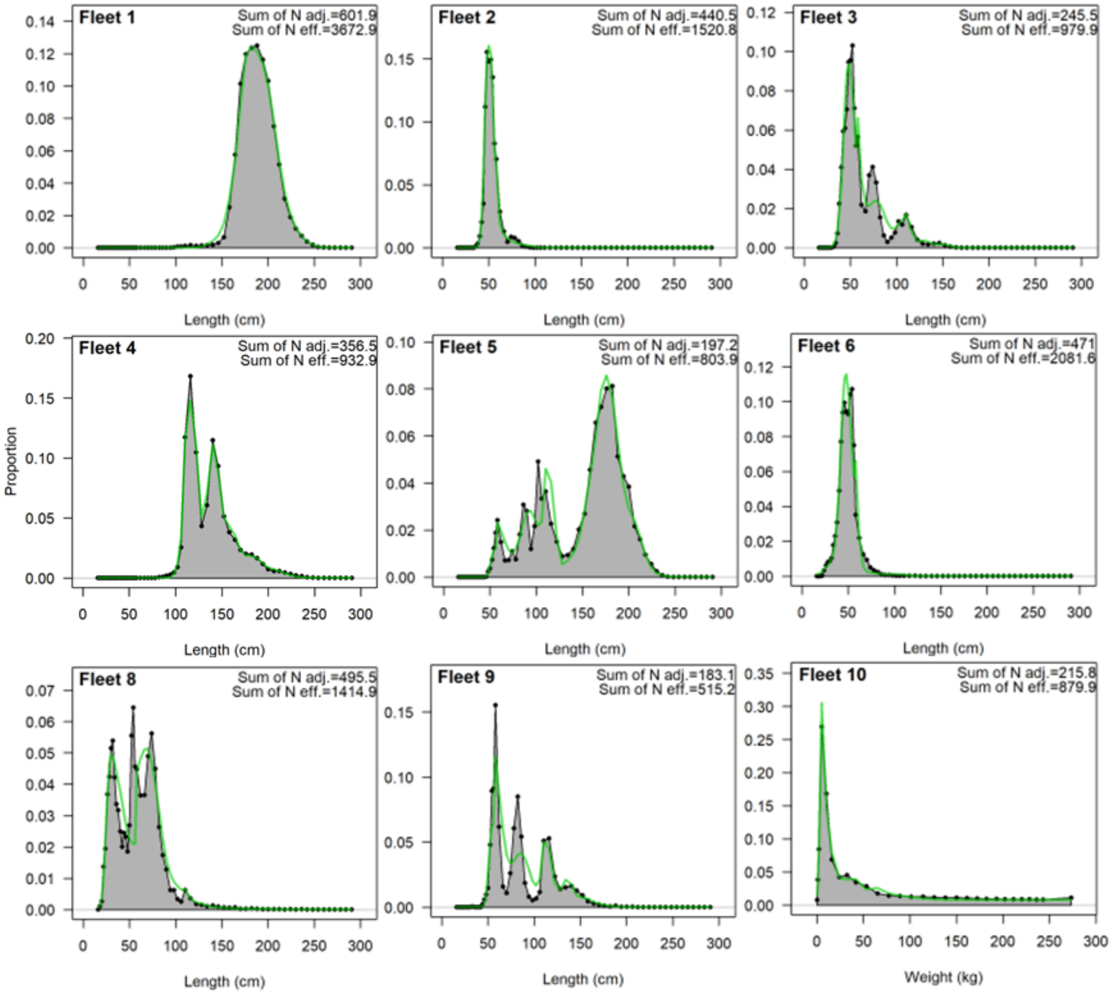


**Figure 5-6.** Overall fits (green line) to the size compositions by fleet across seasons in the base-case model for Pacific bluefin tuna (*Thunnus orientalis*), where grey areas indicate the observations.

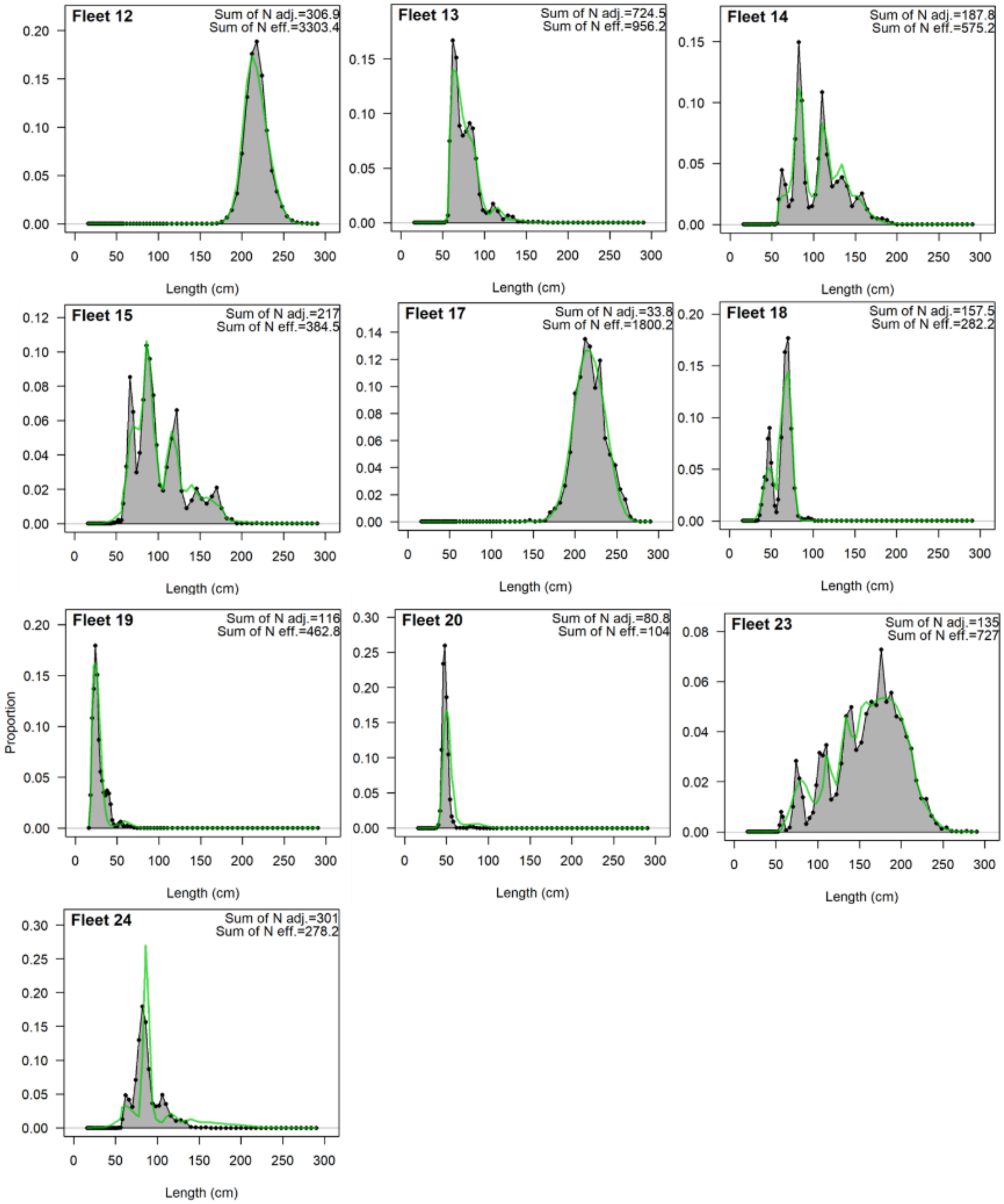


**Figure 5-6.** Cont.

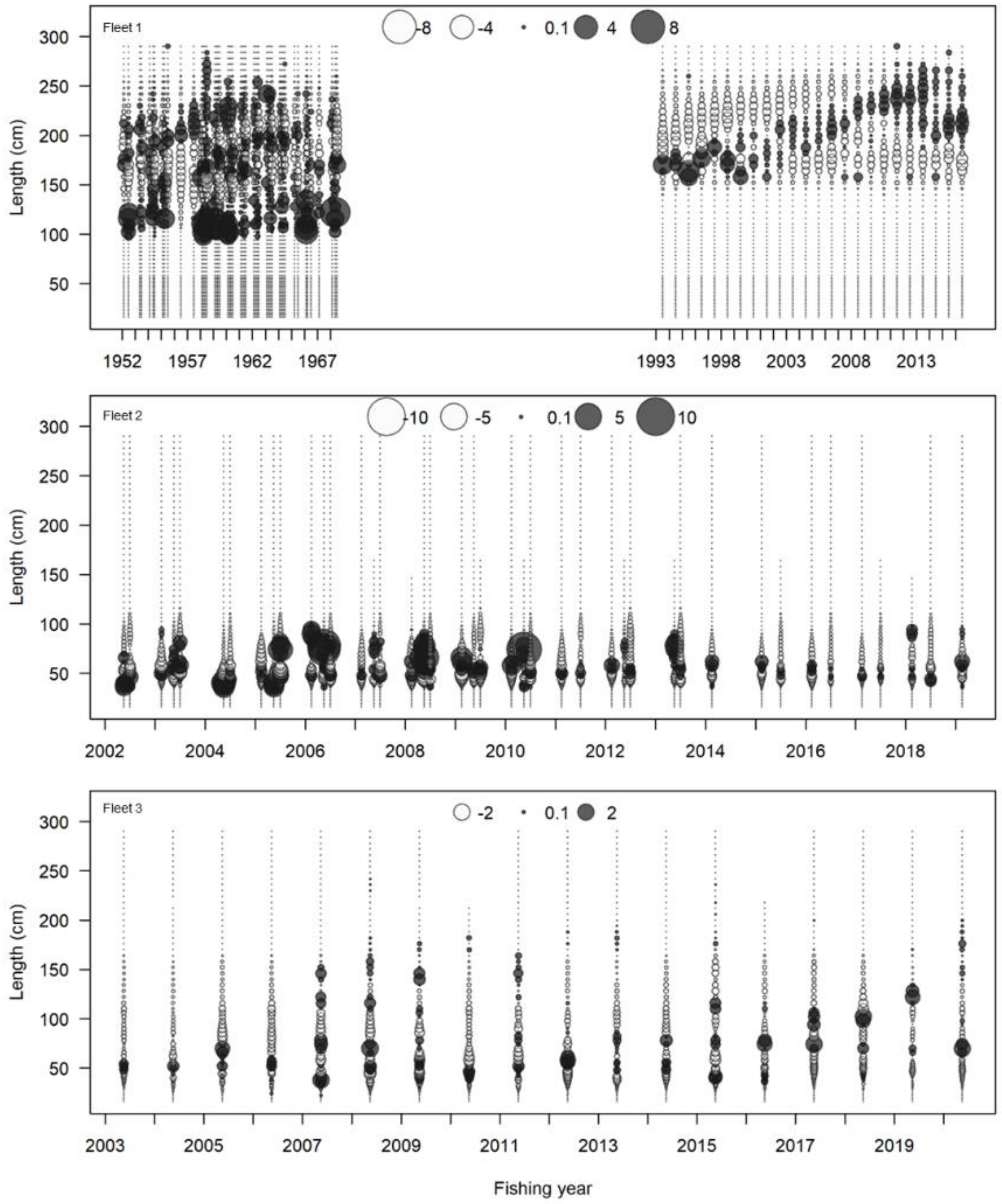


**Figure 5-7.** Pearson residual plots of model fits to the size composition data of Pacific bluefin tuna (*Thunnus orientalis*) by fishery. The hollow and filled circles represent observations that are higher and lower than the model predictions, respectively. The areas of the circles are proportional to the absolute values of the residuals.

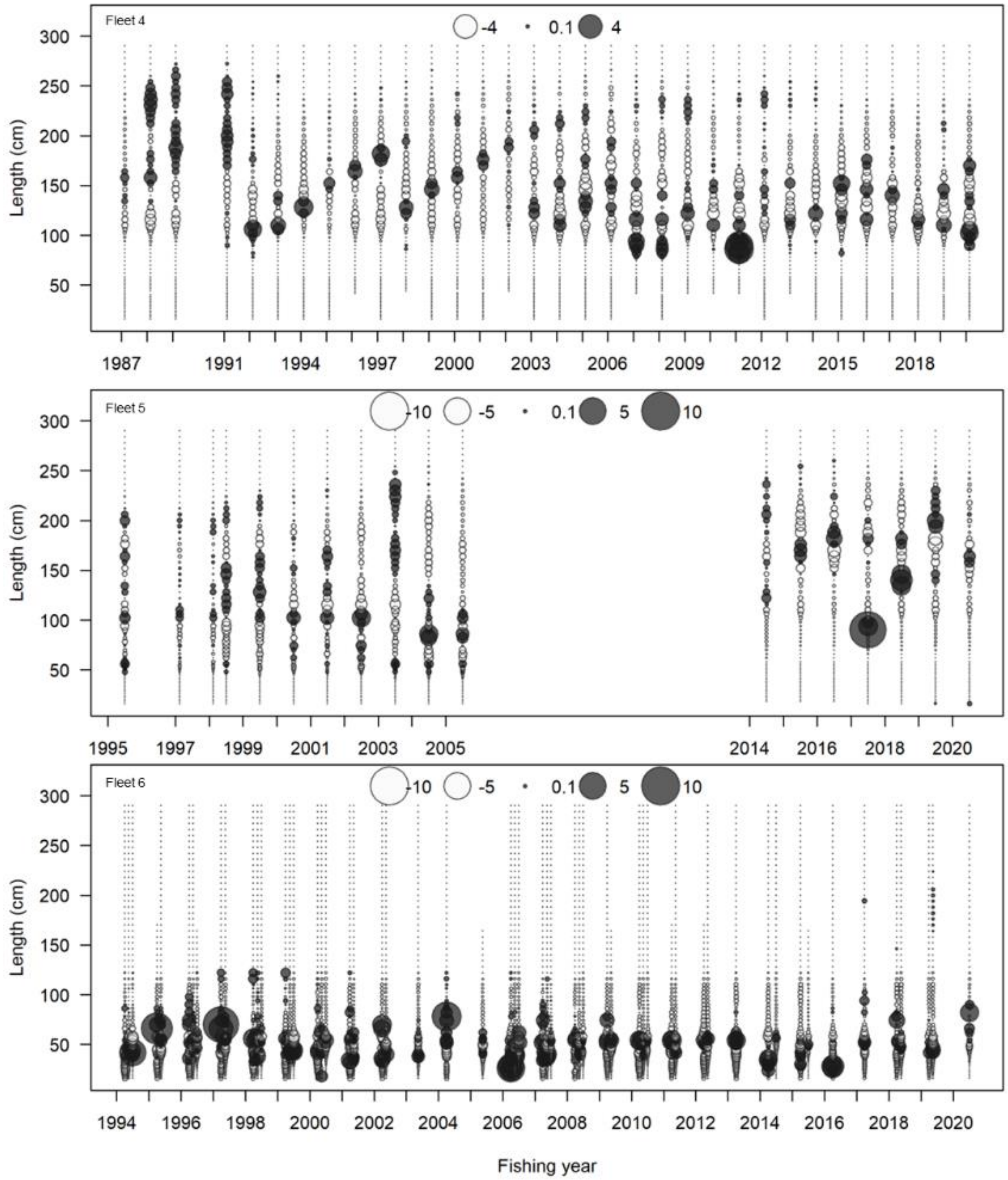


**Figure 5-7.** Cont.

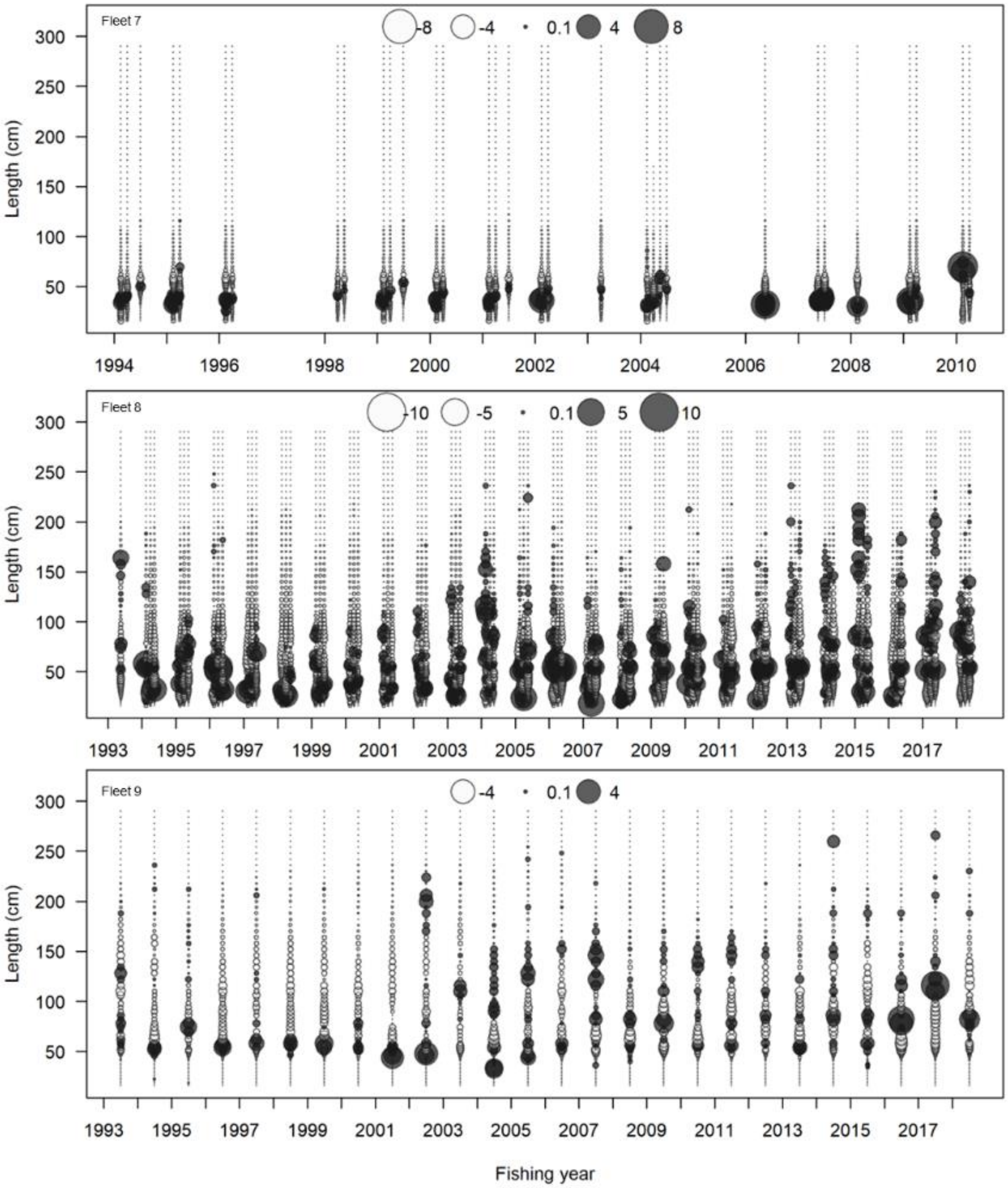


**Figure 5-7.** Cont.

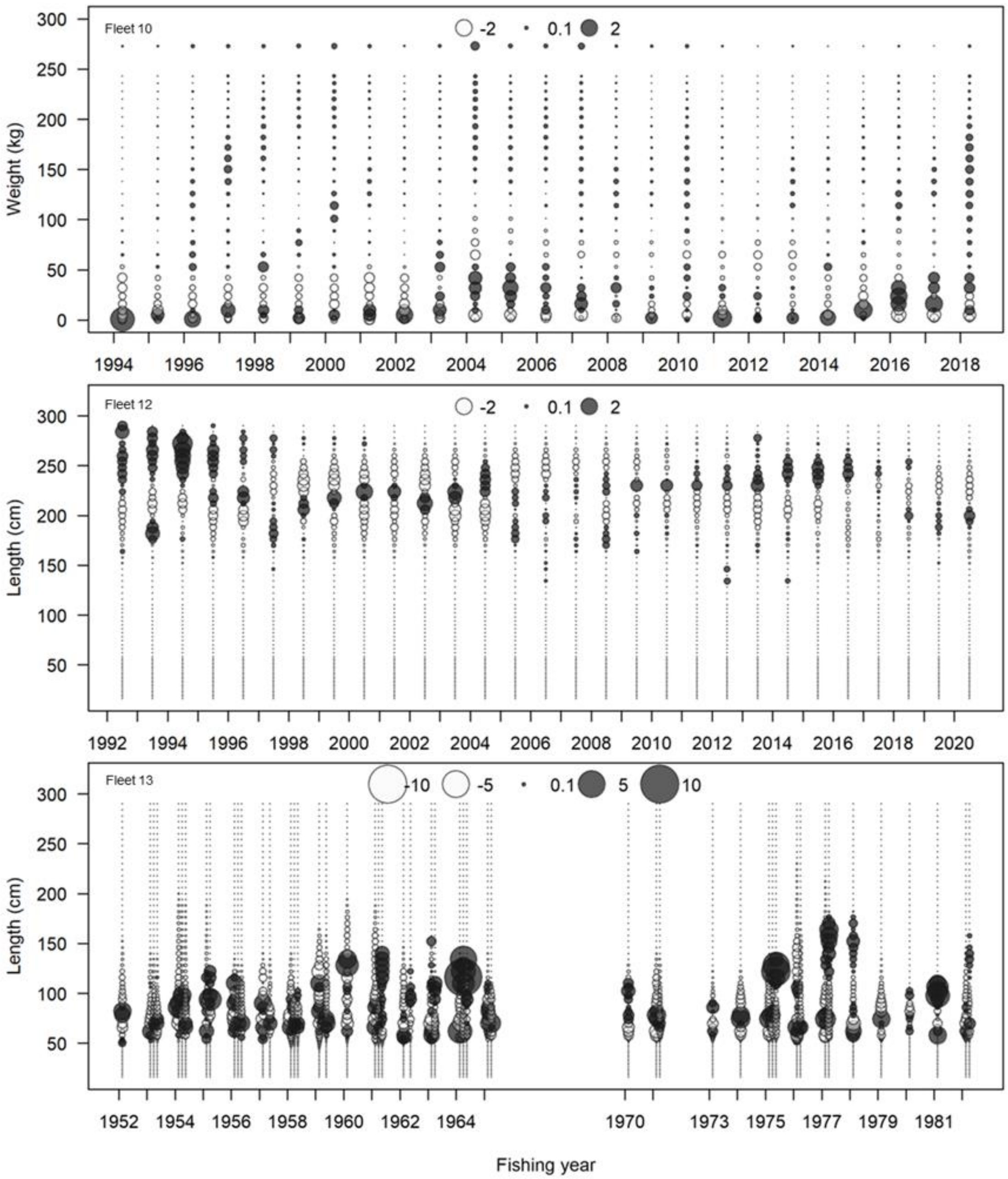


**Figure 5-7.** Cont.

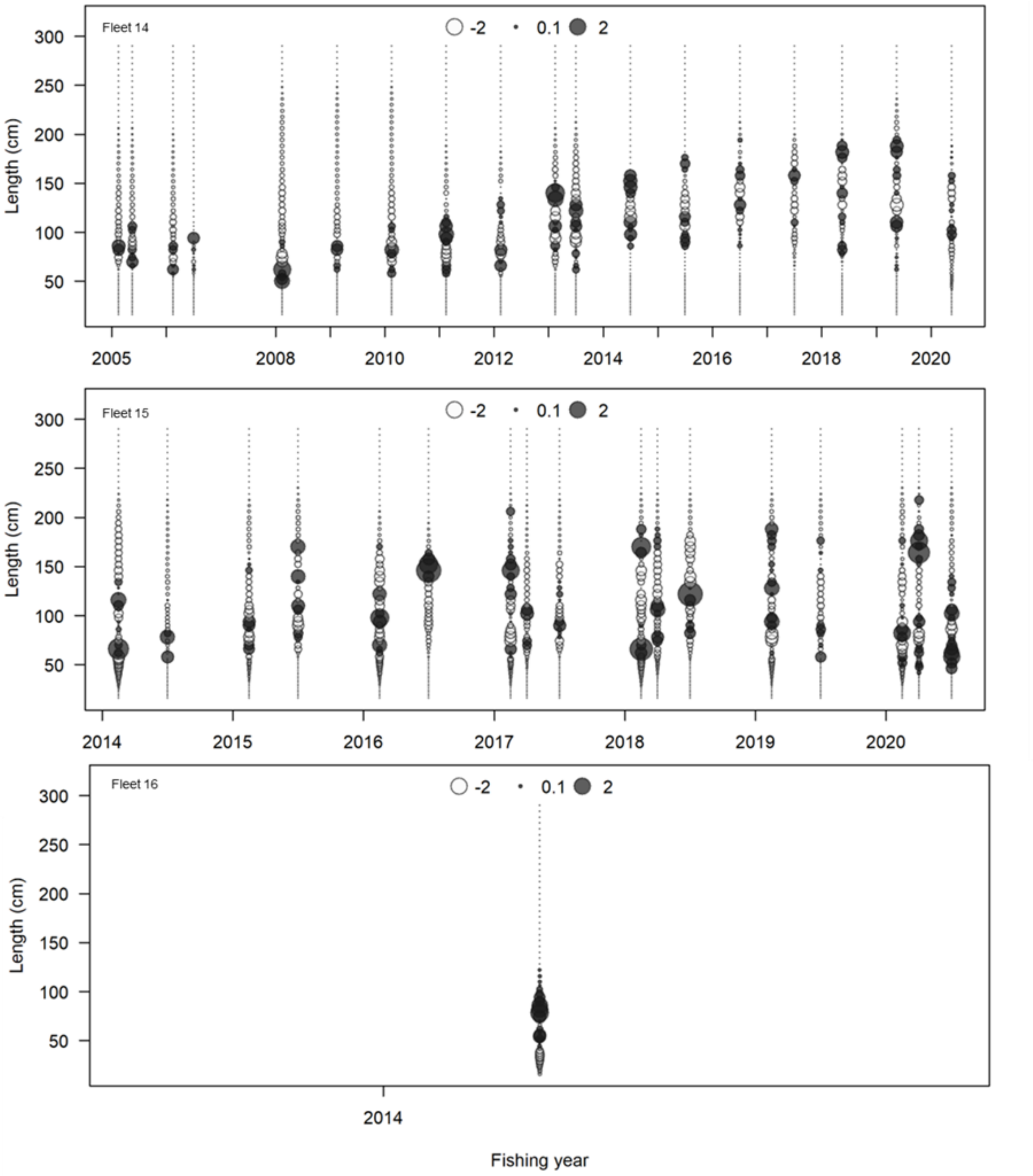


**Figure 5-7.** Cont.

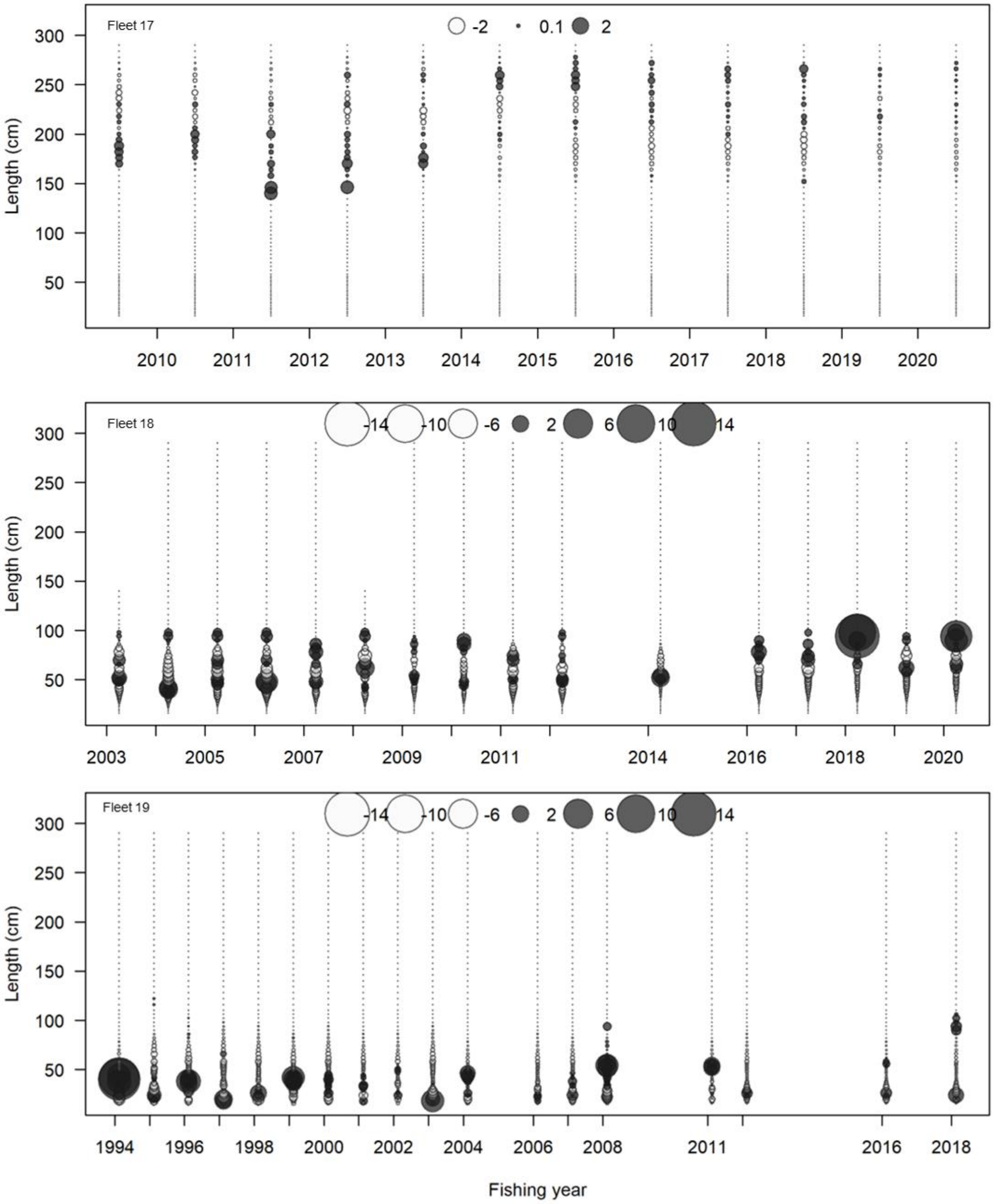


**Figure 5-7.** Cont.

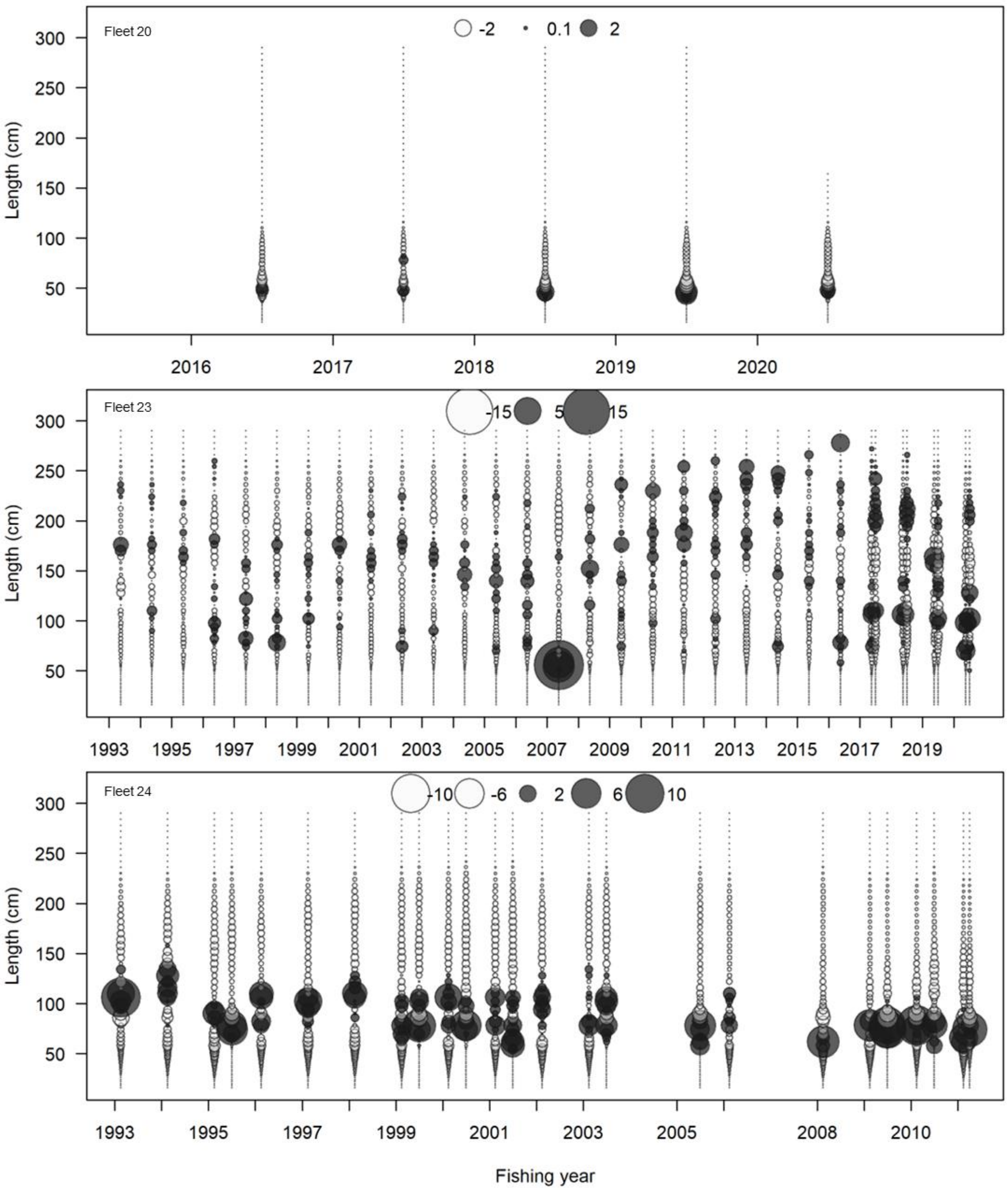
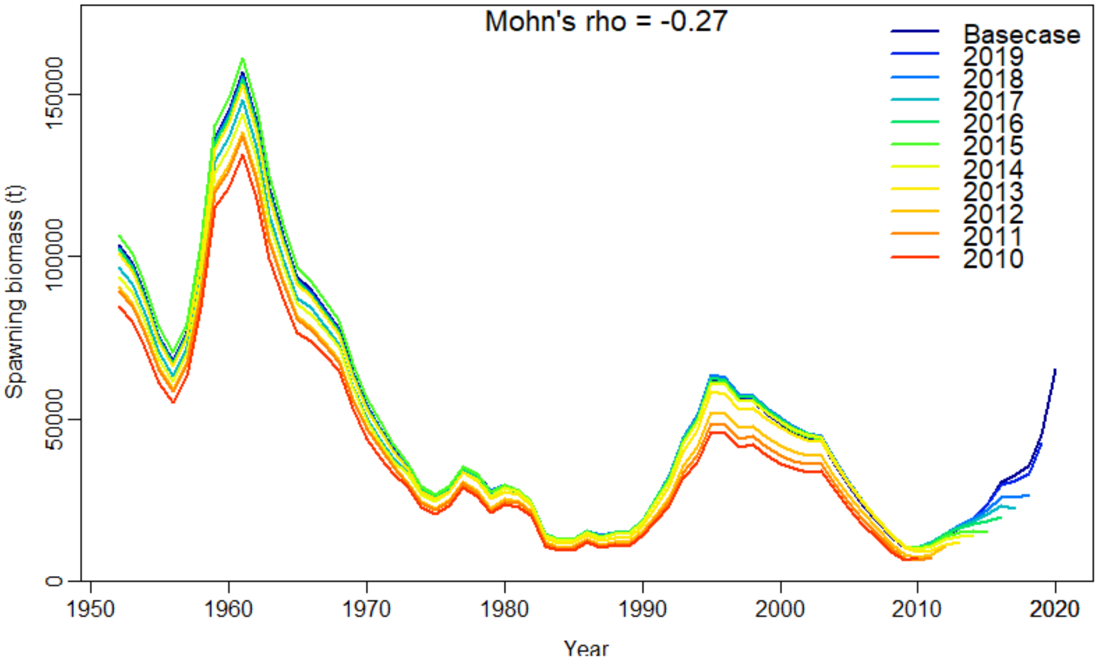


**Figure 5-7.** Cont.

(a)



(b)

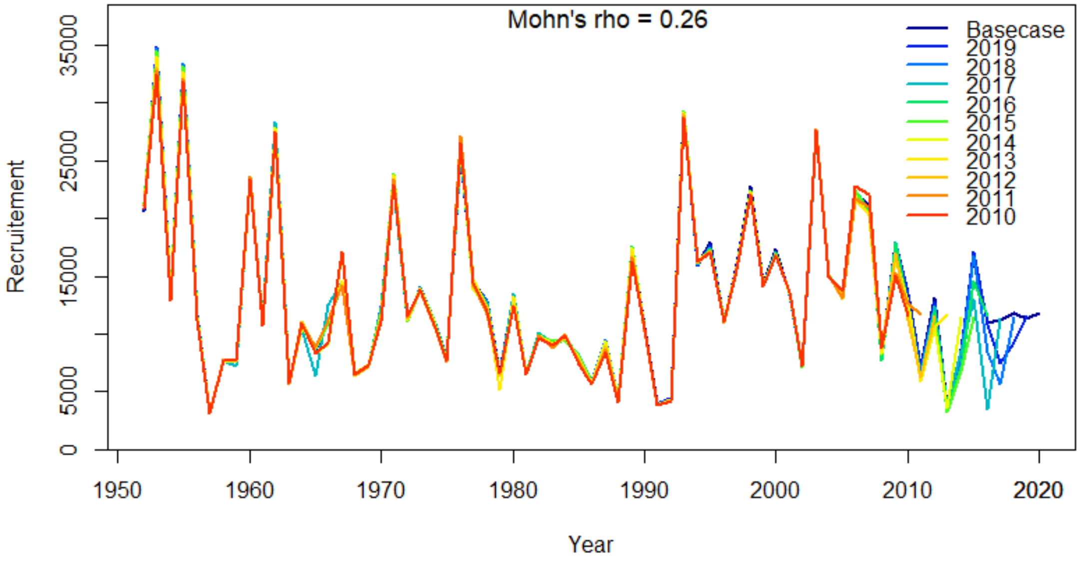


**Figure 5-8.** Nine-year retrospective analysis of the (a) spawning stock biomass and (b) Recruitment of Pacific bluefin tuna (*Thunnus orientalis*) from the base-case.

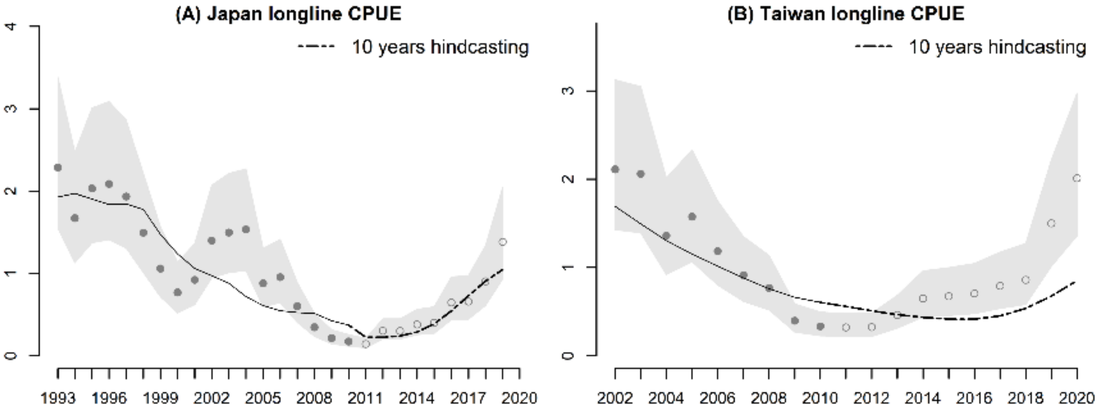


**Figure 5-9.** The expected (black solid lines) and predicted (black dashed lines) (A) Japan longline CPUE and (B) Taiwan longline CPUE from the age-structured production models, where CPUE observations were removed for the recent 10 years (hindcasting the recent 10 years based on the catch at age). The solid circles represent the observations used in the models, open circles represent the missing values, and gray areas represent associated 95% confidence intervals.

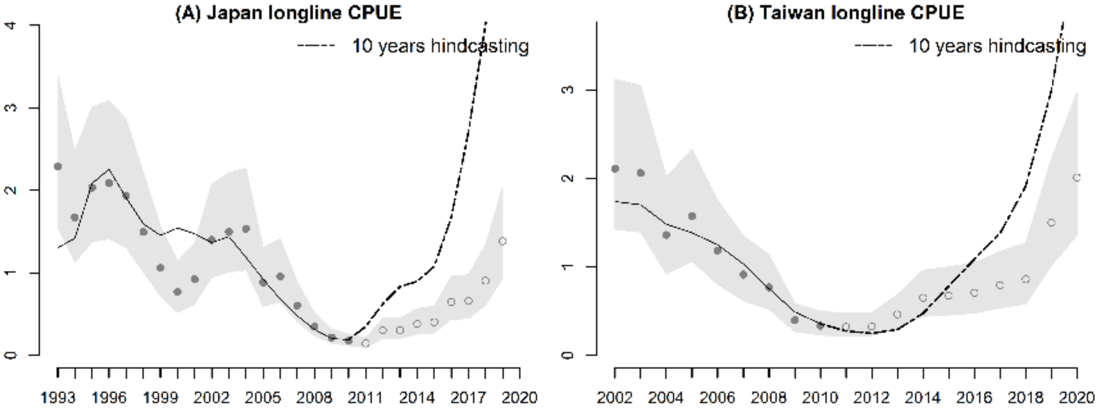


**Figure 5-10.** The expected (black solid lines) and predicted (black dashed lines) (A) Japan longline CPUE and (B) Taiwan longline CPUE from the full dynamics models, where CPUE and size composition observations were removed for the recent 10 years (hindcasting the recent 10 years based on the catch at age). The solid circles represent the observations used in the models, open circles represent the missing values, and gray areas represent associated 95% confidence intervals.

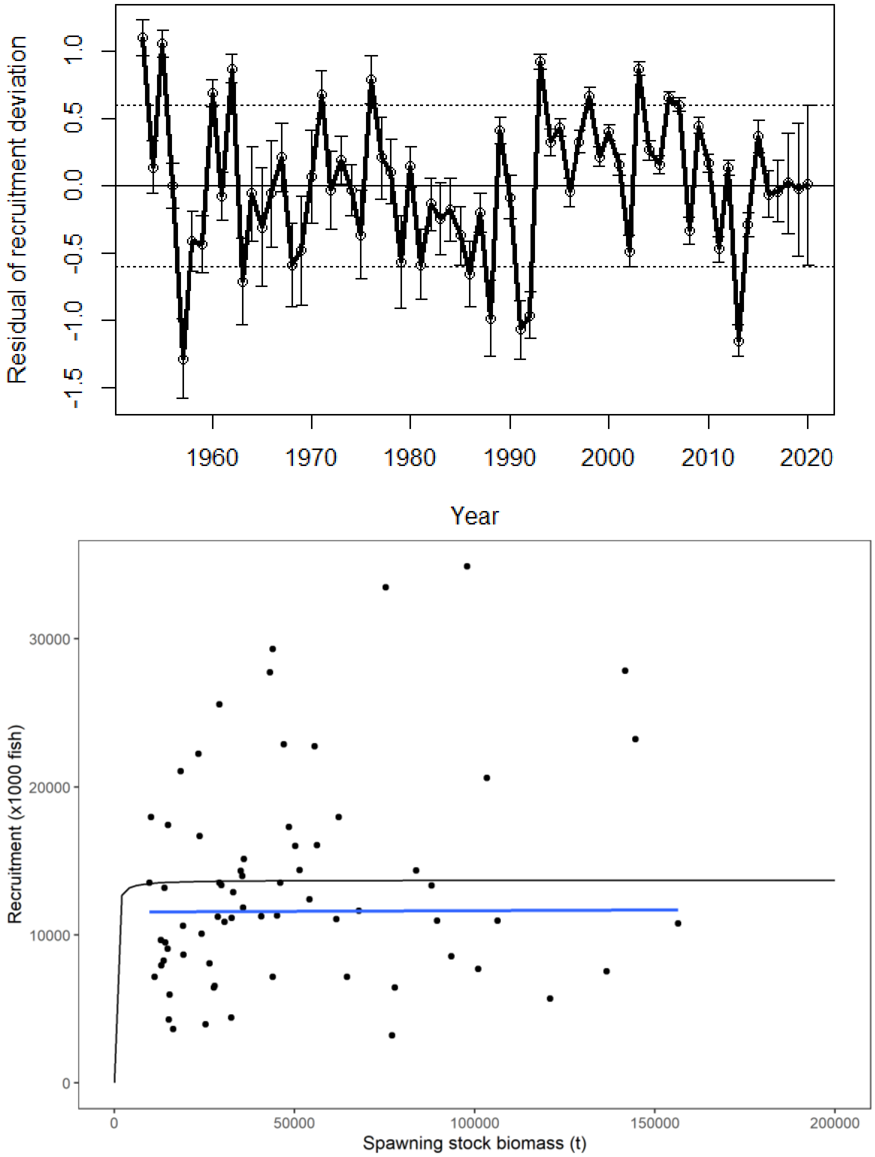


**Figure 5-11.** Time series of recruitment deviations in log space (upper panel) and spawning stock-recruitment relationship (lower panel) in the base-case stock assessment model for Pacific bluefin tuna (*Thunnus orientalis*). In the upper panel, vertical lines are the 95% CI and horizontal dotted lines indicate $\sigma_R$ and $-\sigma_R$. In the lower panel, open circles are the paired estimates of spawning stock biomass and recruitment. Black line and blue line indicate the Beverton-Holt stock recruitment relationship estimated in the base-case and expected recruitment after bias adjustment corresponding to above relationship.

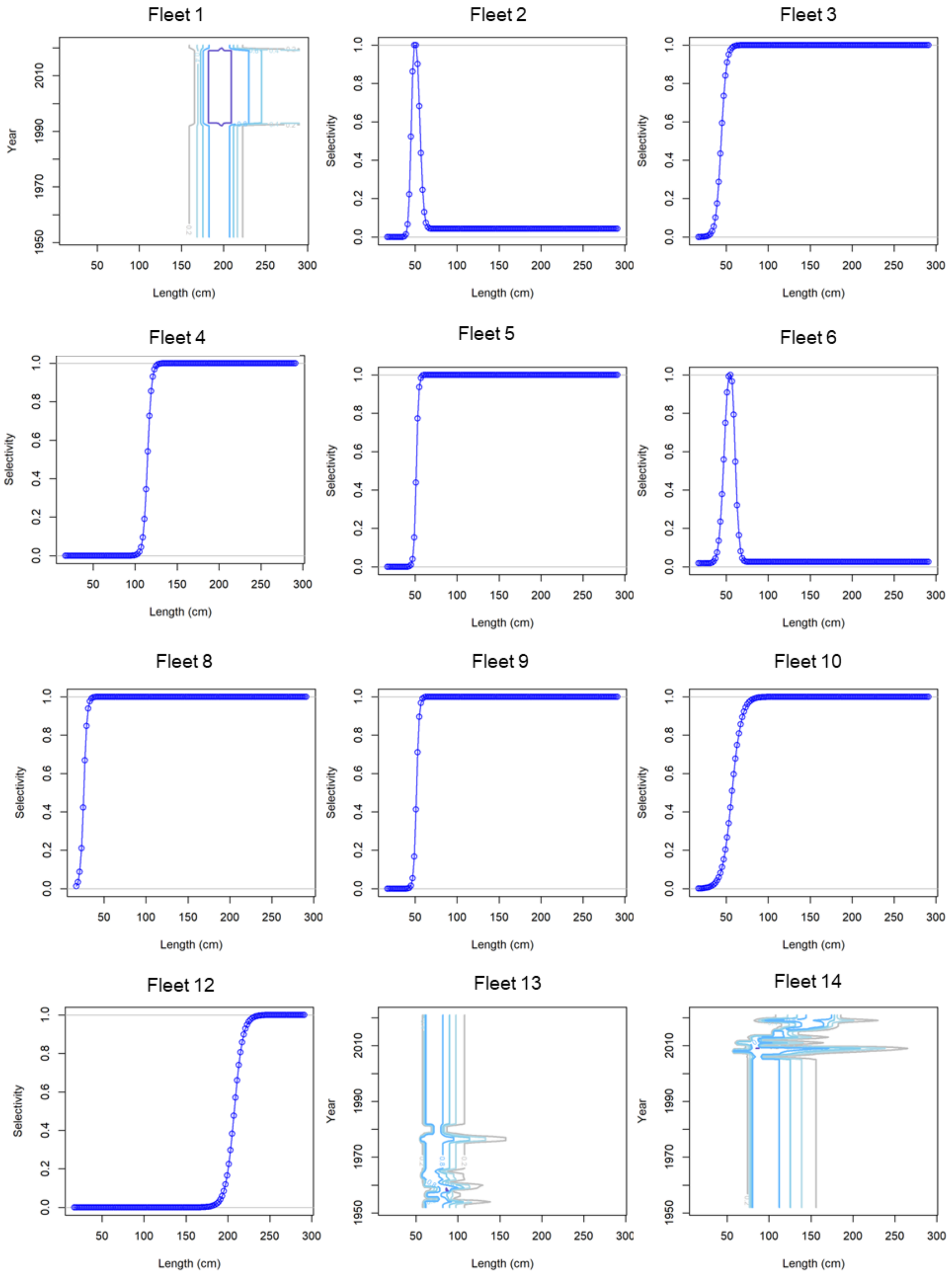


**Figure 5-12.** Size selectivity for Pacific bluefin tuna (*Thunnus orientalis*) by fishery from the base case. Fisheries with time-varying selectivity patterns are displayed in contour plots.

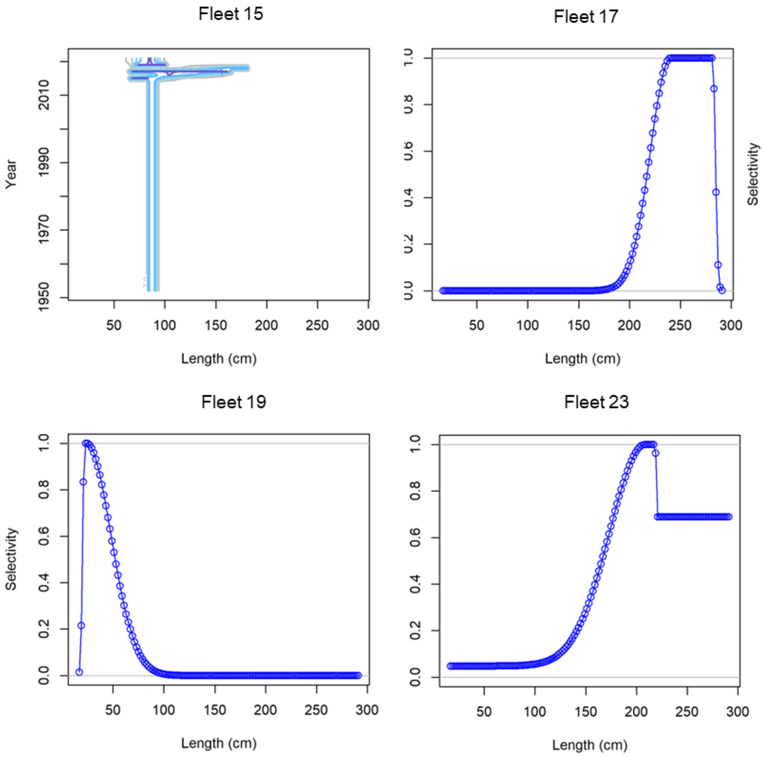


**Figure 5-12.** Cont.

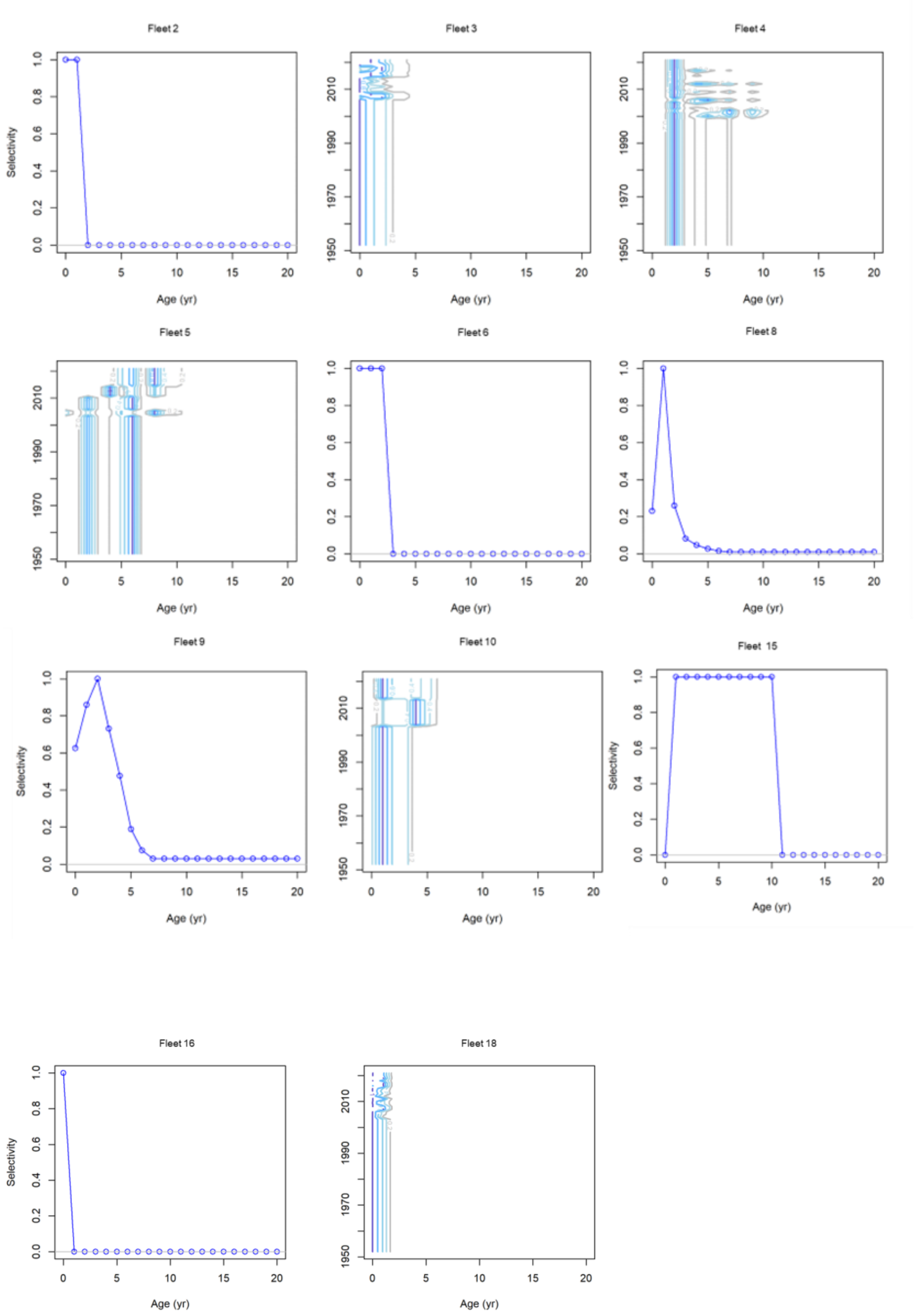


**Figure 5-13.** Age based selectivity for Pacific bluefin tuna (*Thunnus orientalis*) by fishery. Fisheries with time-varying selectivity patterns are displayed in contour plots.

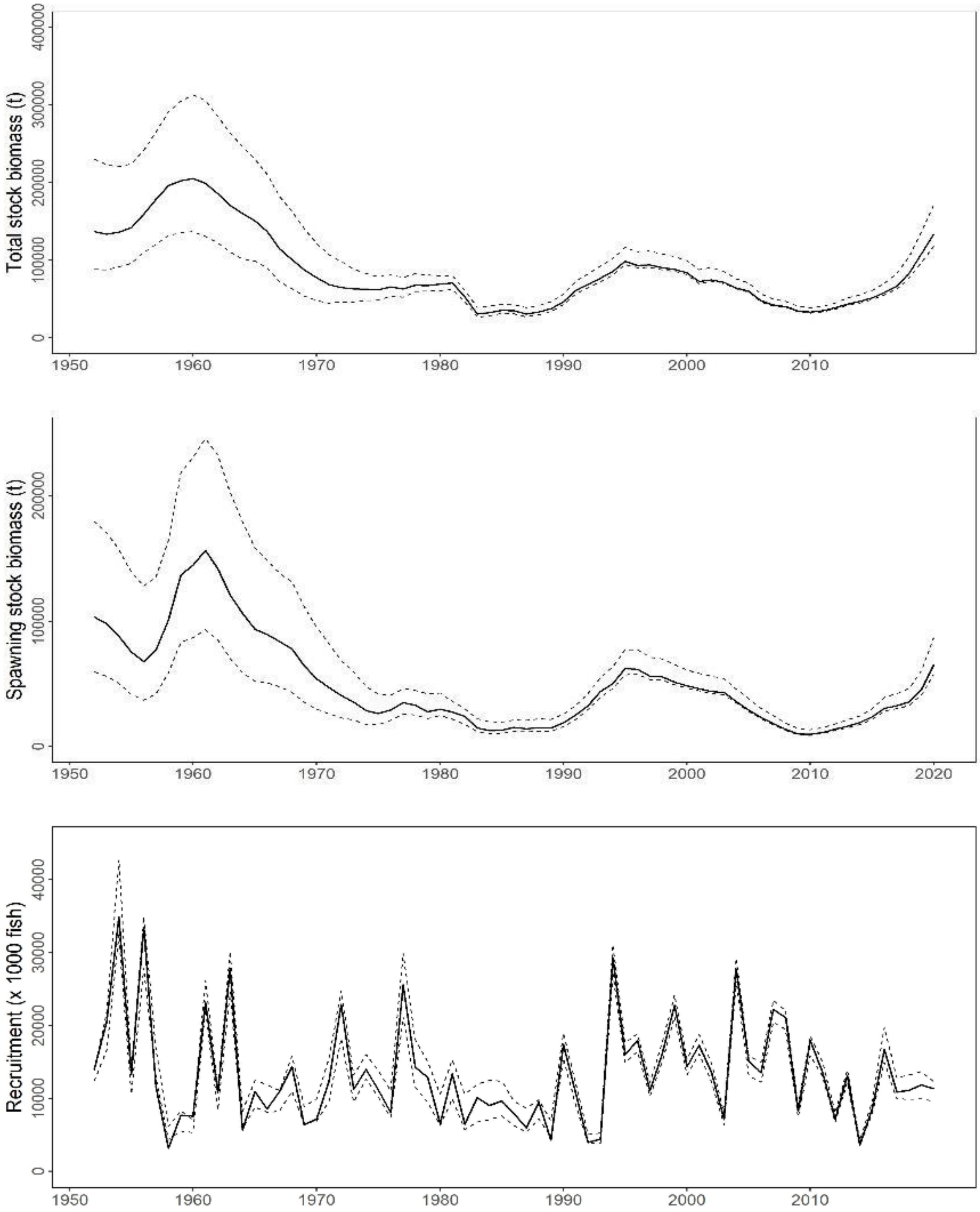


**Figure 5-14.** Total stock biomass (top), spawning stock biomass (middle) and recruitment (bottom) of Pacific bluefin tuna (*Thunnus orientalis*) from the base-case model. The solid line indicates point estimate and dashed lines indicate the 90% confidence interval.

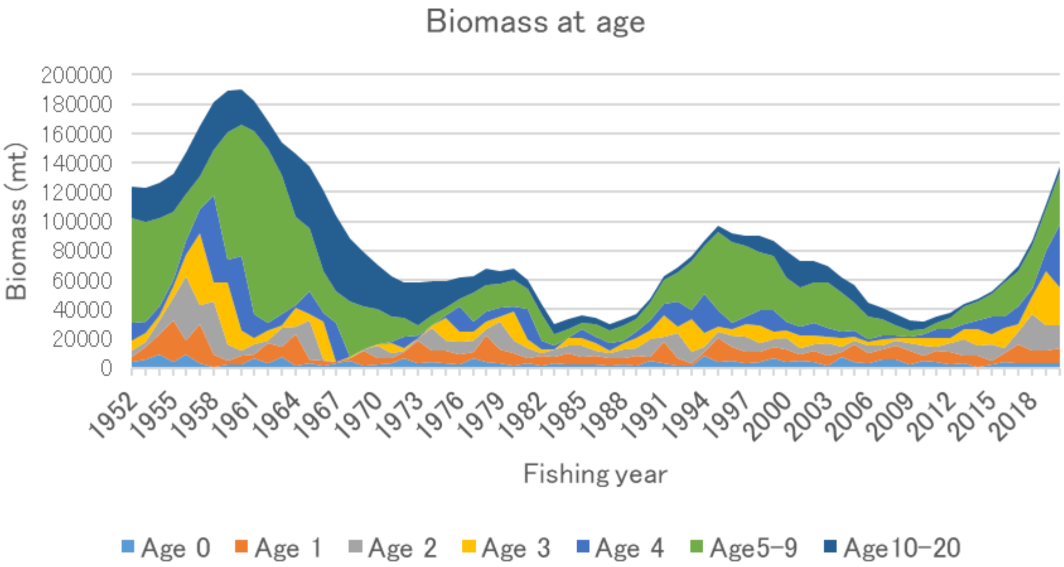


**Figure 5-15.** Total biomass (ton) by age of Pacific bluefin tuna (*Thunnus orientalis*) estimated from the base-case model (1952-2020).

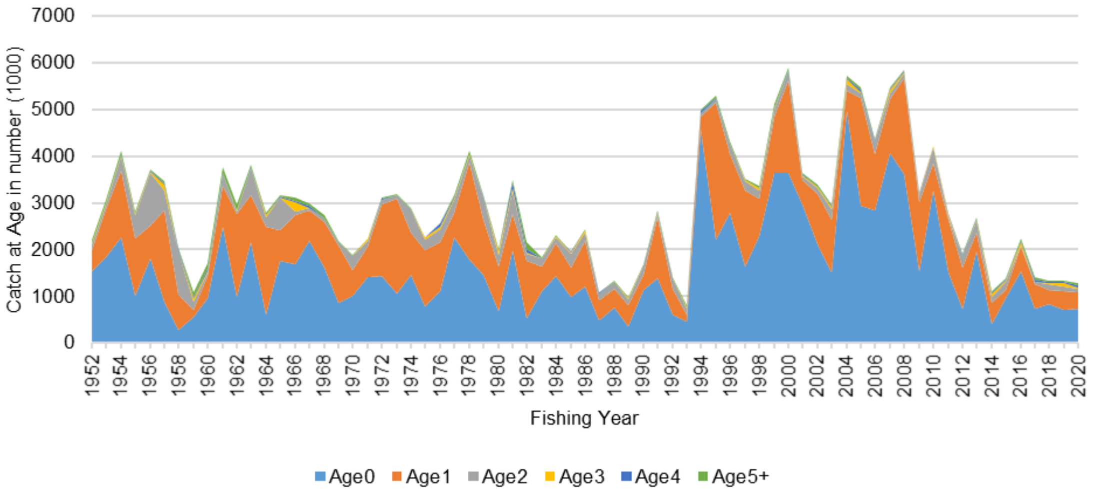


**Figure 5-16.** Annual catch-at-age (in number) of Pacific bluefin tuna (*Thunnus orientalis*) by fishing year (1952-2020) from the base case.

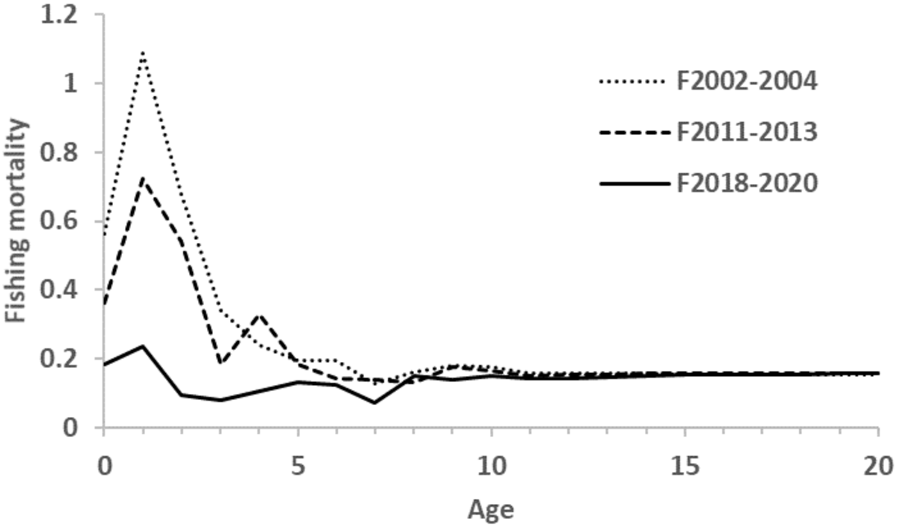


**Figure 5-17.** Geometric means of annual age-specific fishing mortalities of Pacific bluefin tuna (*Thunnus orientalis*) for 2002-2004 (dot-line), 2011-2013 (dashed line) and 2018-2020 (solid line) from the base case.

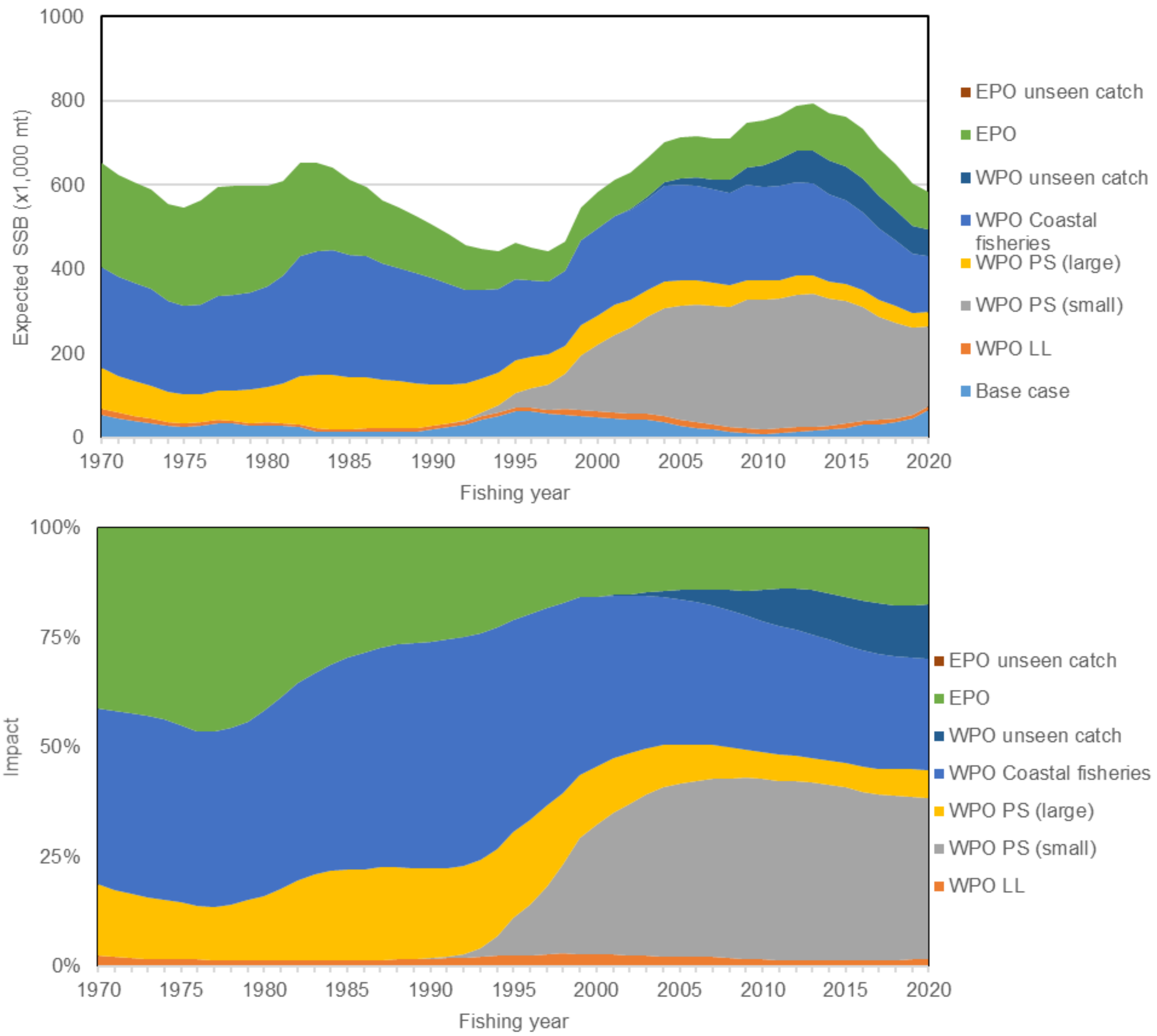


**Figure 5-18.** Trajectory of the spawning stock biomass of a simulated population of Pacific bluefin tuna (*Thunnus orientalis*) when zero fishing mortality is assumed, estimated by the base-case model. (top: absolute impact, bottom: relative impact). Fleet definition; WPO longline: F1, F12, F17, F23. WPO purse seine for small fish: F2, F3, F18, F20. WPO purse seine: F4, F5. WPO coastal fisheries: F6-11, F16, F19. EPO fisheries: F13, F14, F15, F24. WPO unaccounted F21, F22. EPO unaccounted: F25.

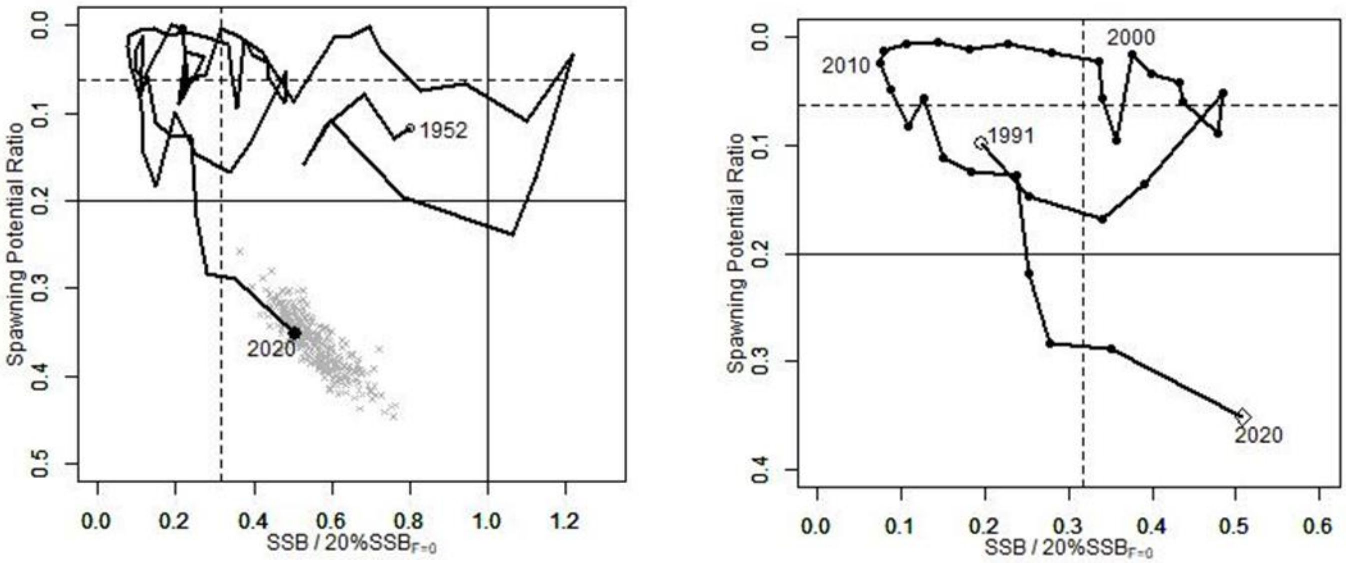


**Figure 5-19.** Kobe plots for Pacific bluefin tuna (*Thunnus orientalis*) estimated from the base-case model. The X-axis shows the annual SSB relative to 20%$SSB_{F=0}$ and the Y-axis shows the spawning potential ratio (SPR) as a measure of fishing mortality. Vertical and horizontal solid lines in the left figure show 20%$SSB_{F=0}$ (which corresponds to the second biomass rebuilding target) and the corresponding fishing mortality that produces SPR, respectively. Vertical and horizontal broken lines in both figures show the initial biomass rebuilding target ($SSB_{MED}$ = 6.4%$SSB_{F=0}$) and the corresponding fishing mortality that produces SPR, respectively. $SSB_{MED}$ is calculated as the median of estimated SSB over 1952-2014. The left figure shows the historical trajectory, where the open circle indicates the first year of the assessment (1952), solid circle indicate the latest year of the assessment (2020), and grey crosses indicate the uncertainty of the terminal year estimated by bootstrapping. The right figure shows the trajectory of the last 30 years.

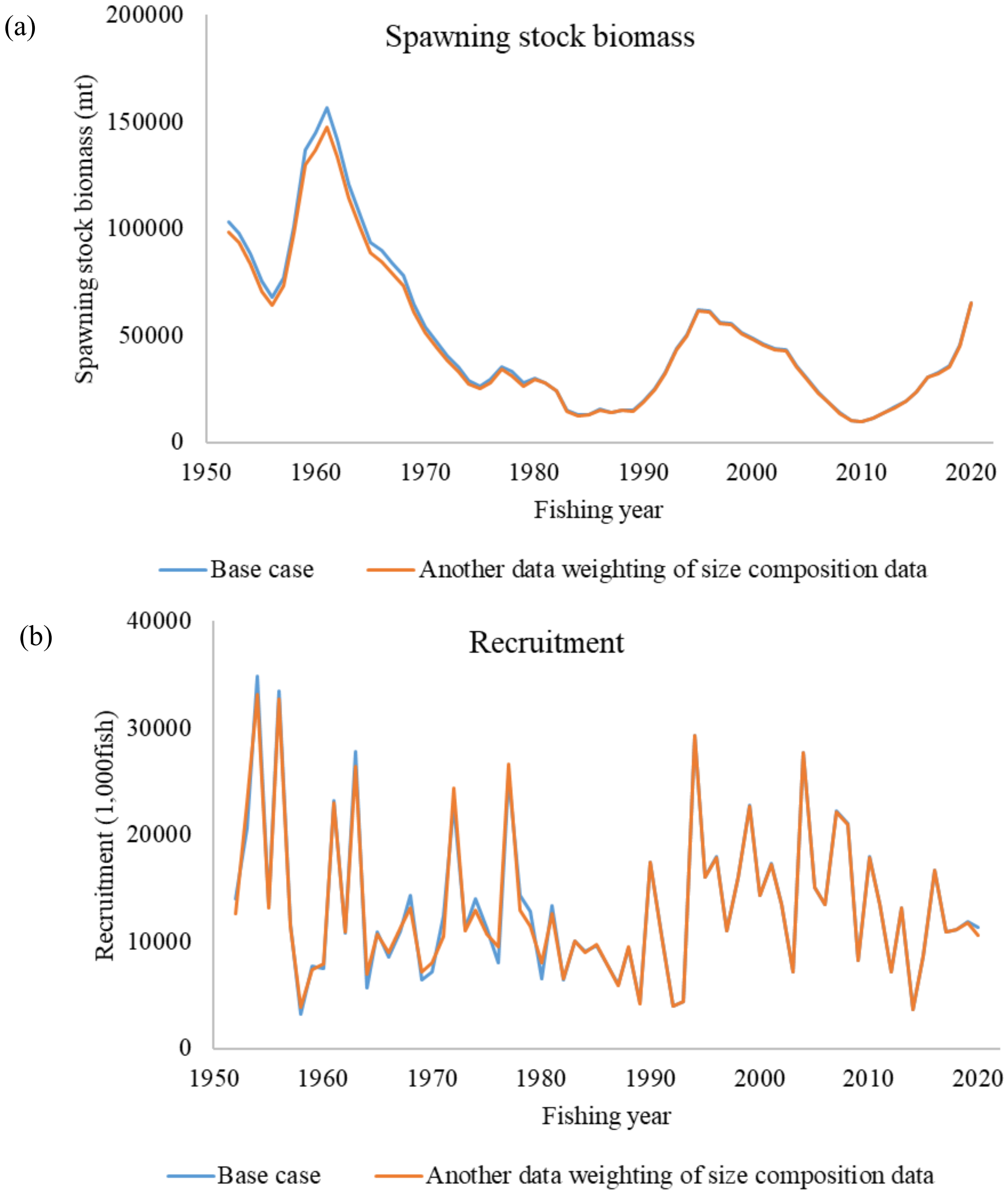


**Figure 5-20.** Estimated (a) spawning stock biomass and (b) recruitment of Pacific bluefin tuna (*Thunnus orientalis*) for the base-case model and sensitivity analyses using alternative weighting which down-weighted the size composition data of Fleets 13 and 20.

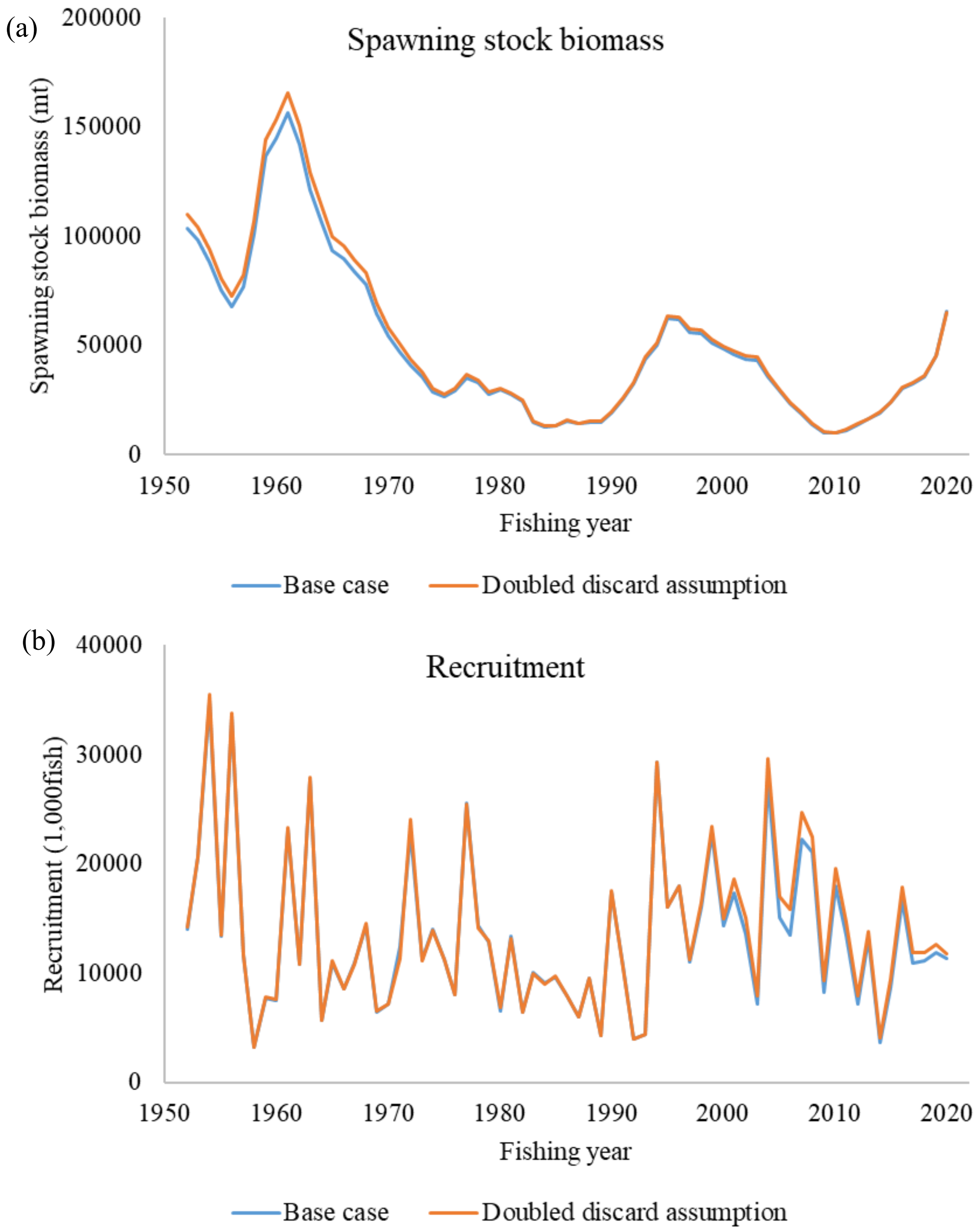


**Figure 5-21.** Estimated (a) spawning stock biomass and (b) recruitment of Pacific bluefin tuna (*Thunnus orientalis*) for the base-case model and sensitivity analysis assuming discard was double the assumed value.

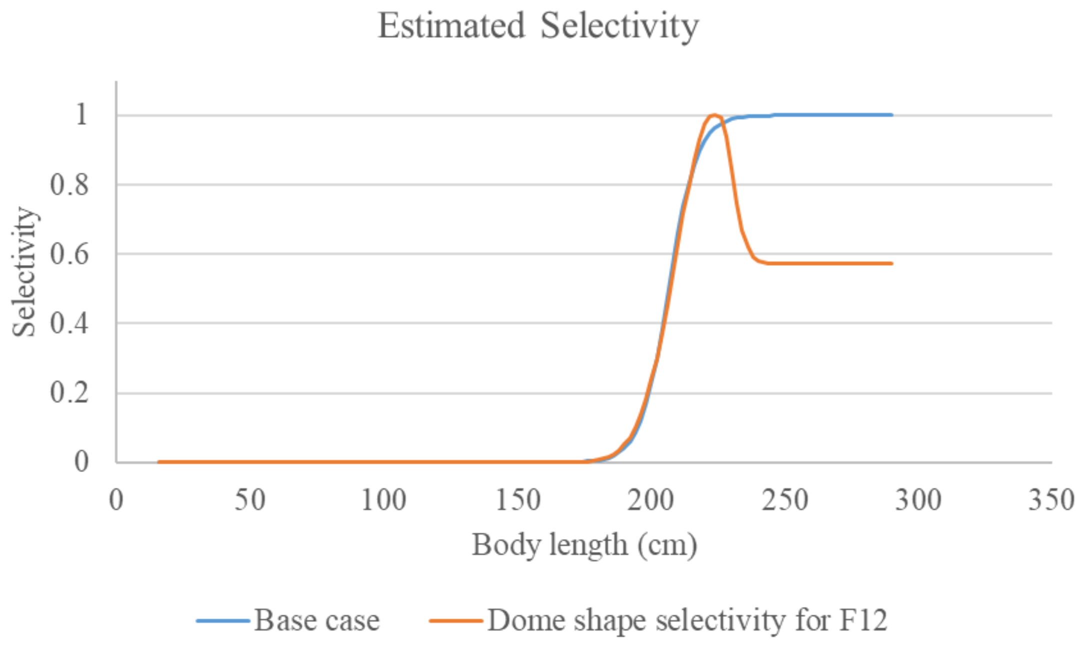


**Figure 5-22.** Estimated selectivity of Pacific bluefin tuna (*Thunnus orientalis*) for the base-case model and sensitivity analysis allowing for a dome-shaped length-based selectivity for the fleet 12.

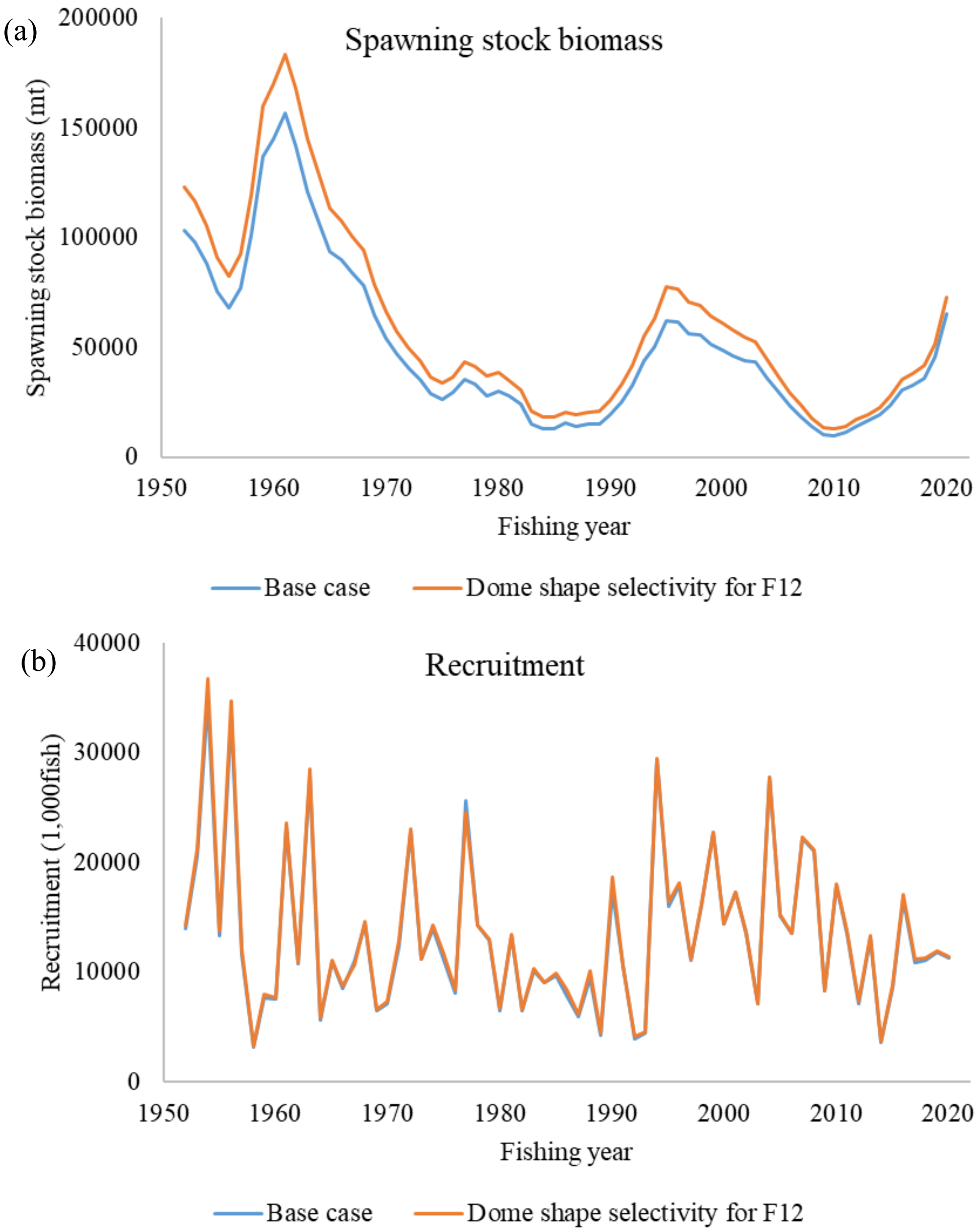


**Figure 5-23.** Estimated (a) spawning stock biomass and (b) recruitment of Pacific bluefin tuna (*Thunnus orientalis*) for the base-case model and sensitivity analysis allowing for a dome-shaped length-based selectivity for the fleet 12.

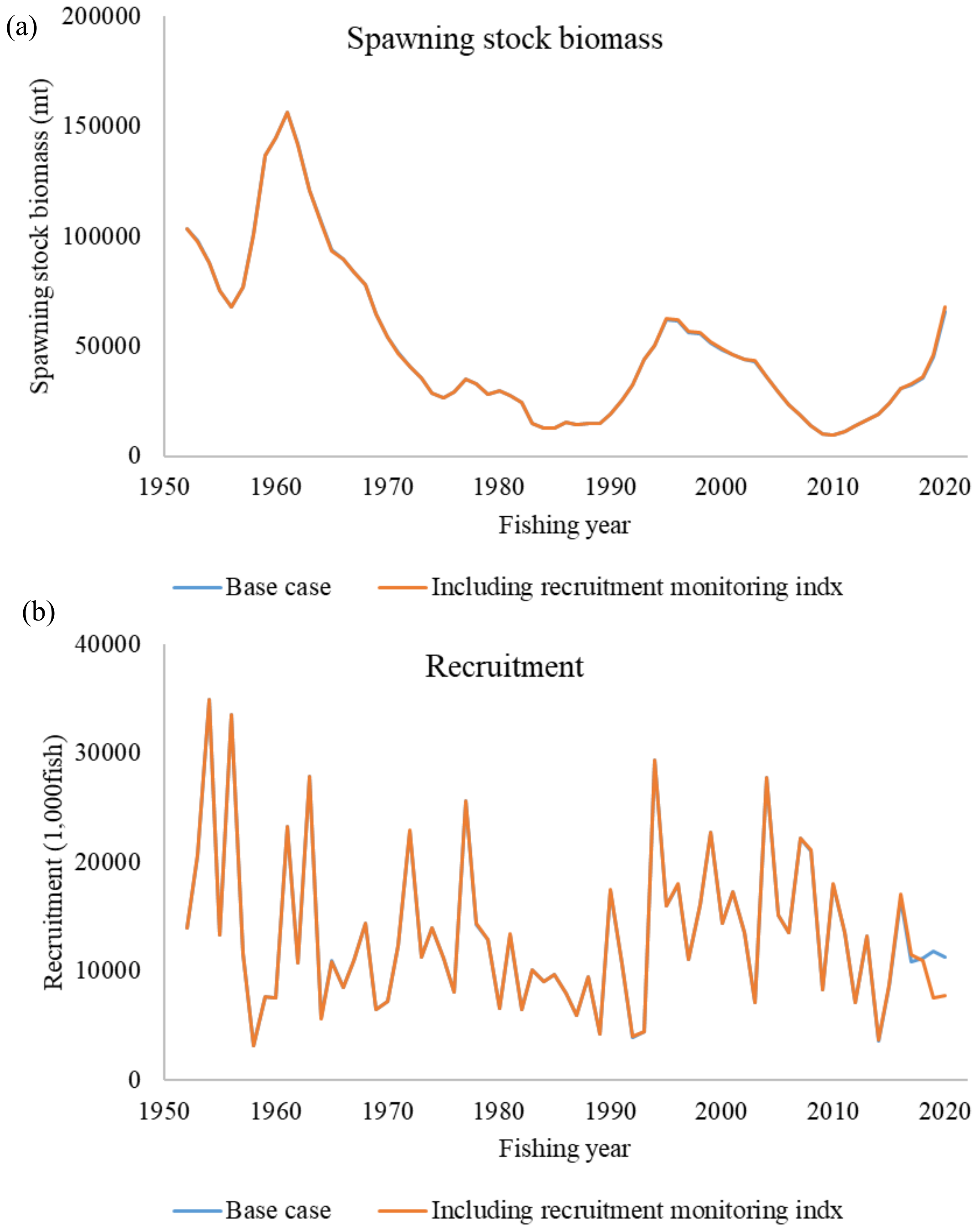
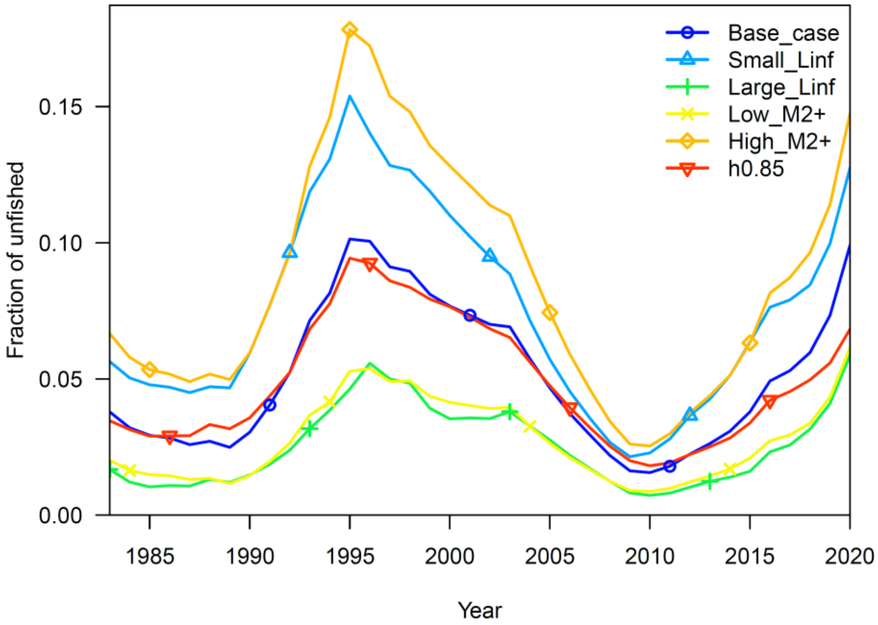


**Figure 5-24.** Estimated (a) spawning stock biomass and (b) recruitment of Pacific bluefin tuna (*Thunnus orientalis*) for the base-case model and sensitivity analysis included the recruitment monitoring survey index from 2017 to 2020.



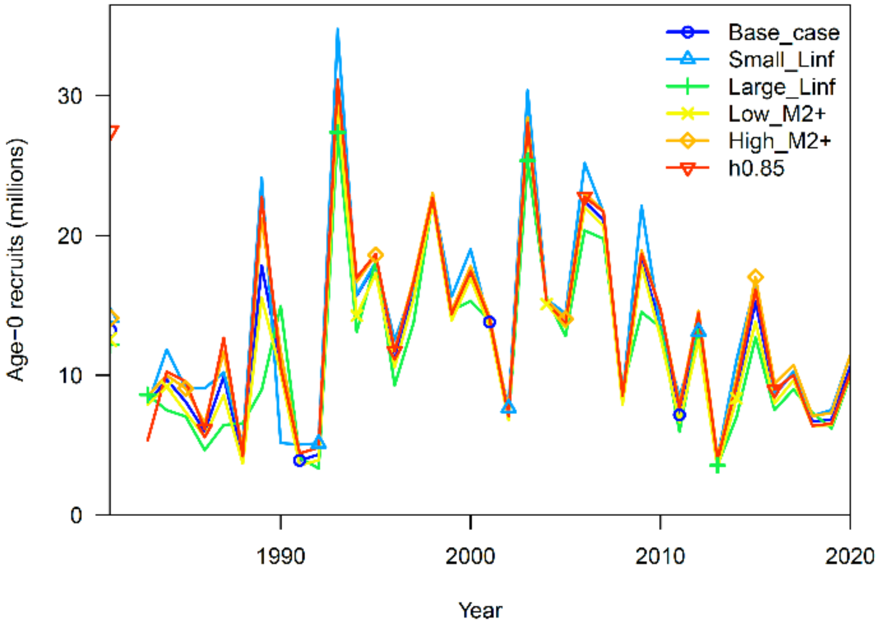


**Figure 5-25.** Estimated (a) spawning stock biomass and (b) recruitment of Pacific bluefin tuna (*Thunnus orientalis*) for the short time-series Base case model and sensitivity analysis with high / low length at age 3, high / low natural mortality for age 2 and older and lower steepness(h=0.85).

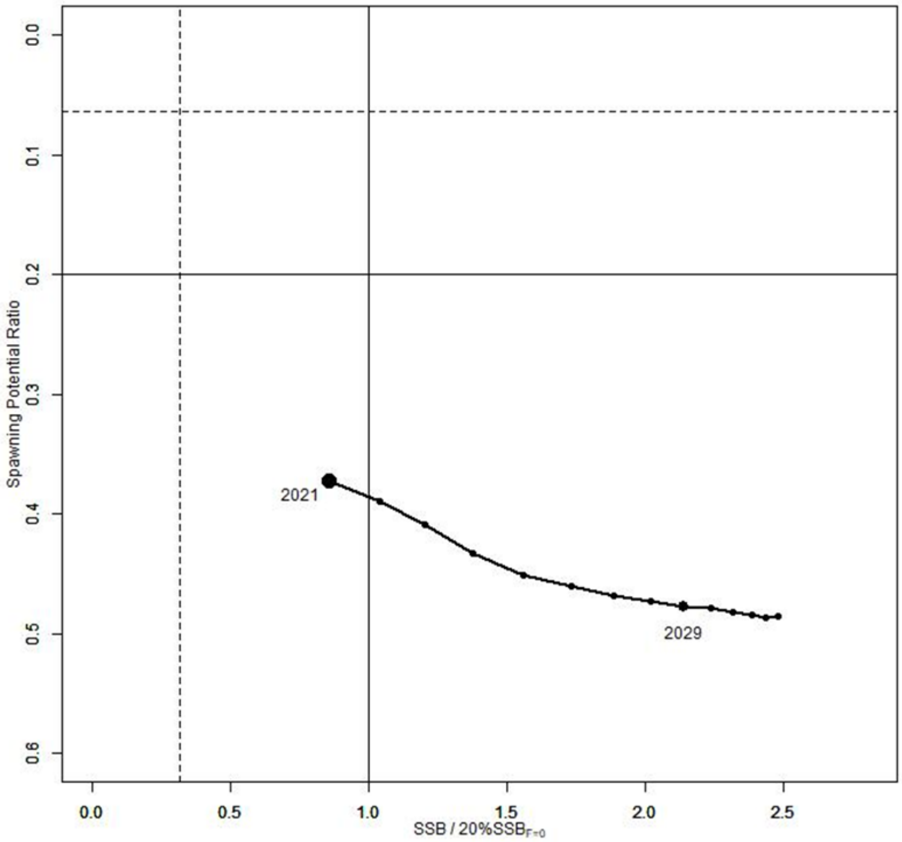


**Figure 6-1**. "Future Kobe Plot" based on the median estimates of SSB and SPR from the projections for Pacific bluefin tuna (*Thunnus orientalis*) from Scenario 1 from Table 4-2. The X-axis shows the annual SSB relative to 20%SSB$_{F=0}$ and the Y-axis shows the spawning potential ratio (SPR) as a measure of fishing mortality. Vertical and horizontal solid lines in the figure show 20%SSB$_{F=0}$ (which corresponds to the second biomass rebuilding target) and the corresponding fishing mortality that produces SPR, respectively. Vertical and horizontal broken lines in both figures show the initial biomass rebuilding target (SSB$_{MED}$ = 6.3%SSB$_{F=0}$) and the corresponding fishing mortality that produces SPR, respectively. SSB$_{MED}$ is calculated as the median of estimated SSB in 1952-2014.

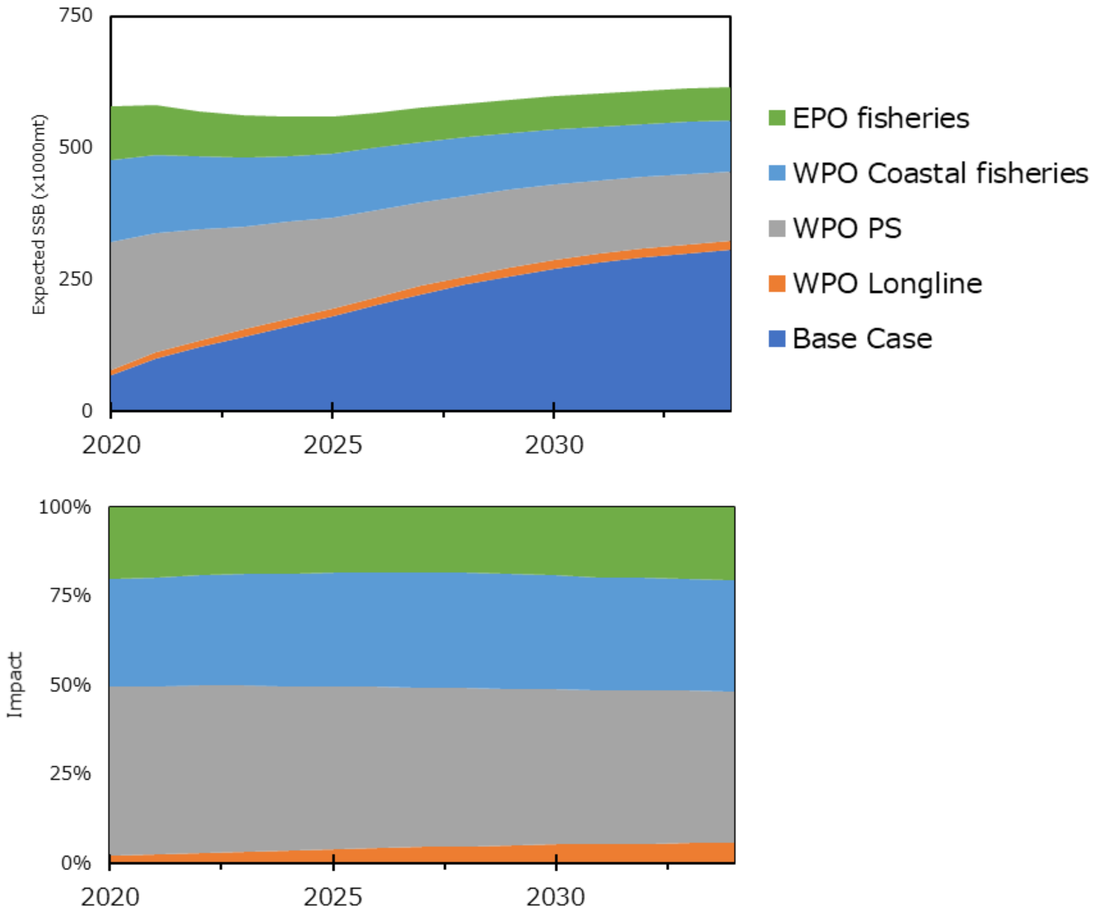


**Fig 6-2**. "Future impact plot" from projection results for Pacific bluefin tuna (*Thunnus orientalis*) from Scenario 1 of Table 4-2. The impact is calculated based on the expected increase of SSB in the absence of the respective group of fisheries.

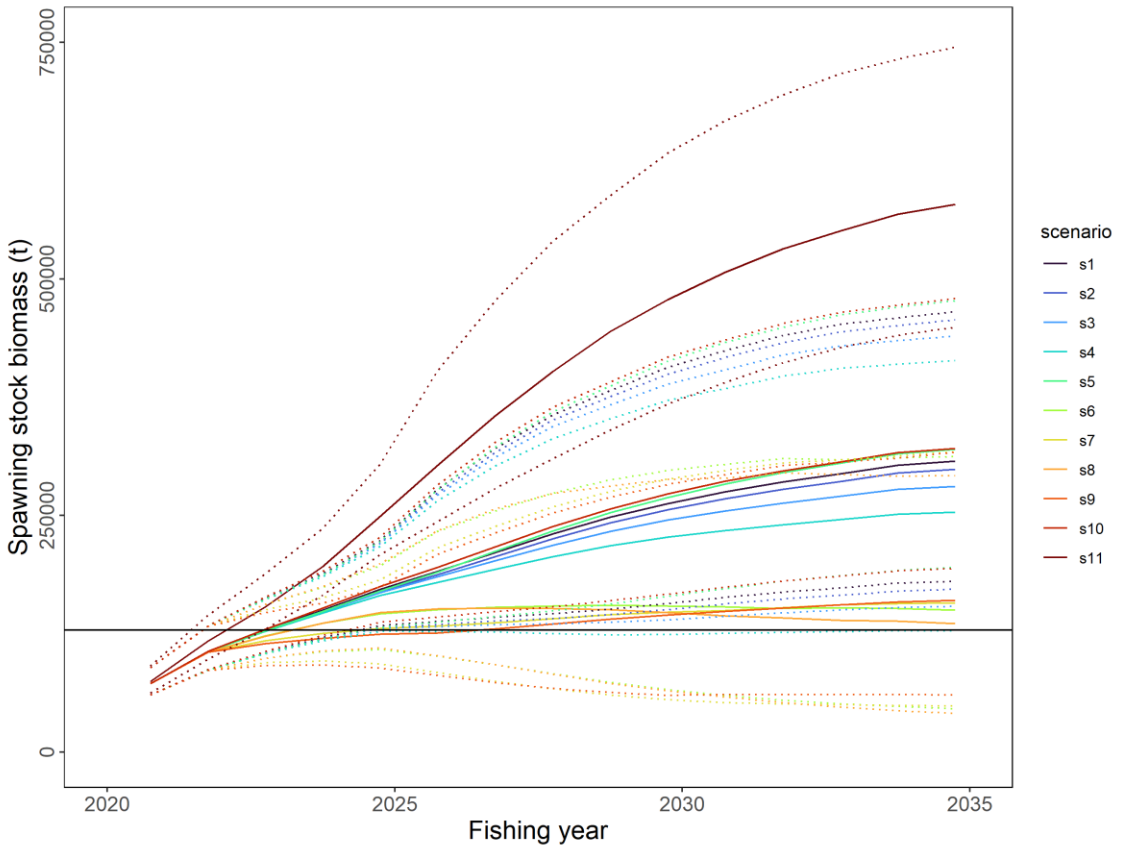


**Figure 6-3.** Comparisons of various projection results for Pacific bluefin tuna (Thunnus orientalis) obtained from bias-adjusted bootstrap projection results. Median of all scenarios (solid lines) and their 90% confidence intervals (dotted lines). Black line indicats 2nd rebuilding target.

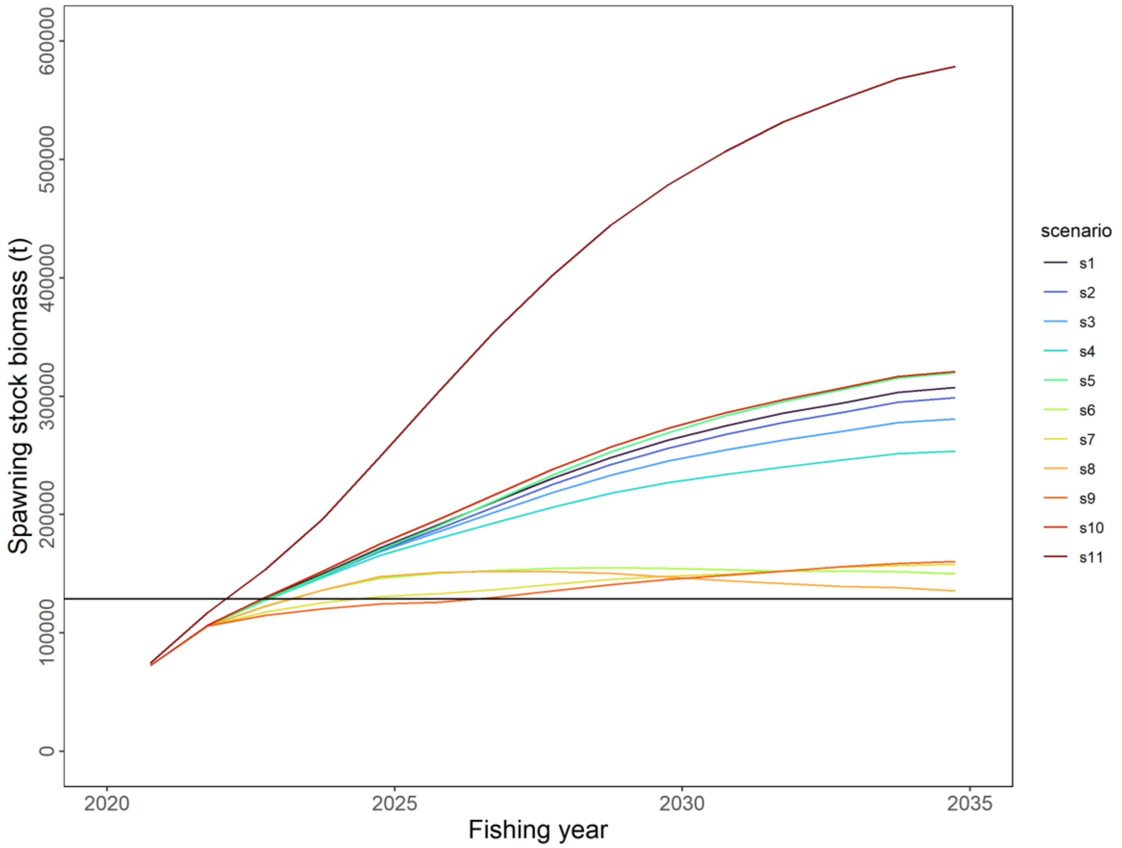


**Figure 6-4.** Comparisons of various projection results for Pacific bluefin tuna (*Thunnus orientalis*) obtained from bias-adjusted bootstrap projection results. Median of all harvest scenarios examined from Table 3. Black line indicats 2$^{nd}$ rebuilding target.

# APPENDIX 1

## Future Impact plots from Future Projection

For additional information, impacts by fleets estimated from future projections under various harvest scenarios from Table 4-2 are provided.

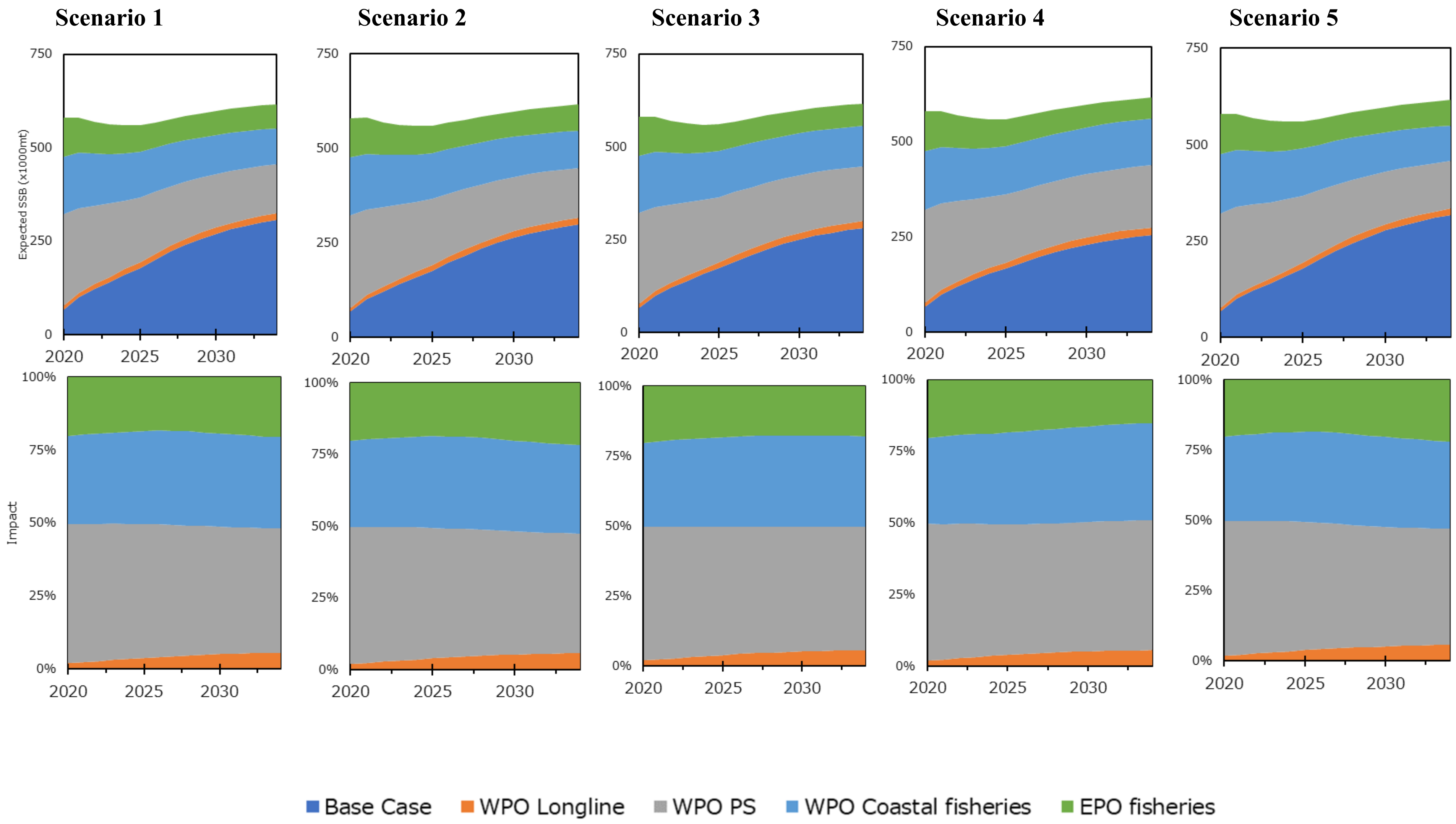


Figure A-1. Result of impacts by fleets estimated from future projections.

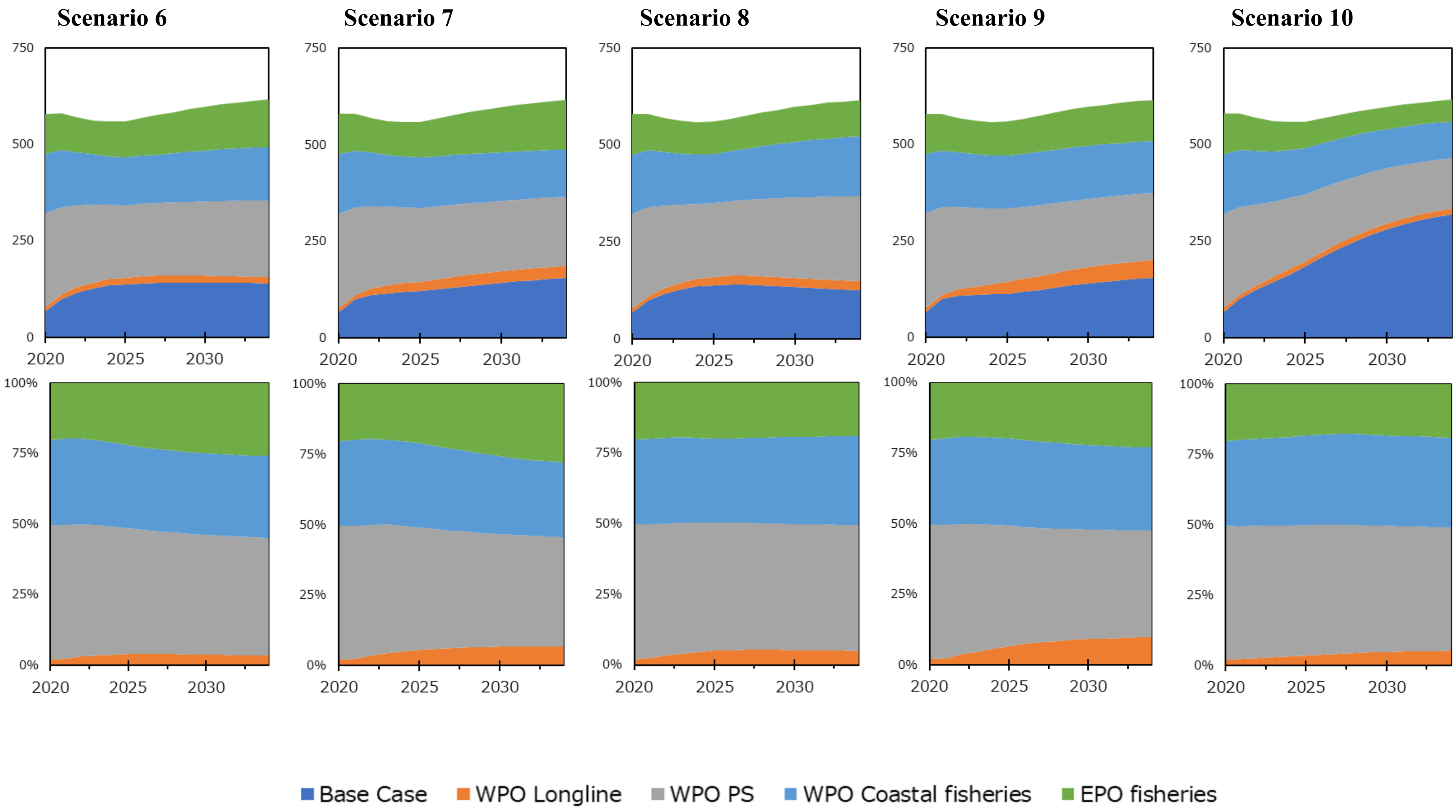


Figure A-1. Cont.