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Stock Assessment and Evaluation for Splendid Alfonsino of Pacific Japan (Fiscal Year 2024)

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Summary

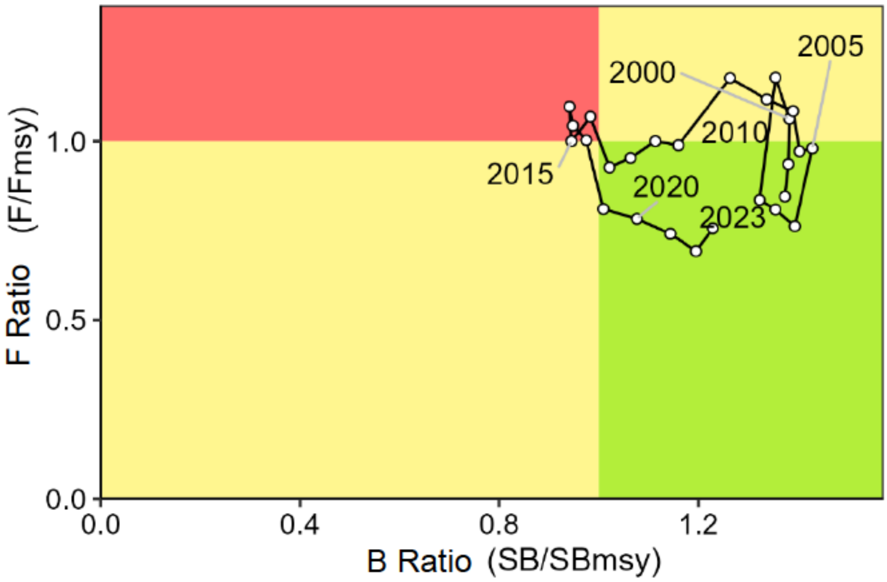
In the stock assessment of this stock, stock abundance was estimated by cohort analysis using abundance indices as tuning indices for the fishing ground, off the Kanto coast to those around the Izu Islands and the southern offshore seamount area of Shikoku, where biological data, including catch composition and age estimation, could be obtained for a long period. The standardized CPUE for eight areas of major landing ports (including two fishing ground at Tokyo Bay entrance) and the nominal CPUE for Hachijojima Island were used to calculate the abundance indices, excluding the marine environmental factors and extracting only the annual fluctuations. The total catch of this stock in 2023 was 5,246 tons, with 4,360 tons being caught in the fishing ground, off the Kanto coast to those around the Izu Islands and the southern offshore seamount area of Shikoku, where stock abundance was estimated. The stock abundance in 2023 was estimated to be 37,000 tons, the spawning stock biomass at 29,900 thousand tons, and the recruitment at 6.9 million individuals. Regarding trends since 2015, the spawning stock biomass (SSB) and stock abundance have increased, while recruitment has temporarily increased but has since shown a declining trend.

At the Research Institute Meeting on Reference Points held in August 2022, a hockey stick model was applied to the stock-recruitment relationship of this stock and based on this relationship, the Maximum Sustainable Yield (MSY) was estimated, and the spawning stock biomass required to achieve MSY (SBmsy) was calculated to be 24,300 tons. Following these criteria, the SSB of this stock in 2023 exceeds the level required to achieve MSY. In addition, the fishing pressure on this stock in the 2023 fishing season was lower than the

fishing pressure level (Fmsy) required to maintain SBmsy. Based on trends seen in the previous 5 years (2019 to 2023), SSB is judged to be in an “increasing” trend.

In this stock, provisional values for reference points, future projections, and other items related to resource management policies were presented based on the materials proposed at the Research Institute Meeting on Reference Points. These will be finalized following discussions at the stakeholder meeting.

Summary Figures and Tables



Kobe plot (chart) of splendid alfonsino of Pacific Japan

Maximum Sustainable Yield (MSY), Spawning Stock Biomass (SSB) Levels and Trends, and Allowable (or Acceptable) Biological Catch (ABC)	
SSB to achieve MSY (SBmsy)	24,300 tons
Level of SSB in 2023	Over the level to achieve MSY
Level of fishing pressure in 2023	Under the level to achieve SBmsy
Changes in SSB in 2023	Increase
Maximum Sustainable Yield (MSY)	47,000 tons
ABC for 2025	-
Comment: • ABC is estimated after Harvest Control Rules (HCRs) for this stock are compiled by the “Stock Management Policy Review Meeting”, and set through the “Fisheries Policy Council”.	

Stock Biomass, Spawning Stock Biomass, Catch, Fishing Pressure (F/Fmsy), and Exploitation Rate for the Most Recent 5 Years and the Next 2 Years					
Year	Stock biomass (Thousand tons)	Spawning stock biomass (Thousand tons)	Catch (Thousand tons)	F/Fmsy	Exploitation rate (%)
2019	34.8	24.5	4.0	0.81	12
2020	36.1	26.2	4.0	0.78	11
2021	36.9	27.8	4.1	0.74	11
2022	37.2	29.0	4.0	0.69	11
2023	37.0	29.9	4.4	0.76	12
2024	37.0	29.7	4.1	0.73	11
2025	37.4	29.2	-	-	-
The values for 2024 and 2025 are estimates based on future projections.					

1. Data Sets

The data sets used for this stock assessment are as follows:

Data Sets	Basic Information & Related Surveys
Catch	Landing by fishing Port (Chiba, Tokyo, Kanagawa, Shizuoka Prefectures), Landing by Kochi City Central Wholesale Market (Kochi), Catch Performance Reports of offshore trawl fisheries, Pacific Ocean Regional Fisheries Coordination Committee Data (Fisheries Agency), Catch by Landing Port (Aichi, Kochi etc.), Volumes handled by Kagoshima City Central Wholesale Market (Kagoshima)
Catch in number at age and by year	Monthly body size composition of landing (grade composition or length composition), biological measurements including age estimation (Chiba ,Tokyo, Kanagawa, Shizuoka, Japan Fisheries Research and Education Agency)
Stock abundance index - Stock biomass - Spawning stock biomass	Catch and fishing effort at major landing ports (Chiba, Tokyo, Kanagawa, Shizuoka)* Catch and fishing effort at major landing ports (Kochi) FRA-ROMS II, Kuroshio current axis data (Japan Fisheries Research and Education Agency)
Natural mortality (M)	Assuming M = 0.1 per year (Tanaka 1960)
Catch composition	Monthly body size composition of landing (grade composition or length composition) (Aichi, Kochi, Kagoshima)

* Indicates the tuning index for cohort analysis. The underlined data were not used for stock abundance estimation but were used as reference data in the appendix.

2. Ecology

(1) Distribution and migration

They are globally distributed across seamounts and continental shelf margins from tropical to temperate regions of the Pacific Ocean, Atlantic Ocean, and Indian Ocean. In Japan, immature fish (fish larvae, juveniles and young fish) inhabit the continental shelf waters at depths of 100-250 m southward from Kushiro (Hokkaido) across the Pacific Ocean and southward from Niigata Prefecture across the Sea of Japan, while adults occupy offshore waters at depths of 200-800 m in the same areas (Ochiai and Tanaka 1998, Hayashi 2013). The primary habitats (fishing grounds) along Japan's Pacific coast are the coastal areas from the Boso Peninsula to the Izu Peninsula, off the coast of Omaezaki, around the Izu Islands, the southern offshore seamount area of Shikoku (including the 1st Kinan Seamount, 2nd Kinan Seamount, Komahashi Seamount, and 2nd Komahashi Seamount), off the coast of Kochi, and the surrounding waters of the Nansei Islands (Fig.

2-1). Results of the release survey of small-tagged fish from the coastal areas of the Kanto region suggest that some individuals remain near the release areas while others migrate to deeper fishing ground such as the Izu Islands. Young, small fish tend to be more abundant on the upper continental slope along the coast, while older, larger fish tend to be more abundant in deeper offshore areas around the Izu Islands and seamounts, etc. Examples of individuals migrating long distances include those released off the Kanto coast moving southward through the ocean areas around the Izu Islands and individuals recaptured in the ocean areas around the Nansei Islands. When these results of release survey of tagged fish are consolidated, it is observed that more than 95% of individuals liberated off the Kanto coast are recaptured in the ocean areas around the Izu Islands even after 4 years, and over 70% are recaptured even after 10 years. Therefore, it is assumed that long-distance migration occurs only in a small portion of the population (Watari et al. 2017). Examples of fish being captured along the Pacific coast of the Tohoku Region, north of Ibaraki Prefecture, have also been reported in stock surveys, etc. (Watari et al., in press).

(2) Age and growth

Although the relationship between age and body length has yielded slightly different results depending on sex, habitat, and age, the fork length at each age is generally 19 cm at age 1, 22 cm at age 2, 25 cm at age 3, 28 cm at age 4, 30 cm at age 5, and around 39 cm at age 10 (Akimoto, 2007) (Fig. 2-2). The oldest fish, as determined by otolith age estimation, was 26 years old (Myojin & Ura, 2003).

(3) Maturation and spawning

Spawning grounds in the ocean areas around Japan are known to be widespread, ranging from the areas off the Kanto coast, the ocean areas around the Izu Islands, the areas off Kochi, the ocean areas around the Nansei Islands, to the areas around the Ogasawara Islands. Spawning is considered to occur wherever adult fish inhabit these ocean areas (Masuzawa et al. 1975, Akimoto 2007). The spawning season is from June to October, with the peak season in July and August (Onishi 1985, Shibata 1985, Kuboshima 1999, Akimoto et al. 2005). The maturity rate at age is 0 up to age 3, 0.5 at age 4, and 1.0 at age 5 and older (Fig. 2-3).

(4) Predator-prey Relationships

Primary prey includes mesopelagic fishes (predominantly myctophids), cephalopods, decapod crustaceans, and euphausiids (Masuzawa et al. 1975; Watari et al. 2017). There is predation by elasmobranchs and cetaceans, while depredation occurs during fishing operations (Horii 2011; Oizumi 2011). Larger splendid alfonsino may also prey on juvenile splendid alfonsino (Ikeda 1980).

3. Fishery Status

(1) Fishery Overview

Splendid alfonsino are abundantly distributed on continental shelf slopes and the slopes and tops of seamounts and sea hills, with fishing grounds scattered along the Pacific coast from the Boso Peninsula to the Nansei Islands, the Izu Islands, and around offshore seamounts. There are various types of fisheries targeting splendid alfonsino, including free fisheries, fisheries licensed by the Prefectural Governor, fisheries licensed by the Minister, and fisheries approved by the Pacific Ocean Regional Fisheries Coordination Committee. In free fisheries and fisheries licensed by the Prefectural Governor, the fish are mainly caught by vertical long line fisheries, trotline fisheries, and driftline fisheries. In fisheries licensed by the Minister, the fish are caught by offshore trawl fishery, long line fishery in the East China Sea, and bottom gill net fishery in the Pacific Ocean, among others. Off the Kanto coast to the waters around northern part of the Izu Islands have a long history of fishing, which dates back to the Meiji period. On the other hand, waters around southern part of the Izu Islands, the coast of Shikoku and those surrounding the Nansei Islands, fishing began in earnest in the 1980s. In Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures (hereinafter referred to as “Tokyo and the three Prefectures”) and Kochi Prefecture, regulations are in place for vertical long line fisheries, drifting dropline fisheries, and trotline fisheries, including closed season, restriction on the number of lines, restriction on the number of hooks, and minimum landing size. In Tokyo and the three Prefectures, a process for resource management has been established since 1996 under the Council of Fisheries Resource Management of Splendid Alfonsino in Tokyo and the three Prefectures, where fishermen voluntarily build consensus on resource management measures based on surveys and research. The Subcommittee on Fisheries Resource Management of Splendid Alfonsino by representative of fishermen was established in 2014, and discussions are underway among the stakeholders to further implementation of fisheries resource management.

(2) Trends in Catch in Weight

As of 2023, splendid alfonsino is not included in the official statistical survey of the catch by the Ministry of Agriculture, Forestry and Fisheries, and the catch is calculated by aggregating the total amount of catch collectet by research institutions. In the stock assessment for the previous fiscal year, a review of the information collection system for fisheries in the designated ocean areas was identified as an ongoing issue. The information on catches was carefully scrutinized to address this issue. The catches from the southern offshore seamount area of Shikoku, which had been partially accounted for until the previous fiscal year, were added. These refer to the catch by Kanagawa Prefecture fishing vessels fishing in the southern offshore seamount area of Shikoku since 2000, which was shipped from the Kochi City Central Wholesale Market, and the catch from bottom gill net fishing caught in Japan's EEZ in the central and southern parts of the Pacific Ocean, under fisheries approved by the Pacific Ocean Regional Fisheries Coordination Committee since 2007. The catch by Kanagawa Prefecture fishing vessels fishing in the southern offshore seamount area of Shikoku, which was shipped from Misaki fishing port, was accounted for in stock assessments prior to the previous fiscal year and included in the stock abundance estimation.

The total catch was collected by aggregating the landings at major ports and volumes handled by wholesale markets from Chiba to Kagoshima Prefectures, Catch Performance Reports for fisheries licensed by the Minister, landings at major ports, and the catch reported to the Regional Fisheries Coordination Committee for fisheries approved by the Pacific Ocean Regional Fisheries Coordination Committee (Fig. 3-1, Table 3-1). The overall catch for 2023 was 5,246 tons, of which 4,360 tons was caught from fishing ground off the Kanto coast to those around the Izu Islands (Tokyo and the three Prefectures), as well as the southern offshore seamount area of Shikoku, 49 tons from Wakayama, Tokushima, and Kochi Prefectures, and 173 tons from the fishing ground around the Nansei Islands (Kagoshima Prefecture and East China Sea region). Offshore trawl fishery has been on the rise in the central and southern Pacific regions since 2013, reaching 627 tons in 2023, accounting for more than 10% of the total catch. In the northern Pacific region, the catch has fluctuated between 0 and 21 tons. Table 3-2 lists the catch by district and fishing method for Tokyo and the three Prefectures and the fishing ground since 1998, which are currently included in the stock assessment. Furthermore, in Tables 3-1 and 3-2, the catch by Kanagawa Prefecture fishing vessels fishing in the southern offshore seamount area of Shikoku, which was shipped from the Kochi City Central Wholesale Market, is added under Kanagawa Prefecture’s trotline fisheries and the catch from the fisheries approved by the Pacific Ocean Regional Fisheries Coordination Committee is recorded in the central and southern parts of the Pacific Ocean (bottom gill net) column.

The data collected included length composition, grade composition, and age assessment of a total of 13 catches by fishery type and fishing area for 10 landing ports in Tokyo and the three Prefectures since 1998 (Chiba Prefecture: Choshi, Katsuura, Tomiura, Katsuyama; Tokyo: Oshima, Kozushima, Hachijojima; Kanagawa Prefecture: Misaki; Shizuoka Prefecture: Shimoda (trotline fisheries) and the east coast region of the Izu Peninsula). Based on this information, the catch in number at age for each landing port, fishing method, and the fishing area was calculated and added, thereby estimating the catch in number at age for all the fishing grounds (Fig. 3-2, Supplementary Table 2-4). The catch in number of young fish (2-3 years old) was small, and catches were dominated by 4–10-year-olds. Catches in the coastal areas of Chiba and Kanagawa Prefectures were decomposed by age based on catch information by grade.

The recreational catch in the central Pacific region as reported by the Ministry of Agriculture, Forestry and Fisheries (Statistics and Information Department, Ministry of Agriculture, Forestry and Fisheries 1993, Statistics Department, Ministry of Agriculture, Forestry and Fisheries 2003) and on the Portal Site for Japanese Government Statistics (https://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00502002&tstat=000001031445&cycle=8&year=20081&month=0&tclass1=000001031446&tclass2=000001031447&tclass3val=0, viewed July 9, 2024), is as follows: 129 tons in 1992, 516 tons in 2002, and 113 tons in 2008. Of this, the catch from Tokyo and the three Prefectures was 503 tons in 2002 and 102 tons in 2008. According to Ozaki (2024), in recent years, the annual recreational catch was estimated to be at least 179.9 tons, based on Web information from 2021-2022. However, since changes over time could not be assessed, the impact of recreational catch was not taken into consideration in the stock assessment of this stock.

(3) Fishing Effort

The number of landings per day per vessel for the catch of splendid alfonsino at major ports in Tokyo and the three Prefectures is used as an indicator of effort, and changes over time are shown in Fig. 3-3. In many regions, there has been a decreasing trend since 2018. Since voluntary management measures have been implemented to reduce the number of hooks and fishing hours, it is necessary to continue to examine whether the number of landings per day per vessel is an appropriate indicator of effort for long-term comparisons.

4. Stock Status

(1) Stock Assessment Methods

A stock assessment was conducted by estimating stock abundance using cohort analysis (VPA) (Pope 1972, Yonezawa et al. 2011) based on stock characteristics such as longevity and the occurrence of dominant year class (Appendix 1 and Appendix 2). Shown in 3(2), the stock assessment was conducted based on the catch information from the fishing ground, off the Kanto coast to those around the Izu Islands and the southern offshore seamount area of Shikoku. Information of the catch by Kanagawa Prefecture fishing vessels fishing in the southern offshore seamount area of Shikoku, which was shipped from the Kochi City Central Wholesale Market, and the catch by bottom gill nets from the fisheries approved by the Pacific Ocean Regional Fisheries Coordination Committee, were newly collected catch and added from this fiscal year. Since 2000, the catch has ranged from 0 to 279 tons, with 172 tons being added in 2023. Biological data, including catch composition and age assessment, have been available since the late 1990s in Tokyo and the three Prefectures. However, among the other prefectures, only Kochi Prefecture has performed the long-term assessment of body length composition of catches, while most other prefectures only assess the catch in weight. The results of the release survey of tagged fish suggest that long-distance migration from the Kanto coast to the fishing ground off Kochi and those around the Nansei Islands do not occur in a short period. In the stock assessment of this stock, VPA with tuning was conducted using the catch per day per vessel (kg/day/vessel) as the abundance index for the fishing ground, off the Kanto coast to those around the Izu Islands and the southern offshore seamount area of Shikoku, which is the largest fishing grounds in Japan and where biological data including catch composition and age estimation have been accumulated for a long time, and measures for sustainable and effective utilization of the stock within the fishing ground were examined without taking into account the movement of fish into and out of the areas. Information on offshore trawl fishery in the central and southern parts of the Pacific Ocean and on the catch compositions of Kochi and Kagoshima Prefectures, etc., have not directly used for stock abundance estimation in the stock assessment for this fiscal year. They were compiled under Appendices (Appendix 9, Appendix 10, and Appendix 11). If biological data, including catch composition and age assessment, are accumulated for these fishing grounds and fisheries through this survey project, this should ideally help in understanding the age structure and estimating the stock abundance and spawning stock biomass for each fishing ground, thus contributing to the proposal of stock management measures for the entire stock.

In this year's stock assessment, standardized CPUE was calculated for a total of nine fishing grounds (including two fishing sites at the Tokyo Bay entrance): Two grounds operated by Chiba Prefecture vessels (Choshi and Katsuura), three fishing grounds operated by Tokyo Prefecture vessels (Kozushima, Miyakejima, Hachijojima), three fishing grounds operated by Shizuoka Prefecture vessels (Ito, Inatori, Omaezaki), and the fishing ground at the Tokyo Bay entrance, where Kanagawa Prefecture vessels (Misaki) and Chiba Prefecture vessels (Tateyama) operate jointly. (In the calculation of the standardized CPUE, catch by drifting dropline fisheries was used for Omaezaki, while catch by vertical long line fisheries was used for other fishing grounds). The standardized CPUE was used as the tuning index for VPA for the eight fishing grounds where the effects of the marine environment can be accounted for. The nominal CPUE was used as the tuning index for VPA for Hachijojima, as the results of standardization showed that there remains room for further consideration on how to express differences in the marine environment across broader fishing sites in other fishing grounds (Appendix 7). For Shimoda, the lack of organized information on the fishing grounds, as well as the fact that the main fishing grounds in the region are operated jointly with Inatori and are believed to be partially supplemented by the indices for Inatori, led to the decision not to use the CPUE for Shimoda as the tuning index for VPA.

(2) Trends in Abundance Indices

Comparing the trends of standardized CPUE and nominal CPUE in nine fishing grounds of Tokyo and the three Prefectures (including two fishing sites at the Tokyo Bay entrance), there has been an increasing trend since 2015 in Choshi, Katsuura, and Omaezaki, with record high values in 2023. However, in the fishing grounds at the Tokyo Bay entrance and Ito, the values were lower than those in the 2000s. At the same time, Inatori, Kozushima, and Miyakejima showed values similar to those in the 2000s (Fig. 4-1). Comparing standardized CPUE and nominal CPUE by year, standardized CPUE tended to be higher in Ito and Inatori in 2004-2005 and also after 2018. These periods coincide with the occurrence of the Kuroshio large meander, as shown on the Japan Meteorological Agency's website (https://www.data.jma.go.jp/kaiyou/data/shindan/b_2/kuroshio_stream/kuroshio_stream.html, viewed July 8, 2024), suggesting that the nominal CPUE, in which marine environmental factors are not excluded, may underestimate the recent stock status (Fig. 4-1, Appendix 7, Supplementary Tables 7-2 and 7-3).

(3) Trends in Stock Biomass and Fishing Pressure

The stock abundance remained flat at 40,000 tons until the early 2000s but showed a declining trend in the early 2010s, turned upward from the late 2010s, and has remained flat since 2015, reaching 37,000 tons in 2023 (Fig. 4-2, Table 4-1, and Supplementary Table 2-4). Recruitment is equal to the stock number of fish age 2, and spawning stock biomass is the sum of spawning stock biomass at age, which is obtained by multiplying stock abundance at age and maturity rate at age (Fig. 2-3.). The spawning stock biomass remained flat at the 30,000-ton level until the early 2000s, but after decreasing to 22,900 tons in 2016. Aftreward it began to increase and was 29,900 tons in 2023 (Fig. 4-2, Table 4-1). On the other hand, recruitment had been on a declining trend since 2005, and it temporarily increased after 2015 to exceed 10 million fish, after which it began to decline, reaching 6.9 million fish in 2023 (Fig. 4-3, Table 4-1). Sensitivity analyses of stock abundance, spawning stock biomass, and recruitment for a ±50% change in the value of the natural mortality coefficient showed that the estimated values in 2023 varied between 83-124% for stock abundance, 84-123% for spawning stock biomass, and 77-135% for recruitment, with no significant change in the increasing or decreasing trend (Fig. 4-4).

The average fishing mortality at age for fish age 2 was 0.03, which increased with age up to age 5 and ranged between 0.12 and 0.4 for fish age 6 and older, suggesting that mainly mature fish aged 6 years and older were exploited. The average fishing mortality (F) across all age groups fluctuated within the range of 0.13 to 0.24 and was 0.14 in 2023 (Fig. 4-5, Supplementary Table 2-4). The exploitation rate fluctuated within the range of 11 to 18% and remained at 11 to 12% between 2019 and 2023 (Fig. 4-6, Supplementary Table 4-4).

The fishery in waters around the Kanto region and Izu Islands primarily employs vertical long lines or bottom-set long lines. Fishing mortality and exploitation rates remained stable from 2010 to 2018, with a declining trend observed from 2019 onward (Fig. 4-1 and Supplementary Table 2-4). This decline is attributed to the implementation of voluntary management measures, such as closed season, as well as reduced fishing efficiency due to environmental factors, including the large meander of the Kuroshio. In the FY 2022 assessment, the current fishing pressure was defined as F (2016-2021), which is the average of F for the six-year period from 2016 to 2021, referring to the non-meandering period of the Kuroshio and the period before the impact of the COVID-19. In the assessment for the previous fiscal year, the current fishing pressure was changed to the average value of the most recent three years, considering the ongoing period of the Kuroshio large meander and the continued declining trend in effort over time (Fig. 3-3). This year, we used the same approach as the previous fiscal year, setting the current fishing pressure to F (2021–2023), the average value of F over the most recent 3 years (2021–2023).

(4) Yield Per Recruitment (YPR), Spawning Per Recruitment (SPR), and current level of Fishing Pressure

To compare fishing pressures while considering selectivity, we compared the findings for spawning per recruitment (SPR) based on scenarios with and without fishing pressure. Fig. 4-7 shows the trends in the SPR ratio (%SPR), which compares SPR in a scenario without fishing pressure to SPR in a scenario with fishing for each year. The lower the fishing pressure, the larger the SPR. From 2019 onwards, %SPR follows an increasing trend, reaching 28% in 2023. Calculations showed that %SPR was 29% using the average F value of the previous 3 years (2021 to 2023) for the current fishing pressure.

The relationship between YPR and %SPR with respect to current fishing pressure (Fmsy) is shown in Fig. 4-8. The selectivity of F was defined as the value used to estimate the level of F (Fmsy) to achieve maximum sustainable yield (Fmsy) (Watari et al. 2022) at the Research Institute Meeting on Reference Points held in August 2022. In addition, the values used to calculate Fmsy were also used for average body weight at age and maturity rate. Fmsy is equivalent to 22% when converted to %SPR. Fmsy is above the current fishing pressure (F2021-2023) and F30% SPR.

(5) Stock-recruitment Relationship

The relationship (stock-recruitment relationship) between spawning stock biomass (weight) and recruitment (individuals) is presented in Fig. 4-9. At the above-mentioned Research Institute Meeting on Reference Points, a hockey stick stock-recruitment model was proposed for the stock-recruitment relationship of this stock (Watari et al., 2022). The data used for parameter estimation of the stock-recruitment relationship comprised spawning stock biomass from 1998-2018 and recruitment from 2000-2020 based on the stock assessment of fiscal year 2022 (Watari et al., 2022), with the least squares method used as the optimization method. Recruitment residual autocorrelation was not accounted for in the analysis. The parameters of the stock-recruitment relationship model are shown in Supplementary Table 6-1.

(6) Levels to Achieve MSY Under Current Environmental Conditions

The maximum sustainable yield (MSY), the SSB (SBmsy) to achieve MSY, and the fishing pressure F (Fmsy) to achieve SBmsy under current environmental conditions (1998 onward), as shown in the document for the Research Institute Meeting on Reference Points published in September 2022 (Watari et al. 2023), are shown in Supplementary Table 6-2.

(7) Stock Levels, Trends and Fishing Pressure Levels

Reference values for SSB to achieve MSY (SBmsy) and fishing pressure required to maintain SBmsy (Fmsy) are shown in a Kobe plot in Fig. 4-10. The spawning stock biomass of 2023 for this stock was over SBmsy. The SSB of 2023 was 1.23 times SBmsy. In addition, the fishing pressure of 2023 was under Fmsy and was 0.76 times Fmsy. The F ratios (F/Fmsy) shown in the Kobe plot are the ratio between F values in each year and the value of F that gives the fishing pressure of Fmsy under the selectivity of F in each year, converted to %SPR. Based on trends seen in the previous 5 years (2019 to 2023), SSB is judged to be in an “increasing” trend. The SSB of this stock was lower than SBmsy from 2014 to 2018. However, since 2019, fishing pressure has decreased to below Fmsy, and the SSB has been maintained and is recovering to levels above SBmsy.

5. Summary of Stock Assessment

The stock abundance in 2023 was estimated to be 37,000 tons, the spawning stock biomass at 29,900 tons, and the recruitment at 6.9 million individuals. The SSB in 2023 exceeded the SSB required to achieve MSY (SBmsy). The results of the cohort analysis indicate that the fishing pressure for this stock has been declining for a long period. Although there is a high level of uncertainty regarding the stock number of fish age 2 in recent years, fishing pressure for young fish is considered to be at a low level. Since 2015, stock abundance and spawning stock biomass have been increasing while recruitment has been on a declining trend after a temporary increase. Since 2019, fishing pressure has decreased below the fishing pressure (Fmsy) required to maintain SBmsy, and it is inferred that continuing fishing with low fishing pressure will effective maintain spawning stock abundance.

6. Others

(1) Yield per recruitment (Relationship between optimum fishing pressure and age)

The stock status from the perspective of yield per recruitment (YPR) indicate, the current F is below Fmax, but even if fishing pressure is increased, further increase in catch cannot be expected because the YPR has almost reached a ceiling (Fig. 4-8). On the other hand, when YPR is analyzed by age group, the expected catch by age group increases or decreases with changes in fishing pressure (Fig. 4-11). Since fishing pressure is currently low for fish aged 6 and below, it is difficult to maximize YPR within the range of current selectivity and realistic changes in fishing pressure. When the YPR was broken down by age group, the fishing pressure that maximized the catch for each age group was 1.6 times the current fishing pressure for ages 7-9, 0.9 times the current fishing pressure for ages 10-12, 0.7 times the current fishing pressure for ages 13-14, and 0.4 times the current fishing pressure for ages 15+. Juveniles are not caught due to reduced fishing pressure, which leads to an increase in the catch of older fish. The analysis method used in the stock assessment of this stock does not explicitly consider spatial distribution. However, for the current status of fisheries, the age structure of fish is taken into account, with small to medium-sized fish being caught mainly along the Kanto coast and medium to large fish being caught mainly in the Izu Islands. Therefore, the optimal fishing pressure to maximize the catch is shown to vary depending on the fishing ground.

(2) Issues to be further considered

In the stock assessment of this stock, tuning indices and age composition are being examined since the species was included in the stock assessment in FY 2016, and standardized CPUE is also being deployed in the stock assessment. Information on fisheries and fishing grounds not currently included in the stock assessment was compiled under 'Appendix' this fiscal year, with the aim of "reviewing the information collection frameworks", which was one of the future challenges summarized in the previous fiscal year. There have been several reports by participating organizations regarding the impacts of predation and recreational fishing, among other factors. To further enhance stock assessment in the future, the progress status of issues discussed by organizations participating in stock assessment has been summarized under Appendix (Appendix 12).

7. Cited literature

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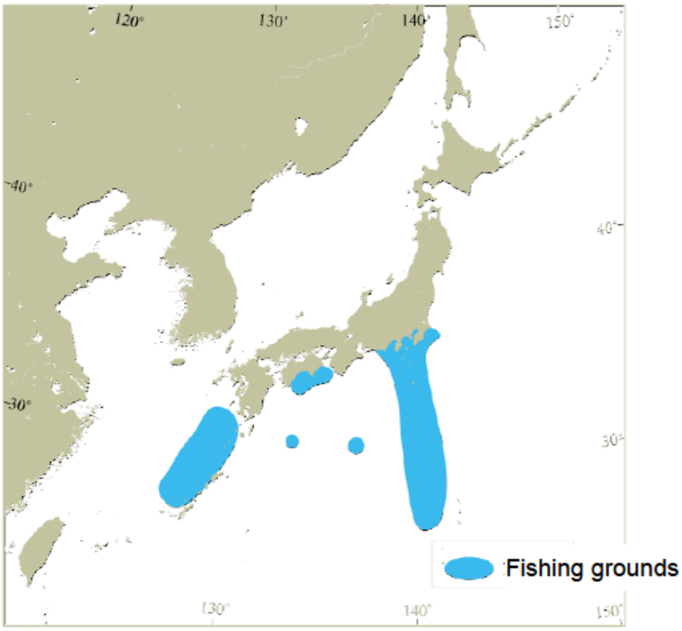


Fig 2-1. Main fishing grounds of the Splendid Alfonsino - Pacific Japan

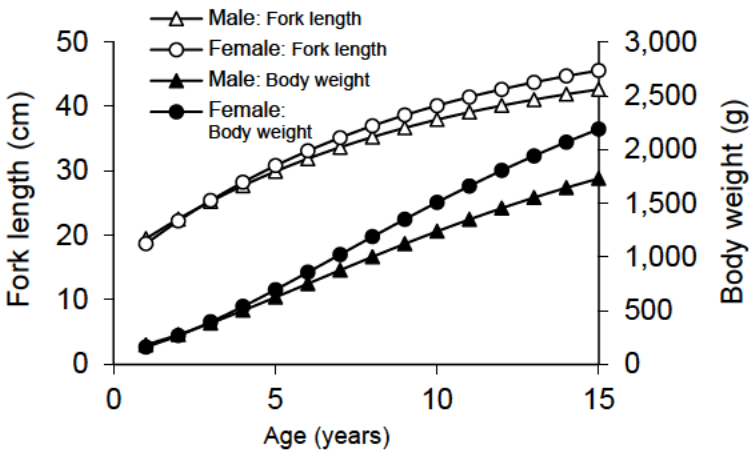


Fig. 2-2. Age and growth

Fig. 2-3. Maturity rate at age

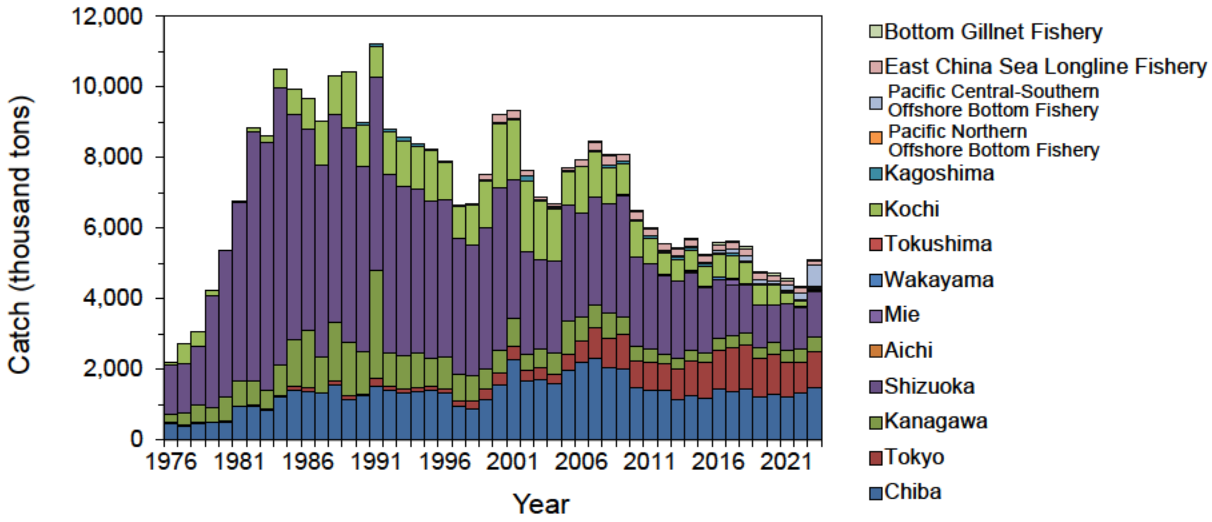


Fig. 3-1. Trends in catch in weight

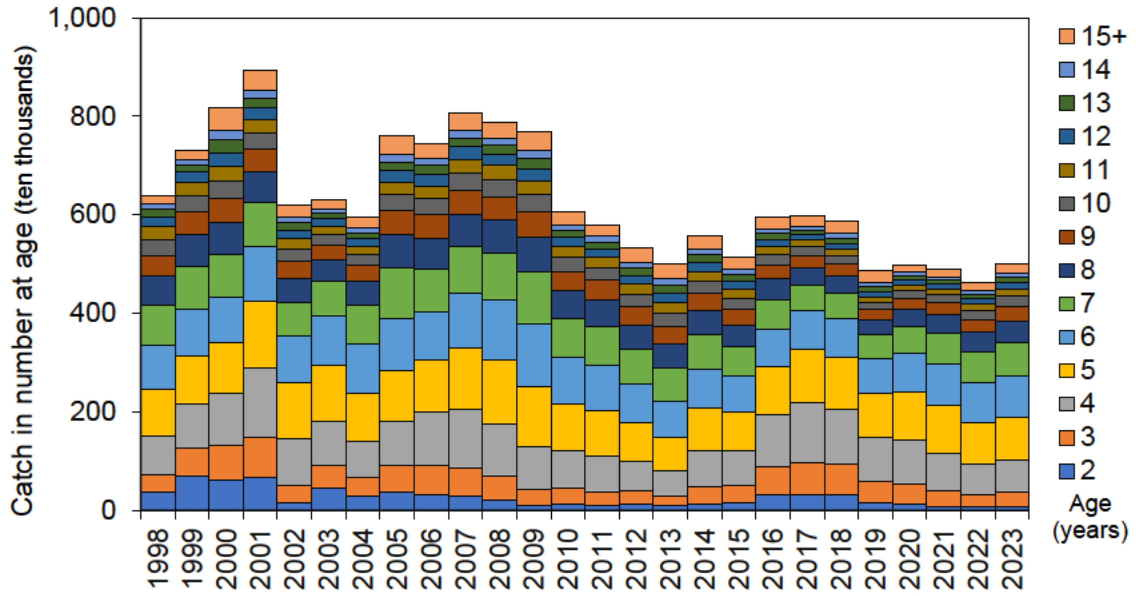


Fig. 3-2. Trends in catch in number at age

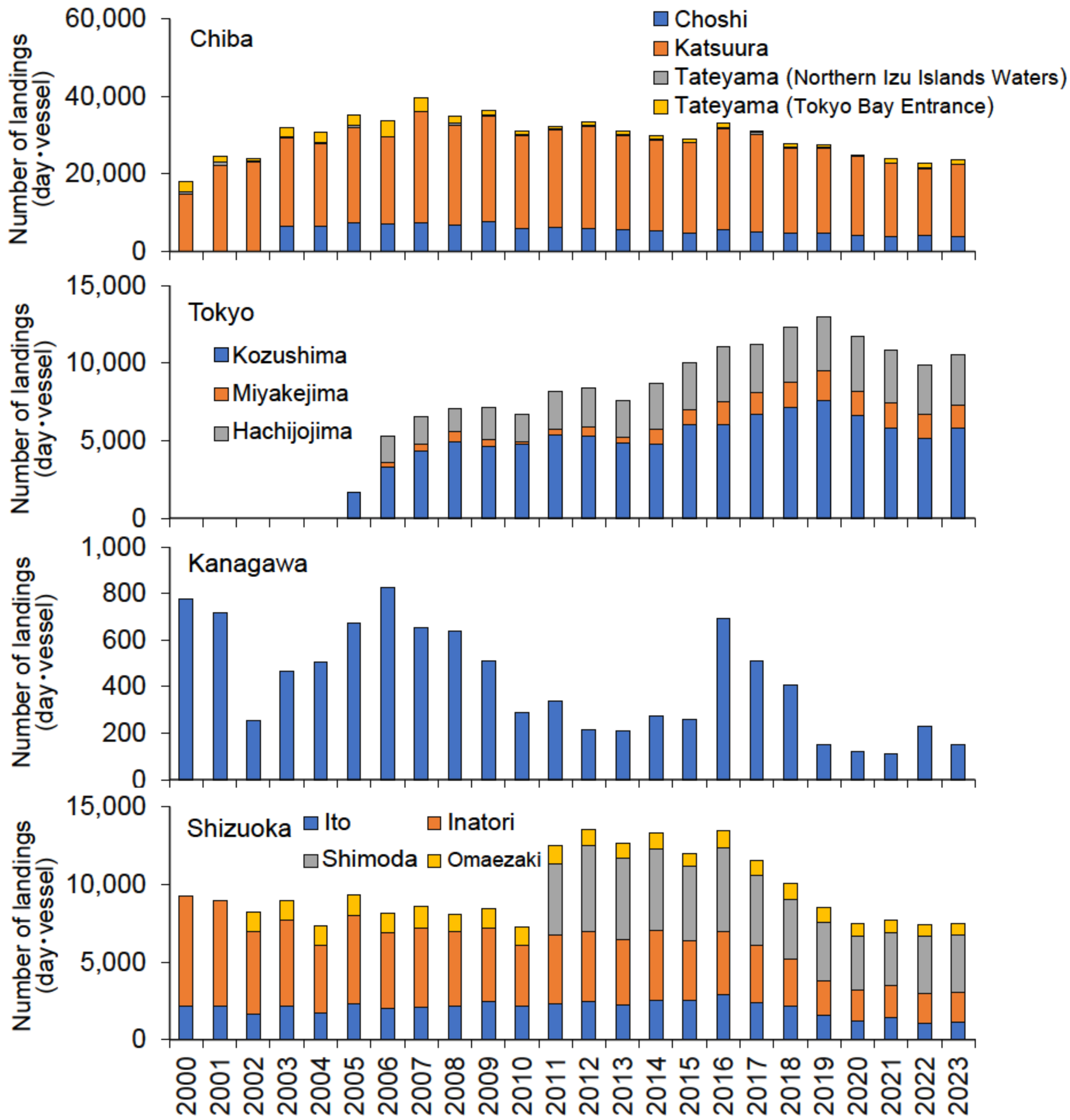


Fig. 3-3. Trends in fishing effort of vertical long line fisheries at major ports in Chiba, Tokyo, Kanagawa, and Shizuoka prefectures (number of landings (day·vessel))
Includes tentative values and uncompiled periods. For Katsuura, Chiba Prefecture, the fishing year is from October of the previous year to June of the current year. For Omaezaki, Shizuoka Prefecture, the fishing effort represents drifting dropline fisheries. For Kanagawa Prefecture, the data represent the number of landings by long line vessels in the Misaki area.

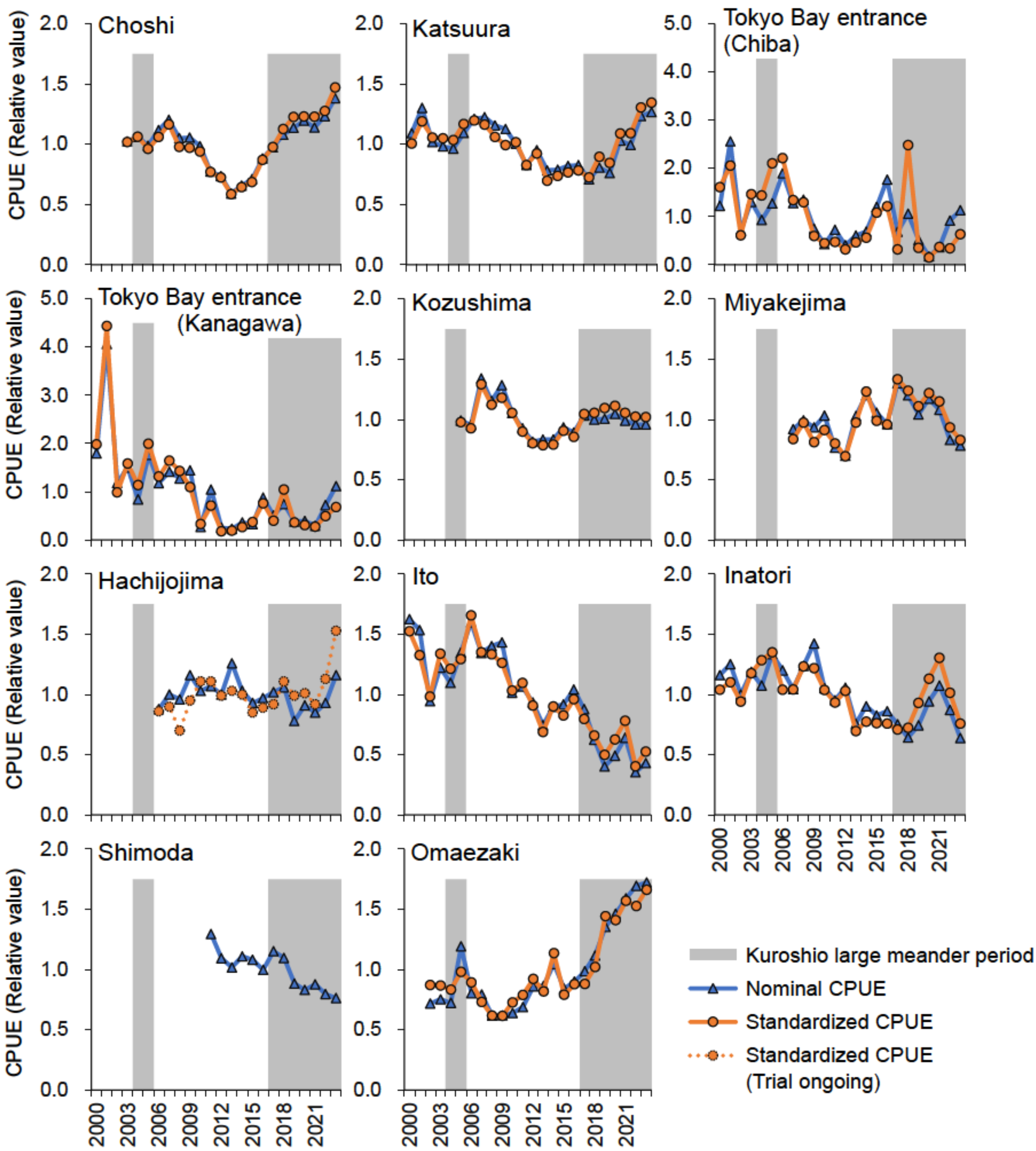


Fig. 4-1. Standardized CPUE and nominal CPUE (relative values divided by the mean of the entire period) for vertical long line fisheries in Choshi, Katsuura, Tokyo Bay entrance (Chiba), Tokyo Bay entrance (Kanagawa), Kozushima, Miyakejima, Hachijojima, Ito, Inatori, and Shimoda, and drifting dropline fisheries in Omaezaki The gray shaded years indicate periods of the Kuroshio large meander.

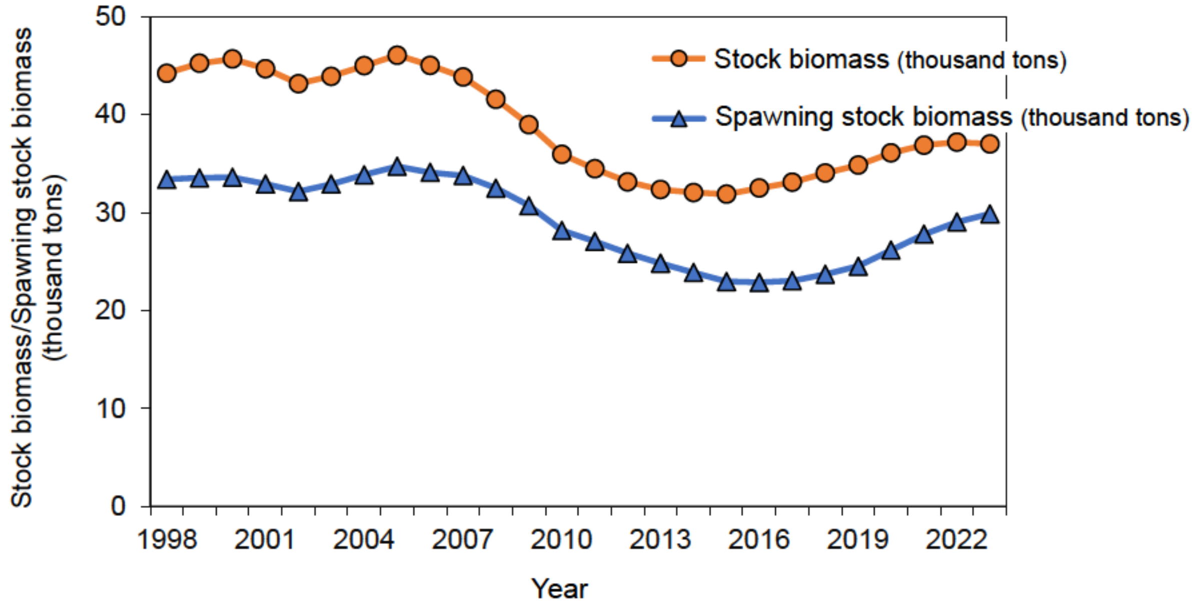


Fig. 4-2. Trends in stock biomass and spawning stock biomass

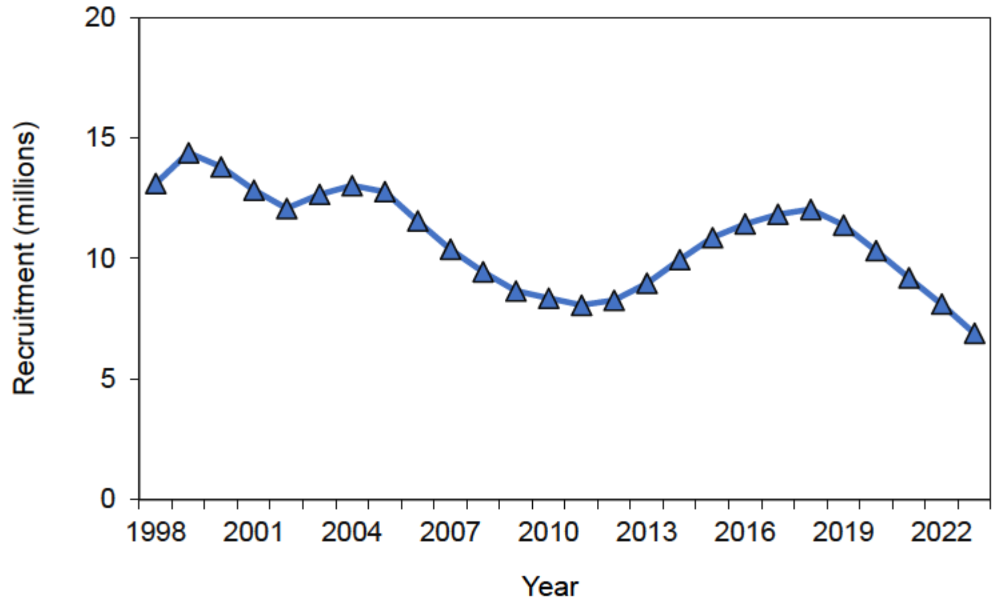


Fig. 4-3. Trends in recruitment

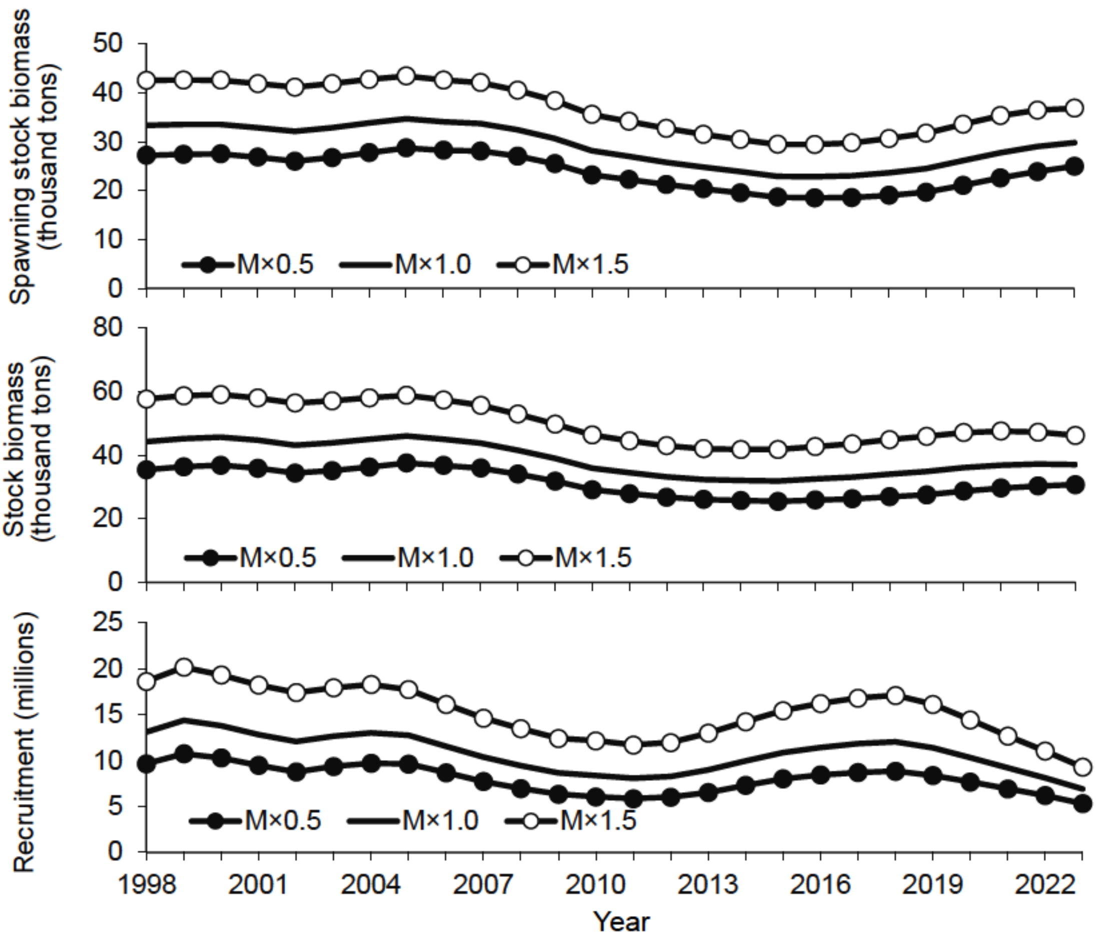
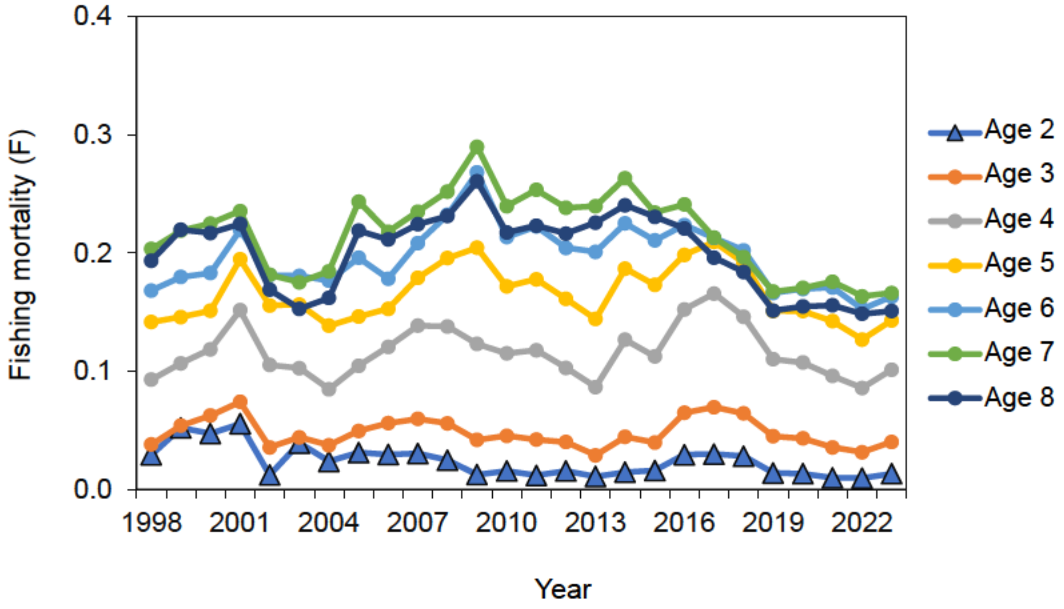


Fig. 4-4. Sensitivity analysis of spawning stock biomass, stock biomass, and recruitment in response to changes in natural mortality coefficient M



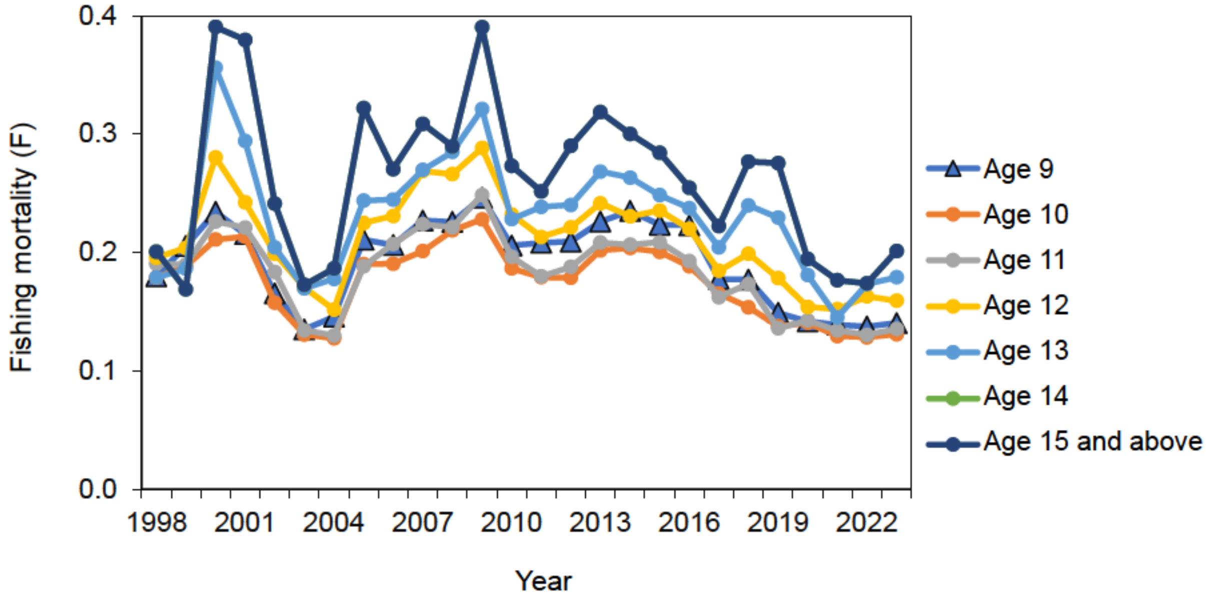


Fig. 4-5. Trends in fishing mortality coefficient F at age (Upper figure: Ages 2–8, lower figure: Ages 9–15 and older)

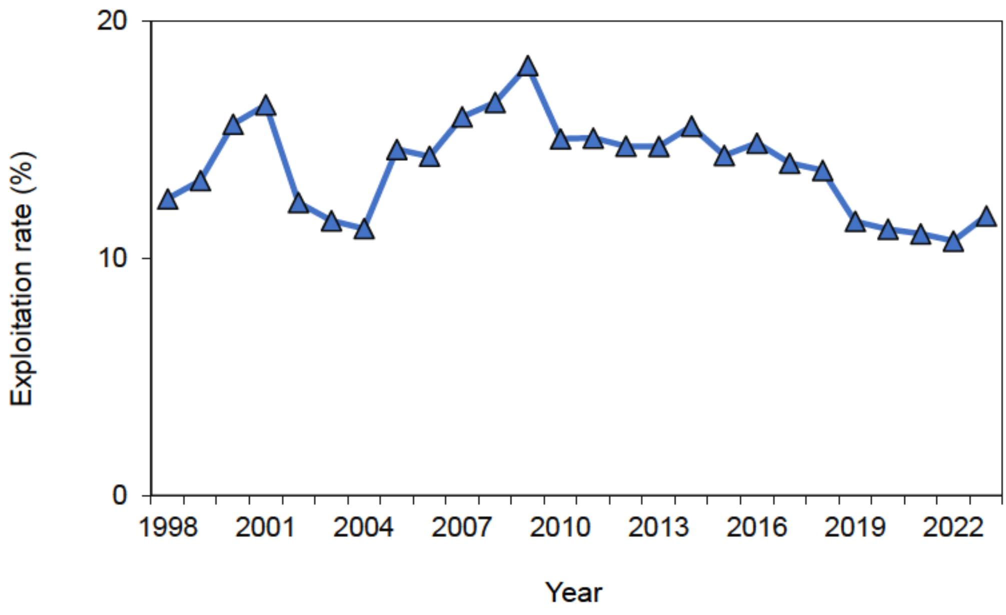


Fig. 4-6. Trends in exploitation rate

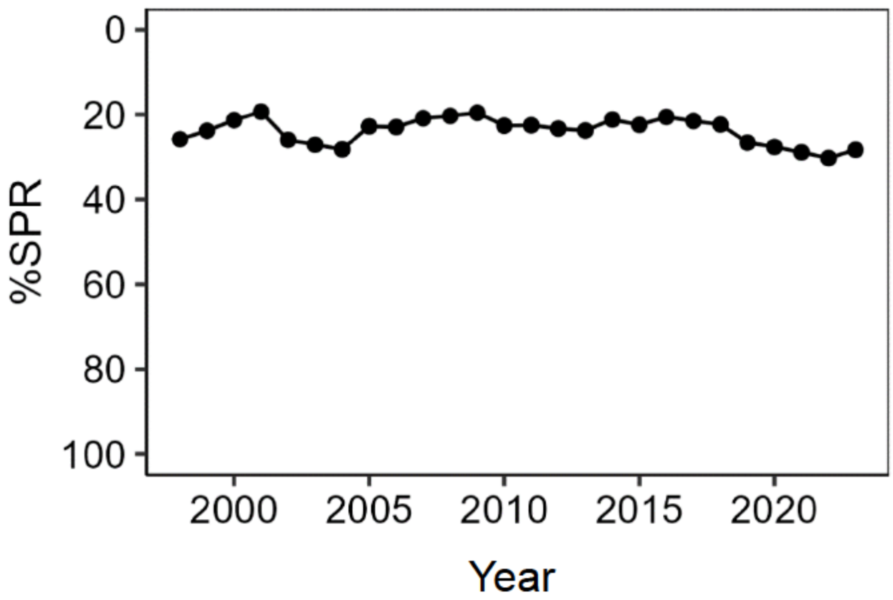


Fig. 4-7. Trends in %SPR

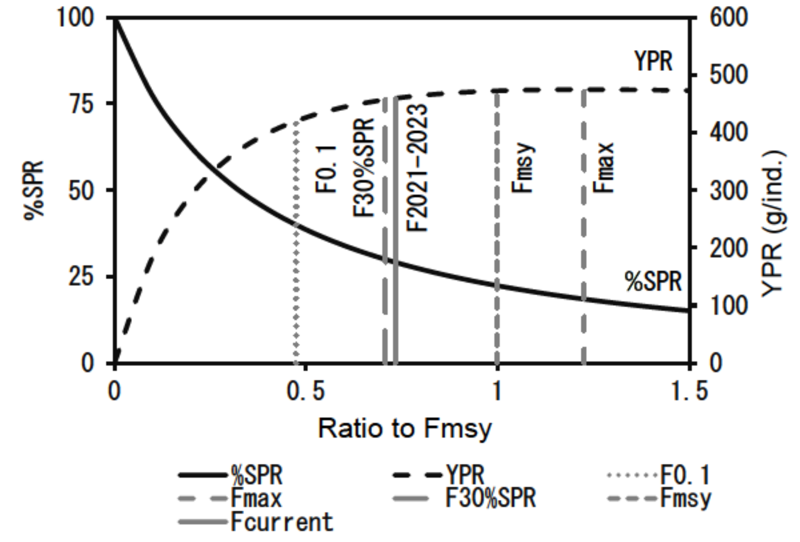


Fig. 4-8. Relationship between YPR and %SPR with respect to Fmsy

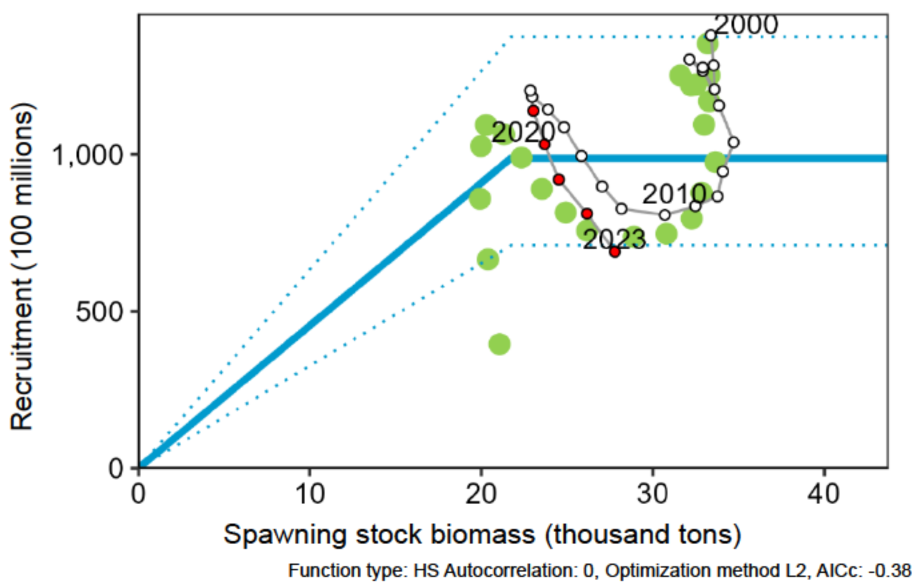


Fig. 4-9. Relationship between spawning stock biomass and recruitment (stock-recruitment relationship)

A hockey stick (HS) type stock-recruitment relationship that does not account for autocorrelation was used, and parameters were estimated using the least squares method. The green circles indicate SSB from 1998 to 2019 and recruitment at age 2 from 2000 to 2021, used for the analysis of the stock-recruitment relationship during the FY 2022 assessment. The numbers in the figure indicate the cohort (birth year) of the recruited stock. The dotted lines above and below the stock-recruitment relationship model (solid blue line) in the figure represent the interval estimated to contain 90% of observed data in the assumed stock-recruitment relationship. The white circular markers indicate SSB from 1998 to 2016 and recruitment at age 2 from 2000 to 2018 for this fiscal year's assessment. The red circular markers indicate SSB from 2017 to 2021 and recruitment from 2019 to 2023.

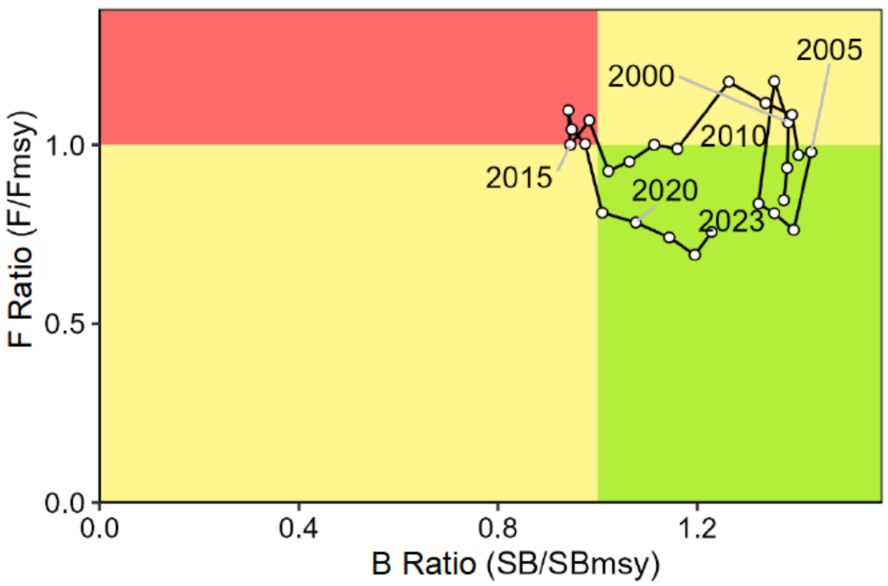


Fig. 4-10. Relationship of SSB to achieve MSY (SBmsy) and fishing pressure required to maintain SBmsy (Fmsy) against past levels of SSB and fishing pressure (Kobe plot)

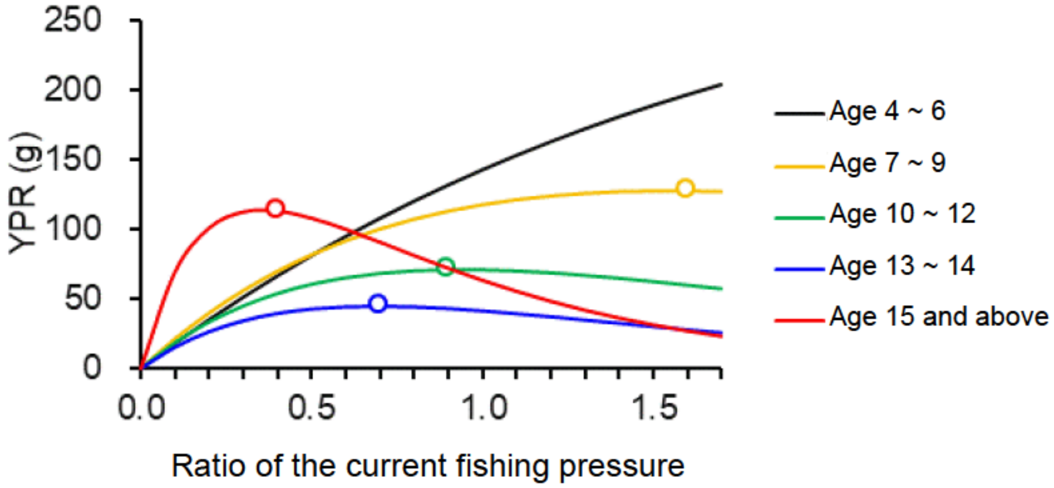


Fig. 4-11. Relationship between YPR and fishing pressure (F2021-2023) by age group
The circles indicate the ratio of the current fishing pressure to the level at which YPR is maximized for each age group.

Table 3-1. Changes in the catch of splendid alfonsino (tons) calculated based on statistical data in each prefecture and ocean region, landings at major ports, Catch Performance Reports, and Regional Fisheries Coordination Committee data

Year	Prefecture*										Pacific Northern Area (Offshore Bottom Fishery)	Pacific Central-Southern Area (Offshore Bottom Fishery)	East China Sea Area (East China Sea Longline Fishery)	Pacific Central-Southern Area (Bottom Gillnet Fishery)	Total
	CB	TK	KN	SO	AC	ME	WK	TO	KO	KG					
1976	471	25	233	1,378					98						2,205
1977	374	34	334	1,414					575						2,731
1978	455	28	484	1,660					440						3,067
1979	479	27	407	3,155					147						4,215
1980	500	34	664	4,155					28						5,381
1981	933	26	717	5,047					49						6,772
1982	950	30	693	7,067					97						8,837
1983	848	24	536	7,007					205						8,620
1984	1,202	54	856	7,844					559						10,515
1985	1,418	81	1,342	6,388					695						9,924
1986	1,369	121	1,603	5,697					869						9,659
1987	1,308	26	1,003	5,442					1,232						9,011
1988	1,557	104	1,649	5,898					1,099						10,307
1989	1,146	98	1,512	6,099					1,582						10,437
1990	1,257	30	1,207	5,250					1,179	58					8,981
1991	1,521	225	3,032	5,493					853	73					11,198
1992	1,400	109	936	5,068					1,205	64					8,782
1993	1,321	117	937	4,783					1,325	91					8,575
1994	1,348	113	990	4,652					1,206	91					8,400
1995	1,400	99	817	4,433					1,442	34					8,224
1996	1,324	127	881	4,448					1,093	35					7,907
1997	936	173	740	3,874					892	24	8				6,646

*Prefecture; CB: Chiba, TK: Tokyo, KN: Kanagawa, SO: Shizuoka, AC: Aichi, ME: Mie, WK: Wakayama, TO: Tokushima, KO: Kochi, KG: Kagoshima

“0” indicates values less than 1 ton after rounding, “blank” indicates that the data has not been aggregated or recorded, and “-” indicates that there is no catch record

Table 3-1. (Continued)

Year	Prefecture CB	TK	KN	SO	AC	ME	WK	TO	KO	KG	Pacific Northern Area (Offshore Bottom Fishery)	Pacific Central-Southern Area (Offshore Bottom Fishery)	East China Sea Area (East China Sea Longline Fishery)	Pacific Central-Southern Area (Bottom Gillnet Fishery)	Total
1998	882	215	708	3,724					1,125	37	2				6,694
1999	1,141	285	597	3,978					1,336	42	2		134		7,515
2000	1,537	338	658	4,613					1,816	44	3		209		9,219
2001	2,252	381	795	3,930					1,707	34	4		230		9,333
2002	1,656	298	459	2,916			-		2,011	125	9		142		7,616
2003	1,722	321	514	2,529			6		1,661	47	8		74		6,882
2004	1,604	264	609	2,582			-		1,502	45	11		85		6,702
2005	1,972	439	1,024	3,283			-	0	915	34	5		113		7,785
2006	2,187	612	681	2,953			-	1	1,324	12	3		176		7,950
2007	2,291	872	747	3,048			9	1	1,258	25	21		232	36	8,540
2008	2,060	832	838	3,104			2	1	1,020	68	16		262	51	8,254
2009	2,022	968	623	3,431			31	0	869	60	9		192	17	8,222
2010	1,492	720	625	2,548			3	0	1,004	60	0		219	18	6,690
2011	1,392	788	582	2,403			15	0	721	61	2		204	27	6,194
2012	1,410	734	496	2,217	1	5	18	1	624	56	1		187	22	5,773
2013	1,144	838	571	2,168	0	3	-	2	613	78	2	14	221	35	5,689
2014	1,236	998	515	2,209	0	12	68	2	570	60	0	19	200	29	5,918
2015	1,177	1,011	467	1,839	0	34	12	2	552	79	1	22	191	73	5,460
2016	1,453	1,083	540	1,687	0	4	54	1	636	65	1	50	162	64	5,801
2017	1,368	1,230	574	1,415	0	151	27	1	676	55	2	121	177	46	5,844
2018	1,429	1,234	571	1,375	0	6	7	2	594	67	2	146	187	52	5,671
2019	1,219	1,093	444	1,210	0	6	-	2	558	53	0	115	167	60	4,927
2020	1,306	1,123	482	1,051	7	8	-	1	564	48	1	57	142	87	4,876
2021	1,220	961	512	1,321	1	11	-	0	295	57	6	175	119	52	4,730
2022	1,315	880	573	1,183	13	10	-	1	149	48	2	184	131	35	4,525
2023	1,470	1,023	557	1,290	14	12	-	2	47	52	10	627	121	20	5,246

In Chiba Prefecture (CB), until 2006, the data was based on the Chiba Prefectural Resident Statistics from the Kanto Agricultural Administration Office. From 2007 onward, it represents landings at three major ports.

In Kanagawa Prefecture (KN), until 2006, the data was based on the Kanagawa Prefectural Resident Statistics from the Kanto Agricultural Administration Office. From 2007 onward, it includes landings at Misaki Market, Matsuwa District, and Manazuru District. Since 2000, it includes the sum of landings at Takamatsu local fishing ports for vessels of the same prefecture.

In Shizuoka Prefecture (SO), the data was based on resident statistics in 2001. From 2002 to 2006, it was the sum of resident statistics and out-of-prefecture-based trawl fisheries. From 2007 onward, it represents landings at major ports.

In Aichi Prefecture (AC), the data represents landings at 2 major ports.

In Mie Prefecture (ME), the data represents landings at major ports.

In Tokushima Prefecture (TO), the landing volume includes splendid alfonsino species.

In Kochi Prefecture (KO), the landing volume was based on three major ports from 1977 to 1988, four major ports from 1989 to 2003, five major ports from 2004 to 2009, and the entire prefectural fisheries cooperative from 2010 onward.

In Kagoshima Prefecture (KG), the landing volume at Kagoshima Fish Market includes shipments from vessels of other prefectures.

In the Pacific Northern Area, the landing volume of splendid alfonsino species is based on the catch performance reports of offshore bottom trawl fisheries.

In the Pacific Central-Southern Area, the landing volume is based on the total landings from offshore bottom trawl fisheries in Aichi and Mie Prefectures. For 2013, the landing volume is for the period from April to December.

In the Pacific Central-Southern Area, the reported values are based on the bottom gillnet fishery approved by the Pacific Ocean Wide Sea-area Fisheries Adjustment Commission.

In the East China Sea area, the landing volume for the longline fishery was recorded at Nagasaki Fish Market from 1999 to 2020. From 2023 onwards, the reported values are based on the catch performance reports.

TK: Tokyo, WK: Wakayama Prefecture

“0” indicates values less than 1 ton after rounding, “blank” indicates that the data has not been aggregated or recorded, and “-” indicates that there is no catch record

Table 3-2. Details of catch (tons) by region and fishing method in Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures

Prefecture/ Sea Area	Chiba				Tokyo				Kanagawa		Shizuoka		Pacific Central-Southern Area
Region	Choshi	Katsu-ura	Tateyama (Tokyo Bay Entrance Area)	Tateyama (Northern Izu Islands Area)	Oshima, Toshima, Niijima, Shikinejima	Kozu-shima	Miyake-jima, Mikura-jima	Hachijo-jima					
Fishing method*	VVL	VVL	VVL	VVL	VVL	VVL	VVL	VVL	VVL	TTL	VVL, DDL	TTL	Bottom gillnet fishery
1998	299	249	138	160	96	32	20	67	339	369	958	2,766	
1999	427	308	207	152	106	45	14	121	269	328	1,200	2,778	
2000	514	650	159	169	168	23	12	135	413	245	1,289	3,324	
2001	665	1,035	105	351	139	28	25	189	522	274	1,128	2,802	
2002	628	903	26	91	76	23	11	188	250	209	661	2,255	
2003	628	828	149	99	62	44	11	204	255	259	792	1,737	
2004	656	697	111	72	61	61	9	133	181	428	687	1,895	
2005	705	854	155	207	103	124	10	202	458	566	1,065	2,218	
2006	738	1,046	371	15	121	249	15	227	164	517	866	2,087	
2007	854	1,179	230	27	116	470	24	268	181	566	892	2,156	36
2008	695	1,106	144	124	119	434	36	242	290	548	930	2,174	51
2009	779	1,086	37	128	114	462	28	364	210	412	1,073	2,358	17
2010	576	840	19	88	63	385	11	261	103	522	484	2,064	18
2011	456	825	13	97	46	392	16	334	85	497	779	1,624	27
2012	412	892	23	83	34	374	21	341	55	441	691	1,526	22
2013	313	701	25	105	34	356	20	429	87	484	685	1,484	35
2014	344	725	35	133	33	479	61	425	75	440	791	1,418	29
2015	313	747	31	86	54	501	56	402	104	362	672	1,167	73
2016	469	781	92	111	67	470	75	471	165	376	725	962	64
2017	478	677	21	191	64	575	90	500	189	385	660	754	46
2018	492	790	50	97	34	572	104	525	154	417	580	794	52
2019	513	648	14	44	24	589	102	378	75	369	493	717	60
2020	469	816	3	18	61	539	97	427	68	414	444	607	87
2021	408	783	16	13	39	453	92	377	78	433	563	758	52
2022	477	768	68	2	25	378	66	411	84	490	477	705	35
2023	508	888	71	3	34	414	61	513	140	417	533	757	20

*Fishing method; VLL: Vertical long line fishing, TTL: Trotline fishing, DDL: Drifting dropline fishing

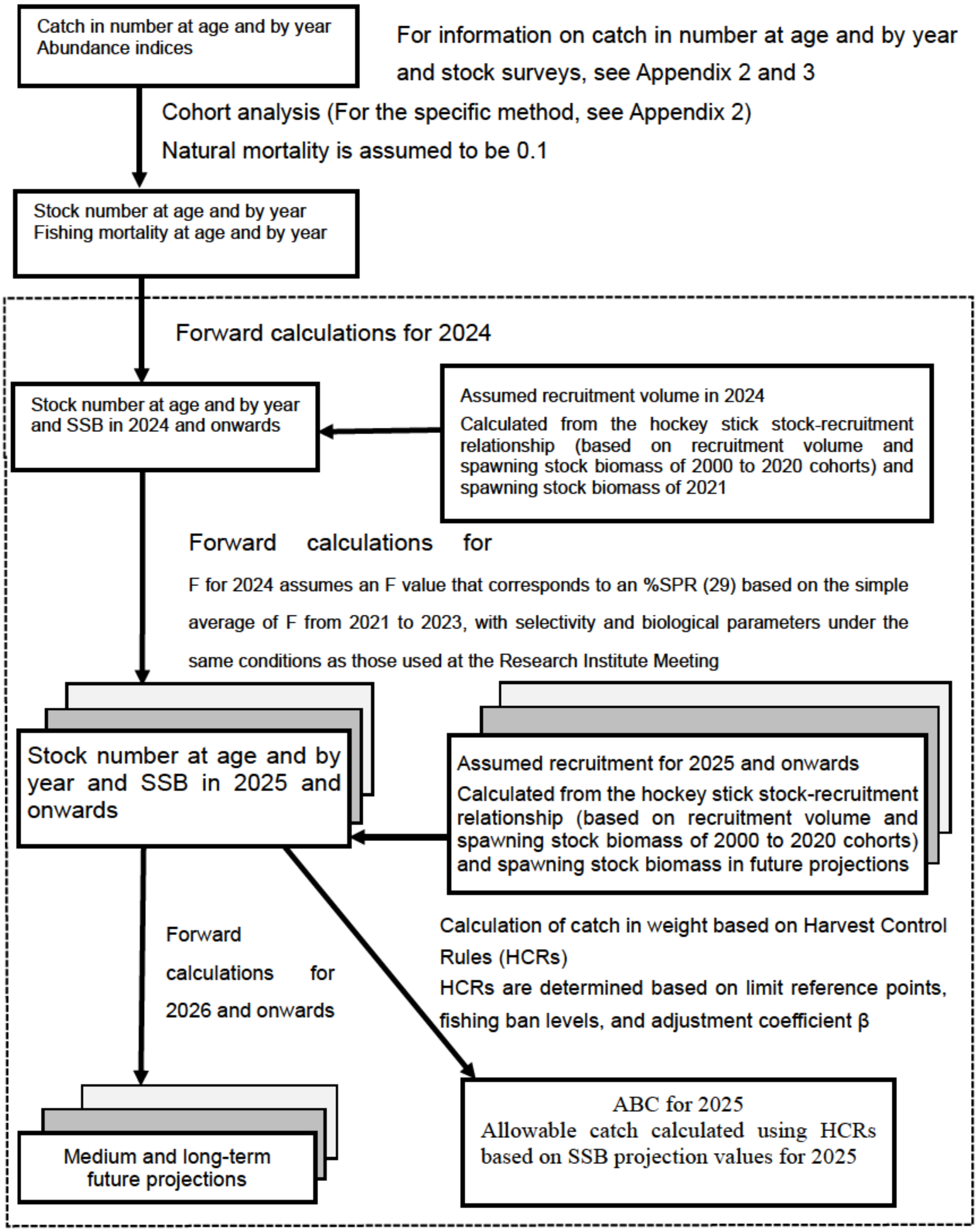
Due to the difference between the aggregate values from the catch statistics and those from major ports, there are years where the total does not match with the total by prefecture in Table 3-1.

Table 4-1. Results of stock analysis of the Splendid Alfonsino - Pacific Japan in the fishing grounds, off the Kanto coast to those around the Izu Islands and the southern offshore seamount area of Shikoku

Year	Catch (Thousand tons)	Stock biomass (Thousand tons)	Spawning stock biomass (Thousand tons)	Exploitation rate (%)	Number of recruits at age 2 (millions)	%SPR	F/Fmsy
1998	5.5	44.2	33.4	13	14	25.8	0.85
1999	6.0	45.2	33.5	13	13	23.8	0.94
2000	7.1	45.7	33.6	16	12	21.3	1.06
2001	7.4	44.7	32.9	16	13	19.3	1.18
2002	5.3	43.2	32.1	12	13	26.0	0.84
2003	5.1	43.9	32.9	12	13	27.1	0.81
2004	5.1	45.0	33.9	11	12	28.2	0.76
2005	6.7	46.1	34.7	15	10	22.8	0.98
2006	6.4	45.0	34.1	14	9	22.9	0.97
2007	7.0	43.8	33.8	16	9	20.9	1.08
2008	6.9	41.6	32.5	17	8	20.3	1.12
2009	7.1	39.0	30.7	18	8	19.6	1.18
2010	5.4	35.9	28.2	15	8	22.6	0.99
2011	5.2	34.5	27.0	15	9	22.5	1.00
2012	4.9	33.1	25.8	15	10	23.3	0.95
2013	4.8	32.3	24.8	15	11	23.7	0.93
2014	5.0	32.0	23.9	16	11	21.2	1.07
2015	4.6	31.9	23.0	14	12	22.4	1.00
2016	4.8	32.5	22.9	15	12	20.6	1.10
2017	4.6	33.1	23.0	14	11	21.5	1.04
2018	4.7	34.0	23.7	14	10	22.3	1.00
2019	4.0	34.8	24.5	12	9	26.6	0.81
2020	4.0	36.1	26.2	11	8	27.6	0.78
2021	4.1	36.9	27.8	11	7	28.9	0.74
2022	4.0	37.2	29.0	11	-	30.3	0.69
2023	4.4	37.0	29.9	12	-	28.3	0.76

The age 2 recruitment was shifted to the year at age 0. Age cohorts of 2022 and 2023 are shown as “-” because they have not yet joined the fishing target stock as of 2024.

Appendix 1 Stock Assessment Flow



* The information inside the dotted line box is based on discussion of reference points, HCRs, etc., at the Stock Management Policy Review Meeting. (http://www.fra.affrc.go.jp/shigen_hyoka/SCmeeting/2019-1/index.html)

Appendix 2 Calculation Methods

(1) Catch in number at age

Based on previous biological measurement results, the maximum age of individuals collected in coastal fishing grounds, such as the waters around the Kanto region, is 14 years old, with the majority of individuals being age 10 and younger. On the other hand, many individuals caught in offshore fishing grounds, such as in the southern part of the Izu Islands, were age 14 and older. Applying the information from the offshore fishing grounds to the coastal fishing grounds when creating the age-length key revealed a large number of older fish in the coastal fishing grounds, which is different from the biological reality obtained from the survey. Therefore, we created two age-length keys, one each for the coastal and offshore fishing grounds, and applied them to each landing port and fishing method in order to calculate the catch in number at age, which consists of fish age 2 to 14 and fish age 15 and older (Supplementary Table 2-1). For areas in Chiba Prefecture for which grade compositions were available, we used the age-grade key, which is the aggregation of age-length key based on the relationship between age and grade (Supplementary Table 2-2). These grades are classified into four to eight categories according to body weight. However, since a single grade category contains multiple age groups, there are limitations in performing highly accurate age stratification for each cohort. Body length composition was determined based on direct fork length measurement conducted several times a month at landing ports by personnel from experimental stations and research institutes and is a portion of the volume handled at said landing ports. On the other hand, grade composition is the total volume handled at landing ports, excluding those classified as “other” grades.

The relationships between age and body length and age and grade (body weight) use data compiled over multiple years, which are updated every year with additional age assessment information. The addition of such information also updates the average body weight at age and age-length key every year, which changes the catch in number at age and the catch, as well as the spawning stock biomass (SSB) and recruitment estimated values derived from cohort analysis, changes the stock-recruitment relationship as well, strictly. To exclude such fluctuations, and until the stock-recruitment relationship is updated, the average body weight (Watari et al. 2022), based on data from 1998 to 2021, presented at the document for the Research Institute Meeting on Reference Points held in August 2022 as well as the age-length key (Watari et al. 2023) used in the FY 2022 stock assessment continued to be used.

Until the FY 2020 assessment, the catch in number at age 1 to 14 and 15 and older were considered to be the plus group, with the age for recruitment set at 1 year. However, some fishery operators were of the opinion that the stock assessment included by catch rather than the target size of the main catch, which did not reflect the actual situation. After subsequent discussions and examinations by the organizations participating in the stock assessment, and in consideration of the fact that the proportion of fish age 1 in the catch in number of fish age 1 and age 2 has been declining year by year and that the proportion of fish age 1 in the total catch is small at less than 0.1%, the age composition of catches from the FY 2021 stock assessment is assumed to consist of fish age 2 to 14 and fish age 15 and older.

The following procedure was followed to calculate the catch in number at age. In 6), the number of fish age 1 was excluded, and the catch in number at age 2 and older and calculated catch was used instead.

1)	Organized aggregation of grade composition and body length composition of each fishing ground
2)	The proportion of catch in number by length class and catch in number by grade class at age was calculated using the age-length key and age-grade key for coastal and offshore fishing grounds to obtain the proportion of catch in number at age
3)	We then calculated the total catch in number for each area based on catch and average body weight
4)	The catch in number at age for each area was calculated
5)	The catch in number at age was then obtained by totaling the number for all areas
6)	Due to setting the average body weight of the plus group, etc., the catch obtained by multiplying the catch in number at age by the average body weight at age in 5) (calculated catch) does not exactly coincidence the fishery catch statistics shown in Table 4-1. Therefore, the catch in number at age was corrected using the following equation Catch in number at each age in each year x catch in Table 4-1 ÷ calculated catch

(2) Cohort Analysis

A cohort analysis was conducted using catch at age data over 26 years (1998-2023) for ages 2-14, with ages 15 and older treated as a plus group to estimate stock abundance (Pope 1972). The stock number $N_{a,y}$ and fishing mortality coefficients $F_{a,y}$ were calculated from catch at age $C_{a,y}$ for year y and age a using the following equation.

$$N_{a,y} = N_{a+1,y+1}\exp(M) + C_{a,y}\exp\left(\frac{M}{2}\right) \qquad (a = 2,\ldots,13,\ y = 1998,\ldots,Y\text{-}1) \qquad (1)$$

$$F_{a,y} = \ln\left(1 - \frac{C_{a,y}\exp\left(\frac{M}{2}\right)}{N_{a,y}}\right) \qquad (y = 1998,\ldots,Y) \qquad (2)$$

Y indicates the most recent year, 2023. Ages 15 and older are treated as a plus group, and fishing mortality for age 14 and age 15+ is assumed to be equal. The stock number was determined by the following equation.

$$N_{14,y} = \frac{C_{14,y}}{C_{14,y} + C_{15+,y}} N_{15+,y+1} \exp(M) + C_{14,y} \exp\left(\frac{M}{2}\right) \quad (y = 1998,\ldots,Y\text{-}1) \quad (3)$$

$$N_{15+,y} = \frac{C_{15+,y}}{C_{14,y} + C_{15+,y}} N_{15+,y+1} \exp(M) + C_{15+,y} \exp\left(\frac{M}{2}\right) \quad (y = 1998,\ldots,Y\text{-}1) \quad (4)$$

The stock number of the most recent year, Y

$$N_{a,Y} = \frac{C_{a,Y}}{1 - \exp(-F_{a,Y})} \exp\left(\frac{M}{2}\right) \quad (a = 2,\ldots,15+) \quad (5)$$

Fishing mortality for 2023 (Y) was tuned using CPUE, and the optimal F was estimated under the conditions that fishing mortality for age 14 and age 15+ are equal and that fishing mortality for ages 2-14 is equal to the average of age-specific selectivity $S_{a,y}$ over the past 5 years.

$$F_{a,y} = \frac{\frac{1}{5}\sum_{y=2018}^{Y-1} S_{a,y}}{\frac{1}{5}\sum_{y=2018}^{Y-1} S_{15+,y}} F_{15+,y} \quad (a = 2,\ldots,14) \quad (6)$$

$$S_{a,y} = \frac{F_{a,y}}{F_{15+,y}} \quad (7)$$

Tuning was performed by using standardized CPUE $u_{y,i}$ by area (i) given in Appendix 7 and the document (FRA-SA2024-SC08-02 ~ -11) for standardized CPUE (Supplementary Table 7-2, 7-3). For CPUE standardization, the possibility of calculating a single CPUE incorporating the effects of the “area” differences was also considered. However, it was calculated by area, considering the ease of explaining the situation in each scattered area. Only for the CPUE in the Hachijojima area, nominal CPUE was used in this analysis because during a series of model selections for CPUE standardization, effects of “year” were not selected within 2 of the minimum AIC, and the impact of the marine environment on fishing efficiency could not be fully considered. For the Tokyo Bay entrance, the mean standardized CPUE value derived from the operational data of vessels in the Kanagawa and Chiba Prefecture fishing grounds was used.

The unknown parameters q_i and $F_{15+,Y}$ that minimize the residuals between the observed value of log converted CPUE ln ($u_{y,i}$) and the calculated value of CPUE in area i in year y were estimated using the least squares method. The catch age range (age_i - A_i) was established for the CPUE in each area with reference to the size composition of the catch. Except for the Tokyo Bay entrance, the minimum age age_i and maximum age Ai were set as 2 years and 15+ years, respectively, for all areas. Since there were very few catches of individuals 12 years and older (> 1.5 kg body weight) in the Tokyo Bay entrance, age_i was set to 2 years, and A_i was set to 11 years. As in the stock assessment of the previous fiscal year, multiple settings with different age ranges for each area were considered, but determined that differences in the age range would have little impact on the stock abundance estimation results (Watari et al., 2023).

$$\mathrm{Ln}(\hat{u}_{i,y}) = \ln q_i \sum_{age_i}^{A_i} N_{a,y} W_a \tag{8}$$

$$RSS = \sum_{i}^{I} \sum_{y_i}^{Y} \left(\ln(u_{i,y}) - \ln(\hat{u}_{i,y})\right)^2 \tag{9}$$

The natural mortality coefficient, M, was set at 0.1 based on the Tauchi-Tanaka formula (M = 2.5 ÷ life span) (Tanaka 1960). The spawning stock biomass SSBy in year y was calculated from the stock number $N_{a,y}$, the average body weight W_a at age a, and the maturity rate (female) fr_a at age a.

$$SSB_y = \sum_{a=2}^{15+} N_{a,y} W_a fr_a \tag{10}$$

Average body weight and maturity rates are based on constant values regardless of the year (Supplementary Table 2-3). Details of the stock analysis results are summarized in Supplementary Table 2-4.

(3) Model Diagnostics

The statistical validity of the VPA used in this stock assessment and the robustness of its assumptions was evaluated according to the “Procedures for Model Diagnostics in Stock Assessment and Guidelines for Providing Reports (FY 2024) (FRA-SA2024-ABCWG02-03)”. Supplementary Figs. 2-1, 2-2, and 2-3 show the residuals between the observed values and model-projected values of the tuning index. Among the 9 areas, the fit was relatively poor for the Tokyo Bay entrance and Omaezaki. In point estimated values, there has been an increasing trend in SSB and a flat trend in biomass observed from 2015 onwards, and the results of the bootstrap analysis, which took into account CPUE errors, suggest that a similar interpretation is possible (Supplementary Fig. 2-4).

We performed a retrospective analysis of the 5-year period tuned VPA results used in this stock assessment, which revealed that estimated values for F and biomass changed after the data was expanded and updated. Retrospective bias (Mohn's ρ; Mohn 1999) was relatively small, with 0.01 for biomass, -0.02 for stock number, -0.02 for fishing mortality, and 0.03 for SSB. However, recruitment volume was larger than the other indices at -0.16. This is believed to be due to low fishing pressure on younger fish due to voluntary body length restrictions imposed by fishermen, making it difficult to obtain catch information (Supplementary Fig. 2-5).

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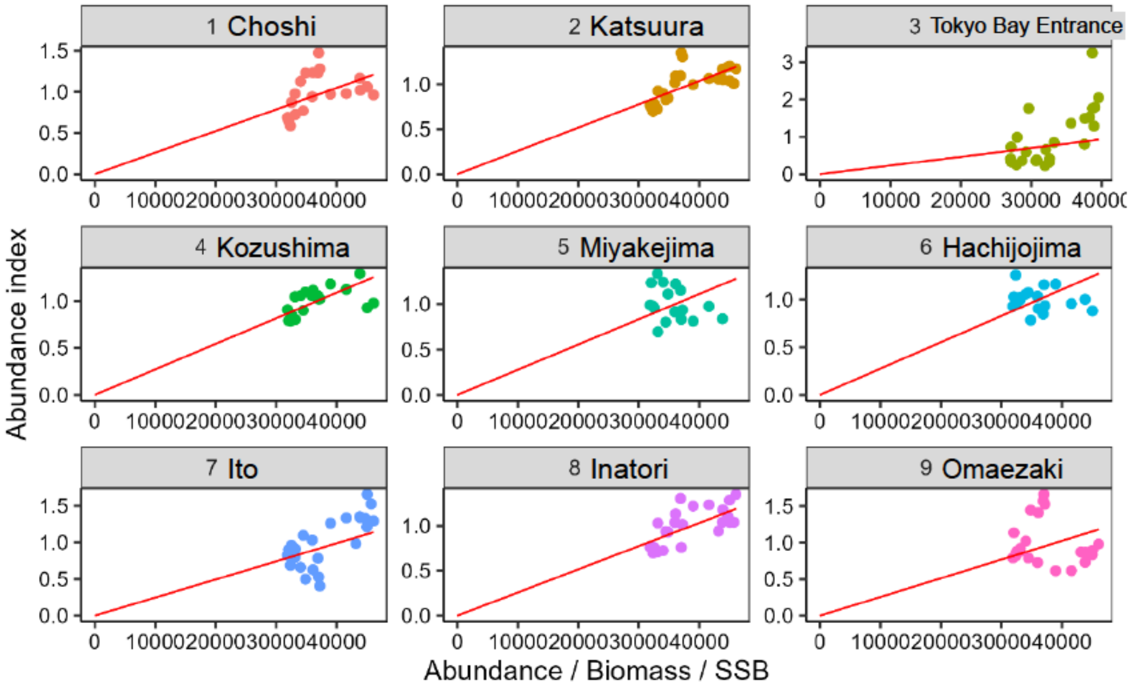
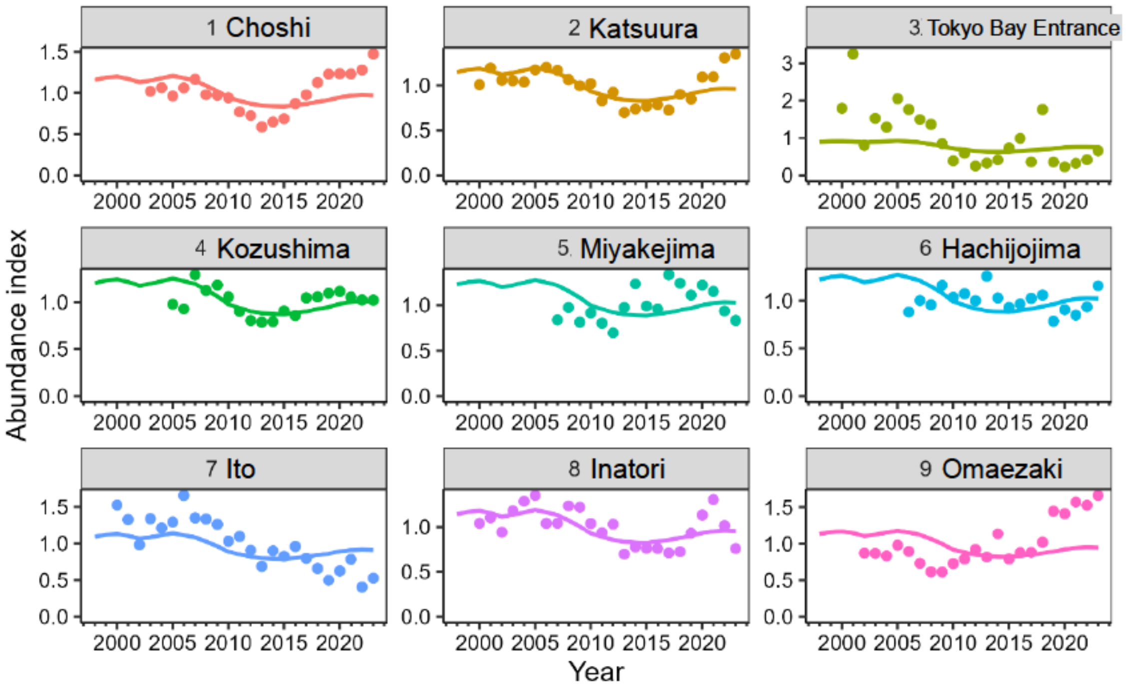
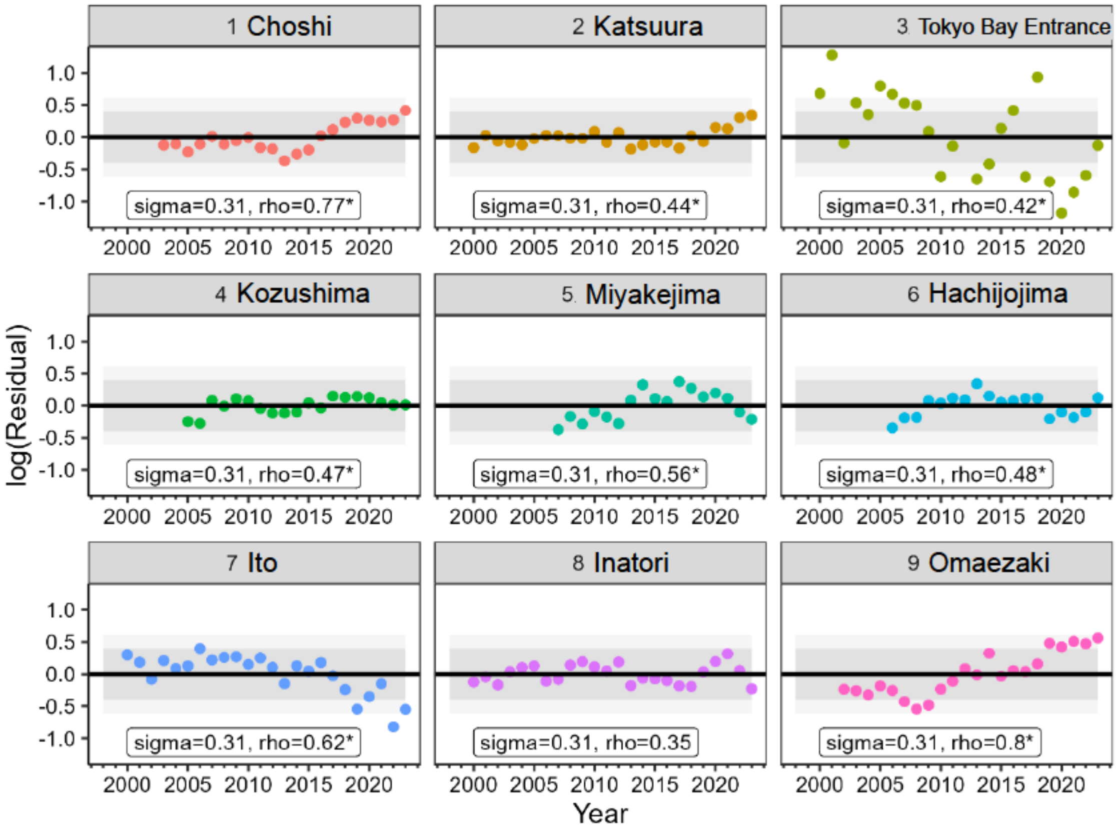


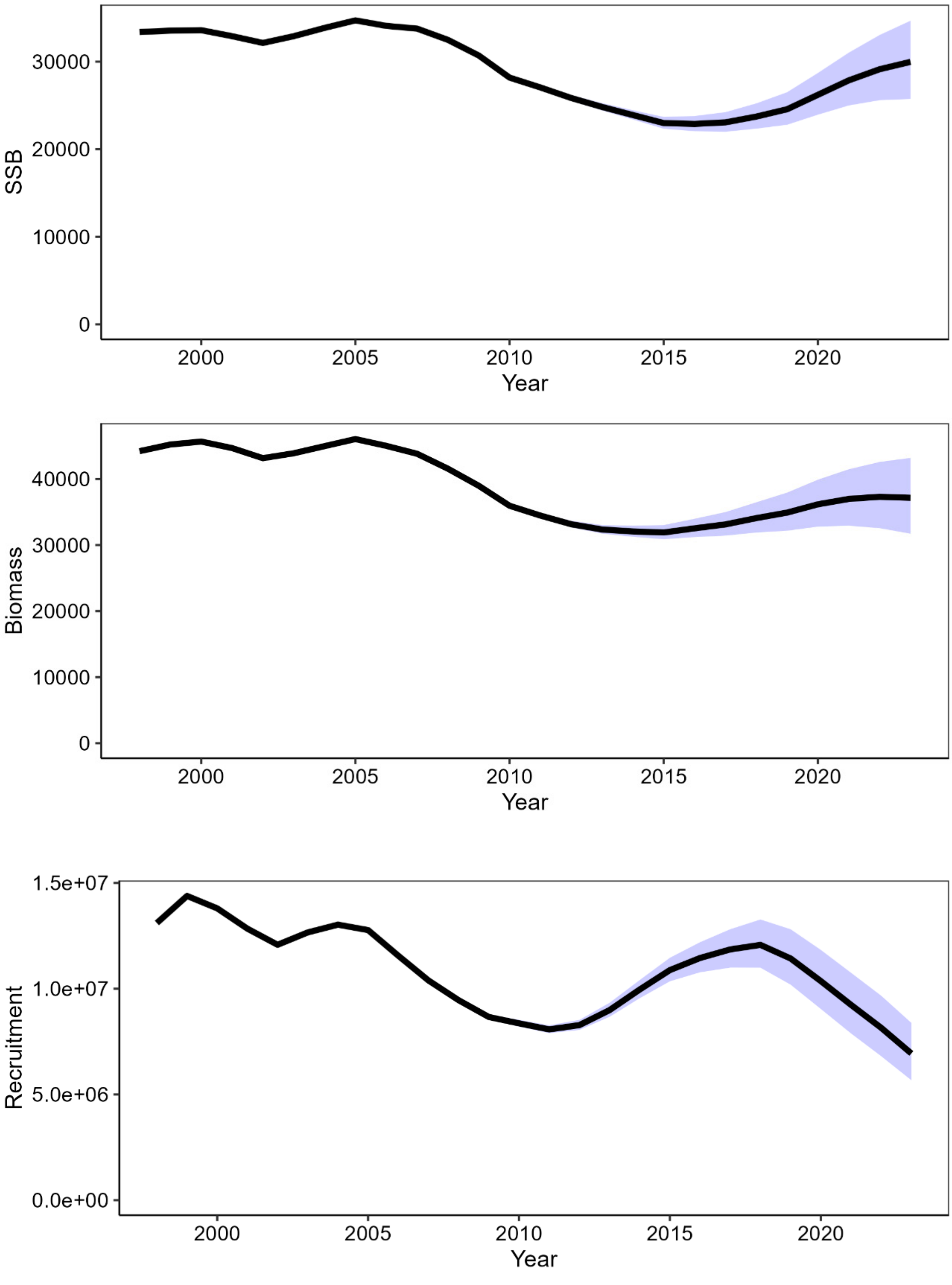
Supplementary Fig. 2-1. Plot of the estimated stock abundance index with respect to the abundance indices



Supplementary Fig. 2-2. Time series plot of observed index values (circular markers) and model-projected values (solid line)

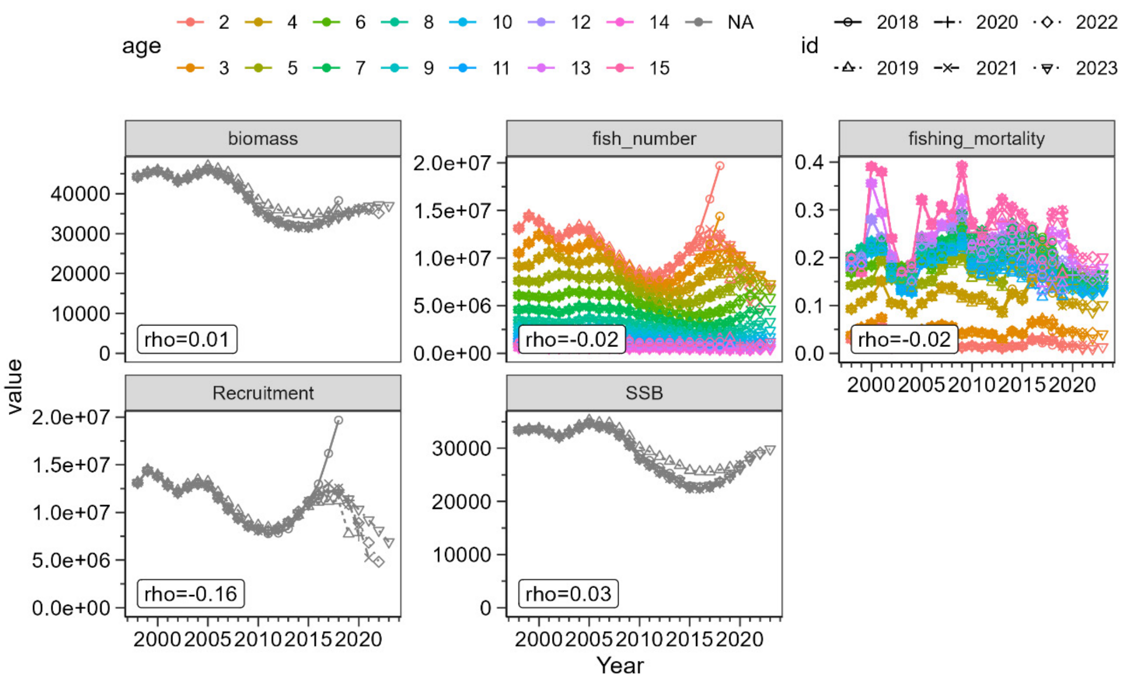


Supplementary Fig. 2-3. Time series plot of residuals showing the differences between observed index values and model-projected values



Supplementary Fig. 2-4. Bootstrap analysis of spawning stock biomass (SSB), biomass, and recruitment

The black solid line represents the estimated values, and the blue indicates the 95% confidence interval.



Supplementary Fig. 2-5. Retrospective analysis (Top left: Stock abundance, Top center: Stock number, Top right: Fishing mortality, Bottom left: Recruitment, Bottom center: Spawning stock biomass)

Supplementary Table 2-1. Age length key

Offshore waters: Hachijojima, Kozushima, Kanagawa trotline, Shizuoka trotline, bottom gillnet fishing

Length (cm)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～18	1.00														
18-20	0.83	0.03	0.13												
20-22	0.01	0.48	0.23	0.26	0.02										
22-24	0.03	0.31	0.29	0.32	0.04	0.01	0.01								
24-26		0.29	0.35	0.26	0.08	0.04									
26-28		0.08	0.30	0.41	0.16	0.04	0.00	0.00	0.00						
28-30		0.01	0.18	0.35	0.29	0.12	0.04	0.01	0.01	0.00					
30-32			0.05	0.23	0.35	0.22	0.11	0.03	0.01	0.00					
32-34			0.01	0.09	0.21	0.27	0.20	0.12	0.06	0.02	0.01	0.01	0.00	0.00	
34-36			0.00	0.02	0.11	0.18	0.23	0.19	0.12	0.08	0.04	0.02	0.01	0.01	0.00
36-38				0.00	0.02	0.07	0.15	0.16	0.17	0.14	0.11	0.07	0.05	0.03	0.03
38-40				0.01	0.01	0.02	0.08	0.13	0.13	0.15	0.15	0.11	0.09	0.06	0.06
40-42				0.00		0.01	0.03	0.05	0.09	0.10	0.14	0.14	0.10	0.09	0.22
42-44					0.00	0.00	0.00	0.03	0.06	0.08	0.10	0.14	0.11	0.11	0.37
44-46					0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.10	0.11	0.10	0.52
46-48										0.02	0.01	0.03	0.06	0.08	0.80
48-50											0.04		0.04	0.06	0.85
50～															1.00

Coastal waters: Choshi, Oshima, Kanagawa vertical long line), Shizuoka vertical long line, Shizuoka drifting dropline

Length (cm)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～16	1.00														
16-18	0.95	0.05													
18-20	0.69	0.29	0.01		0.00										
20-22	0.06	0.77	0.12	0.02	0.02	0.00									
22-24	0.02	0.37	0.25	0.16	0.07	0.06	0.05	0.01							
24-26	0.00	0.17	0.40	0.22	0.09	0.05	0.04	0.02	0.00	0.00					
26-28	0.00	0.07	0.22	0.39	0.20	0.05	0.02	0.03	0.02						
28-30	0.00	0.02	0.11	0.37	0.29	0.10	0.05	0.03	0.01	0.00	0.01				
30-32		0.01	0.04	0.22	0.32	0.24	0.08	0.04	0.02	0.02	0.01	0.00	0.00		
32-34		0.00	0.01	0.06	0.25	0.34	0.18	0.08	0.04	0.02	0.01	0.01	0.00	0.00	0.00
34-36		0.00	0.00	0.03	0.09	0.26	0.31	0.16	0.07	0.05	0.02	0.00	0.00	0.00	0.00
36-38			0.00	0.01	0.01	0.13	0.29	0.22	0.14	0.07	0.04	0.03	0.02	0.01	0.02
38-40						0.13	0.13	0.11	0.13	0.07	0.13	0.13	0.04	0.07	0.07
40-42						0.05	0.05		0.29		0.05	0.19	0.14	0.10	0.14
42～													0.33	0.33	0.33

Supplementary Table 2-2. Age grade key

Choshi

Body weight (kg)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～0.4	0.03	0.39	0.27	0.16	0.07	0.04	0.03	0.01	0.00	0.00					
0.4～0.5	0.00	0.06	0.19	0.39	0.22	0.06	0.03	0.03	0.02	0.00	0.00				
0.5～0.65		0.02	0.11	0.34	0.28	0.14	0.05	0.03	0.01	0.01	0.00	0.00	0.00		
0.65～0.75		0.01	0.03	0.18	0.33	0.27	0.09	0.05	0.02	0.02	0.01	0.01	0.00		
0.75～0.85		0.00	0.01	0.07	0.29	0.31	0.18	0.07	0.03	0.02	0.01	0.01	0.00		
0.85～0.95		0.00	0.00	0.04	0.19	0.33	0.20	0.12	0.05	0.03	0.01	0.01	0.00	0.01	
0.95～1.1			0.00	0.02	0.08	0.22	0.34	0.18	0.07	0.04	0.02	0.01	0.00	0.00	0.01
1.1～				0.02	0.02	0.12	0.25	0.17	0.16	0.07	0.04	0.04	0.04	0.03	0.04

Tokyo Bay Entrance (Chiba) 1

Body weight (kg)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～0.2	0.13	0.79	0.07	0.00	0.01										
0.2～0.3	0.02	0.49	0.23	0.11	0.06	0.04	0.04	0.01							
0.3～0.5	0.01	0.10	0.26	0.34	0.17	0.05	0.03	0.03	0.01	0.00	0.00				
0.5～1.0		0.01	0.05	0.18	0.27	0.24	0.13	0.06	0.03	0.02	0.01	0.01			
1.0～1.5			0.00	0.01	0.05	0.17	0.29	0.19	0.11	0.06	0.04	0.03	0.02	0.01	0.02
1.5～							0.12		0.18	0.06		0.06	0.12	0.24	0.24

Tokyo Bay Entrance (Chiba) 2

Body weight (kg)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～0.2	0.13	0.79	0.07		0.01										
0.2～0.3	0.02	0.49	0.23	0.11	0.06	0.04	0.04	0.01							
0.3～0.5	0.01	0.10	0.26	0.34	0.17	0.05	0.03	0.03	0.01	0.00	0.00				
0.5～1		0.01	0.05	0.18	0.27	0.24	0.13	0.06	0.03	0.02	0.01	0.01	0.00	0.00	0.00
1.0～2.0			0.00	0.01	0.05	0.17	0.29	0.18	0.12	0.06	0.03	0.03	0.02	0.02	0.02
2.0～													0.33	0.33	0.33

Supplementary Table 2-2. (Continued)

Katsuura 1

Body weight (kg)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～0.3	0.04	0.54	0.20	0.09	0.05	0.04	0.03	0.01							
0.3～0.5	0.01	0.10	0.26	0.34	0.17	0.05	0.03	0.03	0.01	0.00	0.00				
0.5～0.7		0.01	0.09	0.31	0.30	0.17	0.05	0.04	0.01	0.01	0.01	0.00	0.00		
0.7～0.9		0.00	0.01	0.07	0.27	0.33	0.17	0.07	0.04	0.02	0.01	0.01	0.00	0.00	0.00
0.9～1.1		0.00	0.00	0.03	0.10	0.24	0.32	0.17	0.06	0.04	0.02	0.01	0.00	0.00	0.01
1.1～				0.02	0.02	0.12	0.25	0.17	0.16	0.07	0.04	0.04	0.04	0.03	0.04

Katsuura 2

Body weight (kg)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～0.5	0.02	0.26	0.24	0.25	0.13	0.05	0.03	0.02	0.01	0.00	0.00				
0.5～0.6		0.02	0.13	0.37	0.28	0.12	0.04	0.03	0.01	0.00	0.01				
0.6～0.8		0.01	0.05	0.20	0.32	0.24	0.09	0.04	0.02	0.01	0.01	0.00	0.00		
0.8～1.0		0.00	0.01	0.04	0.19	0.32	0.23	0.11	0.05	0.03	0.01	0.01	0.00	0.00	0.00
1.0～			0.00	0.01	0.05	0.17	0.29	0.18	0.12	0.06	0.03	0.03	0.02	0.02	0.02

Katsuura 3

Body weight (kg)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11	Age 12	Age 13	Age 14	Age 15 and above
～0.3	0.04	0.54	0.20	0.09	0.05	0.04	0.03	0.01							
0.3～0.6	0.00	0.08	0.22	0.35	0.20	0.07	0.03	0.03	0.01	0.00	0.00				
0.7～1.0		0.00	0.01	0.06	0.24	0.31	0.20	0.09	0.04	0.02	0.01	0.01	0.00	0.00	0.00
1.0～			0.00	0.01	0.05	0.17	0.29	0.18	0.12	0.06	0.03	0.03	0.02	0.02	0.02

Supplementary Table 2-3. Average body weight at age, maturity rates and natural mortality M at age used for stock calculation

Age	Average body weight (g)	Maturity rate	Natural mortality (per year)
Age 2	289	0	0.1
Age 3	434	0	0.1
Age 4	543	0.5	0.1
Age 5	666	1.0	0.1
Age 6	783	1.0	0.1
Age 7	901	1.0	0.1
Age 8	987	1.0	0.1
Age 9	1,111	1.0	0.1
Age 10	1,204	1.0	0.1
Age 11	1,307	1.0	0.1
Age 12	1,439	1.0	0.1
Age 13	1,503	1.0	0.1
Age 14	1,620	1.0	0.1
Age 15 and above	1,721	1.0	0.1

Supplementary Table 2-4. Stock Analysis Results

Catch (number of individuals) by age (thousands)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age 2	361	696	609	662	141	465	291	375	321	297	221	103	124
Age 3	375	580	717	814	368	445	388	532	584	563	475	327	329
Age 4	771	888	1,061	1,420	960	899	730	917	1,083	1,191	1,071	868	756
Age 5	956	976	1,006	1,354	1,135	1,138	978	1,020	1,069	1,256	1,294	1,216	950
Age 6	897	939	945	1,103	948	1,012	988	1,064	960	1,107	1,207	1,278	936
Age 7	803	874	872	896	678	697	782	1,004	874	936	966	1,055	805
Age 8	584	637	632	632	476	438	494	689	631	654	662	702	557
Age 9	431	462	492	459	347	296	327	485	476	493	478	504	398
Age 10	325	341	349	325	253	215	223	328	325	344	345	349	279
Age 11	255	261	303	268	208	169	170	256	266	283	279	283	221
Age 12	203	204	278	233	178	147	150	225	231	247	239	256	188
Age 13	145	145	245	199	143	114	117	180	176	191	181	196	142
Age 14	106	105	208	165	113	91	96	151	141	153	141	161	112
Age 15 & above	184	184	461	402	239	186	227	393	308	349	317	400	255
Total	6,397	7,293	8,178	8,931	6,187	6,311	5,961	7,617	7,445	8,065	7,877	7,699	6,052

Catch by age (tons)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age 2	104	201	176	191	41	134	84	108	93	86	64	30	36
Age 3	163	252	311	354	160	194	168	231	254	245	206	142	143
Age 4	419	482	576	771	521	488	396	498	588	647	582	471	411
Age 5	637	651	670	902	756	758	652	679	713	837	862	811	633
Age 6	703	736	740	864	743	793	774	833	752	867	946	1,001	733
Age 7	724	787	786	807	611	628	705	905	788	843	871	951	725
Age 8	577	629	624	624	470	433	488	680	623	646	654	693	550
Age 9	479	513	546	510	386	329	363	538	529	548	531	560	442
Age 10	392	411	421	392	305	259	269	394	392	415	416	420	336
Age 11	333	341	396	350	272	221	222	334	347	369	364	369	288
Age 12	292	293	399	335	256	211	217	323	333	356	344	368	271
Age 13	218	218	369	298	214	172	176	271	264	288	272	294	213
Age 14	172	169	337	267	183	147	155	244	228	248	229	261	182
Age 15 & above	317	317	793	691	411	319	390	676	530	600	545	688	439
Total	5,529	6,001	7,146	7,358	5,329	5,086	5,059	6,718	6,433	6,994	6,885	7,061	5,403

Fishing mortality

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age 2	0.03	0.05	0.05	0.06	0.01	0.04	0.02	0.03	0.03	0.03	0.02	0.01	0.02
Age 3	0.04	0.05	0.06	0.07	0.04	0.04	0.04	0.05	0.06	0.06	0.06	0.04	0.05
Age 4	0.09	0.11	0.12	0.15	0.11	0.10	0.08	0.10	0.12	0.14	0.14	0.12	0.12
Age 5	0.14	0.15	0.15	0.19	0.16	0.16	0.14	0.15	0.15	0.18	0.20	0.20	0.17
Age 6	0.17	0.18	0.18	0.22	0.18	0.18	0.18	0.20	0.18	0.21	0.23	0.27	0.21
Age 7	0.20	0.22	0.23	0.24	0.18	0.18	0.18	0.24	0.22	0.24	0.25	0.29	0.24
Age 8	0.19	0.22	0.22	0.22	0.17	0.15	0.16	0.22	0.21	0.22	0.23	0.26	0.22
Age 9	0.18	0.21	0.23	0.22	0.17	0.13	0.15	0.21	0.21	0.23	0.23	0.25	0.21
Age 10	0.18	0.19	0.21	0.21	0.16	0.13	0.13	0.19	0.19	0.20	0.22	0.23	0.19
Age 11	0.19	0.19	0.23	0.22	0.18	0.13	0.13	0.19	0.21	0.22	0.22	0.25	0.20
Age 12	0.20	0.20	0.28	0.24	0.20	0.17	0.15	0.22	0.23	0.27	0.27	0.29	0.23
Age 13	0.18	0.19	0.36	0.29	0.20	0.17	0.18	0.24	0.24	0.27	0.28	0.32	0.23
Age 14	0.20	0.17	0.39	0.38	0.24	0.17	0.19	0.32	0.27	0.31	0.29	0.39	0.27
Age 15 & above	0.20	0.17	0.39	0.38	0.24	0.17	0.19	0.32	0.27	0.31	0.29	0.39	0.27
Simple average	0.16	0.16	0.22	0.22	0.16	0.14	0.14	0.19	0.18	0.21	0.21	0.24	0.19

Supplementary Table 2-4. (Continued)

Catch (number of individuals) by age (thousands)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Age 2	91	122	94	138	165	316	332	319	150	130	86	74	87
Age 3	295	272	201	335	331	581	647	620	446	412	309	244	275
Age 4	714	606	500	740	711	1,047	1,204	1,108	884	896	775	636	669
Age 5	918	772	683	855	791	976	1,092	1,058	896	965	954	832	859
Age 6	918	791	730	806	718	762	774	780	697	779	846	801	841
Age 7	800	710	675	690	605	596	530	529	487	548	617	621	676
Age 8	540	490	484	484	428	413	354	341	311	348	387	402	445
Age 9	391	370	373	364	324	299	247	240	212	228	245	267	299
Age 10	260	251	264	246	226	202	166	164	145	157	165	180	202
Age 11	204	206	219	200	186	162	132	134	114	118	119	133	151
Age 12	177	186	194	177	166	144	117	123	105	102	99	113	128
Age 13	139	145	161	149	137	120	98	112	104	81	75	87	95
Age 14	112	118	132	123	112	99	81	95	90	65	60	70	76
Age 15 & above	236	278	292	266	250	225	202	250	237	165	158	163	203
Total	5,795	5,318	5,003	5,574	5,151	5,943	5,976	5,873	4,877	4,994	4,894	4,623	5,006

Catch by age (tons)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Age 2	26	35	27	40	48	91	96	92	43	38	25	21	25
Age 3	128	118	88	146	144	253	281	269	194	179	134	106	119
Age 4	388	329	272	402	386	568	654	602	480	486	421	345	363
Age 5	611	515	455	570	527	651	728	705	597	643	636	554	573
Age 6	719	620	572	631	563	597	606	611	546	610	663	627	659
Age 7	721	640	609	622	546	537	478	477	439	494	556	560	609
Age 8	533	484	478	478	423	408	349	337	307	344	382	397	439
Age 9	434	411	414	404	360	333	274	267	236	254	272	297	332
Age 10	313	302	318	296	273	243	200	198	175	189	199	216	243
Age 11	266	269	287	261	243	212	173	175	149	155	155	173	197
Age 12	255	268	280	255	239	207	168	177	151	146	143	163	184
Age 13	209	218	242	225	205	181	148	168	157	121	113	131	143
Age 14	181	191	214	199	181	160	132	154	146	105	97	113	124
Age 15 & above	406	479	502	458	430	386	347	430	407	285	271	281	349
Total	5,192	4,879	4,756	4,987	4,567	4,827	4,633	4,661	4,026	4,049	4,065	3,986	4,360

Fishing mortality

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Age 2	0.01	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01
Age 3	0.04	0.04	0.03	0.04	0.04	0.06	0.07	0.06	0.05	0.04	0.04	0.03	0.04
Age 4	0.12	0.10	0.09	0.13	0.11	0.15	0.17	0.15	0.11	0.11	0.10	0.09	0.10
Age 5	0.18	0.16	0.14	0.19	0.17	0.20	0.21	0.19	0.15	0.15	0.14	0.13	0.14
Age 6	0.22	0.20	0.20	0.23	0.21	0.22	0.21	0.20	0.17	0.17	0.17	0.15	0.16
Age 7	0.25	0.24	0.24	0.26	0.23	0.24	0.21	0.20	0.17	0.17	0.18	0.16	0.17
Age 8	0.22	0.22	0.23	0.24	0.23	0.22	0.20	0.18	0.15	0.15	0.16	0.15	0.15
Age 9	0.21	0.21	0.23	0.24	0.22	0.22	0.18	0.18	0.15	0.14	0.14	0.14	0.14
Age 10	0.18	0.18	0.20	0.20	0.20	0.19	0.17	0.15	0.14	0.14	0.13	0.13	0.13
Age 11	0.18	0.19	0.21	0.21	0.21	0.19	0.16	0.17	0.14	0.14	0.13	0.13	0.14
Age 12	0.21	0.22	0.24	0.23	0.24	0.22	0.18	0.20	0.18	0.15	0.15	0.16	0.16
Age 13	0.24	0.24	0.27	0.26	0.25	0.24	0.20	0.24	0.23	0.18	0.15	0.17	0.18
Age 14	0.25	0.29	0.32	0.30	0.28	0.25	0.22	0.28	0.28	0.19	0.18	0.17	0.20
Age 15 & above	0.25	0.29	0.32	0.30	0.28	0.25	0.22	0.28	0.28	0.19	0.18	0.17	0.20
Simple average	0.18	0.19	0.19	0.20	0.19	0.19	0.17	0.18	0.16	0.14	0.13	0.13	0.14

Supplementary Table 2-4. (Continued)

Stock number of individuals at age (thousands)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age 2	13,108	14,387	13,798	12,838	12,077	12,661	13,028	12,770	11,558	10,387	9,453	8,659	8,357
Age 3	10,534	11,562	12,404	11,953	11,030	10,835	11,057	11,556	11,242	10,192	9,152	8,375	7,767
Age 4	9,114	9,211	9,949	10,583	10,081	9,668	9,417	9,674	9,989	9,654	8,721	7,860	7,295
Age 5	7,593	7,544	7,520	8,026	8,259	8,242	7,925	7,858	7,913	8,041	7,634	6,900	6,313
Age 6	6,072	5,986	5,921	5,872	6,000	6,421	6,402	6,267	6,166	6,168	6,107	5,701	5,108
Age 7	4,574	4,660	4,542	4,478	4,282	4,546	4,868	4,873	4,679	4,686	4,548	4,397	3,960
Age 8	3,484	3,389	3,400	3,294	3,214	3,243	3,465	3,676	3,469	3,417	3,365	3,211	2,988
Age 9	2,749	2,608	2,471	2,486	2,390	2,465	2,528	2,677	2,683	2,550	2,480	2,425	2,247
Age 10	2,086	2,086	1,929	1,776	1,820	1,840	1,957	1,985	1,969	1,983	1,846	1,797	1,722
Age 11	1,544	1,585	1,569	1,419	1,303	1,412	1,467	1,565	1,491	1,479	1,473	1,348	1,300
Age 12	1,200	1,160	1,191	1,137	1,033	985	1,122	1,170	1,177	1,101	1,074	1,072	955
Age 13	930	896	859	817	811	769	755	876	849	849	765	747	730
Age 14	611	707	676	547	553	600	590	574	623	604	589	522	492
Age 15 & above	1,062	1,243	1,496	1,335	1,169	1,229	1,398	1,499	1,365	1,378	1,322	1,299	1,120
Total	64,660	67,022	67,726	66,561	64,023	64,918	65,979	67,019	65,173	62,489	58,527	54,313	50,354

Biomass at age(tons)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age 2	3,791	4,161	3,991	3,713	3,493	3,662	3,768	3,693	3,343	3,004	2,734	2,504	2,417
Age 3	4,576	5,022	5,388	5,193	4,792	4,707	4,803	5,020	4,884	4,428	3,976	3,638	3,374
Age 4	4,949	5,001	5,402	5,747	5,474	5,250	5,113	5,253	5,424	5,242	4,735	4,268	3,961
Age 5	5,060	5,027	5,011	5,349	5,504	5,493	5,281	5,237	5,273	5,359	5,087	4,599	4,207
Age 6	4,757	4,690	4,639	4,600	4,701	5,030	5,016	4,910	4,831	4,833	4,784	4,466	4,002
Age 7	4,122	4,200	4,094	4,036	3,859	4,097	4,387	4,392	4,217	4,223	4,099	3,963	3,569
Age 8	3,440	3,346	3,357	3,253	3,173	3,202	3,422	3,630	3,426	3,374	3,322	3,170	2,950
Age 9	3,053	2,897	2,745	2,762	2,655	2,738	2,809	2,974	2,980	2,833	2,755	2,694	2,496
Age 10	2,513	2,512	2,323	2,139	2,192	2,216	2,357	2,391	2,372	2,388	2,224	2,165	2,074
Age 11	2,018	2,071	2,051	1,854	1,703	1,846	1,917	2,045	1,949	1,932	1,925	1,761	1,698
Age 12	1,726	1,669	1,714	1,636	1,487	1,418	1,614	1,684	1,694	1,585	1,545	1,543	1,374
Age 13	1,398	1,347	1,291	1,229	1,218	1,156	1,135	1,316	1,276	1,276	1,149	1,124	1,097
Age 14	990	1,145	1,095	886	896	973	956	930	1,010	978	954	846	798
Age 15 & above	1,826	2,139	2,574	2,297	2,012	2,115	2,406	2,578	2,348	2,371	2,274	2,235	1,927
Total	44,221	45,228	45,676	44,691	43,160	43,903	44,983	46,053	45,025	43,825	41,564	38,975	35,945

SSB at age (tons)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Age 2	-	-	-	-	-	-	-	-	-	-	-	-	-
Age 3	-	-	-	-	-	-	-	-	-	-	-	-	-
Age 4	2,474	2,501	2,701	2,873	2,737	2,625	2,557	2,626	2,712	2,621	2,368	2,134	1,981
Age 5	5,060	5,027	5,011	5,349	5,504	5,493	5,281	5,237	5,273	5,359	5,087	4,599	4,207
Age 6	4,757	4,690	4,639	4,600	4,701	5,030	5,016	4,910	4,831	4,833	4,784	4,466	4,002
Age 7	4,122	4,200	4,094	4,036	3,859	4,097	4,387	4,392	4,217	4,223	4,099	3,963	3,569
Age 8	3,440	3,346	3,357	3,253	3,173	3,202	3,422	3,630	3,426	3,374	3,322	3,170	2,950
Age 9	3,053	2,897	2,745	2,762	2,655	2,738	2,809	2,974	2,980	2,833	2,755	2,694	2,496
Age 10	2,513	2,512	2,323	2,139	2,192	2,216	2,357	2,391	2,372	2,388	2,224	2,165	2,074
Age 11	2,018	2,071	2,051	1,854	1,703	1,846	1,917	2,045	1,949	1,932	1,925	1,761	1,698
Age 12	1,726	1,669	1,714	1,636	1,487	1,418	1,614	1,684	1,694	1,585	1,545	1,543	1,374
Age 13	1,398	1,347	1,291	1,229	1,218	1,156	1,135	1,316	1,276	1,276	1,149	1,124	1,097
Age 14	990	1,145	1,095	886	896	973	956	930	1,010	978	954	846	798
Age 15 & above	1,826	2,139	2,574	2,297	2,012	2,115	2,406	2,578	2,348	2,371	2,274	2,235	1,927
Total	33,379	33,544	33,595	32,912	32,138	32,910	33,856	34,713	34,087	33,772	32,487	30,699	28,173

Supplementary Table 2-4. (Continued)

Stock number of individuals at age (thousands)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Age 2	8,070	8,272	8,978	9,950	10,865	11,433	11,833	12,041	11,393	10,323	9,199	8,113	6,901
Age 3	7,473	7,243	7,397	8,066	8,906	9,712	10,084	10,431	10,633	10,206	9,253	8,273	7,299
Age 4	6,741	6,507	6,320	6,527	7,007	7,774	8,268	8,543	8,884	9,233	8,878	8,110	7,282
Age 5	5,906	5,442	5,333	5,264	5,223	5,687	6,064	6,362	6,704	7,228	7,533	7,325	6,760
Age 6	4,829	4,490	4,207	4,193	3,966	3,990	4,236	4,467	4,771	5,235	5,645	5,934	5,861
Age 7	3,748	3,511	3,324	3,126	3,041	2,918	2,898	3,110	3,314	3,669	4,013	4,322	4,626
Age 8	2,830	2,642	2,513	2,376	2,181	2,185	2,083	2,127	2,321	2,546	2,810	3,057	3,333
Age 9	2,184	2,056	1,932	1,821	1,697	1,573	1,591	1,555	1,607	1,812	1,981	2,184	2,393
Age 10	1,661	1,611	1,515	1,400	1,308	1,233	1,144	1,210	1,183	1,258	1,428	1,566	1,729
Age 11	1,298	1,262	1,224	1,125	1,037	972	928	881	943	936	993	1,140	1,251
Age 12	970	985	950	903	831	765	728	716	673	747	738	789	909
Age 13	688	712	717	678	651	597	558	550	533	511	582	575	609
Age 14	528	492	509	498	473	461	427	413	393	385	387	457	440
Age 15 & above	1,114	1,160	1,123	1,078	1,060	1,048	1,063	1,084	1,031	982	1,022	1,074	1,169
Total	48,039	46,384	46,042	47,003	48,247	50,348	51,902	53,489	54,382	55,072	54,462	52,918	50,562

Biomass at age(tons)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Age 2	2,334	2,392	2,597	2,878	3,142	3,307	3,422	3,482	3,295	2,986	2,660	2,346	1,996
Age 3	3,246	3,146	3,213	3,504	3,869	4,219	4,381	4,531	4,619	4,433	4,019	3,594	3,171
Age 4	3,660	3,533	3,431	3,544	3,805	4,221	4,489	4,639	4,824	5,013	4,820	4,403	3,954
Age 5	3,936	3,627	3,554	3,508	3,481	3,790	4,041	4,240	4,468	4,817	5,020	4,882	4,505
Age 6	3,783	3,517	3,296	3,285	3,107	3,126	3,318	3,499	3,737	4,101	4,423	4,649	4,592
Age 7	3,378	3,164	2,996	2,817	2,740	2,630	2,612	2,803	2,987	3,307	3,617	3,895	4,170
Age 8	2,794	2,609	2,481	2,346	2,154	2,157	2,056	2,100	2,291	2,514	2,775	3,019	3,291
Age 9	2,426	2,284	2,147	2,023	1,885	1,748	1,768	1,727	1,785	2,013	2,200	2,426	2,659
Age 10	2,001	1,940	1,825	1,687	1,575	1,485	1,377	1,458	1,425	1,515	1,720	1,886	2,083
Age 11	1,696	1,649	1,600	1,470	1,356	1,270	1,212	1,151	1,232	1,224	1,297	1,490	1,635
Age 12	1,396	1,417	1,367	1,299	1,196	1,101	1,048	1,031	968	1,076	1,061	1,135	1,308
Age 13	1,034	1,071	1,078	1,018	979	897	838	827	802	768	875	865	915
Age 14	855	797	825	807	767	748	693	669	637	624	628	741	712
Age 15 & above	1,917	1,996	1,932	1,855	1,824	1,803	1,829	1,865	1,774	1,690	1,759	1,847	2,011
Total	34,457	33,143	32,341	32,040	31,880	32,501	33,083	34,022	34,843	36,080	36,876	37,177	37,000

SSB at age (tons)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Age 2	-	-	-	-	-	-	-	-	-	-	-	-	-
Age 3	-	-	-	-	-	-	-	-	-	-	-	-	-
Age 4	1,830	1,767	1,716	1,772	1,902	2,111	2,245	2,319	2,412	2,507	2,410	2,202	1,977
Age 5	3,936	3,627	3,554	3,508	3,481	3,790	4,041	4,240	4,468	4,817	5,020	4,882	4,505
Age 6	3,783	3,517	3,296	3,285	3,107	3,126	3,318	3,499	3,737	4,101	4,423	4,649	4,592
Age 7	3,378	3,164	2,996	2,817	2,740	2,630	2,612	2,803	2,987	3,307	3,617	3,895	4,170
Age 8	2,794	2,609	2,481	2,346	2,154	2,157	2,056	2,100	2,291	2,514	2,775	3,019	3,291
Age 9	2,426	2,284	2,147	2,023	1,885	1,748	1,768	1,727	1,785	2,013	2,200	2,426	2,659
Age 10	2,001	1,940	1,825	1,687	1,575	1,485	1,377	1,458	1,425	1,515	1,720	1,886	2,083
Age 11	1,696	1,649	1,600	1,470	1,356	1,270	1,212	1,151	1,232	1,224	1,297	1,490	1,635
Age 12	1,396	1,417	1,367	1,299	1,196	1,101	1,048	1,031	968	1,076	1,061	1,135	1,308
Age 13	1,034	1,071	1,078	1,018	979	897	838	827	802	768	875	865	915
Age 14	855	797	825	807	767	748	693	669	637	624	628	741	712
Age 15 & above	1,917	1,996	1,932	1,855	1,824	1,803	1,829	1,865	1,774	1,690	1,759	1,847	2,011
Total	27,046	25,838	24,815	23,886	22,966	22,865	23,036	23,688	24,517	26,154	27,786	29,035	29,857

Appendix 3 Proposed Reference Points and Proposed Fishing Ban Level

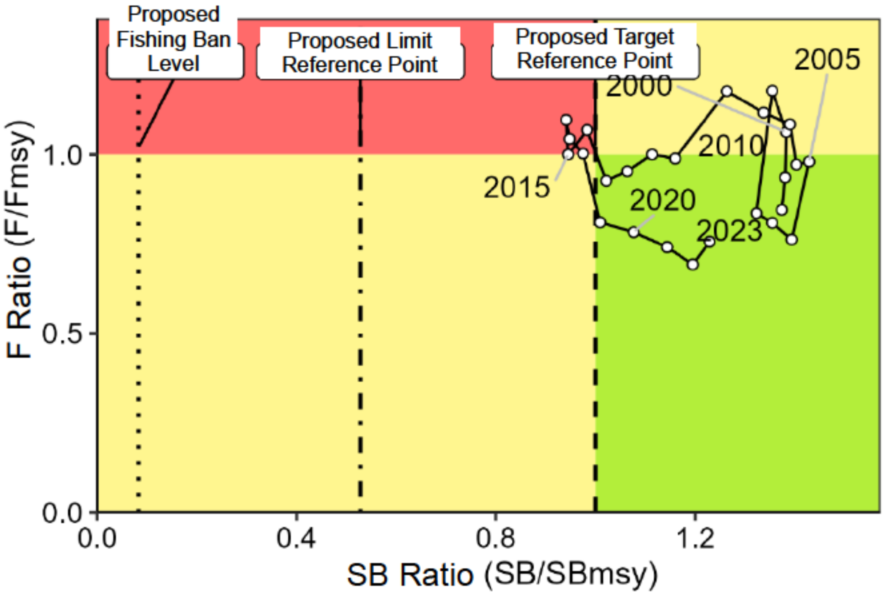
The “Research Institute Meeting on Reference Points” held in August 2022 proposed the adoption of the following: SSB to achieve MSY (SBmsy: 24,300 tons) as a target reference point (SBtarget), SSB to achieve 60% MSY (SB0.6msy: 12,800 tons) as a limit reference point (SBlimit), and SSB to achieve 10% MSY (SB0.1msy: 2,000 tons) as a fishing ban level (SBban) (Watari et al. 2022, Supplementary Table 6-2).

Supplementary Fig. 3-1 shows the proposed target reference points and a Kobe plot based on the fishing pressure (Fmsy) required to maintain SBmsy. SSB in 2023 (SB2023: 29,857 tons) obtained through cohort analysis exceeds the proposed target reference point, the proposed limit reference point, and the proposed fishing ban level. The fishing pressure of this stock since 2019 was judged to be below the fishing pressure to achieve SBmsy (Supplementary Table 6-3).

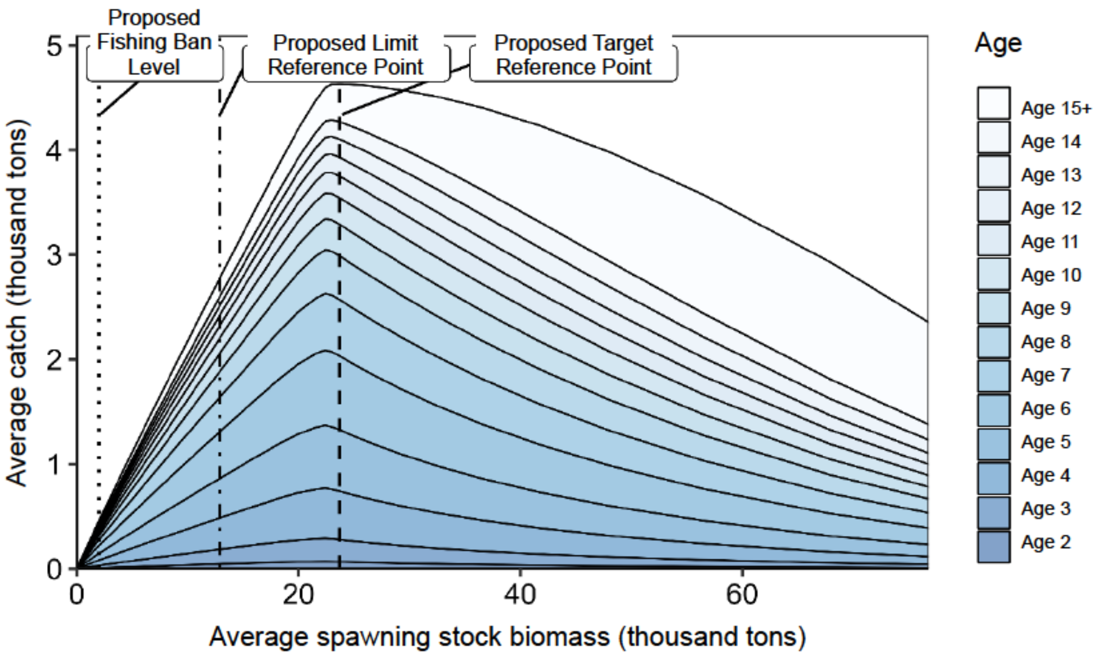
The relationship between average SSB and average catch in weight at age at equilibrium is shown in Supplementary Fig. 3-2. Fishing pressure on younger fish age 2 and age 3 is also low. At levels below the proposed target reference points, fluctuations in the proportion of younger fish in the catch are small.

Cited literature

Watari, S., Kawauchi, Y., Aoki, K., Takemura, S., Takeshige, A., and Hanzawa, Y. (2022) FY 2022 Materials for the Research Institute Meeting for Splendid Alfonsino - Pacific Japan. FRA-SA2022-BRP04-01, Japan Fisheries Research and Education Agency, Yokohama, 48 pp.
https://www.fra.affrc.go.jp/shigen_hyoka/SCmeeting/2019-1/20220805/FRA-SA2022-BRP04-01.pdf



Supplementary Fig. 3-1. Relationship between proposed reference points and SSB/fishing pressure (Kobe plot)



Supplementary Fig. 3-2. Relationship of average SSB and average catch in weight at age at equilibrium (catch in weight curve)

Appendix 4 Future Projections Based on Proposed HCRs

(1) Setting Future Projections

Future projection calculations were performed from 2024 to 2055 using a forward method for cohort analysis applied to stock abundance estimates from the 2023 stock assessment.

The future projections take into account the uncertainty of recruitment volume. Recruitment in future projections was predicted based on values for SSB in each year using the stock-recruitment relationship model, and uncertainty in recruitment was accounted for by introducing errors, which follow a log-normal distribution, to the predicted value. The degree of uncertainty was indicated through calculations replicated 1,000 times, introducing randomly selected errors from log-normal distribution to the projected value and determining their average value and 90% prediction interval.

The catch in 2024 was assumed based on the projected stock abundance and the current fishing pressure (F2021-2023). The current fishing pressure is set to the F value that gives the %SPR corresponding to fishing pressure from 2021 to 2023 in this assessment, using the same selectivity and biological parameters (average body weight, etc.) as those used in the calculation of proposed reference points. Fishing pressure in 2025 was calculated based on SSB projections for each year in accordance with the following proposed HCRs. The calculation method of future projections is shown in Appendix 5.

(2) Proposed Harvest Control Rules

Proposed HCRs guidelines, which aim for better results than proposed target reference points in consideration of the probability of success for both maintenance and recovery of SSB, set fishing pressure (F) and other factors that correspond to SSB. The “Basic Guidelines for Harvest Control Rules and ABC Calculation” propose a linear reduction in fishing pressure down to the proposed fishing ban level when the spawning stock biomass (SSB) falls below the proposed limit reference point. Fmsy multiplied by adjustment coefficient β when SSB is above the proposed limit reference points used as the upper limit of fishing pressure. Supplementary Fig. 4-1 presents the Harvest Control Rules proposed in the “Materials for the Research Institute Meeting on Reference Points” for the stock. An example is shown where the adjustment coefficient β is set to 0.8. The proposal from the Research Institute states that “when β is lower than 0.9, there is a 50% or higher probability that values will exceed the proposed target reference points in 10 years”.

(3) Projected Values for 2025

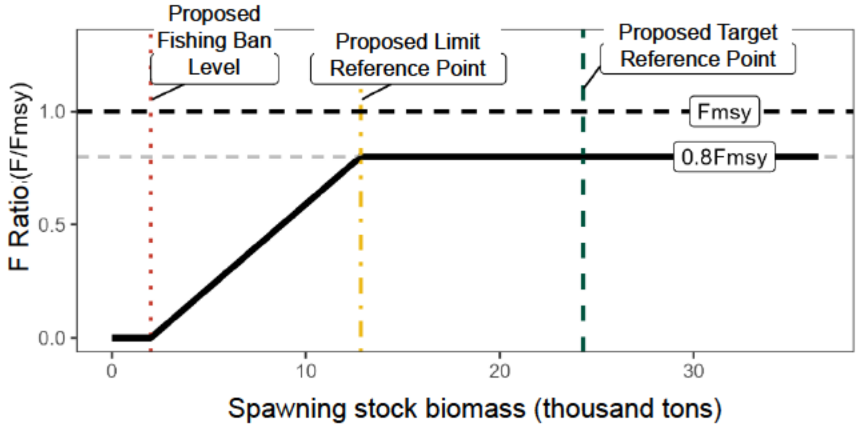
The average catch in 2025, as calculated based on proposed HCRs, will be 4,400 tons if β is set to 0.8 and 5,400 tons if β is set to 1.0 (Supplementary Table 6-4).

The projected SSB in 2025 is forecast to be an average of 29,200 tons, which exceeds the limit reference point in replicated calculations using both values.

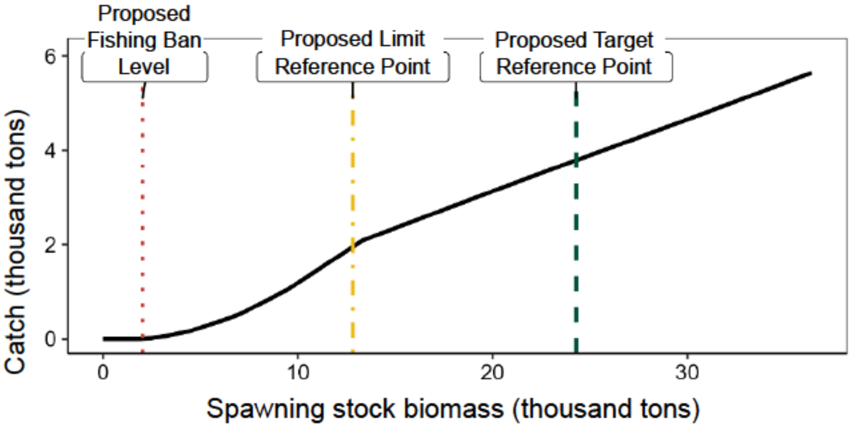
(4) Projections for 2026 onwards

Results of future projections, including 2026 and onwards, are shown in Supplementary Fig. 4-2 and Supplementary Tables 4-1 and 4-2. If management based on these proposed HCRs is continued for 10 years, then projected values for SSB in 2035 will be 29,200 tons if β is set to 0.8 (90% prediction interval: 20,000 to 96,000 tons) and averaging 24,400 tons if β is set to 1.0 (90% prediction interval: 22,000 to 26,900 tons) (Supplementary Table 6-5). If β is 1.0 or lower, then there is a 50% or higher probability that the projected value will exceed the proposed target reference point. If β is 1.0 or lower, then there is a 50% or higher probability that the projected value will exceed the proposed limit reference point. If the current fishing pressure (F2021 to 2023) is continued, the projected value for average SSB in 2035 is 31,100 tons (90% prediction interval of 28,300 to 34,100 tons), with a 100% probability that the value will exceed the target reference point, and a 100% probability that it will exceed the limit reference point.

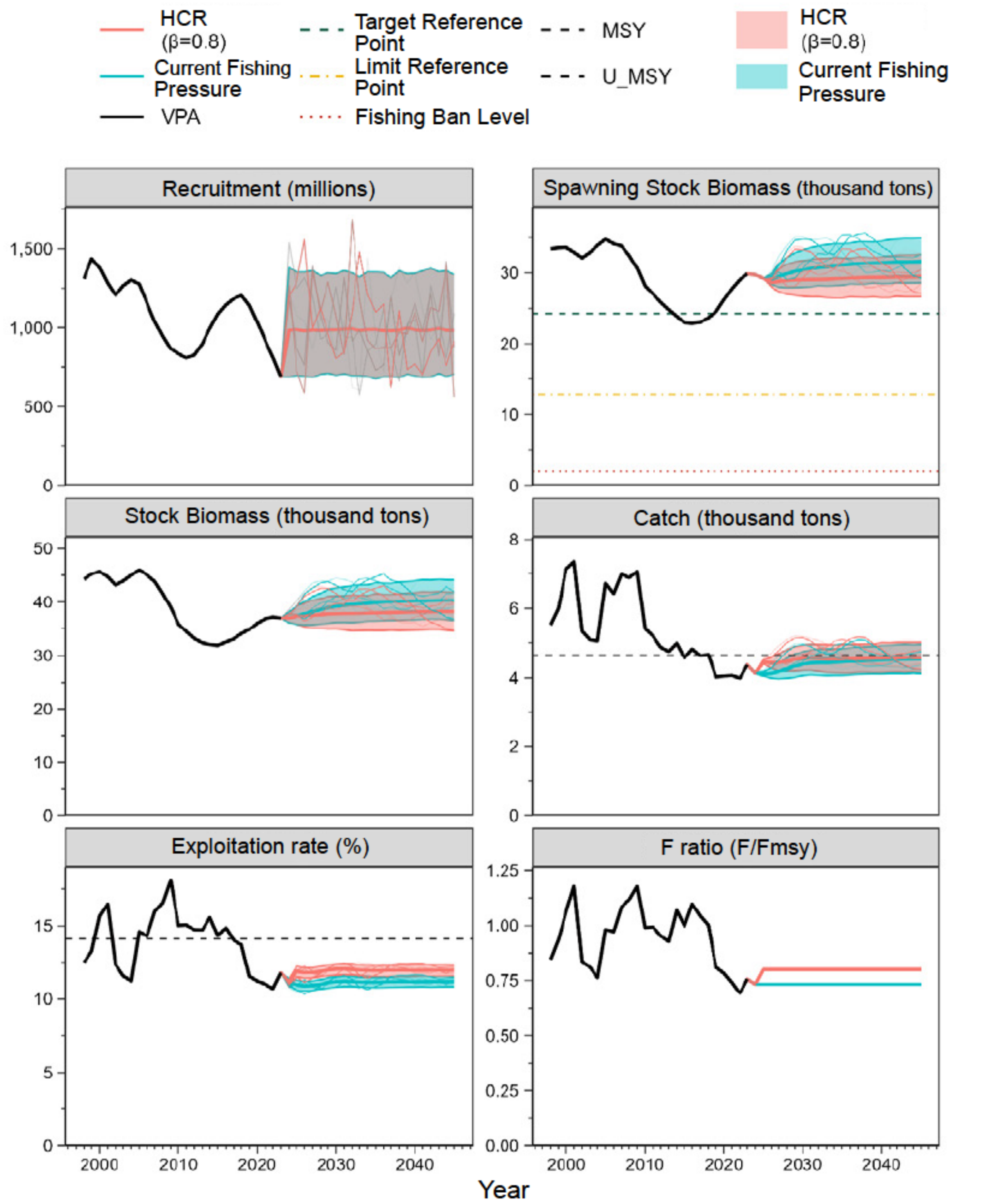
a) When the vertical axis is fishing pressure



b) When the vertical axis is catch



Supplementary Fig. 4-1. Proposed HCRs (β = 0.8), (a) is the scenario when the vertical axis shows fishing pressure, and (b) is the scenario when the vertical axis shows catch in weight



Supplementary Fig. 4-2. Future projections based on proposed HCRs (red line) and future projections if the current fishing pressure (F2021-2023) is continued (blue line)

The solid line indicates average values, the shaded area indicates the prediction interval, which contains 90% of simulation results, and the thin lines indicate 5 future projections. In the SSB graph, the green dashed line indicates the proposed target reference point, the yellow dotted line indicates the proposed limit reference point, and the red dotted line indicates the proposed fishing ban level. In the catch graph, the dashed line indicates the maximum sustainable yield MSY. In the exploitation rate graph, the dashed line indicates the level of exploitation rate (Umsy) that maintains the proposed target reference points. β = 0.8 was used as the adjustment coefficient in the proposed HCRs. The catch in 2024 was assumed based on the projected stock abundance and the current fishing pressure (F2021-2023).

Supplementary Table 4-1. Probability of future spawning stock biomass exceeding the proposed limit reference point

a) Probability of exceeding the proposed target reference point (%)

β	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2045	2055
1.0	100	100	100	100	97	89	77	67	60	56	53	53	49	49
0.9			100	100	100	99	98	98	96	95	94	93	92	93
0.8			100	100	100	100	100	100	100	100	100	100	100	100
0.7			100	100	100	100	100	100	100	100	100	100	100	100
0.6			100	100	100	100	100	100	100	100	100	100	100	100
0.5			100	100	100	100	100	100	100	100	100	100	100	100
0.4			100	100	100	100	100	100	100	100	100	100	100	100
0.3			100	100	100	100	100	100	100	100	100	100	100	100
0.2			100	100	100	100	100	100	100	100	100	100	100	100
0.1			100	100	100	100	100	100	100	100	100	100	100	100
0.0			100	100	100	100	100	100	100	100	100	100	100	100
Current fishing pressure			100	100	100	100	100	100	100	100	100	100	100	100

b) Probability of exceeding the proposed limit reference point (%)

β	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2045	2055
1.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
0.9			100	100	100	100	100	100	100	100	100	100	100	100
0.8			100	100	100	100	100	100	100	100	100	100	100	100
0.7			100	100	100	100	100	100	100	100	100	100	100	100
0.6			100	100	100	100	100	100	100	100	100	100	100	100
0.5			100	100	100	100	100	100	100	100	100	100	100	100
0.4			100	100	100	100	100	100	100	100	100	100	100	100
0.3			100	100	100	100	100	100	100	100	100	100	100	100
0.2			100	100	100	100	100	100	100	100	100	100	100	100
0.1			100	100	100	100	100	100	100	100	100	100	100	100
0.0			100	100	100	100	100	100	100	100	100	100	100	100
Current fishing pressure			100	100	100	100	100	100	100	100	100	100	100	100

The results of future projections when β is varied from 0 to 1.0 are shown. The catch for 2024 has been set at 4,100 tons, predicted based on the current fishing pressure (F2021-2023), and from 2025 onward, the catch is determined according to the Harvest Control Rules. For comparison, results are also shown for the case where fishing continues at the current fishing pressure (F2021-2023, corresponding to β = 0.73).

Supplementary Table 4-2. Future average spawning stock biomass (thousand tons)

β	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2045	2055
1.0	29.7	29.2	27.6	26.9	26.3	25.8	25.4	25.0	24.8	24.6	24.5	24.4	24.3	24.2
0.9			28.2	27.8	27.6	27.4	27.2	27.0	26.8	26.7	26.7	26.7	26.7	26.7
0.8			28.7	28.8	28.9	29.0	29.1	29.1	29.1	29.1	29.2	29.2	29.5	29.5
0.7			29.2	29.8	30.4	30.8	31.1	31.4	31.6	31.8	32.0	32.2	32.8	32.8
0.6			29.8	30.9	31.9	32.7	33.4	34.0	34.5	34.9	35.3	35.6	36.8	36.9
0.5			30.3	31.9	33.4	34.8	35.9	36.8	37.7	38.4	39.0	39.5	41.7	41.9
0.4			30.9	33.1	35.1	37.0	38.6	40.0	41.2	42.3	43.3	44.1	47.7	48.2
0.3			31.4	34.2	36.9	39.3	41.5	43.5	45.3	46.8	48.3	49.5	55.3	56.3
0.2			32.0	35.5	38.8	41.9	44.7	47.4	49.8	52.0	54.0	55.8	65.0	67.1
0.1			32.6	36.7	40.7	44.6	48.3	51.7	54.9	57.9	60.7	63.2	77.7	82.0
0.0			33.2	38.0	42.8	47.6	52.1	56.5	60.7	64.6	68.4	71.9	94.5	103.2
Current fishing pressure			29.0	29.5	29.9	30.2	30.4	30.6	30.7	30.9	31.0	31.1	31.6	31.6

The results of future projections when β is varied from 0.0 to 1.0 are shown. The catch for 2024 has been set at 4,100 tons, predicted based on the current fishing pressure (F2021-2023), and from 2025 onward, the catch is determined according to the Harvest Control Rules. For comparison, results are also shown for the case where fishing continues at the current fishing pressure (F2021-2023, corresponding to β = 0.73).

Supplementary Table 4-3. Future average catch (thousand tons)

β	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2045	2055
1.0	4.1	5.4	5.2	5.1	5.0	5.0	4.9	4.9	4.8	4.7	4.7	4.7	4.7	4.6
0.9		5.0	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6	4.6	4.6	4.6
0.8		4.4	4.4	4.4	4.5	4.5	4.5	4.6	4.5	4.5	4.5	4.5	4.6	4.6
0.7		3.9	4.0	4.0	4.1	4.2	4.3	4.3	4.4	4.4	4.4	4.4	4.5	4.5
0.6		3.4	3.5	3.6	3.7	3.9	4.0	4.0	4.1	4.1	4.2	4.2	4.4	4.4
0.5		2.9	3.0	3.1	3.3	3.4	3.6	3.7	3.8	3.8	3.9	3.9	4.2	4.2
0.4		2.3	2.5	2.6	2.8	3.0	3.1	3.2	3.3	3.4	3.5	3.5	3.9	3.9
0.3		1.7	1.9	2.1	2.2	2.4	2.5	2.6	2.8	2.8	2.9	3.0	3.4	3.5
0.2		1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.7	2.8
0.1		0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.7	1.8
0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Current fishing pressure		4.1	4.1	4.2	4.3	4.3	4.4	4.4	4.4	4.4	4.4	4.4	4.5	4.5

The results of future projections when β is varied from 0.0 to 1.0 are shown. The catch for 2024 has been set at 4,100 tons, predicted based on the current fishing pressure (F2021-2023), and from 2025 onward, the catch is determined according to the Harvest Control Rules. For comparison, results are also shown for the case where fishing continues at the current fishing pressure (F2021-2023, corresponding to β = 0.73).

Appendix 5 Future Projection Methods

Future projections were performed using the stock-recruitment relationship (Watari et al. 2022) used to estimate the fishing pressure required to maintain SBmsy (Fmsy) at the Materials for the Research Institute Meeting on Reference Points held in August 2022, as well as the various settings shown in Supplementary Table 5-1 (natural mortality, maturity rate, average body weight at age, and current fishing pressure) according to the HCRs for Stock Group 1 in “The Basic Guidelines for Harvest Control Rules and ABC Calculation at FY 2024”. FRA-SA2024-ABCWG02-01. Japan Fisheries Research and Education Agency (2024). The statistical software R (version 4.4.1) and the calculation package frasyr (Commit number 27b5718) were used to calculate projections for stock number and catch based on the “Technical Notes on Stock-Recruitment Relationship Estimates, Reference Point Calculations, and Future Projection Simulations (FRA-SA2024-ABCWG02-04)”. The stock number for ages 3 to 14 in future projections was determined by the following equation.

$$N_{a,y} = N_{a-1,y-1}\, exp(-M_{a-1} - F_{a-1,y-1}) \quad (a=3,\ldots,14) \qquad (11)$$

The stock number for the plus group (ages 15 and older) was determined by the following equation.

$$N_{15+,y} = N_{14,y-1}\, exp(-M_{14} - F_{14,y-1}) - N_{15+,y-1}\, exp(-M_{15+,} - F_{15+,y-1}) \qquad (12)$$

The fishing pressure (F) in future projections was calculated according to the proposed harvest control rule for Stock Unit 1 by the following equation.

$$F_{a,y} = \begin{cases} 0 & if\ SB_t < SB_{ban} \\ \beta\gamma(SB_t)F_{msy} & if\ SB_{ban} \le SB_t < SB_{limit} \\ \beta F_{msy} & if\ SB_t \ge SBlimit \end{cases} \qquad (13)$$

$$\gamma(SB_y) = \frac{SB_y - SB_{ban}}{SB_{limit} - SB_{ban}} \qquad (14)$$

Here, SBy represents the spawning stock biomass (SSB) in year y, while Fmsy, SBtarget, SBlimit, and SBban are reference points for spawning stock biomass, proposed in Supplementary Table 6-2. The catch in number at each age was determined by the following equation.

$$C_{a,y} = N_{a,y}(1 - exp(-F_{a,y}))\, exp(-M_a/2) \qquad (15)$$

The biomass and catch in weight in future projections were obtained by multiplying the stock number of individuals at age or catch in number of individuals obtained here by the average body weight in Supplementary Table 5-1. SSB was calculated by multiplying this biomass by the maturity rate at age.

Cited literature

Japan Fisheries Research and Education Agency (2024) The Basic Guidelines for Harvest Control Rules and ABC Calculation (FY 2024). FRA-SA2024-ABCWG02-01, Japan Fisheries Research and Education Agency, Yokohama, 23 pp.
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Japan Fisheries Research and Education Agency (2024) Technical Notes on Stock-Recruitment Relationship Estimates, Reference Point Calculations, and Future Projection Simulations for FY 2024. FRA-SA2024-ABCWG02-04, Japan Fisheries Research and Education Agency, Yokohama, 15 pp.
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https://www.fra.affrc.go.jp/shigen_hyoka/SCmeeting/2019-1/20220805/FRA-SA2022-BRP04-01.pdf

Supplementary Table 5-1. Setting values used for calculation of future projections

Age	Selectivity (Note 1)	Fmsy (Note 2)	F2021-2023 (Note 3)	Average weight (g)	Natural mortality coefficient	Maturity rate
Age 2	0.099	0.03	0.02	289	0.1	0.0
Age 3	0.234	0.06	0.05	434	0.1	0.0
Age 4	0.543	0.14	0.10	543	0.1	0.5
Age 5	0.712	0.19	0.14	666	0.1	1.0
Age 6	0.775	0.20	0.15	783	0.1	1.0
Age 7	0.789	0.21	0.15	901	0.1	1.0
Age 8	0.737	0.19	0.14	987	0.1	1.0
Age 9	0.704	0.18	0.14	1,111	0.1	1.0
Age 10	0.633	0.17	0.12	1,204	0.1	1.0
Age 11	0.652	0.17	0.13	1,307	0.1	1.0
Age 12	0.768	0.20	0.15	1,439	0.1	1.0
Age 13	0.890	0.23	0.17	1,503	0.1	1.0
Age 14	1.000	0.26	0.19	1,620	0.1	1.0
15 years or more	1.000	0.26	0.19	1,721	0.1	1.0

Note 1: Selectivity used to estimate the level to achieve MSY at the FY 2022 Research Institute Meeting (i.e., selectivity of Fcurrent (Fishing pressure averaged over 2016 to 2021) in the FY 2022 stock assessment).

Note 2: Fmsy estimated at the FY 2022 Research Institute Meeting (i.e., Fcurrent in the FY 2022 stock assessment multiplied by Fmsy/Fcurrent).

Note 3: F was assumed to be the value that gives the same fishing pressure as the average F by age in 2021 to 2023, estimated in this stock assessment calculated in terms of %SPR under the selectivity described above. This F value was used as an assumption for the 2024 catch.

Appendix 6 Summary of Various Parameters and Assessment Results

Supplementary Table 6-1. Parameters for stock-recruitment relationship model

Stock-recruitment relationship model	Optimization method	Autocorrelation	a	b	S.D.	ρ
Hockey stick type	Least squares method	No	454.85	21,723.3	0.201	-

In this table, a and b are the estimated parameters of the stock-recruitment relationship model, S.D. is the standard deviation of recruitment volume, and ρ is the autocorrelation coefficient.

Supplementary Table 6-2. Proposed reference points and MSY

Item	Value	Explanation
SBtarget (proposed)	24,300 tons	Proposed target reference points. Spawning stock biomass to achieve Maximum Sustainable Yield MSY (SBmsy).
SBlimit (proposed)	12,800 tons	Proposed limit reference point. SSB to achieve a catch of 60% of MSY (SB0.6msy)
SBban (proposed)	2,000 tons	Proposed fishing ban level. SSB to achieve a catch of 10% of MSY (SB0.1msy)
Fmsy	Fishing pressure to maintain SBmsy (Age 2, Age 3, Age 4, Age 5, Age 6, Age 7, Age 8, Age 9, Age 10, Age 11, Age 12, Age 13, Age 14, Age 15+) = (0.03, 0.06, 0.14, 0.19, 0.20, 0.21, 0.19, 0.18, 0.17, 0.17, 0.20, 0.23, 0.26, 0.26)	
%SPR (Fmsy)	22%	%SPR corresponding to Fmsy
Maximum Sustainable Yield (MSY)	47,000 tons	Maximum Sustainable Yield (MSY)

Supplementary Table 6-3. SSB and fishing pressure in the most recent year

Item	Value	Explanation
SB2023	29,900 tons	SSB in 2023
F2023	Fishing pressure in 2023 (fishing mortality F) (Age 2, Age 3, Age 4, Age 5, Age 6, Age 7, Age 8, Age 9, Age 10, Age 11, Age 12, Age 13, Age 14, Age 15+) = (0.01, 0.04, 0.1, 0.14, 0.16, 0.17, 0.15, 0.14, 0.13, 0.14, 0.16, 0.18, 0.2, 0.2)	
U2023	12%	Exploitation rate of 2023
%SPR (F2023)	28%	%SPR of 2023
%SPR (F2021-2023)	29%	%SPR corresponding to current fishing pressure (2021 to 2023)*
Comparison with proposed reference point		
SB2023/ SBmsy (SBtarget)	1.23	B ratio to achieve MSY to SSB (proposed target reference points) in the 2023 fishing season
F2023/ Fmsy	0.76	F ratio in 2023 to F required to maintain SBtarget*
Level of SSB	Over the level to achieve MSY	
Level of fishing pressure	Under the level to achieve SBmsy	
Trends of spawning stock biomass	Increase	

* Ratio calculated by converting the F that gives fishing pressure for Fmsy under 2023 selectivity into %SPR.

Supplementary Table 6-4. Projected catch in weight and projected spawning stock biomass (SSB)

SSB in 2025 (average projected value): 22,900 tons			
Item	ABC of 2025 Catch (Thousand tons)	Relationship between current fishing pressure (F/F2021-2023)	ABC of 2025 Exploitation rate (%)
β proposed in the Materials for the Research Institute Meeting (Maximum value)			
β = 0.9	5.0	1.23	13
If a β different from the above is used			
β = 1.0	5.4	1.36	15
β = 0.8	4.4	1.09	12
β = 0.6	3.4	0.82	9
β = 0.4	2.3	0.55	6
β = 0.2	1.2	0.27	3
β = 0.0	0	0	0
F2021-2023	4.1	1.00	11

Supplementary Table 6-5. Results of future projections using various β

Uncertainty under consideration: Recruitment					
Item	SSB in 2035 (Thousand tons)	90% Prediction interval (Thousand tons)	Probability (%) that SSB will exceed the following proposed reference points in 2035		
			SBtarget (proposed)	SBlimit (proposed)	SBban (proposed)
β proposed in the Materials for the Research Institute Meeting (Maximum value)					
β = 0.9	26.7	24.1-29.3	93	100	100
If a β different from the above is used					
β = 1.0	24.4	22.0-26.9	53	100	100
β = 0.8	29.2	26.5-32.1	100	100	100
β = 0.6	35.6	32.5-38.9	100	100	100
β = 0.4	44.1	40.5-48.0	100	100	100
β = 0.2	55.8	51.4-60.5	100	100	100
β = 0.0	71.9	66.7-77.5	100	100	100
F2021-2023	31.1	28.3-34.1	100	100	100

Appendix 7 Standardized catch per unit effort (CPUE)

(1) Background of CPUE standardization

In the FY 2021 stock assessment, to obtain a highly accurate tuning index for cohort analysis, a modeling for CPUE standardization was attempted by aggregating catch and effort records of the vertical longline fisheries collected from main landing ports in Chiba, Tokyo, Kanagawa, and Shizuoka Prefectures and taking environmental factors such as the Kuroshio current path into account (Watari and Hanzawa 2022). However, this examined model did not sufficiently account for changes in fishing efficiency due to the proximity of fishing grounds to the Kuroshio. Additionally, the model did not also account for the differences in fishing operation, gear and the age-structure of target stock among areas. As the result, the model diagnostics indicated poor performances. In the FY 2022 stock assessment, CPUE standardization was performed separately for a total of seven areas, including two areas in which vessels of Chiba Prefecture operate (Choshi and Katsuura), two areas where vessels of Tokyo operate (Kozushima and Hachijojima), two areas where vessels of Shizuoka operate (Ito and Inatori), and a area with two sub-areas in the entrance of the Tokyo Bay where is a common fishing ground operated by vessels of Kanagawa and Chiba Prefectures (Watari et al. 2023). In the FY 2023 stock assessment, standardized CPUE using data from the Omaezaki area in Shizuoka Prefecture and the Miyakejima area in Tokyo was newly incorporated. This fiscal year, we updated the standardized models and the standardized CPUEs obtained from these by adding data for the latest year (2023) in each of the areas examined up to the previous fiscal year. Then, these CPUEs were used as the tuning indices.

(2) Method

The data used for CPUE standardization was monthly aggregated records (not including operating location information), since there were cases in previous years where daily information were not available. In addition, location information on the northern edge of the Kuroshio (13 nautical miles from the current axis) was taken from Quick Bulletin of Ocean Conditions provided by the JMA’s Marine Information Department, and marine environment information within the fishing grounds was taken from the operational ocean forecast system FRA-ROMS II (Kuroda et al. 2017, data access date: April 4, 2024) and included as explanatory variables. In this fiscal year, the CPUE standardization for each area was performed by using a generalized linear model with a lognormal error distribution (log-normal GLM). The full model that considers only the main effects was indicated as follows:

Log (CPUE) = Intercept + Year + Season + Water temperature + Current speed +Current direction + the latitude of the northern edge of the Kuroshio at the offshore area + Latitudinal difference in the northern edge of the Kuroshio between longitudes.

Reanalyzed water temperature, current speed, and current directionof FRA-ROMS II were used for our analysis. In the full model, all 5 depths (0 m, 100 m, 200 m, 400 m, and bottom) were included as explanatory variables, except for shallow-depth areas and waters. The location of fishing grounds in each area taken from FRA-ROMS II was determined from the 0.1-degree latitude/longitude grid shown in Supplementary Fig. 7-1 after due consultation with the organizations participating in the stock assessment from Tokyo and the three prefectures. As mentioned above, vessels of Kanagawa and Chiba Prefectures operate in common fishing grounds of the entrance of the Tokyo Bay. However, the main fishing grounds for vessels from the two prefectures are slightly different (Kanagawa vessels: western side of Nojimazaki, Chiba vessels: eastern side of Nojimazaki). Therefore, independent models were constructed for the fishing areas of both prefectures (i.e., sub-areas), and reanalysis values in separate grids were used as the explanatory variables in each model (see FRA-SA2024-SC07-04 and FRA-SA2024-SC07-05 for details). The latitude of the northern edge of the Kuroshio at offshore areas was determined as the latitude on the longitude closest to the fishing grounds which was chosed from 138°E, 139°E, 140°E, and 141°E, after due consultation with Tokyo and the three prefectures (Supplementary Fig. 7-2). The explanatory variables for the Kuroshio current path were calculated as the latitudinal differences in the northern edge of the Kuroshio between longitudes (138°E - 139°E, 139°E - 140°E, and 140°E - 141°E). This value can also be rewritten as the latitudinal differences in the northern edge of the Kuroshio devided by the longitudinal differences (the longitudinal difference is always 1°), which is synonymous with slope of the Kuroshio northern edge. A positive slope indicates that the Kuroshio flows in a southeasterly direction, while a negative slope indicates flow in a northeasterly direction. Therefore, this was considered an indicator of “Kuroshio inflow” into the coastal region and implemented as an explanatory variable in this stock assessment. Since only monthly CPUE data is currently available, considering various interactions would result in the number of estimated parameters exceeding the number of data points and could complicate the interpretation. Therefore, a model that considers only the main effects was introduced.

The best model was selected from candidate models with all possible combinations of explanatory variables on the basis of the Akaike Information Criterion (AIC). Among the models within the minimum AIC +2 range, the one with the fewest explanatory variables was chosen, also considering its explanatory power in environmental and fishery aspects. However, during the variable selection based on AIC, models including identical explanatory variables obtained from FRA-ROMS II in multiple depth layers (e.g., models including both water temperatures at 0 m and 100 m depth) were preemptively excluded in consideration of interpretational simplicity and overfitting. The best model was selected from candidate models that contained only the variable in a single depth layer.

(3) Results

Supplementary Table 7-1 shows the best model for nine areas (including two sub-areas in the entrance of the Tokyo Bay) selected through a series of processes and the explanatory variables that were frequently included within the range of minimum AIC+2. The effects shown in yellow are the variables in the best model for each area, while those shown in light blue are the variables that occurred frequently within the minimum AIC+2 model, and those in black have no applicable depth. Additionally, the number in each grid represents the number of models including the variable corresponding to each within the range of minimum AIC +2.

The intercept and coefficient values of the year effect were extracted from the above best model to calculate the annual trend of standardized CPUE. The relative values of the annual trends in standardized and nominal CPUEs for nine areas (including 2 sub-areas within the entrance of the Tokyo Bay) are shown in Supplementary Tables 7-2 and 7-3. Details on the calculation method for year trends, the procedures for constructing the above models, model diagnostic results, and standardization are shown in the documents on standardized CPUE (Choshi: FRA-SA2024-SC07-02, Katsuura: FRA-SA2024-SC07-03, the entrance of the Tokyo Bay (Chiba): FRA-SA2024-SC07-04, the entrance of the Tokyo Bay (Kanagawa): FRA-SA2024-SC07-05, Kozushima: FRA-SA2024-SC07-06, Miyakejima: FRA-SA2024-SC07-07, Hachijojima: FRA-SA2024-SC07-08, Ito: FRA-SA2024-SC07-09, Inatori: FRA-SA2024-SC07-10, Omaezaki: FRA-SA2024-SC07-11). In addition to the 9 areas (including 2 sub-areas at the entrance of the Tokyo Bay), the nominal CPUEs for the Shimoda area, which is currently being prepared, are also shown in Supplementary Table 7-3.

In the model for Hachijojima, nominal CPUE continued to be used instead of standardized CPUE as the abundance index in the stock assessment of this fiscal year since the year effect was not selected based on the model selection criteria described above and we believe that the impact of the marine environment may not have been fully removed by standardization. Therefore, the best model for Hachijojima in Supplementary Table 7-1 is the model including year effect with lowest AIC and smallest degree of freedom, and was shown for reference.

In addition to year and seasonal effects, latitudinal difference of the northern edge of the Kuroshio between 138°E and 139°E was selected in the best models of Omaezaki, Hachijojima, the entrance of the Tokyo Bay (Chiba), and Choshi. Although not selected in the best model, the same variable was also included in many models within the range of minimum AIC+2 for Inatori and the entrance of the Tokyo Bay (Kanagawa). This is because the current direction of the Kuroshio turns to a northeastward around 138°E to 139°E, as in the example of December 2018 during the Kuroshio large meander event (Supplementary Fig. 7-3 c), and thus this explanatory variable is considered to be informative of whether or not the large meander occured. The latitudinal differences between 140°E and 141°E were selected in the best model for Kozushima, and the same variable was included in many models within the range of minimum AIC+2 for Miyakejima. As in the example of May 2009 (Supplementary Fig. 7-3 a), the entire Izu Islands often fall within the inner Kuroshio region when the current flows in a north-northeasterly direction around these areas. While the latitude of the northern edge of the Kuroshio at offshore areas was selected for both Ito and Omaezaki and was also included in many models within the range of minimum AIC+2 for various areas along the Honshu coast, such as Katsuura and Choshi, it tended not to be selected for Kozushima and Hachijojima. On the other hand, it is possible that the effect of water temperature was detected as one of the complex changes behind increased water temperature, increased current speed, and changes in current direction within the fishing grounds due to the proximity of the Kuroshio.

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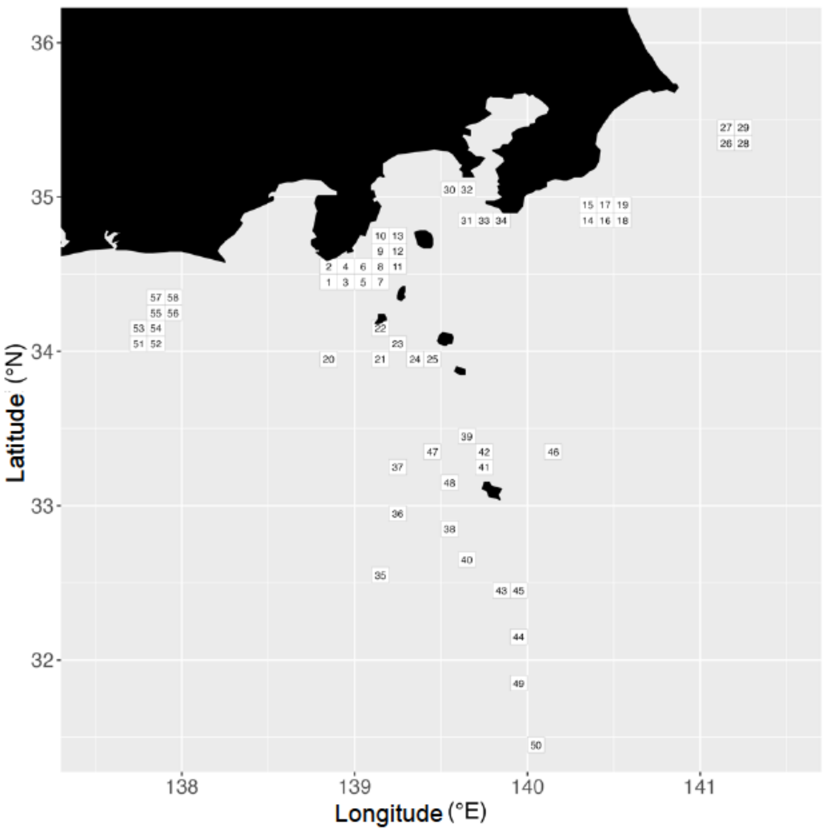
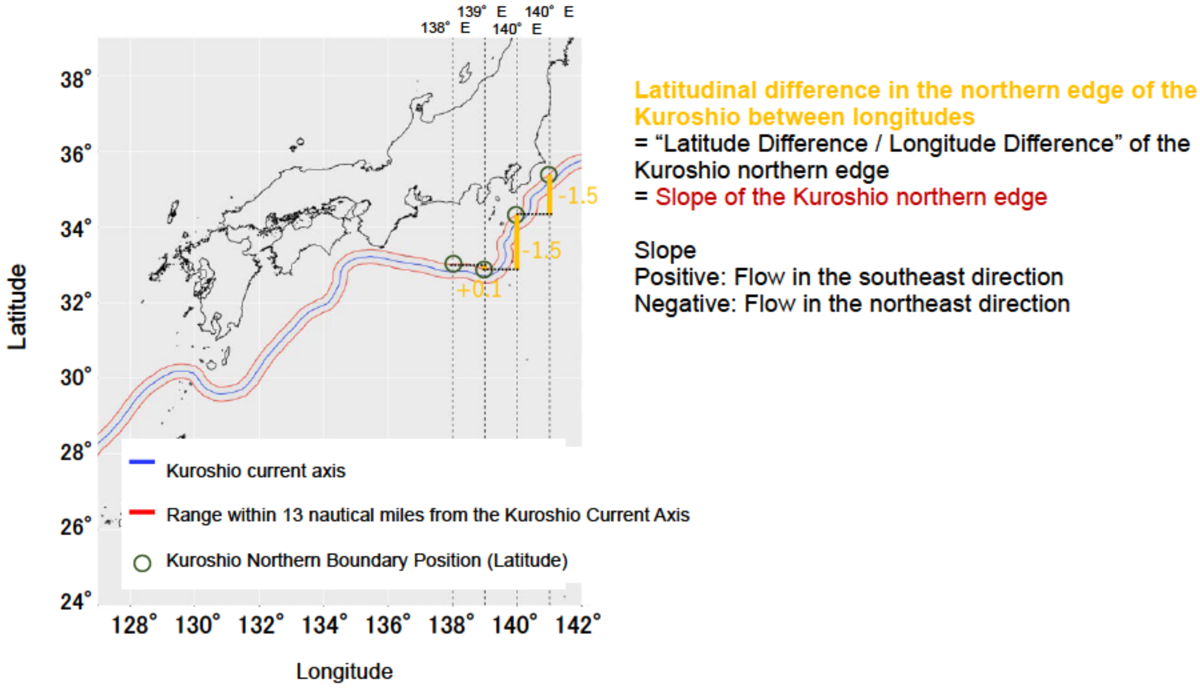
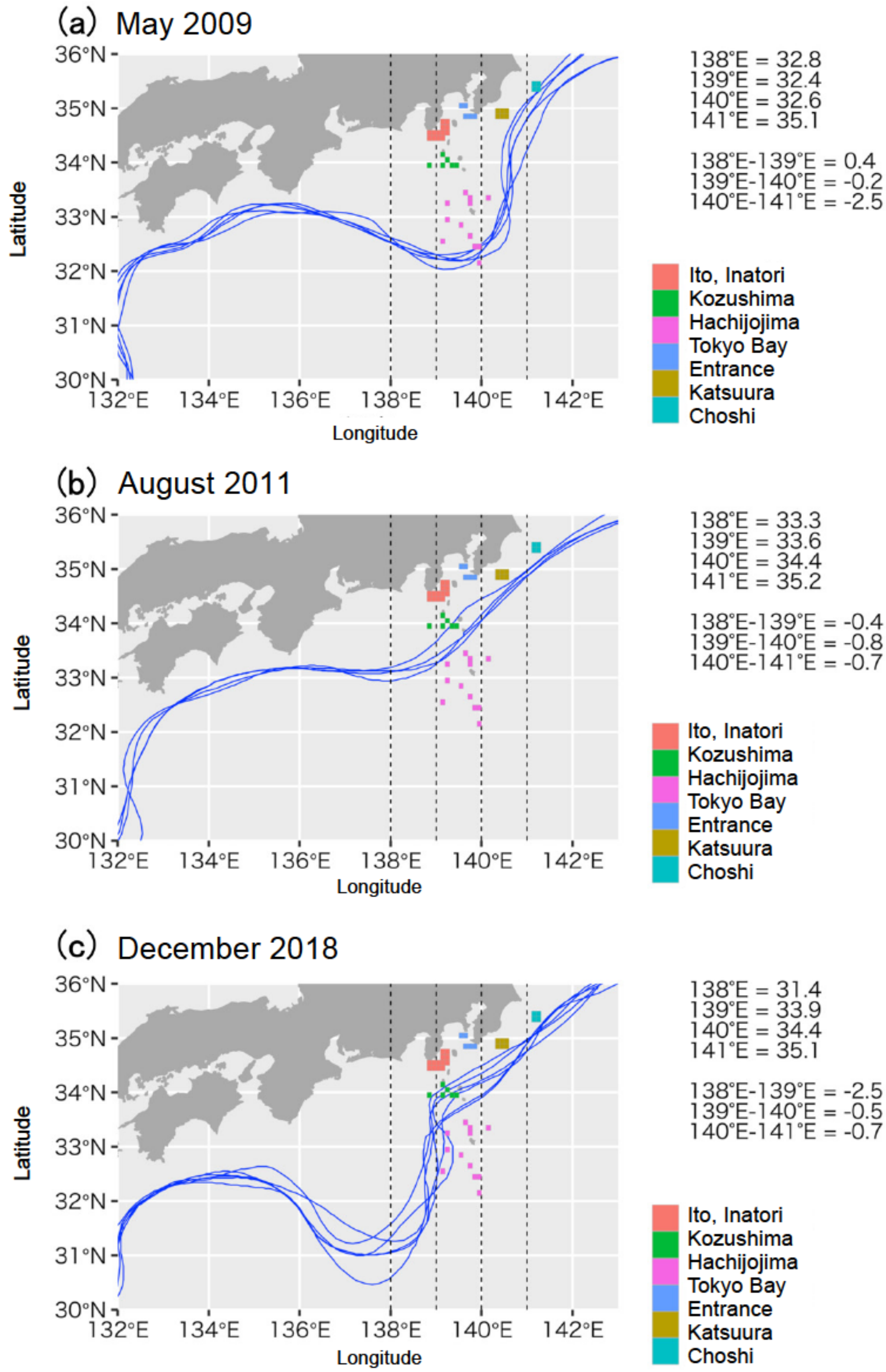


Supplementary Fig. 7-1. Candidate fishing ground locations (grids) for extracting reanalysis values from FRA-ROMS II



Supplementary Fig. 7-2. Conceptual diagram of various Kuroshio-related indices used for CPUE standardization



Supplementary Fig. 7-3. Examples of the latitude of the northern edge of the Kuroshio and the latitudinal differences in the northern edge of the Kuroshio between longitudes

Supplementary Table 7-1. Best models for the 9 selected areas (including 2 sub-areas in the the entrance of the Tokyo Bay) and explanatory variables included in the models within the range of minimum AIC+2

Metropolitan Prefecture Sea Area	Kuroshio northern edge latitude Extracted longitude	Flow direction					Kuroshio Northern Edge latitude	Latitudinal difference of the Kuroshio northern edge between longitudes			Flow speed					Water temperature					Season	No. of candidate models
		0	100	200	400	Bottom		138-139	139-140	140-141	0	100	200	400	Bottom	0	100	200	400	Bottom		
Choshi	141	9	10				11	24	2	6	4	1	8	10		17	2	4	1		26	26
Katsuura	140	1	4				4	1	1	5	5					5					5	5
Bay entrance Chiba	140			2		24	4	30	30	15	5	2	2	1	2	1	2	2	2	3	30	30
Bay entrance Kanagawa	140	14					1	11	1	1	11	7					1	9		5	18	18
Kozushima	139				1		1	1	1	10	1	1	1	1			10				10	10
Miyakejima	139					6	4	5	2	6	11									11	11	11
Hachijojima*	139	5	12				1	17	1	1	1	2	2	2	1		13	1	2		17	17
Ito	139					2	8	2	8	1					8	4				2	8	8
Inatori	139			8			1	2	6	1	10					8					10	10
Omaezaki	138						26	26	14	9	4	4	6	4	2			28	8			26

The effects shown in yellow are the variables of the best model for each area, while those shown in light blue are the variables included within the minimum AIC+2 model, and those in black were not used as variables due to shallow depth. Additionally, the number in each grid represents the number of models including the variable corresponding to each within the range of minimum AIC +2.

*For Hachijojima, the number of models within the minimum AIC+2 under conditions including year effects is shown for reference, and the effects in yellow indicate the explanatory variables of the model with the smallest parameter degrees of freedom and the lowest AIC.

Supplementary Table 7-2. Standardized CPUEs for the 9 areas (for the entrance of Tokyo Bay, CPUEs in the fishing areas on the Chiba Prefecture side, CPUEs in the fishing areas on the Kanagawa Prefecture side, and the average values in both sub-areas)

Metropolitan Prefecture Sea Area	Choshi	Katsuura	Tokyo Bay Entrance (Chiba)	Tokyo Bay Entrance (Kanagawa)	Tokyo Bay Entrance Average	Kozu-shima	Miyake-jima	Hachijo-jima	Ito	Inatori	Omaezaki
2000		**1.01**	1.61	1.98	**1.80**				**1.53**	**1.04**	
2001		**1.19**	2.06	4.44	**3.25**				**1.33**	**1.10**	
2002		**1.06**	0.62	0.99	**0.80**				**0.98**	**0.94**	**0.87**
2003	**1.02**	**1.05**	1.47	1.59	**1.53**				**1.34**	**1.18**	**0.87**
2004	**1.06**	**1.04**	1.44	1.14	**1.29**				**1.21**	**1.29**	**0.83**
2005	**0.96**	**1.17**	2.11	2.00	**2.05**	**0.98**			**1.29**	**1.35**	**0.98**
2006	**1.06**	**1.20**	2.22	1.32	**1.77**	**0.93**		0.86	**1.66**	**1.04**	**0.89**
2007	**1.17**	**1.16**	1.34	1.65	**1.49**	**1.29**	**0.84**	0.90	**1.35**	**1.04**	**0.73**
2008	**0.98**	**1.06**	1.30	1.43	**1.36**	**1.12**	**0.97**	0.70	**1.33**	**1.23**	**0.62**
2009	**0.97**	**0.99**	0.60	1.10	**0.85**	**1.18**	**0.81**	0.95	**1.26**	**1.22**	**0.62**
2010	**0.94**	**1.02**	0.45	0.33	**0.39**	**1.06**	**0.91**	1.11	**1.03**	**1.04**	**0.73**
2011	**0.77**	**0.83**	0.48	0.71	**0.59**	**0.90**	**0.80**	1.11	**1.10**	**0.93**	**0.79**
2012	**0.73**	**0.92**	0.32	0.18	**0.25**	**0.80**	**0.69**	0.99	**0.91**	**1.03**	**0.92**
2013	**0.59**	**0.70**	0.47	0.19	**0.33**	**0.79**	**0.97**	1.03	**0.69**	**0.70**	**0.82**
2014	**0.65**	**0.74**	0.56	0.27	**0.41**	**0.79**	**1.23**	1.00	**0.90**	**0.78**	**1.14**
2015	**0.69**	**0.77**	1.09	0.37	**0.73**	**0.91**	**0.99**	0.85	**0.83**	**0.76**	**0.79**
2016	**0.87**	**0.78**	1.22	0.76	**0.99**	**0.86**	**0.96**	0.89	**0.96**	**0.76**	**0.88**
2017	**0.98**	**0.73**	0.32	0.40	**0.36**	**1.04**	**1.33**	0.92	**0.80**	**0.71**	**0.88**
2018	**1.13**	**0.90**	2.48	1.05	**1.77**	**1.05**	**1.24**	1.11	**0.66**	**0.72**	**1.02**
2019	**1.23**	**0.85**	0.35	0.36	**0.36**	**1.09**	**1.11**	0.99	**0.50**	**0.93**	**1.44**
2020	**1.23**	**1.09**	0.15	0.31	**0.23**	**1.11**	**1.22**	1.01	**0.63**	**1.13**	**1.41**
2021	**1.23**	**1.09**	0.37	0.28	**0.32**	**1.05**	**1.15**	0.92	**0.78**	**1.30**	**1.57**
2022	**1.28**	**1.31**	0.35	0.49	**0.42**	**1.02**	**0.93**	1.13	**0.40**	**1.01**	**1.53**
2023	**1.47**	**1.35**	0.64	0.68	**0.66**	**1.02**	**0.83**	1.53	**0.53**	**0.76**	**1.66**

The CPUEs represent relative values divided by the long-term average for the entire period in each area, with bold text indicating the CPUE used for tuning.

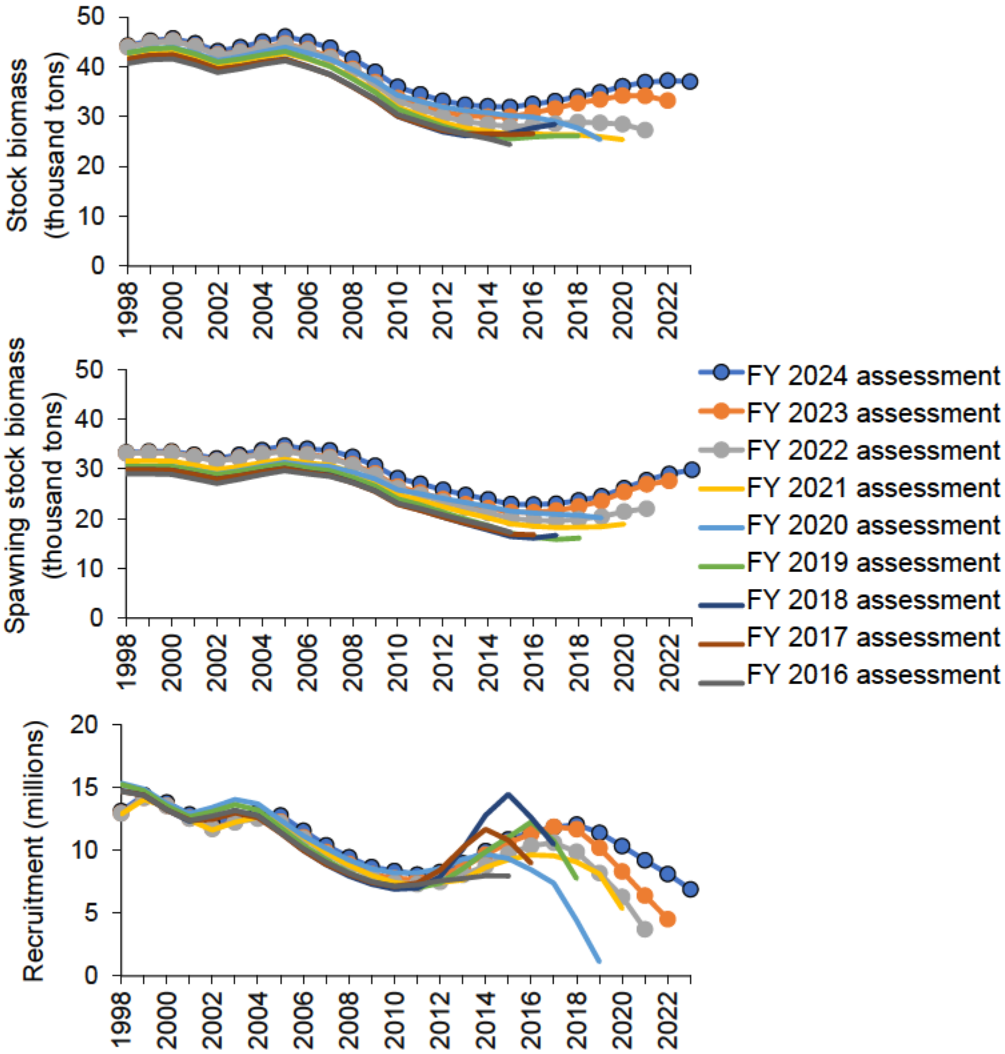
Supplementary Table 7-3. Nominal CPUEs for 10 areas where catch and fishing effort data are available (including 2 sub-area in the entrance of the Tokyo Bay)

Metropolitan Prefecture Sea Area	Choshi	Katsuura	Tokyo Bay Entrance (Chiba)	Tokyo Bay Entrance (Kanagawa)	Kozushima	Miyake-jima	Hachijo-jima	Ito	Inatori	Shimoda	Omaezaki
2000		1.09	1.22	1.80				1.63	1.16		
2001		1.30	2.56	4.06				1.54	1.25		
2002		1.02	0.71	1.18				0.94	1.00		0.72
2003	1.02	0.98	1.31	1.50				1.22	1.19		0.75
2004	1.06	0.97	0.93	0.84				1.10	1.07		0.72
2005	0.99	1.09	1.28	1.76	0.99			1.35	1.34		1.19
2006	1.12	1.21	1.90	1.18	0.96		**0.88**	1.60	1.20		0.80
2007	1.20	1.23	1.28	1.42	1.34	0.92	**1.00**	1.35	1.05		0.79
2008	1.05	1.16	1.35	1.28	1.15	0.99	**0.96**	1.40	1.24		0.62
2009	1.06	1.13	0.75	1.44	1.29	0.93	**1.16**	1.43	1.42		0.62
2010	0.99	1.00	0.43	0.27	1.05	1.03	**1.03**	1.01	1.05		0.64
2011	0.77	0.83	0.73	1.05	0.93	0.77	**1.07**	1.07	0.95	1.29	0.69
2012	0.74	0.95	0.41	0.26	0.81	0.70	**1.00**	0.93	1.06	1.09	0.86
2013	0.59	0.78	0.61	0.23	0.83	1.03	**1.26**	0.75	0.76	1.02	0.87
2014	0.66	0.79	0.69	0.36	0.83	1.20	**1.03**	0.90	0.90	1.11	1.05
2015	0.71	0.82	1.20	0.33	0.93	1.06	**0.93**	0.92	0.83	1.08	0.84
2016	0.88	0.83	1.77	0.88	0.89	0.96	**0.97**	1.04	0.86	1.00	0.90
2017	0.98	0.71	0.69	0.51	1.03	1.30	**1.02**	0.88	0.75	1.15	0.99
2018	1.08	0.81	1.06	0.75	1.00	1.20	**1.06**	0.63	0.64	1.10	1.12
2019	1.14	0.76	0.52	0.38	1.01	1.04	**0.78**	0.40	0.74	0.88	1.35
2020	1.20	1.03	0.18	0.39	1.05	1.17	**0.91**	0.49	0.94	0.83	1.46
2021	1.14	1.00	0.36	0.29	0.99	1.08	**0.85**	0.64	1.07	0.88	1.59
2022	1.23	1.24	0.92	0.72	0.96	0.83	**0.93**	0.35	0.87	0.80	1.70
2023	1.38	1.27	1.13	1.12	0.96	0.78	**1.16**	0.43	0.64	0.76	1.72

The CPUEs represent relative values divided by the long-term average for the entire period in each area, with bold text indicating the CPUE used for tuning.

Appendix 8 Comparison with previous years' assessment results

The major changes between the stock assessment results before the previous fiscal year and the stock assessment results of this fiscal year are that we have newly determined and added the catch in weight shipped from Kochi City local wholesale markets from fishing vessels of Kanagawa Prefecture operating in the southern offshore seamount area of Shikoku from 2000 onwards, as well as the catch in weight of bottom gill net fisheries operating as fisheries approved by the Pacific Regional Fisheries Coordination Committee from 2007 onwards. These catches range from approximately 100 to 200 tons per year, resulting in an upward revision of about 1,000 to 2,000 tons for stock abundance and spawning stock biomass over the entire period.

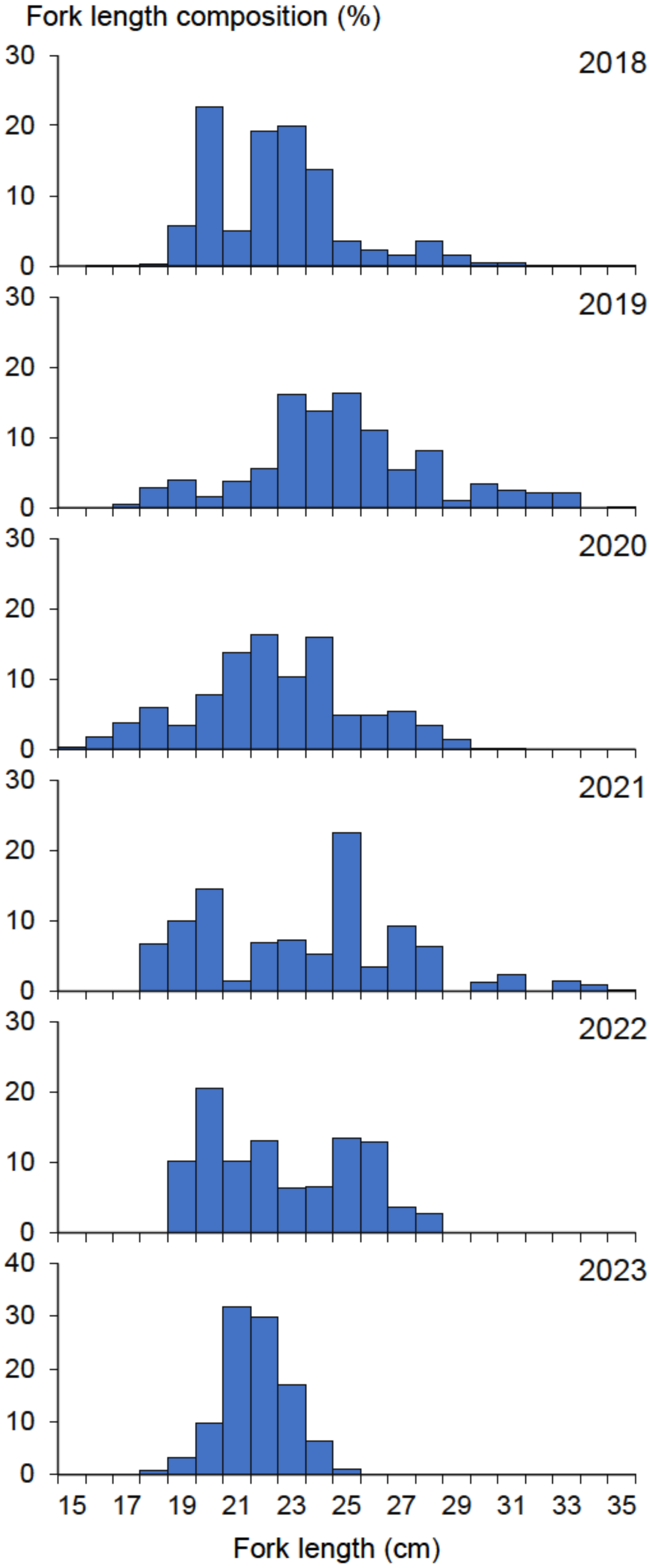


Supplementary Fig. 8-1. Comparison of trends in estimated stock biomass (top), spawning stock biomass (middle), and recruitment (bottom) by assessment year

Appendix 9 Status of stock assessment surveys in offshore bottom trawl fisheries

Splendid alfonsino is caught by offshore trawl fishery in the northern, central, and southern regions of the Pacific. In the northern region of the Pacific, fisheries have been required to prepare catch performance reports even before the revision of the Fishery Act, while fisheries in the central and southern regions of the Pacific have been required to prepare catch performance reports after the revision of the Fishery Act. Catch in Table 3-1 was determined from the same information available in the catch performance reports for periods when such information was available and from information on landings at major ports for periods not subject to such reports. Catch information for the northern region of the Pacific has been determined since 1997 and for the central and southern regions of the Pacific since 2013. Catch performance reports for offshore trawl fishery are reported by operational fishing area in a 10-minute latitude/longitude grid. From these records, it is becoming clear that the increase in catch observed in the central region of the Pacific from 2021 onwards is due to the concentration of catches in specific operational fishing areas rather than uniform catches throughout the entire fishing area. Continued collection and analysis of information on the relationship between the marine environment and fishing areas where fish are caught in large numbers is considered to be a challenge for the future.

At the Aichi Prefectural Fisheries Research Institute, fork length composition is measured during market surveys at landing ports for offshore trawl fishery. The length composition since 2018, which forms the framework of the current survey, is shown in Supplementary Fig. 9-1. The catch on the survey day is sorted into specific size categories and packed into boxes. Boxes of each size category were measured in whole or in part, and the total box count data was used to estimate the overall composition on the survey day. These were added together to determine the annual fork length composition. In addition to talking with market officials who indicated that individuals of the same size are not landed every time, it is important to note that this data is based on the number of surveys, which is not sufficient in some years, as measurements are performed 2 to 8 times per year.



Supplementary Fig. 9-1. Annual fork length composition of catches in offshore trawl fishery in Aichi Prefecture.

Appendix 10 Status of stock assessment surveys in Kochi Prefecture

Splendid alfonsino fishery in Kochi Prefecture began around 1976, and has continued to the present day using both stand line fishing and handline fishing methods. The main fishing grounds are South Mountain off Cape Muroto, Shinsho and other knolls, and the Ashizuri knoll off the southeast coast of Cape Ashizuri. From 2021 onwards, the number of vessels operating with stand lines has decreased as splendid alfonsino fishermen switch to Pacific drifting dropline fishing due to the sharp decline in the catch. With the decline in amount of catches in recent years, fishing operations are also being conducted in Tosabae, a former fishing ground, in addition to traditional fishing grounds.

(1) Trends in Catch in Weight and CPUE, etc.

Of the total catch of this prefecture, the Kochi Prefectural Fisheries Experiment Station independently aggregated the catch of the Kochi Prefecture Fisheries Cooperative, Muroto Branch (then the Muroto Fisheries Cooperative) until 2009, and has been aggregating the catch of the Kochi Prefecture Fisheries Cooperative from 2010 onwards, with this data covering most of the catch within Kochi Prefecture (Table 3-1). The catch of the Muroto Branch has been decreasing since 2010, but this is thought to be due to fishermen switching to coral fishing. CPUE showed an increasing trend until 2020, but from 2021 onward, as the catch decreased, CPUE also declined sharply. Catch in 2023 was only 47 tons (Table 3-1, Supplementary Fig. 10-1). The cause of this decrease in catch is thought to be the change in sea conditions in the splendid alfonsino fishing grounds due to the large meander of the Kuroshio and the decrease in the number of individuals migrating from the waters surrounding the Kanto region and the Izu Islands (Yanagawa, 2024).

CPUE is estimated using the same method as in Appendix 7, with the latitude of the northern edge of the Kuroshio at the offshore area being 134°E and the latitudinal differences in the northern edge of the Kuroshio between longitudes (133°E - 134°E, 134°E - 135°E, and 135°E -136°E) in the surrounding sea as explanatory variables related to the Kuroshio current path. Although it is still being estimated, the best model has selected effects such as the latitudinal differences in the northern edge of the Kuroshio between the longitudes 134°E - 135°E and 135°E - 136°E, and water temperature at the surface layer, in addition to annual and seasonal effects. The analysis results shown in Supplementary Fig. 10-1 have been obtained at the time of estimation, but further study is required on the interpretation of explanatory variables, etc. Since the interview information on fishing areas has been accumulated over the years, we are considering more detailed analysis methods, such as taking into account the effect of “sea area” and the interaction effect of “year and sea area”, which have not been considered for the sea areas surrounding the Kanto region to the Izu Islands.

(2) Fork length composition

Changes in the annual fork length composition of splendid alfonsino landed at the Kochi Prefecture Fisheries Cooperative, Muroto Branch, and Muroto Misaki Branch have been measured over time (Supplementary Fig. 10-2). The appearance of small fish in 1999, by their recognition as a dominant year class in 2001, is believed to have helped with good catches until 2004. A peak in small fish also appeared in 2017, but the mode cannot be tracked from the fork length composition from 2019 onwards. The size of fish has been decreasing since 2019 due to a decrease in individuals with a fork length of 35 cm or more, and since 2020, the mode of fork length has remained around 30 cm.

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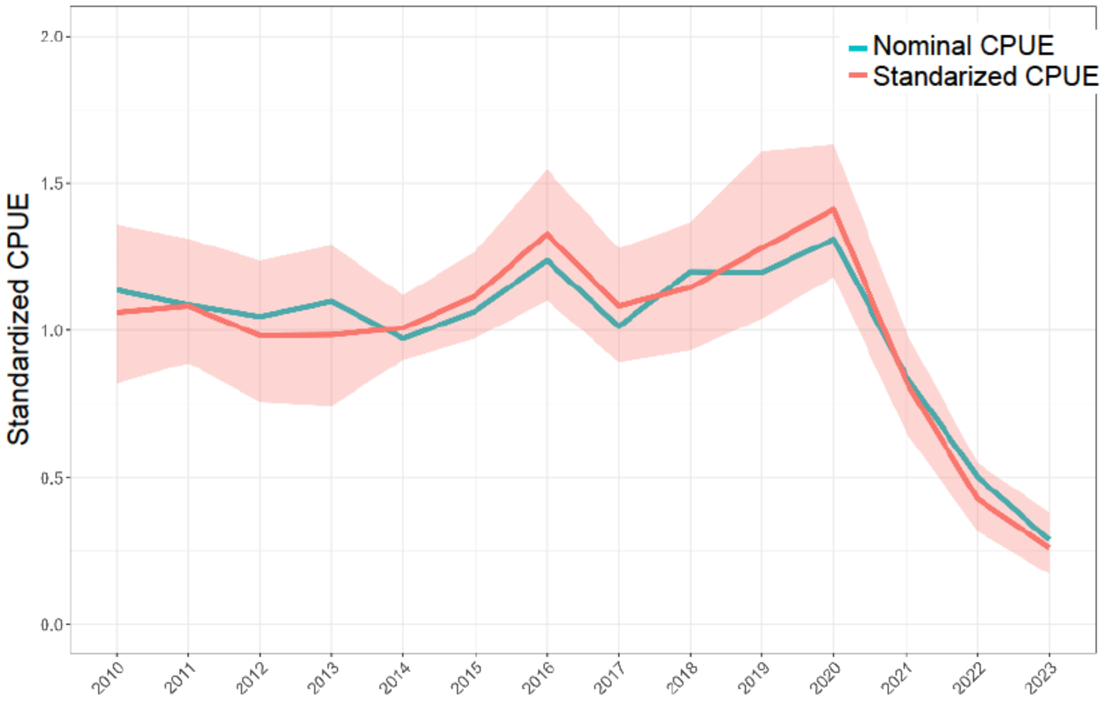
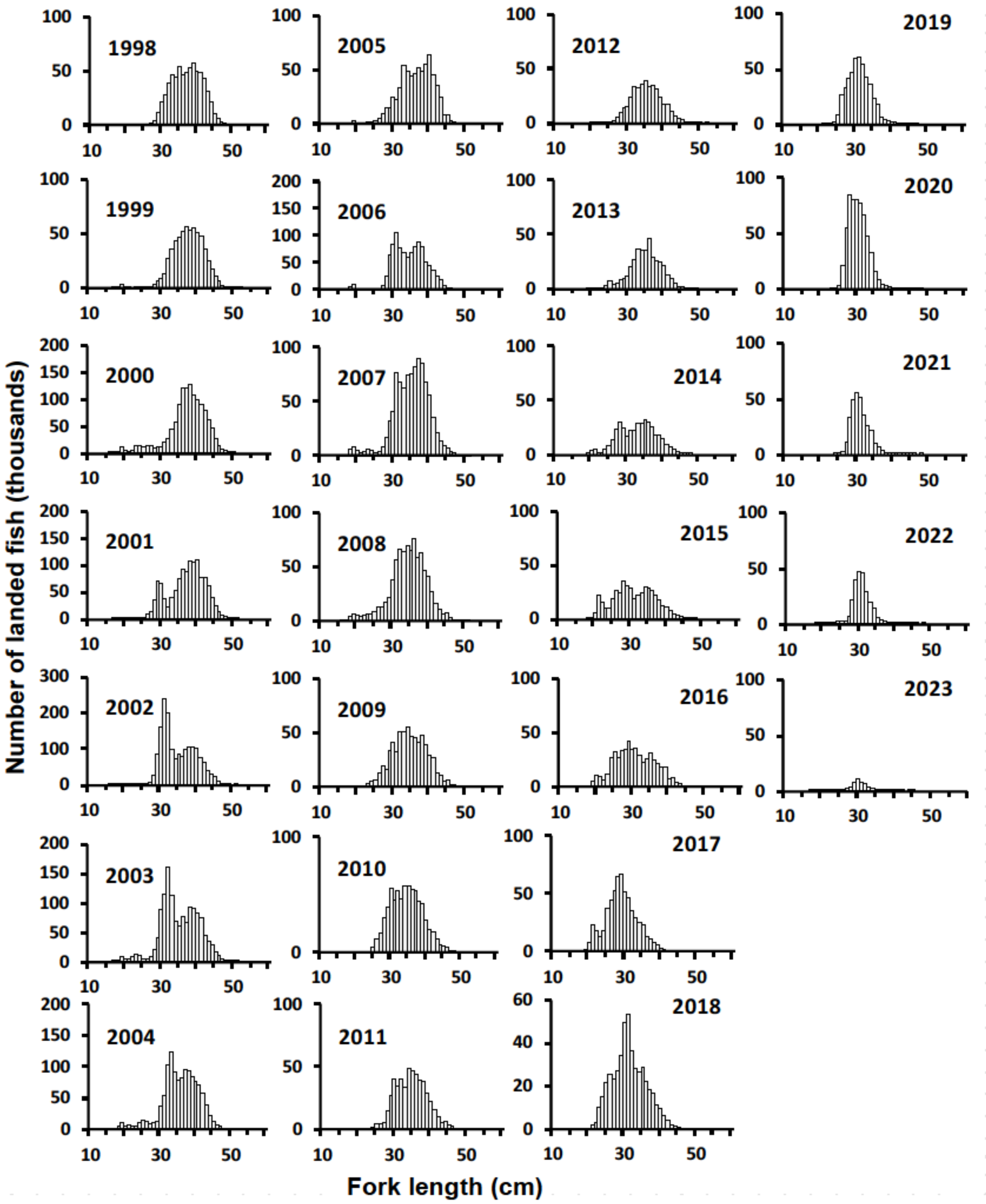


Supplementary Fig. 10-1. Examples of standardized CPUE and nominal CPUE during trials



Supplementary Fig. 10-2. Annual fork length composition of catch in Kochi prefecture (Muroto area)

Appendix 11 Status of stock assessment surveys in Kagoshima Prefecture

In the waters of Kagoshima Prefecture, several dozen of the fishing vessels belonging to fisheries cooperatives under the jurisdiction of the prefecture mainland, Kumage and Amami, operate in the waters off the Tokara Islands on the east side of the Okinawa boat basin to the northwest of the Amami Islands, using handline fishing or bottom stand line fishing (Watari et al. 2017). Splendid alfonsino caught by these fisheries include three species: *Beryx splendens*, *B. mollis*, and *B. decadactyius*. Some fishery cooperatives in Kagoshima Prefecture do not have a code for handling splendid alfonsino as a single species during trade and treat the fish as a mix of different species, such as *B. decadactyius* and *B. mollis*. At the Kagoshima City Central Wholesale Market, *Beryx splendens, B. mollis*, and *B. decadactyius* are handled separately under the names “naga-kinme”, “bake-kinme”, and “hira-kinme”, respectively. In addition, since the prefecture’s catch of splendid alfonsino is traded primarily through the Kagoshima City Central Wholesale Market, the volume of splendid alfonsino handled at that market is used in this report as the catch for Kagoshima Prefecture. Table 3-1 shows the annual changes in the catch of splendid alfonsino in the same market. Since this data is compiled from wholesale market records, it includes shipments from some fishing vessels outside Kagoshima Prefecture, which makes the separation difficult.

The weight composition of splendid alfonsino in the waters of Kagoshima Prefecture was compiled using recorded data on the weight per box and the number of fish per box surveyed at the same market. Supplementary Figs. 11-1 and 11-2 show catch and exploitation rate by average body weight class, categorized into eight groups: 1,500 g and above, 1,200–1,500 g, 1,000–1,200 g, 800–1,000 g, 700–800 g, 600–700 g, 500–600 g, and 500 g or less. Catch weighing 600 g or less accounted for less than 10% of the total, indicating that the catch of immature fish (fish larvae, juveniles and young fish) was minimal, with the focus primarily on adult fish weighing 600 g or more.

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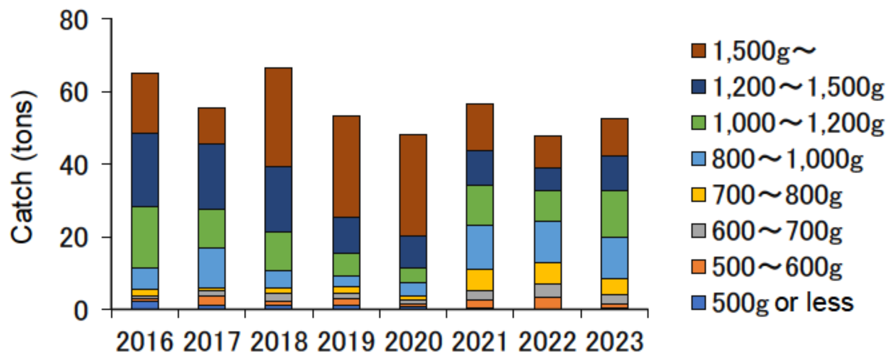
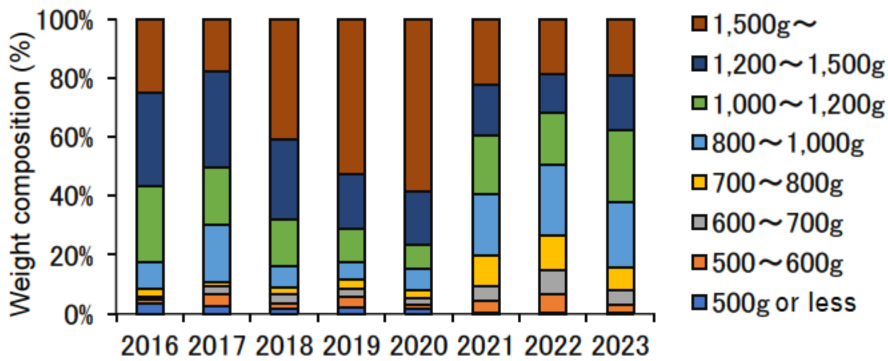
Watari, S., Yonezawa, J., Takeuchi, H., Kato, M., Yamakawa, M., Hagiwara, Y., Ochi, Y., Yonezaki, S., Fujita, K., Sakai, T., Ihara, R., Shishidou, H., and Tanaka, E. (2017) Fisheries biology and resource management of splendid alfonsino *Beryx splendens*. Bull. Jap. Fish. Res. Edu. Agen., **44**, 1-46.



Supplementary Fig. 11-1. Catch by average body weight class, calculated based on the handling volume at the Kagoshima City Central Wholesale Market



Supplementary Fig. 11-2. Proportion by average body weight class, calculated based on the handling volume at the Kagoshima City Central Wholesale Market.

Appendix 12 Summary of issues to be further considered

The issues to be examined from this fiscal year onward during the stock assessment of this stock group concerning CPUE standardization, recreational fishing, predation damage, and fisheries in the target area were summarized as issues to be addressed in the future (Supplementary Table 12-1).

(1) Stock assessment method

Creating an age length key for each year to accurately determine the abundance of each age cohort is ideal. However, due to the wide age range and the limited number of individuals measured annually, creating age-length key annually has not yet been implemented for this stock assessment. Therefore, the catch in number for each age may include individuals from other age cohorts. In such cases, the appearance of a dominant year class in a certain year would simultaneously increase the catch in number of the cohort born in the year before and after the year in which it appeared. In estimating the stock-recruitment relationship and making future projections, it is desirable to consider the current structure of the age-length key. In order to improve the accuracy of estimating the catch in number at age, other prefectures are considering methods to estimate body length composition from images of catches at landing ports, as with Higuchi et al. (2024).

To further enhance stock assessment, further consideration of the VPA method, consideration of the structure of the age-length key, and exploration of methods and recruitment indices other than tuned VPA are considered medium- to long-term challenges for the sustainable use of splendid alfonsino.

(2) CPUE standardization

Some major ports for vertical long line fishery and some areas for bottom vertical long line fishery may not have data available, so it is important to utilize the CPUE of these areas as an indicator for tuned VPA. In addition, although monthly data is currently used for CPUE standardization, it is necessary to maintain and expand the system for aggregating data in more detailed units, such as by every ten days or by day. Since the fishing areas for bottom stand line fishing cover a vast area, future considerations, such as applying the method of Higuchi et al. (2022), are necessary. In Hachijojima, Tokyo, the annual effect was not selected in the current model selection criteria for CPUE standardization, and standardized CPUE has not yet been incorporated into the stock assessment. The Hachijojima area differs significantly from other areas that conduct vertical long line fishery in that it operates over a wide area, and this may be one of the reasons why the annual effect was not selected. It is necessary to continue considering methods to handle environmental factors that are appropriate for models representing the monthly CPUE of Hachijojima.

(3) Recreational fishing, depredation damage, and fisheries in the target area

Depredation damage during splendid alfonsino fishery is the phenomenon in which the catch caught on the hook is preyed upon by sharks and other predators during fishing operations. Catch in number in the current stock assessment does not take into account the number of fish lost during fishing due to predation damage. If this ratio remains the same over time, the trends in SSB, abundance, and recruitment will not change, as in the sensitivity analysis when natural mortality M fluctuates (Fig. 4-4). If there is an increasing or decreasing trend over time, the fluctuation trends in abundance, SSB, and recruitment may change. With respect to depredation damage, it is necessary to consider data collection scheme with refer to Takagi et al. (2022), Takada et al. (2024).

As for recreational fishing, an estimate of annual recreational catch was made by Ozaki (2024) based on web information from 2021-2022, and it was found to be at least 179.9 tons. Currently, there is no information on long-term recreational catch prior to 2020, which makes tracking changes over time impossible. Hence, this information is not taken into consideration in the stock assessment. However, we believe that more information on recreational catch must be collected in the future.

This stock assessment targets fisheries in the waters off the Kanto coast to the Izu Islands and the southern offshore seamount area of Shikoku that perform stand line, bottom stand line, drift net, and bottom gillnet fishing and does not take into consideration the inflows and outflows of these fisheries. This fiscal year, we have compiled the survey status as supplementary data for offshore trawl fishery, Kochi Prefecture, and Kagoshima Prefecture as catch data of the target sea areas (Appendix 9, 10 and 11). It is essential to continue gathering data on these fisheries and regions in the future.

(4) Incorporate into stock assessment

Catch from the southern offshore seamount area of Shikoku, which until the previous fiscal year was partially unknown, was added as a target for estimation of stock abundance in the stock assessment of this fiscal year. In addition, we are collecting data on fisheries that are not included in the current stock assessment, such as offshore trawl fishery, where a rapid increase in catch has been observed, so there is a possibility that the scope of stock abundance estimation will be expanded. Accordingly, we will consider updating the reference points as necessary.

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Supplementary Table 12-1. Summary of issues to be further considered

	Issues for consideration
Stock assessment method	- Improving the accuracy in estimating catch in number at age and by year - Further consideration of methods for improving stock assessment
CPUE standardization	- Improving the precision of standardized CPUE - Expansion to areas and fisheries where CPUE standardization has not been conducted - Considering data collection frameworks for detailed information, such as every ten days or daily variations
Recreational fishing, depredation damage, and fisheries in the target area	- Reviewing the information collection frameworks
Incorporate into stock assessment	- Continue collecting data and consider expanding resource assessment areas and fisheries