Stock Assessment for Central and Western Seto Inland Sea Stock of Japanese Seabream (*Pagrus major*) in Fiscal Year 2022

Fisheries Stock Assessment Center, Fisheries Resources Institute, Japan Fisheries Research and Education Agency

Participating Organizations: Fisheries & Marine Technology Center, Hiroshima Prefectural Technology Research Institute; Inland Sea Research Division, Yamaguchi Prefectural Fisheries Research Center; Fisheries Research Institute, Oita Prefectural Agriculture, Forestry and Fisheries Research Center; Research Institute of Cultivation Resources, Fisheries Research Center, Ehime Research Institute of Agriculture, Forestry and Fisheries; and National Association for Promotion of Productive Seas (NAPPS)

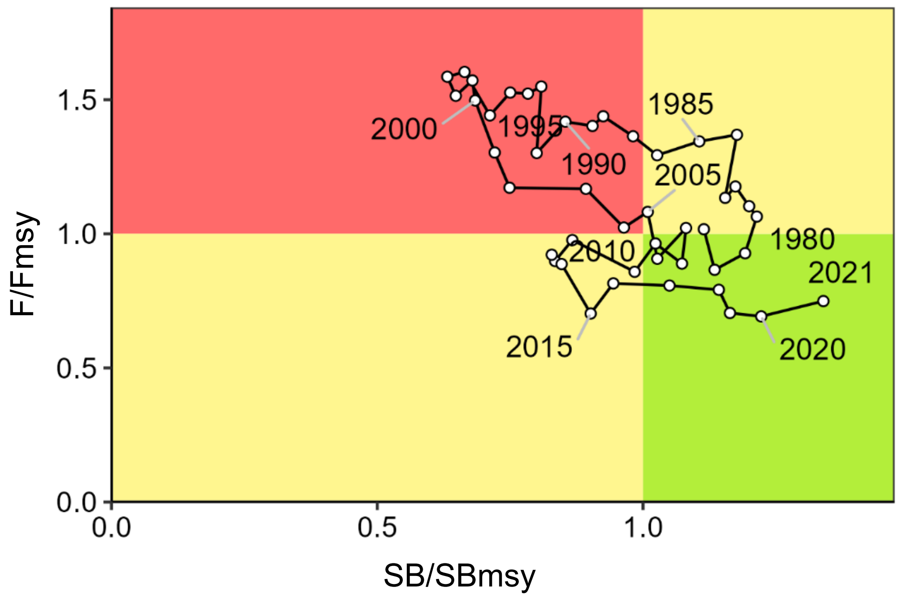
Summary

The biomass of this stock was estimated using a cohort analysis. Biomass reached a record high of 12,500 tons in 1980, followed by a gradual decline until 1995. It remained steadysteady from 1996 to 2000, and then increased from 2001 to 2005. After that, biomass declined gradually starting in 2006, and then increased again starting in 2013, with the estimated biomass of 12,800 tons in 2021. The SSB (spawning stock biomass) decreased from 6,900 tons in 1980 to 3,600 tons in 1997. It was in an increasing trend up to 2007, then started to decline in 2008. It has been in another increasing trend since 2014, and was 7,600 tons in 2021. The recruitment from wild origins in 2021 was 11.47 million fish, which has remained steadysteady at between 10.66 million to 11.70 million over the past five years (2017 to 2021). This species is a target species of artificial stocking, and 1.59 million hatchery-reared fish were released in 2020. The contribution rate of hatchery-released age 0 fish in the 2020 catch was 0.3%, and the survival to recruitment of released fish (the survival rate of released fish to fishery recruitment) is estimated to be extremely low at 0.02.

At the Research Institute Meeting held in September 2021, a Ricker model that takes autocorrelation into account was applied to the stock-recruitment relationship of this stock, and based on this model, the level of SSB required for MSY (SBmsy) was estimated to be 5,700 tons. Following these criteria, SSB of this stock in 2021 exceeds the level required for MSY. In addition, the fishing pressure for this stock in 2021 was lower than the fishing pressure level required for MSY (Fmsy). Based on the trend seen in the previous 5 years (2017 to 2021), SSB is judged to be in an “increasing” trend.

In this stock, the reference points, future projections, and other items are provisional values as proposed at the Research Institute Meeting, which will be finalized based on discussions of the stakeholder meeting.

Summary Figures and Tables



x axis: ratio of SSB (SB/SBmsy), y-axis: ratio of fishing pressure (F/Fmsy)

MSY, SSB Levels and Trends, and ABC	
SSB required for MSY	5,700 tons
Level of SSB in 2021	Over the level required for MSY
Level of fishing pressure in 2021	Under the level required for MSY
Changes in SSB in 2021	Increasing
Maximum Sustainable Yield (MSY)	2,800 tons
ABC for 2023	-
Comments: ・ABC is estimated after Harvest Control Rules (HCRs) for this stock are compiled by the stakeholder meeting, and set through the Fishery Policy Council. ・ It is important to note that recruitment volume in recent years has consistently been below the average expected from the stock-recruitment relationship.	

Recent Biomass, Catch, Fishing Pressure, and Exploitation Rate					
Year	Biomass (hundred tons)	SSB (hundred tons)	Catch (hundred tons)	F/Fmsy	Exploitation rate (%)
2017	113	60	22	0.81	20
2018	118	65	25	0.77	21
2019	120	66	24	0.69	20
2020	123	70	22	0.68	18
2021	128	76	26	0.73	20
2022	129	78	27	0.72	21
2023	128	76	-	-	-

・ The values for 2022 and 2023 are estimated averages 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 at age by year	Fishery Trends in the Seto Inland Sea and Southern Pacific Ocean Areas (Statistics Department, Chugoku-Shikoku Regional Agricultural Administration Office), 2020 Catch in Weight by Prefecture/Fishery Type/Species and Approximate Values for 2021 (Ministry of Agriculture, Forestry and Fisheries) Biological Information Survey and Survey on Catch Status by Fishing Ground 2020 Catch in Weight by Area (*nada*-sea section)/Fishery Type/Species in Kagawa and Approximate Values for 2021 (Ministry of Agriculture, Forestry and Fisheries) Length-age relationship (Ehime Prefecture) Length-fork length relationship (Ehime Prefecture) Length-weight relationship (Ehime Prefecture) Survey on Catch Status by Fishing Ground (Hiroshima, Yamaguchi, Ehime, and Oita prefectures) Survey on Fork Length Measurement by Fishing Method (Ehime Prefecture)
Natural mortality (M)	M at age per year = 0.39 (age 0), 0.24 (age 1), and 0.17 (age 2 and older) (Shimamoto 1999).
Fishing effort	Fishery Trends in the Seto Inland Sea and Southern Pacific Ocean Areas (Chugoku-Shikoku Regional Agricultural Administration Office)
Number of hatchery-released fish	Results of production, procurement, and release of seeds for stock enhancement (National Association for Promotion of Productive Seas (NAPPS))
Contribution rate	Biological Information Survey (Ehime Prefecture) and Survey on Catch Status by Fishing Ground (Yamaguchi Prefecture)
Catch at age	(Reference) Recruitment Surveys from Sample Vessel Surveys (Ehime Prefecture)

2. Ecology

(1) Distribution / Migration

The distribution of the central and western Seto Inland Sea stock of Japanese seabream is shown in Fig. 2-1. Japanese seabream is widely distributed from Hokkaido to Kyushu. There are six stocks of Japanese seabream distributed across Japan, and the central and western Seto Inland Sea stock is distributed throughout the entire area of Hiuchi-nada, Bingo-Geiyo Seto, Aki-nada, Iyo-nada, and Suo-nada, as well as in the Bungo Channel. The fishes distribute in the nursery area near the spawning grounds until it reaches a fork length of approximately 10 cm, and then expands its habitat gradually as it grows.

(2) Age / Growth

This species is known to reach 12.3 cm (38.3 g) by age 1 (with May as a reference date), 19.4 cm (150.5 g) by age 2, 25.4 cm (338.6 g) by age 3, and 30.5 cm (586.4 g) by age 4 (source: Hiroshima Prefecture 1983) (Fig. 2-2). Lifespan is 15 to 20 years (Hiroshima Prefecture 1983). Data from literature published on this stock is shown as a reference. The average weight of the catch by age was used to calculate biomass.

(3) Maturation / Spawning

Half of individuals join the spawning stock at age 3 and reach full maturity at age 4 and older (Fig. 2-3). However, in Hiroshima Bay, the majority of males reach maturity at age 3 and females at age 4 (Kitajima 1978), indicating slightly earlier maturation. Spawning season is in spring, with spawning stock migrating to major spawning grounds in Hiuchi-nada, Bingo-Geiyo Seto, and Aki-nada in the central Seto Inland Sea from mid-May to mid-June, and Iyo-nada in March to early April for multiple spawnings (Hiroshima Prefecture, 1983).

(4) Predator-Prey Relationships

Japanese seabream of this stock feeds primarily on crustaceans as well as polychaetes, larvaceans, and fish (Takaba 1992). It is preyed upon by piscivorous fish during the larva and juvenile stages.

3. Fishery Status

(1) Fishery Overview

Japanese seabream in the central and western Seto Inland Sea have primarily been caught by boat seine fishing (“Gochi” seine fishery, i.e., Small-scale Danish seine), Small trawl fishery, and anglings. The proportion caught by “Gochi” seine fishery is higher than in the stock in eastern Seto Inland Sea. In 2021, 32% of this stock was caught by “Gochi” seine fishery, 31% by Small trawl fishery, 14% by Gill net fishery, 13% by anglings, and 9% by Small-scale set nets (Fig. 3-1, Table 3-1).

(2) Trends in Catch in Weight

The catch for this stock of Japanese seabream was at 4,552 tons in 1953, followed by a decreasing trend, reaching a record low of 1,715 tons in 1970 (Fig. 3-1 and 3-2, Table 3-2). It later started to increase and recovered to 3,351 tons in 1984, but once again shifted to a decreasing trend, and was 2,057 tons in 2015. It then increased slightly and was 2,609 tons in 2021.

A survey on the recreational fishing of the entire region of Seto Inland Sea was conducted in 1997 and reported that 120 tons of Japanese seabream were caught in 1997. This represents 3% of the 3,907 tons of Japanese seabream caught in the same area that year. Of this total, 48 tons were caught in the central and western areas (Hiroshima, Yamaguchi, Fukuoka, Oita, and Ehime), accounting for

2% of the total catch of 2,828 tons (Fisheries Coordination Division, Resource Management Department, Fisheries Agency 1998). Another similar survey reported that 195 tons of Japanese seabream, or 4% of the total catch of 4,529 tons, were caught in 2002 (Fisheries Coordination Division, Resource Management Department, Fisheries Agency 2003). Then, in 2008, a similar survey reported that 331 tons, or 8% of the total Japanese seabream catch of 4,175 tons, were caught (Fisheries Coordination Division, Resource Management Department, Fisheries Agency 2008 Recreational Catch Survey Report Datahttp://www.e-stat.go.jp/stat-search/files?page=1&layout=datalist&toukei=00502002&kikan=00502&tstat =000001031445&cycle=8&tclass1=000001031446&tclass2=000001031447&result_page=1&second2=1, August 8, 2018). No survey on recreational catch have been conducted since.

(3) Fishing Effort

The number of vessel days (the product of number of operated vessels and operation days) at sea for small trawl fishery, which accounts for approximately 30% of the catch of Japanese seabream in the central and western Seto Inland Sea, declined from the 1960s up to 2006 (Fig. 3-3, Table 3-3). The total number of vessel days at sea for “gochi” seine fishery increased slightly from 1996 to 2000, when statistics were first compiled, followed by a decline, and remained steadysteady from 2004 to 2006. The number of operated days at sea since 2007 has not been disclosed.

4. Stock Status

(1) Stock Assessment Methods

The fishing mortality, stock population, biomass, and SSB at age and by year were estimated using cohort analysis based on the catch in number at age and by year for the 45-year period between 1977 and 2021 (Appendix 1 and 2, Supplementary Tables 2-1 to 2-4). Calculations used in stock assessment assumed that the fishing pressure (F value) for the most recent year was equal to the average fishing pressure over the past five years and that recruitment volume for the most recent year was the average stock population at age 0 for the past five years excluding the most recent year (2016 to 2020).

(2) Trends in Abundance Indices

CPUE (catch per unit effort, kg/vessel day) for small trawl fishery was 0.09 in 1969, but increased to 0.95 in 1975 (Fig. 4-1, Table 3-3). After a brief decline, this number increased again in the 1980s, and then reached an all-time high of 3.33 in 1996. It remained relatively steady between 2.3 to 2.8 until 2006, the last year of the statistical data.

The CPUE of “Gochi” seine fishery was generally in an increasing trend from 1996 to 2006, while the CPUE of Small trawl fishery, which remained steadysteady, has increased since the late 1990s (Fig. 4-1, Table 3-3). No data is available from 2007 onward.

(3) Trends in Biomass and Fishing Pressure

Biomass reached 12,500 tons in 1980, followed by a gradual decline until 1995. It remained steadysteady from 1996 to 2000, and then increased from 2001 to 2005. Since 2006 it returned to a gradual decline, then has been increasing again since 2013. In 2021, it increased to a record high of 12,800 tons. Compared to the stock assessment of the previous year, estimated values are not significantly different from those prior to 2000, but biomass and SSB from 2001 to 2020 have been revised upward (Appendix 7, Supplementary Fig. 7-1, 7-2, and 7-3). This is due to a 15% increase in catch in 2021 over the previous year and a retroactive upward revision of recruitment volume. The exploitation rate fluctuated between 18.1 and 31.5%. The exploitation rate was particularly high between 1992 and 2000, averaging 30.2 (Fig. 4-2). Since 2001, the rate has remained relatively stable between 18.1 and 26.3%, and in 2021 it was slightly higher than the previous year at 20.4%.

SSB decreased from 6,900 tons in 1980 to 3,600 tons in 1997 (Fig. 4-3, Table 4-1). It was in an increasing trend up to 2007, then started to decline in 2008. It has been in another increasing trend since 2014. In 2021, it increased to a record high of 7,600 tons.

Changes over time in fishing mortality (F) by age are shown (Fig. 4-4). The F value for age 0 fish remained steady at an extremely low value after 2010, and then increased slightly in 2016 before decreasing again in 2021. The F for age 1 fish was high between 1984 and 1994. Levels subsequently declined, except in 2002, and have remained low since 2010. Similarly, the F for age 2 fish were at high levels from 1984 to 1988, then declined gradually. The F for age 3, 4, and 5 (values for age 6 and older were equal to age 5) has remained generally steady since 2002 despite some fluctuations.

Sensitivity analysis with increasing and decreasing natural mortality (M) by 30% shifted the results as 85 to 121% for biomass, 72 to 143% for recruitment volume, and 87 to 117% for SSB, respectively (Fig. 4-5). The range of variation compared to the variation of M was slightly high for the estimated values for recruitment volume and slightly low for the estimated values of biomass and SSB.

(4) Stock enhancement and recruitment

This species is a target species of stock enhancement, and hatchery-reared fish have been released as stock since 1963. The largest number of hatchery-released fish was 4.6 million in 1987. This figure entered a downward trend until 2007 and has remained steady in recent years. 1.59 million hatchery-reared fish were released in 2020 (Fig. 6-1, Table 3-2).

The contribution rate of hatchery-released fish age 0 has had an extremely low average of 0.6% since 2006 (average from 2006 to 2020), and the survival to recruitment (the survival rate of released fish to fishery recruitment) was similarly low at 0.04 (average for 2006 to 2020). In 2020, the adjusted contribution rate and survival to recruitment were estimated to be extremely low at 0.3% and 0.02 respectively. Note that the accuracy of the contribution rate data used here is believed to be low due to the fact that there is no data collection system established for the entire stock and information is limited. However, since the figures themselves are extremely low, the impact of low accuracy on overall stock estimates is also thought to be extremely low.

Recruitment of hatchery-reared fish reached a record high of 3.4 million in 1986, but later entered a downward trend, and has remained at low levels around 60,000 since 2006 (average for 2006 to 2020). Recruitment for hatchery-reared fish in 2020 was 30,000. Recruitment of hatchery-reared fish in 2021, for which data on the number of released fish has yet to be published, was estimated by multiplying the average survival to recruitment from 2017 to 2020 by the average number of hatchery-released fish, for an estimated recruitment of 50,000.

(5) Yield Per Recruit (YPR), Spawning Per Recruit (SPR), and Current Fishing Pressure

In order to compare fishing pressures with consideration for selectivity, we compared findings for spawning per recruit (SPR) in scenarios with and without fishing pressure. Fig. 4-6 shows changes in the SPR ratio (%SPR), which compares SPR in a scenario without fishing pressure against SPR in a scenario with fishing for each year. Lower fishing pressure means higher %SPR levels. The %SPR in 2021 was 20%.

The relationship between current fishing pressure and YPR and %SPR is shown in Fig. 4-7. The current fishing pressure (F2022), the value used to estimate the F (Fmsy) required for maximum sustainable yield (MSY) at the Research Institute Meeting held in September 2021 (Yamamoto et al. 2021) was used for selectivity, and the 2021 value (20%) was used for %SPR. In addition, the values used to calculate Fmsy were also used for average body weight at age and the maturity rate. Fmsy is equivalent to 14% when converted to %SPR. The current fishing pressure (F2022) is below Fmsy, but above F30%SPR.

(5) Stock-Recruitment Relationship

The relationship (stock-recruitment relationship) between SSB (in weight) and recruitment volume (individuals) is shown in Fig. 4-8. The above-mentioned Research Institute Meeting applied a Ricker model for stock-recruitment relationships to the stock-recruitment relationship model of this stock (Yamamoto et al. 2021). The data used to estimate the parameters of this stock-recruitment relationship was based on SSB and recruitment volume reported in the FY 2021 stock assessment (Yamamoto and Katamachi 2022), and the optimization method was the least squares method. Additionally, autocorrelation regarding residuals in recruitment volume is considered within the estimation. The parameters of the stock-recruitment relationship model are shown in Supplementary Table 6-1.

(7) Levels Required for MSY Under Current Environmental Conditions

The SSB required for maximum sustainable yield (SBmsy) and the catch in weight required for maximum sustainable yield, under current environmental conditions (2021 and onward), were defined as the values estimated at the Research Institute Meeting (Yamamoto et al. 2021), and are shown in Supplementary Table 6-2.

(8) Stock Levels/Trends and Fishing Pressure Levels

Reference values for SSB and fishing pressure required for MSY are shown in a Kobe plot in Fig. 4-9. In addition, a summary of SSB and fishing pressure in 2021 is shown in Supplementary Table 6-3. SSB of this stock in the 2021 fishing season was higher than the SSB required for MSY (SBmsy), specifically, SSB in the 2021 fishing season was 1.34 times the value of SBmsy. In addition, the fishing pressure in 2021 was lower than the fishing pressure required for MSY (Fmsy), specifically, it was 0.75 times the value of 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. The trend in SSB was determined to be an increase based on the trend over the previous 5 years (2017 to 2021). The SSB of this stock was below SBmsy from 2010 to 2016, but since 2004, fishing pressure has been reduced to below Fmsy, and since 2017, SSB has recovered to a level consistently above SBmsy.

5. Summary of Stock Assessment

In 2021, stock abundance was 12,800 tons and SSB was 7,600 tons, which exceeds the SSB level required for MSY (5,700 tons). Fishing pressure in 2021 was below the level required for MSY. SSB is on an upward trend.

6. Additional Comments

In this stock, juveniles have not actively been treated as catch targets in recent years, and the catch in number of juveniles (age 0 to 1) decreased significantly until 2004. However, the catch in number for age 0 fish has increased since 2015. We suspect that there is an increase in the number of juveniles, and an increase in by-catch, during fishing operations targeting other species due to increased density and expanded distribution area.

7. References

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Kitajima, C. (1978) Study on the Egg Harvesting and Mass Production of Juvenile Japanese Seabream. Special report of Nagasaki Prefectural Institute of Fisheries, 5, 95 pp.

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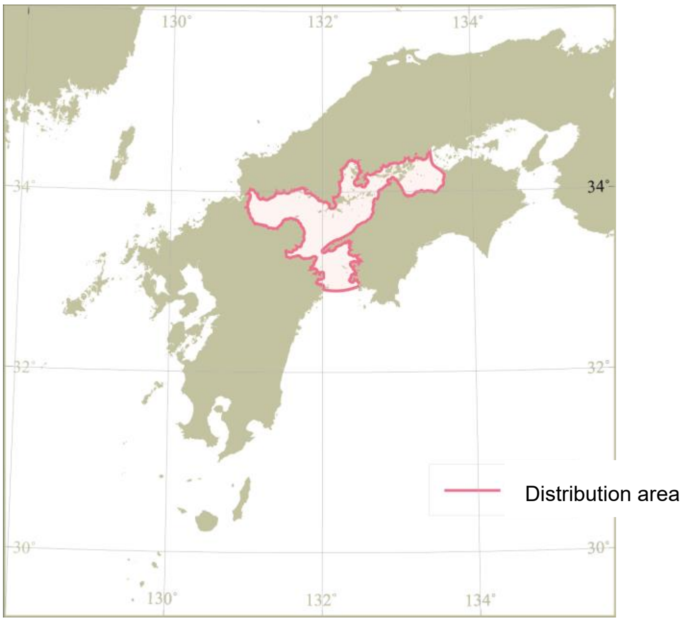


Fig. 2-1. Distribution area of the central and western Seto Inland Sea stocks of Japanese seabream

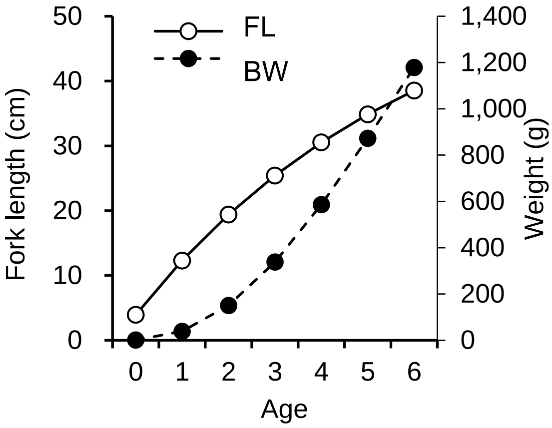


Fig. 2-2. The relationship between age and growth (reference values)

Note) The average weights by age shown in Appendix 2 were used for biomass calculations.

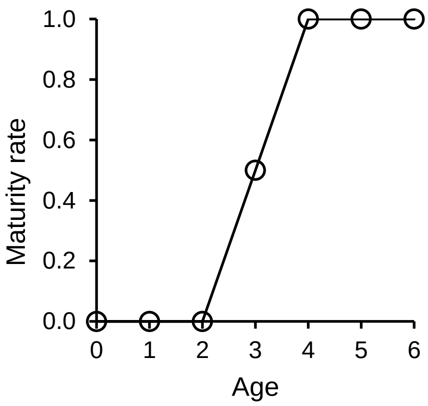


Fig. 2-3. The relationship between age and maturity rate

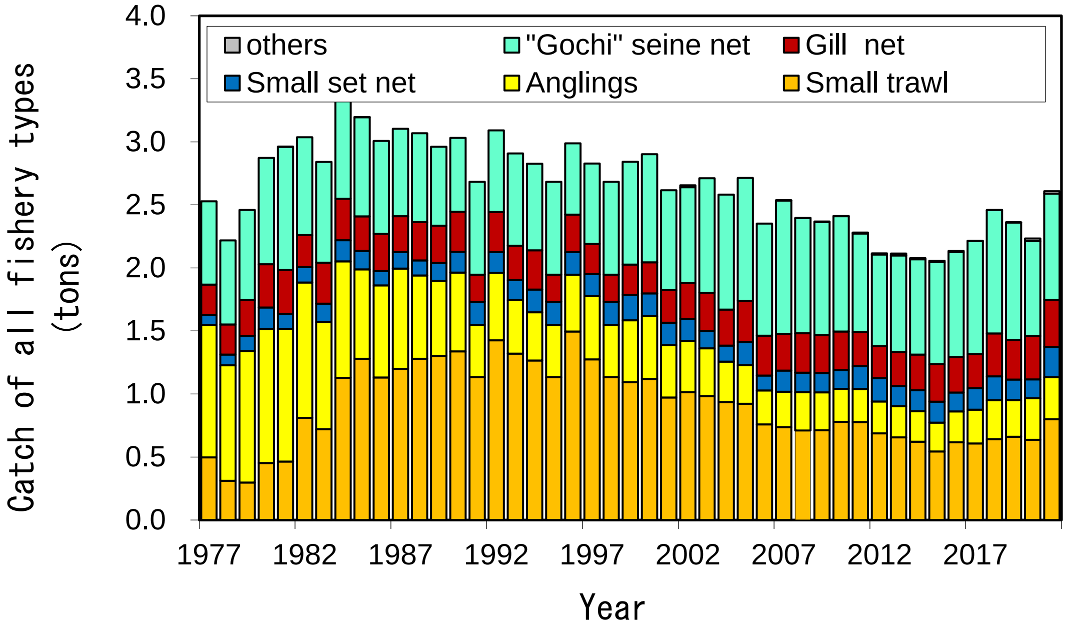


Fig. 3-1. Trends in catch of the central and western Seto Inland Sea stocks of Japanese seabream

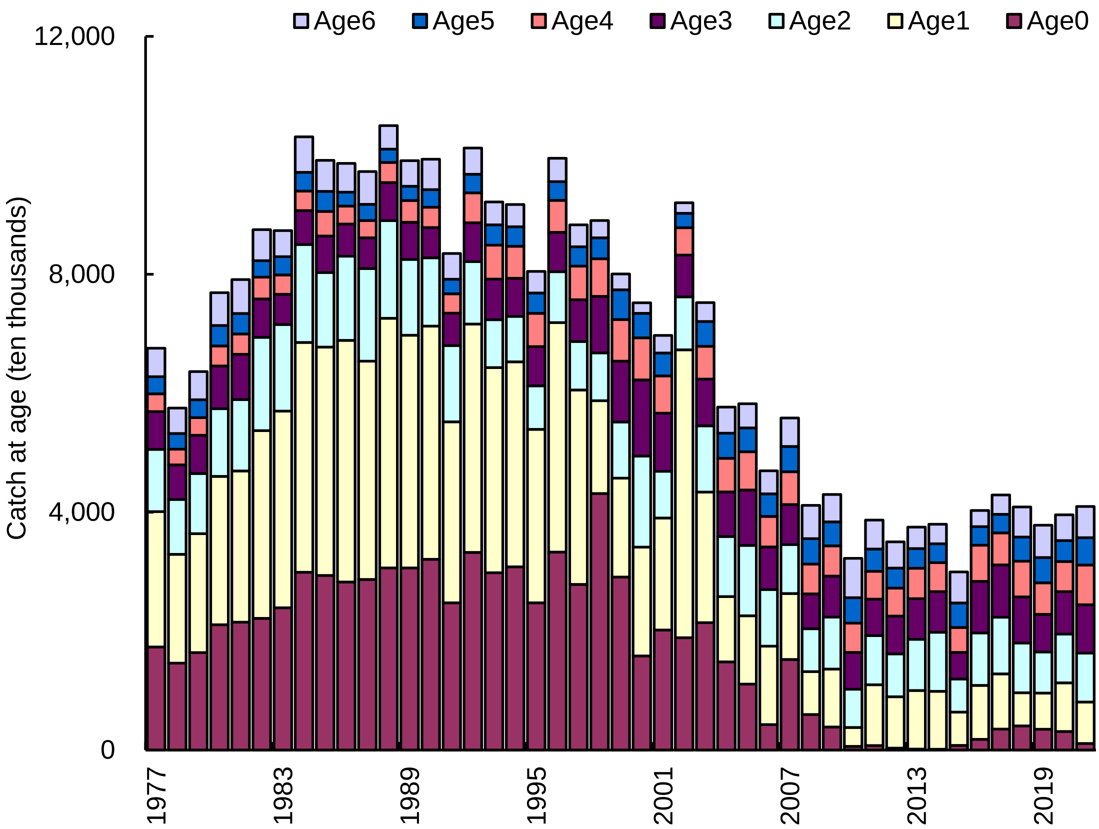


Fig. 3-2. Changes in catch in number at age over time

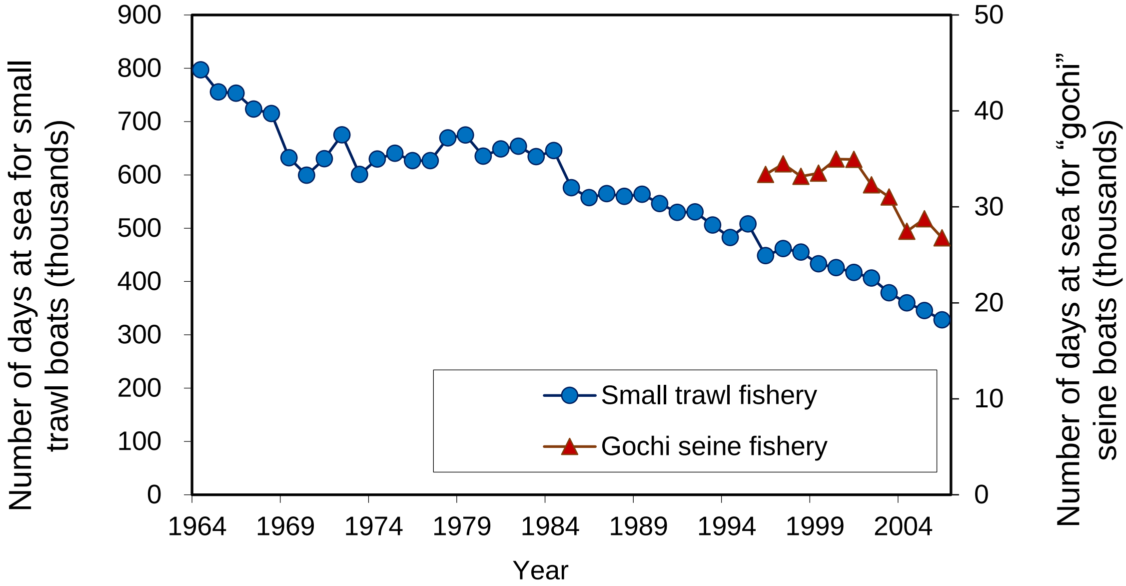


Fig. 3-3. The total number of vessel days at sea for small bottom trawlers and "gochi" seine fishery boats (1964 to 2006)

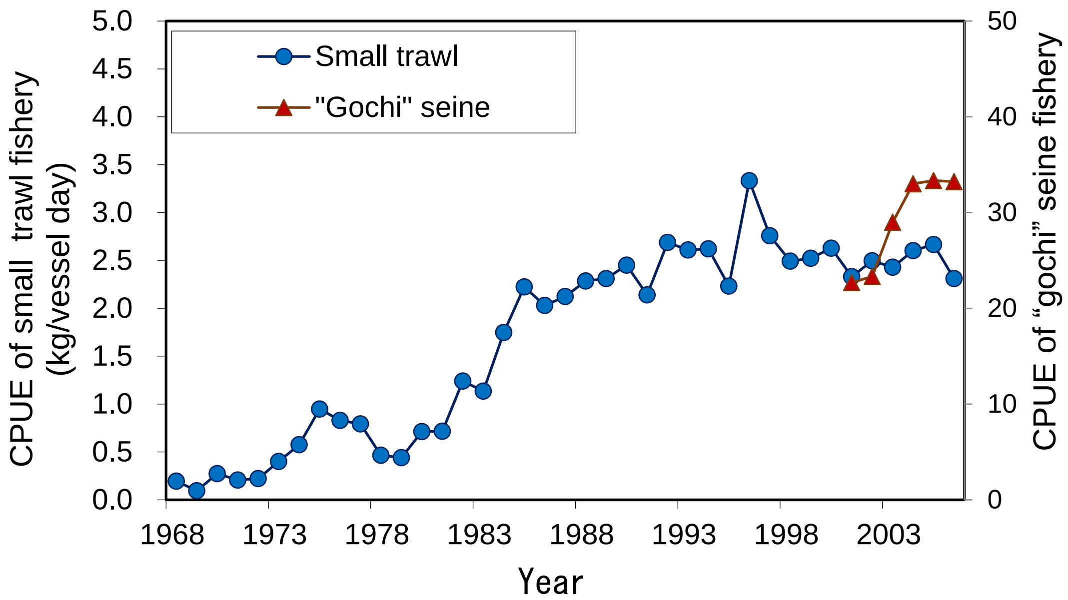


Fig. 4-1. Trends in CPUE of small trawl fishery and "gochi" seine fishery

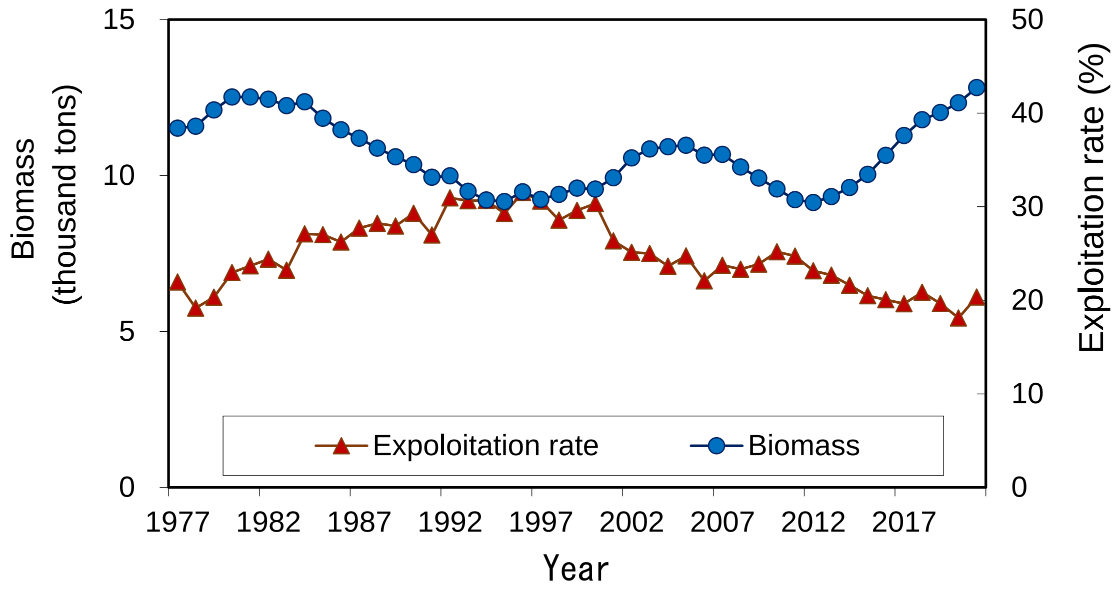


Fig. 4-2. Trends in biomass and exploitation rate

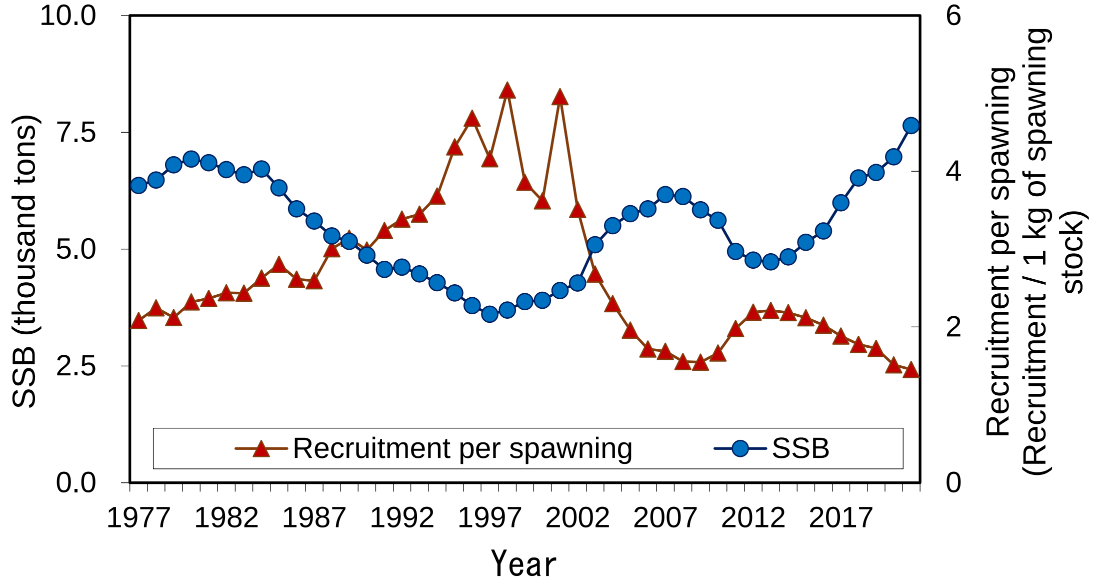


Fig. 4-3. Trends in SSB and recruitment per spawning

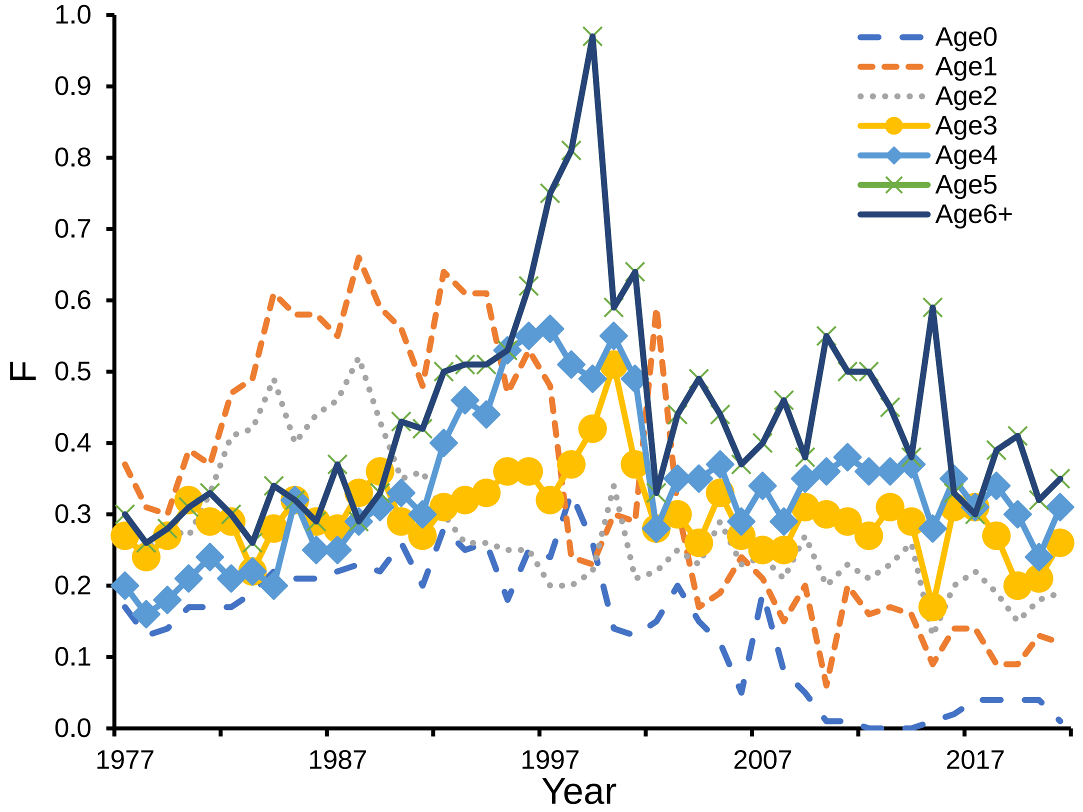


Fig. 4-4. Changes to fishing mortality (F) at age over time

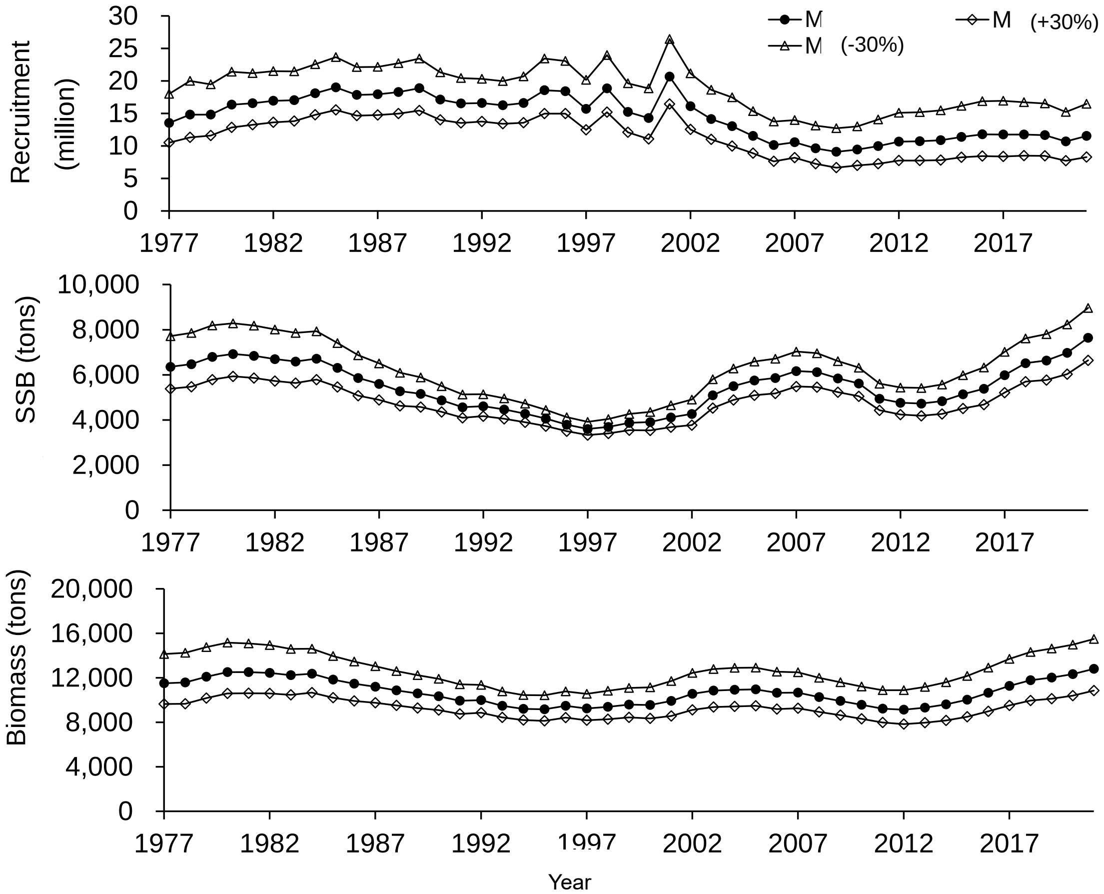


Fig. 4-5. Trends in estimated results based on variation in natural mortality

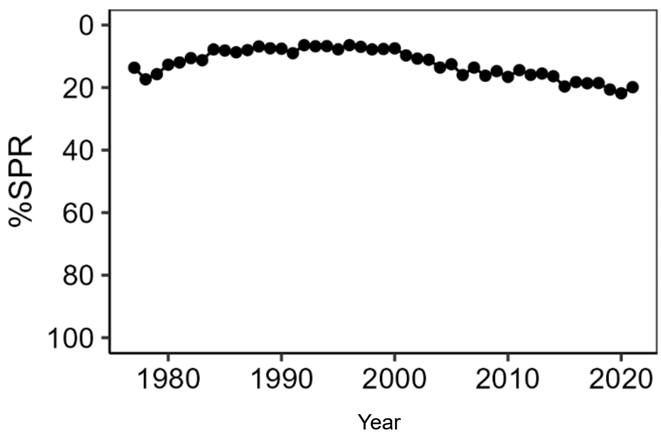


Fig. 4-6. Trends in %SPR

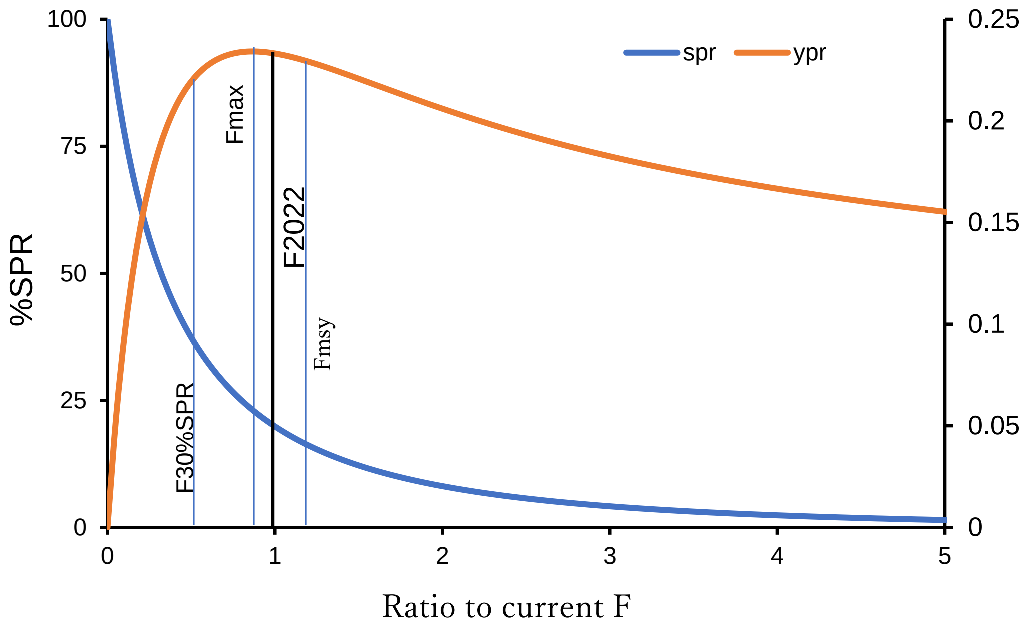


Fig. 4-7. Relationship between current fishing pressure (F2022) and YPR and %SPR

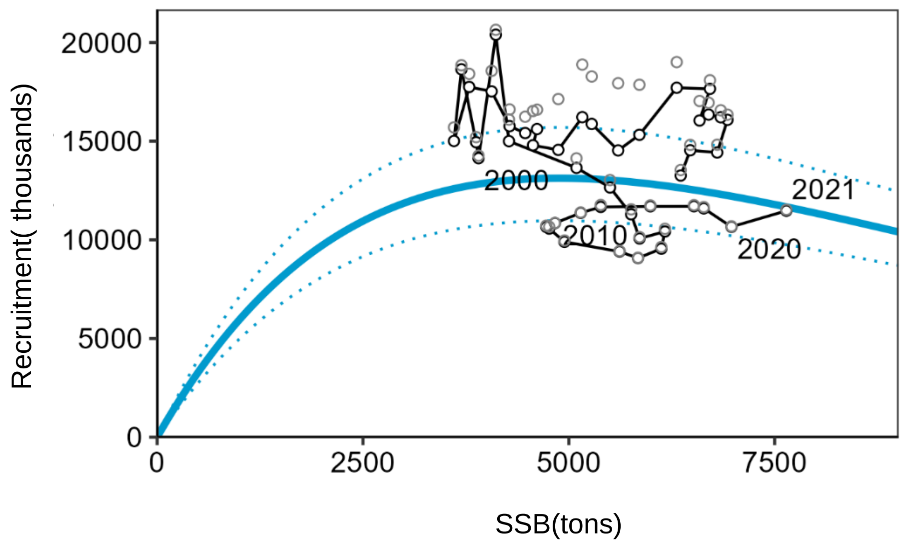


Fig. 4-8. The relationship between SSB and recruitment volume. The thick blue line represents the projected values of a Ricker stock-recruitment model applied to this stock (blue), and the dotted blue lines represent the range estimated to contain 90% of observed data in each assumed stock-recruitment relationship. The parameters for each stock-recruitment relationship model are based on values presented at the Research Institute Meeting held in September 2021 (Yamamoto et al. 2021). The white circles indicate SSB and recruitment (1977 to 2021) in the 2022 stock assessment, black represents wild only, and gray represents the recruitment volume

when released stock is taken into account. The numbers in the figure indicate the cohort (birth year) of the recruited stock.

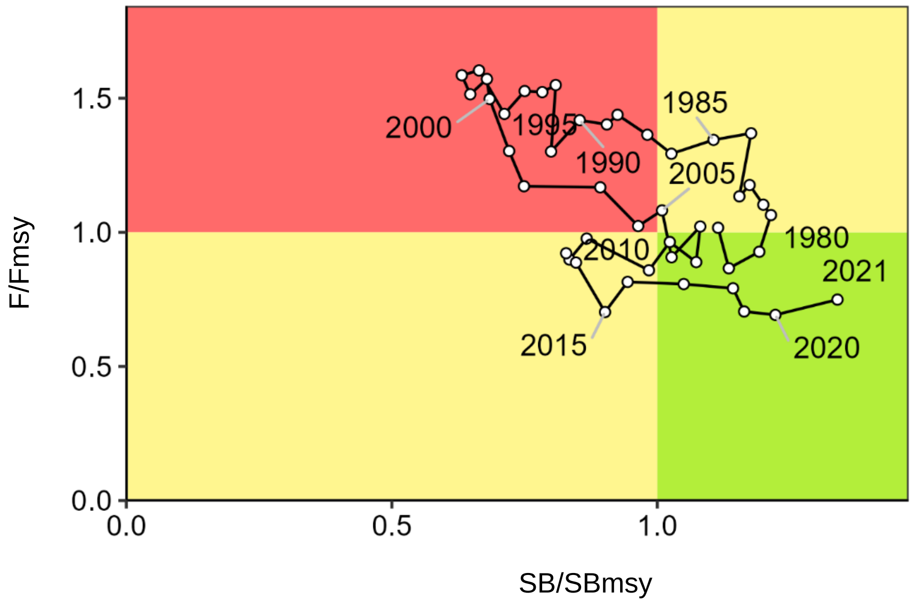


Fig. 4-9. Kobe plot

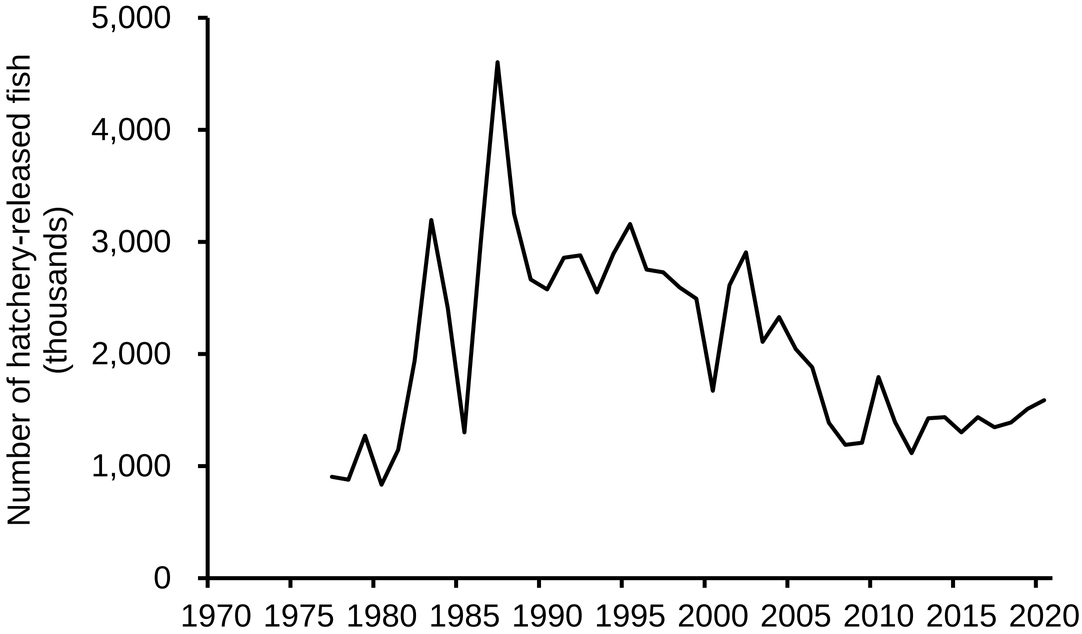


Fig. 6-1. Number of released fish for the central and western Seto Inland Sea stocks of Japanese seabream

Table 3-1. Catch (tons) by fishing method for the central and western Seto Inland Sea stocks of Japanese seabream. The legends are year, “gochi” seine, small bottom trawls, gillnets, anglings, small-scale set nets, and other fishery from left to right, respectively.

Year	″Gochi″ seine fishery	Small trawl fishery	Gill net fishery	Anglings	Set net fishery	others
1977	661	497	243	1,049	79	0
1978	668	311	239	917	84	0
1979	715	297	284	1,043	121	0
1980	844	452	343	1,063	171	0
1981	977	464	349	1,053	118	2
1982	776	811	255	1,073	122	0
1983	799	720	325	851	146	0
1984	802	1,128	329	924	168	0
1985	787	1,280	274	709	146	1
1986	738	1,131	295	731	113	0
1987	694	1,199	284	796	131	0
1988	706	1,279	303	661	120	0
1989	627	1,302	296	595	142	0
1990	586	1,338	318	625	165	0
1991	738	1,134	214	414	184	0
1992	648	1,426	317	536	164	0
1993	732	1,320	272	425	159	0
1994	687	1,265	312	383	180	0
1995	738	1,134	214	414	184	0
1996	565	1,495	297	451	180	0
1997	637	1,274	241	502	174	0
1998	738	1,134	214	414	184	0
1999	815	1,093	240	491	203	0
2000	858	1,119	246	498	181	0
2001	793	972	258	416	177	0
2002	761	1,014	283	408	174	15
2003	909	984	303	378	138	0
2004	913	936	286	321	127	0
2005	975	922	326	307	184	0
2006	889	758	317	270	118	0
2007	1,057	737	292	281	168	2
2008	914	710	312	304	155	1
2009	897	712	300	301	153	5
2010	915	779	305	262	149	1
2011	783	778	269	262	181	8
2012	728	688	253	252	186	8
2013	765	656	270	248	160	16
2014	756	622	284	241	166	9
2015	810	544	297	229	166	11
2016	833	616	281	246	150	9
2017	896	608	271	268	170	2
2018	976	642	340	308	190	1
2019	931	661	315	324	163	1
2020	752	636	344	330	150	22
2021	842	799	374	334	240	20

Table 3-2. Trends in catch and released volume for central and western Seto Inland Sea stocks of Japanese seabream

Year	Catch (tons)	Number of released fish (thousands)	Year	Catch (tons)	Number of released fish (thousands)
1952	2,888	-	1987	3,104	4,604
1953	4,552	-	1988	3,069	3,252
1954	3,825	-	1989	2,962	2,665
1955	3,463	-	1990	3,032	2,577
1956	3,504	-	1991	2,684	2,859
1957	3,359	-	1992	3,091	2,881
1958	2,995	-	1993	2,908	2,549
1959	2,616	-	1994	2,827	2,894
1960	2,547	-	1995	2,684	3,160
1961	2,396	-	1996	2,988	2,754
1962	2,051	-	1997	2,828	2,729
1963	2,141	-	1998	2,684	2,594
1964	2,219	-	1999	2,842	2,494
1965	2,466	-	2000	2,902	1,672
1966	2,198	-	2001	2,616	2,614
1967	2,352	-	2002	2,655	2,907
1968	2,136	-	2003	2,712	2,109
1969	2,107	-	2004	2,583	2,329
1970	1,715	-	2005	2,714	2,044
1971	1,801	-	2006	2,352	1,882
1972	1,737	-	2007	2,537	1,387
1973	1,764	-	2008	2,396	1,189
1974	1,894	-	2009	2,368	1,208
1975	2,440	-	2010	2,411	1,795
1976	2,629	-	2011	2,281	1,391
1977	2,529	904	2012	2,115	1,116
1978	2,219	879	2013	2,115	1,427
1979	2,460	1,271	2014	2,078	1,436
1980	2,873	834	2015	2,057	1,301
1981	2,963	1,145	2016	2,135	1,436
1982	3,037	1,941	2017	2,215	1,346
1983	2,841	3,196	2018	2,460	1,389
1984	3,351	2,409	2019	2,362	1,511
1985	3,197	1,301	2020	2,234	1,587
1986	3,008	3,011	2021	2,609	

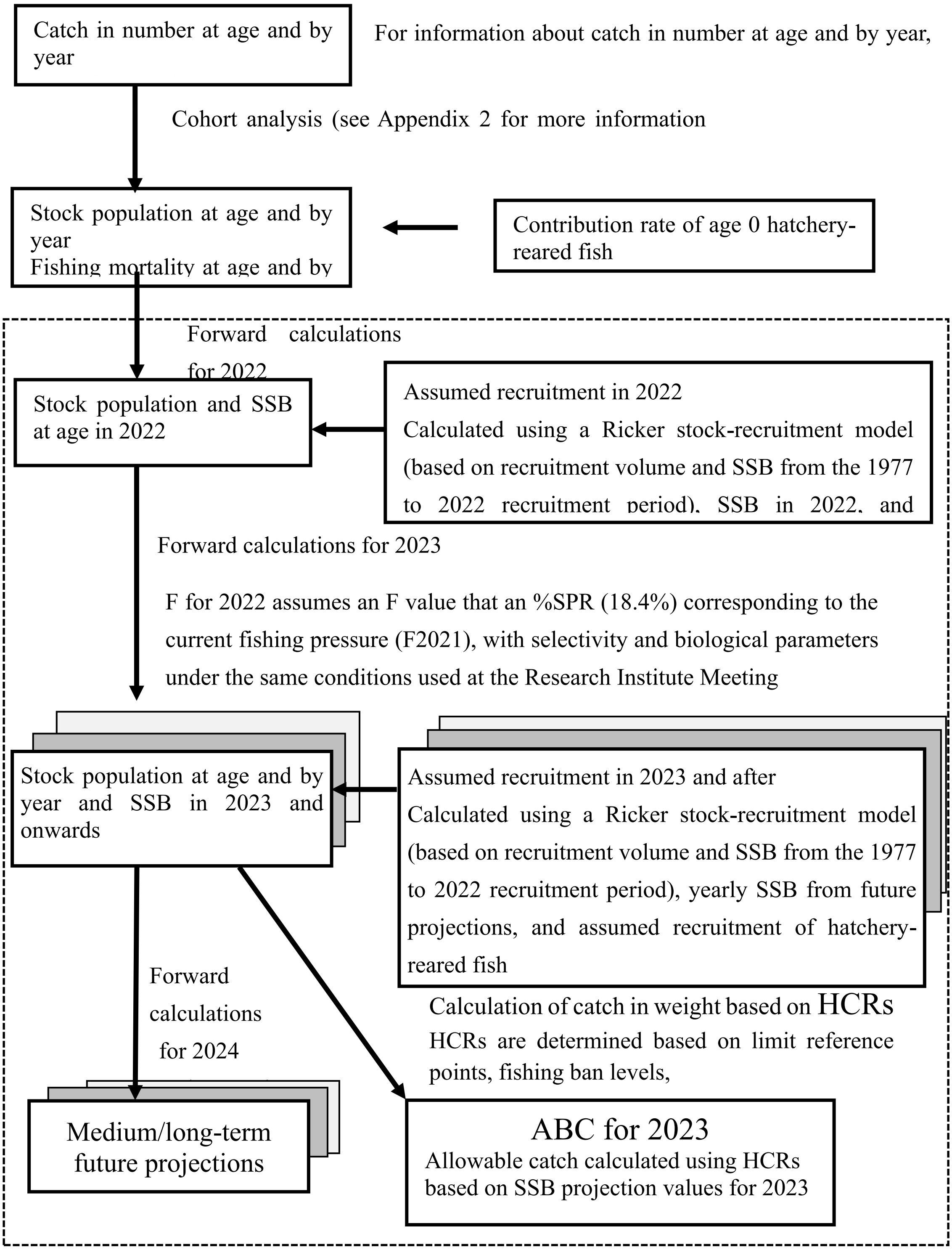
Table 3-3. Trends in total vessel days at sea and CPUE for small bottom trawlers and “gochi” seine fishry boats in the central and western Seto Inland Sea. The legends are year, total vessel days and CPUE of small bottom trawls, and total vessel days and CPUE of “gochi” seine fishery. CPUE is described as kg/vessel days.

Year	Small trawl fishery		"Gochi" seine fishery	
	Total vessel days	CPUE（kg/vessel days）	Total vessel days	CPUE（kg/vessel days）
1964	796,901			
1965	755,659			
1966	753,015			
1967	723,284			
1968	715,095	0.19		
1969	632,084	0.09		
1970	599,295	0.27		
1971	630,356	0.21		
1972	674,944	0.22		
1973	600,716	0.40		
1974	629,814	0.57		
1975	640,510	0.95		
1976	626,597	0.83		
1977	626,727	0.79		
1978	669,456	0.46		
1979	674,799	0.44		
1980	634,928	0.71		
1981	648,573	0.72		
1982	653,764	1.24		
1983	634,269	1.14		
1984	645,659	1.75		
1985	575,857	2.22		
1986	557,396	2.03		
1987	564,863	2.12		
1988	559,620	2.29		
1989	563,501	2.31		
1990	546,127	2.45		
1991	529,766	2.14		
1992	530,601	2.69		
1993	505,924	2.61		
1994	482,581	2.62		
1995	508,114	2.23		
1996	448,545	3.33	33,373	16.9
1997	461,875	2.76	34,483	18.5
1998	454,987	2.49	33,173	22.2
1999	433,293	2.52	33,510	24.3
2000	425,874	2.63	34,977	24.5
2001	417,031	2.33	34,943	22.7
2002	406,323	2.50	32,296	23.3
2003	378,825	2.43	31,020	29.0
2004	359,732	2.60	27,455	33.0
2005	345,488	2.67	28,757	33.3
2006	328,128	2.31	26,764	33.2

Table 4-1. Stock analysis results for the central and western Seto Inland Sea stocks of Japanese seabream. The legends are year, catch (ton), biomass (ton), SSB (ton), exploitation rate (%), recruitment (thousand fish) of both wild and hatchery-reared, and wild, and RPS (fish/kg).

Year	Catch (tons)	Abundance(tons)	SSB（tons)	Exploitation rate （%）	Recruitment （thousands)		%SPR	F/Fmsy	RPS
					Total	Wild			
1977	2,529	11,517	6,362	22.0	13,539	13,258	14	1.02	2.08
1978	2,219	11,580	6,477	19.2	14,811	14,539	17	0.87	2.24
1979	2,460	12,100	6,803	20.3	14,820	14,426	16	0.93	2.12
1980	2,873	12,516	6,929	23.0	16,342	16,083	13	1.06	2.32
1981	2,963	12,516	6,848	23.7	16,568	16,213	12	1.10	2.37
1982	3,037	12,447	6,702	24.4	16,949	16,347	11	1.18	2.44
1983	2,841	12,239	6,590	23.2	17,038	16,047	11	1.13	2.44
1984	3,351	12,363	6,716	27.1	18,088	17,653	8	1.37	2.63
1985	3,197	11,836	6,312	27.0	19,009	17,708	8	1.34	2.81
1986	3,008	11,468	5,861	26.2	17,860	15,324	9	1.29	2.61
1987	3,104	11,197	5,602	27.7	17,938	14,530	8	1.36	2.59
1988	3,069	10,876	5,281	28.2	18,280	15,872	7	1.44	3.01
1989	2,962	10,600	5,165	27.9	18,883	16,218	7	1.40	3.14
1990	3,032	10,350	4,872	29.3	17,135	14,558	8	1.42	2.99
1991	2,684	9,946	4,566	27.0	16,528	14,792	9	1.30	3.24
1992	3,091	9,990	4,614	30.9	16,595	15,616	6	1.55	3.38
1993	2,908	9,492	4,469	30.6	16,240	15,411	7	1.52	3.45
1994	2,827	9,216	4,283	30.7	16,608	15,761	7	1.53	3.68
1995	2,684	9,166	4,063	29.3	18,564	17,524	8	1.44	4.31
1996	2,988	9,478	3,792	31.5	18,413	17,750	6	1.60	4.68
1997	2,828	9,239	3,607	30.6	15,699	15,008	7	1.59	4.16
1998	2,684	9,395	3,696	28.6	18,850	18,642	8	1.51	5.04
1999	2,842	9,597	3,875	29.6	15,207	14,948	8	1.57	3.86
2000	2,902	9,563	3,906	30.3	14,267	14,139	7	1.50	3.62
2001	2,616	9,928	4,113	26.3	20,645	20,397	10	1.30	4.96
2002	2,655	10,563	4,274	25.1	16,094	15,000	11	1.17	3.51
2003	2,712	10,852	5,095	25.0	14,131	13,651	11	1.17	2.68
2004	2,583	10,923	5,503	23.6	13,031	12,654	14	1.02	2.30
2005	2,714	10,968	5,758	24.7	11,546	11,292	13	1.08	1.96
2006	2,352	10,654	5,862	22.1	10,139	10,068	16	0.91	1.72
2007	2,537	10,679	6,168	23.8	10,558	10,420	14	1.02	1.69
2008	2,396	10,271	6,126	23.3	9,637	9,551	16	0.89	1.56
2009	2,368	9,921	5,841	23.9	9,093	9,075	15	0.96	1.55
2010	2,411	9,572	5,618	25.2	9,434	9,405	17	0.86	1.67
2011	2,281	9,227	4,948	24.7	9,966	9,896	14	0.98	1.98
2012	2,115	9,136	4,763	23.2	10,665	10,569	16	0.90	2.19
2013	2,115	9,325	4,727	22.7	10,721	10,657	16	0.92	2.21
2014	2,078	9,615	4,834	21.6	10,860	10,848	16	0.89	2.18
2015	2,057	10,039	5,146	20.5	11,387	11,364	20	0.70	2.12
2016	2,135	10,647	5,389	20.1	11,768	11,668	18	0.82	2.02
2017	2,215	11,280	5,992	19.6	11,744	11,698	19	0.81	1.88
2018	2,460	11,788	6,522	20.9	11,758	11,701	19	0.79	1.78
2019	2,362	12,018	6,640	19.7	11,660	11,594	21	0.70	1.73
2020	2,234	12,333	6,977	18.1	10,687	10,658	22	0.69	1.51
2021	2,609	12,818	7,644	20.4	11,523	11,473	20	0.75	1.45

Appendix 1 Flow of Stock Assessment



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

Appendix 2 Calculation Methods

(1) Biomass Estimation Methods and Parameters Used for Cohort Analysis

Stock population at age, biomass, and fishing mortality were estimated using cohort analysis based on the catch in number at age and by fishery type for the 45-year period between 1977 and 2021. May 1 was used as the starting date for age.

Natural mortality (Ma) was differentiated by age *a*, at M0 = 0.39, M1 = 0.24, M2+ = 0.17 (Shimamoto 1999). Average body weight by age shown in Supplementary Table 2-1 were used to convert stock population into biomass.

(2) Methods for Calculating Stock Population at Age by Year and Fishing Mortality (F)

Stock population at age by year and fishing mortality (F) were determined using Pope's approximation formula, which is shown below (Hiramatsu 1999).

$$N_{a,y} = N_{a+1,y+1}\exp(M_a) + C_{a,y}\exp\left(\frac{M_a}{2}\right)$$

$$F_{a,y} = -\ln\left(1 - \frac{C_{a,y}\exp\left(\frac{M_a}{2}\right)}{N_{a,y}}\right)$$

In these equations, $N_{a,y}$ is the stock population of fish age *a* in year *y*, and $F_{a,y}$ is the fishing mortality of fish age *a* in year *y*, and $C_{a.y}$ is the catch in number of fish age *a* in year *y.*

Fish age 6 and older were deemed the plus group, the fishing mortality was assumed to be equal for age 5 and age 6 and older, and stock population was obtained using the following equations.

$$N_{5,y} = \left(\frac{C_{5,y}}{(C_{5,y} + C_{6+,y})}\right) N_{6+,y+1}\exp(M_5) + C_{5,y}\exp\left(\frac{M_5}{2}\right)$$

$$N_{6+,y} = \left(\frac{C_{6+,y}}{C_{5,y}}\right) N_{5,y}$$

Stock population for age 1 to 6+ in the most recent year in the cohort analysis was obtained using the following equation.

$$N_{a,y} = \frac{C_{a,y}}{1 - \exp(-F_{a,y})}\exp\left(\frac{M_a}{2}\right)$$

Stock population for age 0 in the most recent year is highly uncertain, and similar calculations using the average F value for age 1 and older using the average F value in recent years leads to a phenomenon in which estimated stock population (N0) soars to irrationally high levels. To correct this, the average N0 for the most recent 5-year period (excluding the most recent year) was used as the value of N0 in the most recent year for estimating biomass of this stock, and this year's assessment also adopted a method of using the average N0 for the most recent 5-year period (2016 to 2020, excluding the most recent year) as the value of N0 in 2021. Note that this N0 value includes both wild age 0 fish and hatchery-reared age 0 fish.

$$N_{0,y} = \frac{\sum_{b=1}^{5} N_{0,y-b}}{5}$$

For F in the most recent year (excluding age 0), F6+y was obtained in an exploratory manner in Solver for Excel so that F6+,y = F5,y using F6+,y as an unknown parameter, while assuming that F values of F1,y to F5,y were equivalent to the average of the most recent 5-year period (excluding the most recent year).

The age 0 F value in the most recent year (F0,y) was calculated using N0, which has already been obtained as the average value of N0 for the most recent 5-year period excluding the most recent year (2016 to 2020), as well as the age 0 catch in number in the most recent year (C0,y) and the age 0 natural mortality (M0).

$$F_{0,y} = -\ln\left(1 - \frac{C_{0,y}\exp\left(\frac{M_0}{2}\right)}{N_{0,y}}\right)$$

(3) Stratification of Stock Population by Wild Age 0 Fish and Hatchery-Reared Age 0 Fish

The following equation was used to stratify the stock abundance of fish age 0 calculated in the cohort analysis into age 0 wild fish and age 0 hatchery-reared fish.

$$Ra_y = N_{0,y} \times \text{corrected contribution rate}$$

$$\text{survival to recruitment of released fish} = \frac{N_{0,y} \times \text{corrected contribution rate}}{\text{the number of hatchery} - \text{released fish at year } y}$$

$$Rn_y = N_{0,y} - Ra_y$$

Here,

Ray: the stock population of age 0 hatchery-reared fish

Rny: the stock population of age 0 wild fish

N0y: the stock population of age 0 fish in year y estimated using cohort analysis

Values from Yamaguchi prefecture were used for the contribution rate (Supplementary Table 2-2). Survival to recruitment after 2021 was assumed to be 0.04, the average value for the five most recent years excluding the most recent year (2016 to 2020).

(4) SPR and YPR Calculations

SPR and YPR were calculated using the following formulas. The values shown in the table in Appendix 2 were used as various parameters.

$$\mathrm{SPR} = \sum_{a=0}^{\infty}\left[\prod_{k=0}^{a} exp\{-(F_k + M_k)\}\right] \times W_a \times SR_a$$

$$\mathrm{YPR} = \sum_{a=0}^{\infty}\left[\prod_{k=0}^{a} exp\{-(F_k + M_k)\}\right] \times W_a \times \exp\left(-\frac{M_a}{2}\right) \times \{1 - exp(-F_a)\}$$

Detailed analysis results are shown in Supplementary Tables 2-3 and 2-4.

(5) Model Diagnosis Results

The robustness of the statistical validity of the VPA and assumptions used for this stock assessment were diagnosed according to the Stock Assessment Model Diagnostic Procedures and Data Provision Guidelines (FY 2022) (FRA-SA2022-ABCWG02-03).

The results of the retrospective analysis are shown in Supplementary Figures 2-1 to 2-3. A trend toward upward revision in biomass, SSB, and stock population for age 0 fish was observed when data was added or updated.

(6) Additional Comments

VPA tuning was subject to investigation in the stock assessment for this stock. Data such as small bottom trawler CPUE were considered as candidates for the abundance index; however, no index was found to meet the conditions of a suitable index, such as being representative of major ocean areas or having supplementary data that could be used to standardize CPUE. For this reason, attempts at tuning have been discontinued at this point in time.

References

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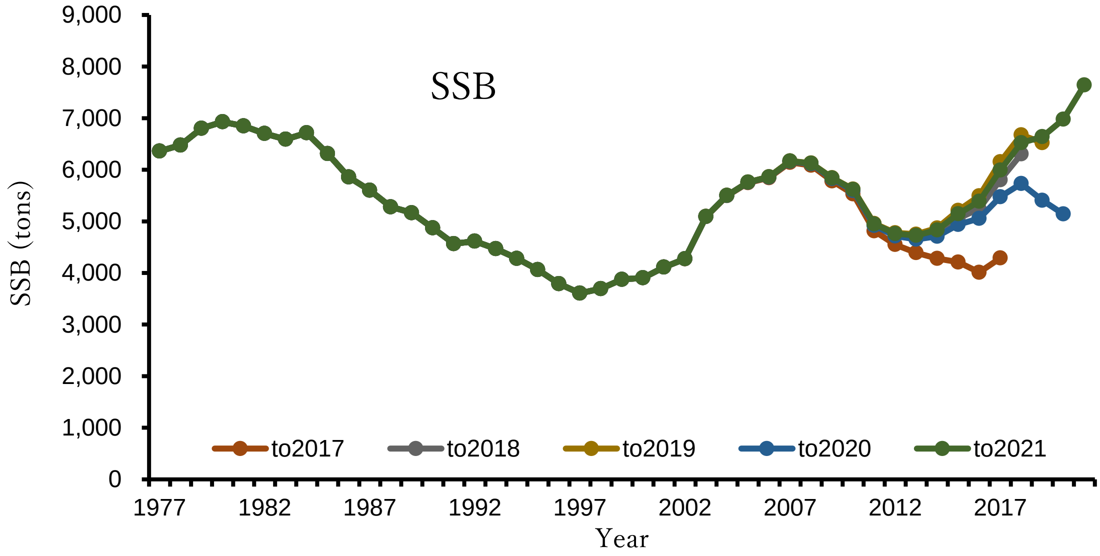
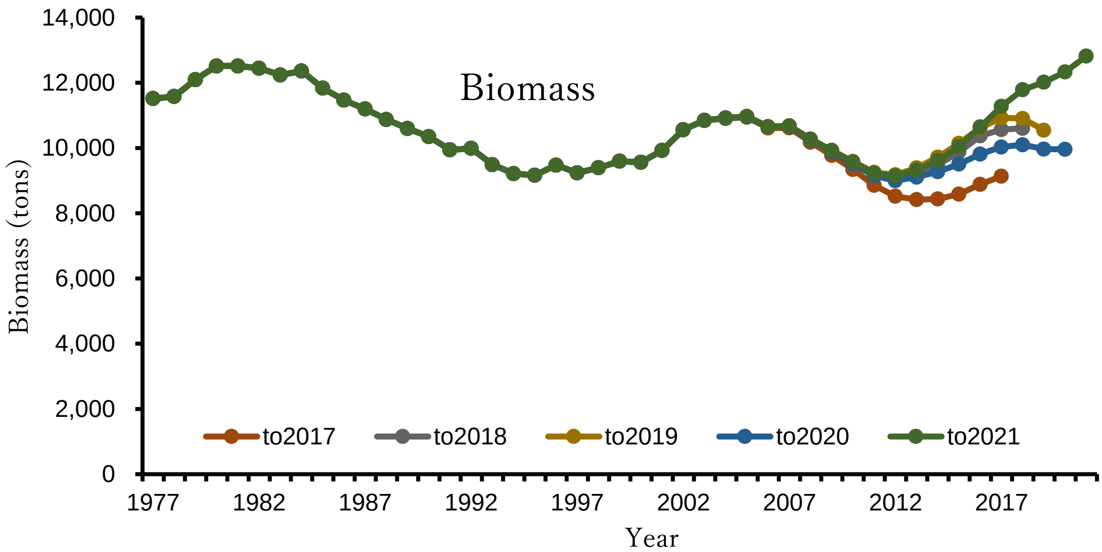
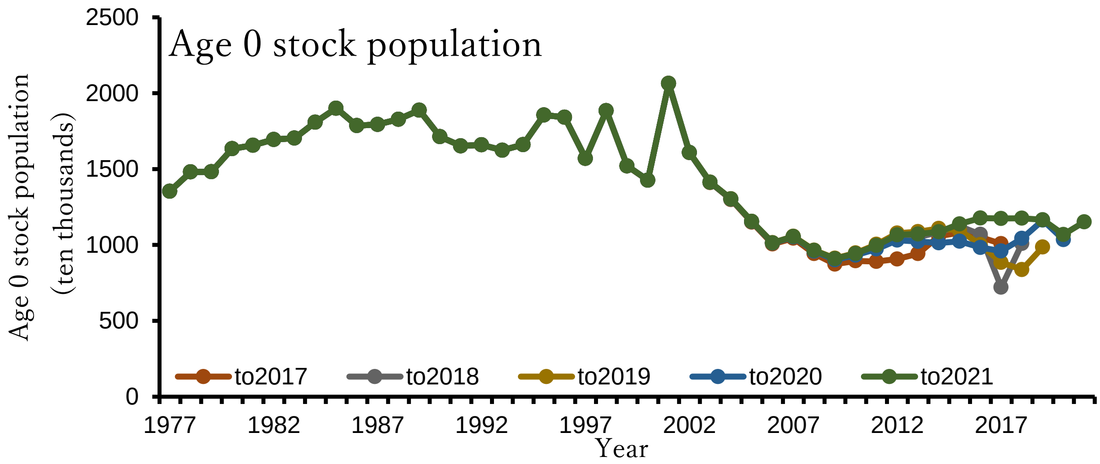
Shimamoto, N. (1999) Study on Population Dynamics and Stock Enhancement of Red Sea Bream, Pagrus major, in Eastern Waters of the Inland Sea of Japan. Bull. Hyogo Pref. Fish. Exp. Stn., 35, 43-112.



Supplementary Fig. 2-1. Results of retrospective analysis of SSB
The numbers in the legend show the final year of VPA.



Supplementary Fig. 2-2. Results of retrospective analysis of biomass (B)
The numbers in the legend show the final year of VPA.



Supplementary Fig. 2-3. Results of retrospective analysis of age 0 stock population (R)
The numbers in the legend show the final year of VPA.

Supplementary Table 2-1. Parameters used for the cohort analysis

Age	Average weight (g)	Maturity rate	Selectivity	M
0	77	0	0.28	0.39
1	201	0	1.00	0.24
2	353	0	1.39	0.17
3	534	0.5	1.65	0.17
4	734	1	1.88	0.17
5	967	1	2.46	0.17
6+	1,526	1	2.46	0.17

Supplementary Table 2-2. Number of hatchery-released fish, recruitment, survival to recruitment, and contribution rate of central and western Seto Inland Sea stocks of Japanese seabream

Year	Recruitment (thousands)		Hatchery-reared juveniles(thousands)	Survival to recruitment of released fish	Contribution rate(%) without correction
	total	wild			
1977	13,539	13,258	904	0.310	
1978	14,811	14,539	879	0.310	
1979	14,820	14,426	1,271	0.310	
1980	16,342	16,083	834	0.310	
1981	16,568	16,213	1,145	0.310	
1982	16,949	16,347	1,941	0.310	
1983	17,038	16,047	3,196	0.310	6.7
1984	18,088	17,653	2,409	0.180	2.4
1985	19,009	17,708	1,301	1.000	16.8
1986	17,860	15,324	3,011	0.842	14.2
1987	17,938	14,530	4,604	0.740	19.0
1988	18,280	15,872	3,252	0.740	
1989	18,883	16,218	2,665	1.000	31.0
1990	17,135	14,558	2,577	1.000	28.6
1991	16,528	14,792	2,859	0.607	10.5
1992	16,595	15,616	2,881	0.340	5.9
1993	16,240	15,411	2,549	0.325	5.1
1994	16,608	15,761	2,894	0.293	5.1
1995	18,564	17,524	3,160	0.329	5.6
1996	18,413	17,750	2,754	0.241	3.6
1997	15,699	15,008	2,729	0.253	4.4
1998	18,850	18,642	2,594	0.080	1.1
1999	15,207	14,948	2,494	0.104	1.7
2000	14,267	14,139	1,672	0.077	0.9
2001	20,645	20,397	2,614	0.095	1.2
2002	16,094	15,000	2,907	0.376	6.8
2003	14,131	13,651	2,109	0.228	3.4
2004	13,031	12,654	2,329	0.162	2.9
2005	11,546	11,292	2,044	0.124	2.2
2006	10,139	10,068	1,882	0.038	0.7
2007	10,558	10,420	1,387	0.099	1.3
2008	9,637	9,551	1,189	0.073	0.9
2009	9,093	9,075	1,208	0.015	0.2
2010	9,434	9,405	1,795	0.016	0.3
2011	9,966	9,896	1,391	0.050	0.7
2012	10,665	10,569	1,116	0.086	0.9
2013	10,721	10,657	1,427	0.045	0.6
2014	10,860	10,848	1,436	0.008	0.1
2015	11,387	11,364	1,301	0.018	0.2
2016	11,768	11,668	1,436	0.070	0.9
2017	11,744	11,698	1,346	0.034	0.4
2018	11,758	11,701	1,389	0.041	0.5
2019	11,660	11,594	1,511	0.044	0.6
2020	10,687	10,658	1,587	0.018	0.3
2021	11,523	11,473			0.4

*1 Survival to recruitment (the rate at which released fish survive long enough to be caught)
Before 1983: Assumed to be 0.310.
1985, 1989-1990: The value was set to 1.000 because a value exceeding 1 was calculated.
1988: Since no data exist, 0.740, the same value as the previous year (1987), was used.
Note that the accuracy of the contribution rate data used here is not necessarily believed to be high due to the fact that there is no data collection system established and data collection methods are inconsistent. However, since the figures themselves are extremely low, their impact on ABC calculations is also thought to be extremely low.
*2 Contribution rate
1994: Since no data exist, a value of 5.1, the same value as the previous year (1993), was used.
2013: Since the result was 0.0%, the average for the five most recent years (2008 to 2012), 0.6%, was used.
*3 Recruitment of wild age 0 fish, number of hatchery-released fish, survival to recruitment, and contribution rate in 2021
The projected values are based on the following assumptions:
Number of released fish: the average number of released fish over the most recent 5-year period (2016 to 2020)
Survival to recruitment: the average of survival to recruitment over the five most recent years (2016 to 2020)
Recruitment of wild age 0 fish: age 0 recruitment (wild + hatchery-released) - number of released fish × survival to recruitment
Contribution rate: number of released fish × survival to recruitment / age 0 recruitment (wild + hatchery-released)

Supplementary Table 2-3 (1). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

～1981	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.28	0.00	0.38	0.06	0.35
Age2	0.08	0.28	0.00	0.02	0.32	0.37
Age3	0.02	0.17	0.12	0.01	0.25	0.08
Age4	0.02	0.08	0.20	0.00	0.09	0.05
Age5	0.01	0.08	0.37	0.00	0.09	0.01
Age6＋	0.04	0.10	0.32	0.00	0.19	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1982	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.29	0.00	0.38	0.11	0.35
Age2	0.08	0.40	0.00	0.02	0.27	0.37
Age3	0.02	0.15	0.12	0.01	0.17	0.08
Age4	0.02	0.07	0.20	0.00	0.10	0.05
Age5	0.01	0.04	0.37	0.00	0.10	0.01
Age6＋	0.04	0.04	0.32	0.00	0.25	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1983	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.39	0.00	0.38	0.05	0.35
Age2	0.08	0.46	0.00	0.02	0.10	0.37
Age3	0.02	0.09	0.12	0.01	0.22	0.08
Age4	0.02	0.03	0.20	0.00	0.19	0.05
Age5	0.01	0.02	0.37	0.00	0.20	0.01
Age6＋	0.04	0.02	0.32	0.00	0.26	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1984	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.01	0.00	0.58	0.00	0.13
Age1	0.49	0.30	0.00	0.38	0.04	0.35
Age2	0.08	0.43	0.00	0.02	0.29	0.37
Age3	0.02	0.14	0.12	0.01	0.13	0.08
Age4	0.02	0.05	0.20	0.00	0.10	0.05
Age5	0.01	0.03	0.37	0.00	0.15	0.01
Age6＋	0.04	0.04	0.32	0.00	0.29	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1985	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.31	0.00	0.38	0.05	0.35
Age2	0.08	0.37	0.00	0.02	0.21	0.37
Age3	0.02	0.15	0.12	0.01	0.23	0.08
Age4	0.02	0.07	0.20	0.00	0.17	0.05
Age5	0.01	0.05	0.37	0.00	0.15	0.01
Age6＋	0.04	0.05	0.32	0.00	0.19	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (2). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

1986	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.34	0.00	0.38	0.31	0.35
Age2	0.08	0.36	0.00	0.02	0.29	0.37
Age3	0.02	0.14	0.12	0.01	0.13	0.08
Age4	0.02	0.07	0.20	0.00	0.05	0.05
Age5	0.01	0.04	0.37	0.00	0.06	0.01
Age6＋	0.04	0.04	0.32	0.00	0.15	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1987	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.23	0.00	0.38	0.13	0.35
Age2	0.08	0.43	0.00	0.02	0.41	0.37
Age3	0.02	0.13	0.12	0.01	0.16	0.08
Age4	0.02	0.05	0.20	0.00	0.08	0.05
Age5	0.01	0.05	0.37	0.00	0.09	0.01
Age6＋	0.04	0.11	0.32	0.00	0.13	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1988	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.25	0.00	0.38	0.29	0.35
Age2	0.08	0.32	0.00	0.02	0.45	0.37
Age3	0.02	0.19	0.12	0.01	0.15	0.08
Age4	0.02	0.10	0.20	0.00	0.05	0.05
Age5	0.01	0.06	0.37	0.00	0.03	0.01
Age6＋	0.04	0.08	0.32	0.00	0.03	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1989	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.09	0.00	0.38	0.32	0.35
Age2	0.08	0.38	0.00	0.02	0.32	0.37
Age3	0.02	0.25	0.12	0.01	0.17	0.08
Age4	0.02	0.15	0.20	0.00	0.06	0.05
Age5	0.01	0.07	0.37	0.00	0.05	0.01
Age6＋	0.04	0.07	0.32	0.00	0.08	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1990	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.18	0.00	0.38	0.20	0.35
Age2	0.08	0.44	0.00	0.02	0.14	0.37
Age3	0.02	0.19	0.12	0.01	0.15	0.08
Age4	0.02	0.08	0.20	0.00	0.13	0.05
Age5	0.01	0.06	0.37	0.00	0.14	0.01
Age6＋	0.04	0.05	0.32	0.00	0.24	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (3). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

1991	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.17	0.00	0.38	0.04	0.35
Age2	0.08	0.50	0.00	0.02	0.38	0.37
Age3	0.02	0.19	0.12	0.01	0.22	0.08
Age4	0.02	0.07	0.20	0.00	0.12	0.05
Age5	0.01	0.04	0.37	0.00	0.09	0.01
Age6＋	0.04	0.03	0.32	0.00	0.15	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1992	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.03	0.00	0.38	0.11	0.35
Age2	0.08	0.33	0.00	0.02	0.25	0.37
Age3	0.02	0.33	0.12	0.01	0.20	0.08
Age4	0.02	0.19	0.20	0.00	0.19	0.05
Age5	0.01	0.08	0.37	0.00	0.13	0.01
Age6＋	0.04	0.04	0.32	0.00	0.13	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1993	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.05	0.00	0.38	0.04	0.35
Age2	0.08	0.30	0.00	0.02	0.11	0.37
Age3	0.02	0.38	0.12	0.01	0.25	0.08
Age4	0.02	0.21	0.20	0.00	0.28	0.05
Age5	0.01	0.06	0.37	0.00	0.19	0.01
Age6＋	0.04	0.01	0.32	0.00	0.12	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1994	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.05	0.00	0.38	0.04	0.35
Age2	0.08	0.30	0.00	0.02	0.11	0.37
Age3	0.02	0.38	0.12	0.01	0.25	0.08
Age4	0.02	0.21	0.20	0.00	0.28	0.05
Age5	0.01	0.06	0.37	0.00	0.19	0.01
Age6＋	0.04	0.01	0.32	0.00	0.12	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1995	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.05	0.00	0.38	0.04	0.35
Age2	0.08	0.30	0.00	0.02	0.11	0.37
Age3	0.02	0.38	0.12	0.01	0.25	0.08
Age4	0.02	0.21	0.20	0.00	0.28	0.05
Age5	0.01	0.06	0.37	0.00	0.19	0.01
Age6＋	0.04	0.01	0.32	0.00	0.12	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (4). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

1996	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.05	0.00	0.38	0.04	0.35
Age2	0.08	0.30	0.00	0.02	0.11	0.37
Age3	0.02	0.38	0.12	0.01	0.25	0.08
Age4	0.02	0.21	0.20	0.00	0.28	0.05
Age5	0.01	0.06	0.37	0.00	0.19	0.01
Age6＋	0.04	0.01	0.32	0.00	0.12	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1997	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.34	0.00	0.00	0.58	0.00	0.13
Age1	0.49	0.05	0.00	0.38	0.04	0.35
Age2	0.08	0.30	0.00	0.02	0.11	0.37
Age3	0.02	0.38	0.12	0.01	0.25	0.08
Age4	0.02	0.21	0.20	0.00	0.28	0.05
Age5	0.01	0.06	0.37	0.00	0.19	0.01
Age6＋	0.04	0.01	0.32	0.00	0.12	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1998	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.62	0.00	0.00	0.58	0.00	0.13
Age1	0.16	0.05	0.00	0.38	0.04	0.35
Age2	0.08	0.30	0.00	0.02	0.11	0.37
Age3	0.07	0.38	0.12	0.01	0.25	0.08
Age4	0.03	0.21	0.20	0.00	0.28	0.05
Age5	0.01	0.06	0.37	0.00	0.19	0.01
Age6＋	0.02	0.01	0.32	0.00	0.12	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

1999	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.47	0.00	0.00	0.58	0.00	0.13
Age1	0.23	0.05	0.00	0.38	0.02	0.35
Age2	0.13	0.30	0.00	0.02	0.11	0.37
Age3	0.08	0.38	0.12	0.01	0.29	0.08
Age4	0.04	0.21	0.20	0.00	0.28	0.05
Age5	0.03	0.06	0.37	0.00	0.23	0.01
Age6＋	0.03	0.01	0.32	0.00	0.07	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2000	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.17	0.00	0.00	0.58	0.02	0.13
Age1	0.29	0.05	0.00	0.38	0.15	0.35
Age2	0.23	0.30	0.00	0.02	0.32	0.37
Age3	0.14	0.38	0.12	0.01	0.28	0.08
Age4	0.07	0.21	0.20	0.00	0.16	0.05
Age5	0.06	0.06	0.37	0.00	0.07	0.01
Age6＋	0.04	0.01	0.32	0.00	0.00	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (5). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

2001	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.33	0.00	0.00	0.58	0.00	0.13
Age1	0.36	0.05	0.00	0.38	0.09	0.35
Age2	0.05	0.30	0.00	0.02	0.27	0.37
Age3	0.06	0.38	0.12	0.01	0.34	0.08
Age4	0.06	0.21	0.20	0.00	0.19	0.05
Age5	0.06	0.06	0.37	0.00	0.08	0.01
Age6＋	0.07	0.01	0.32	0.00	0.03	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2002	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.17	0.00	0.00	0.58	0.00	0.13
Age1	0.68	0.11	0.11	0.38	0.61	0.35
Age2	0.05	0.32	0.23	0.02	0.15	0.37
Age3	0.03	0.32	0.26	0.01	0.11	0.08
Age4	0.02	0.19	0.21	0.00	0.08	0.05
Age5	0.02	0.06	0.11	0.00	0.04	0.01
Age6＋	0.03	0.00	0.08	0.00	0.02	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2003	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.55	0.00	0.00	0.00	0.03	0.13
Age1	0.24	0.27	0.11	0.05	0.44	0.35
Age2	0.05	0.27	0.23	0.23	0.24	0.37
Age3	0.03	0.21	0.26	0.28	0.14	0.08
Age4	0.03	0.16	0.21	0.13	0.09	0.05
Age5	0.04	0.08	0.11	0.20	0.04	0.01
Age6＋	0.05	0.02	0.08	0.11	0.02	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2004	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.32	0.00	0.00	0.66	0.00	0.13
Age1	0.29	0.16	0.11	0.00	0.11	0.35
Age2	0.19	0.29	0.23	0.01	0.19	0.37
Age3	0.09	0.27	0.26	0.06	0.19	0.08
Age4	0.05	0.16	0.21	0.14	0.14	0.05
Age5	0.04	0.06	0.11	0.10	0.14	0.01
Age6＋	0.03	0.05	0.08	0.04	0.23	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2005	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.22	0.00	0.00	0.66	0.02	0.13
Age1	0.28	0.16	0.11	0.00	0.23	0.35
Age2	0.18	0.35	0.23	0.01	0.27	0.37
Age3	0.10	0.30	0.26	0.06	0.21	0.08
Age4	0.06	0.09	0.21	0.14	0.14	0.05
Age5	0.05	0.06	0.11	0.10	0.07	0.01
Age6＋	0.11	0.04	0.08	0.04	0.05	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (6). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

2006	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.20	0.00	0.00	0.05	0.05	0.13
Age1	0.27	0.18	0.11	0.32	0.32	0.35
Age2	0.15	0.27	0.23	0.22	0.22	0.37
Age3	0.10	0.23	0.26	0.16	0.16	0.08
Age4	0.08	0.16	0.21	0.11	0.11	0.05
Age5	0.07	0.11	0.11	0.08	0.08	0.01
Age6＋	0.13	0.05	0.08	0.06	0.06	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2007	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.55	0.00	0.00	0.00	0.07	0.13
Age1	0.21	0.06	0.11	0.17	0.23	0.35
Age2	0.08	0.13	0.23	0.26	0.20	0.37
Age3	0.04	0.22	0.26	0.23	0.16	0.08
Age4	0.03	0.24	0.21	0.17	0.13	0.05
Age5	0.03	0.20	0.11	0.11	0.10	0.01
Age6＋	0.07	0.15	0.08	0.07	0.10	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2008	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.38	0.04	0.00	0.02	0.03	0.13
Age1	0.17	0.24	0.11	0.16	0.17	0.35
Age2	0.10	0.30	0.23	0.22	0.17	0.37
Age3	0.06	0.18	0.26	0.22	0.16	0.08
Age4	0.05	0.12	0.21	0.18	0.16	0.05
Age5	0.06	0.08	0.11	0.13	0.15	0.01
Age6＋	0.19	0.05	0.08	0.07	0.16	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2009	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.18	0.00	0.00	0.02	0.08	0.13
Age1	0.27	0.11	0.11	0.16	0.26	0.35
Age2	0.15	0.27	0.23	0.22	0.21	0.37
Age3	0.08	0.28	0.26	0.22	0.15	0.08
Age4	0.07	0.16	0.21	0.18	0.11	0.05
Age5	0.07	0.12	0.11	0.13	0.09	0.01
Age6＋	0.17	0.05	0.08	0.07	0.09	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2010	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.05	0.00	0.00	0.02	0.00	0.13
Age1	0.17	0.02	0.11	0.16	0.02	0.35
Age2	0.21	0.21	0.23	0.22	0.17	0.37
Age3	0.13	0.26	0.26	0.22	0.20	0.08
Age4	0.08	0.21	0.21	0.18	0.18	0.05
Age5	0.08	0.17	0.11	0.13	0.18	0.01
Age6＋	0.28	0.13	0.08	0.07	0.25	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (7). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

2011	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.03	0.00	0.00	0.02	0.02	0.13
Age1	0.27	0.08	0.11	0.16	0.36	0.35
Age2	0.14	0.29	0.23	0.22	0.23	0.37
Age3	0.09	0.26	0.26	0.22	0.14	0.08
Age4	0.08	0.18	0.21	0.18	0.10	0.05
Age5	0.09	0.13	0.11	0.13	0.08	0.01
Age6＋	0.30	0.06	0.08	0.07	0.06	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2012	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.02	0.00	0.00	0.02	0.00	0.13
Age1	0.38	0.17	0.11	0.16	0.22	0.35
Age2	0.13	0.30	0.23	0.22	0.22	0.37
Age3	0.10	0.26	0.26	0.22	0.19	0.08
Age4	0.08	0.16	0.21	0.18	0.14	0.05
Age5	0.07	0.08	0.11	0.13	0.11	0.01
Age6＋	0.22	0.04	0.08	0.07	0.11	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2013	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.00	0.00	0.00	0.02	0.00	0.13
Age1	0.52	0.02	0.11	0.16	0.16	0.35
Age2	0.15	0.28	0.23	0.22	0.29	0.37
Age3	0.07	0.36	0.26	0.22	0.21	0.08
Age4	0.05	0.21	0.21	0.18	0.17	0.05
Age5	0.05	0.09	0.11	0.13	0.11	0.01
Age6＋	0.16	0.04	0.08	0.07	0.07	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2014	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.00	0.00	0.00	0.02	0.00	0.13
Age1	0.49	0.06	0.11	0.16	0.19	0.35
Age2	0.16	0.43	0.23	0.22	0.30	0.37
Age3	0.09	0.31	0.26	0.22	0.18	0.08
Age4	0.06	0.16	0.21	0.18	0.14	0.05
Age5	0.05	0.03	0.11	0.13	0.11	0.01
Age6＋	0.16	0.01	0.08	0.07	0.06	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2015	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.06	0.00	0.00	0.02	0.00	0.13
Age1	0.37	0.10	0.11	0.16	0.00	0.35
Age2	0.23	0.31	0.23	0.22	0.00	0.37
Age3	0.12	0.26	0.26	0.22	0.04	0.08
Age4	0.07	0.20	0.21	0.18	0.17	0.05
Age5	0.05	0.10	0.11	0.13	0.32	0.01
Age6＋	0.12	0.03	0.08	0.07	0.47	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (8). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

2016	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.14	0.00	0.00	0.02	0.00	0.13
Age1	0.32	0.08	0.11	0.16	0.23	0.35
Age2	0.10	0.33	0.23	0.22	0.27	0.37
Age3	0.12	0.39	0.26	0.22	0.23	0.08
Age4	0.14	0.13	0.21	0.18	0.15	0.05
Age5	0.07	0.02	0.11	0.13	0.08	0.01
Age6＋	0.11	0.05	0.08	0.07	0.04	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2017	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.25	0.00	0.00	0.02	0.01	0.13
Age1	0.28	0.10	0.11	0.16	0.23	0.35
Age2	0.11	0.39	0.23	0.22	0.25	0.37
Age3	0.11	0.35	0.26	0.22	0.22	0.08
Age4	0.07	0.11	0.21	0.18	0.14	0.05
Age5	0.04	0.02	0.11	0.13	0.09	0.01
Age6＋	0.13	0.03	0.08	0.07	0.05	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2018	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.33	0.01	0.00	0.02	0.00	0.13
Age1	0.14	0.14	0.11	0.16	0.13	0.35
Age2	0.12	0.30	0.23	0.22	0.23	0.37
Age3	0.09	0.23	0.26	0.22	0.22	0.08
Age4	0.07	0.13	0.21	0.18	0.19	0.05
Age5	0.07	0.03	0.11	0.13	0.13	0.01
Age6＋	0.19	0.15	0.08	0.07	0.10	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2019	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.27	0.01	0.00	0.02	0.02	0.13
Age1	0.24	0.14	0.11	0.16	0.12	0.35
Age2	0.08	0.30	0.23	0.22	0.22	0.37
Age3	0.07	0.23	0.26	0.22	0.21	0.08
Age4	0.07	0.13	0.21	0.18	0.18	0.05
Age5	0.08	0.03	0.11	0.13	0.14	0.01
Age6＋	0.20	0.15	0.08	0.07	0.12	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

2020	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.24	0.01	0.00	0.02	0.01	0.13
Age1	0.21	0.21	0.11	0.16	0.23	0.35
Age2	0.12	0.25	0.23	0.22	0.24	0.37
Age3	0.10	0.20	0.26	0.22	0.21	0.08
Age4	0.09	0.11	0.21	0.18	0.14	0.05
Age5	0.08	0.05	0.11	0.13	0.09	0.01
Age6＋	0.17	0.16	0.08	0.07	0.07	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-3 (9). The age composition by fishing method for catches of central and western Seto Inland Sea stocks of Japanese seabream

2021	Small trawl fishery	Anglings	Set net fishery	Gill net fishery	"Gochi" seine fishery	others
Age0	0.02	0.01	0.00	0.02	0.04	0.13
Age1	0.13	0.21	0.11	0.16	0.19	0.35
Age2	0.13	0.25	0.23	0.22	0.21	0.37
Age3	0.15	0.20	0.26	0.22	0.21	0.08
Age4	0.16	0.11	0.21	0.18	0.17	0.05
Age5	0.13	0.05	0.11	0.13	0.12	0.01
Age6＋	0.28	0.16	0.08	0.07	0.06	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00

Supplementary Table 2-4 (1). Stock analysis results for the central and western Seto Inland Sea stocks of Japanese seabream (1977 to 1987)

Catch at age in number(thousands)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Age0	1,734	1,463	1,639	2,107	2,150	2,214	2,394	2,991	2,937	2,825	2,870
Age1	2,275	1,829	2,000	2,494	2,543	3,156	3,306	3,862	3,839	4,064	3,668
Age2	1,047	921	1,010	1,138	1,201	1,571	1,455	1,647	1,253	1,416	1,559
Age3	636	582	645	720	760	645	508	570	613	541	516
Age4	297	264	295	336	343	365	326	329	416	300	290
Age5	289	265	302	345	343	277	306	314	335	234	274
Age6+	479	428	473	552	572	522	440	598	524	484	551
Total	6,757	5,751	6,364	7,692	7,911	8,750	8,735	10,311	9,917	9,862	9,729

Catch at age(tons)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Age0	133	112	126	162	165	170	184	230	226	217	221
Age1	458	368	403	502	512	636	666	778	773	819	739
Age2	369	325	356	401	423	554	513	581	442	499	550
Age3	340	311	345	385	406	345	271	305	327	289	276
Age4	218	194	216	247	252	268	240	242	305	220	213
Age5	280	256	292	334	332	268	296	304	324	226	265
Age6+	731	653	722	842	873	797	671	912	799	738	841
Total	2,529	2,219	2,460	2,873	2,963	3,037	2,841	3,351	3,197	3,008	3,104

Fishing mortality at age

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Age0	0.17	0.13	0.14	0.17	0.17	0.17	0.19	0.22	0.21	0.21	0.22
Age1	0.37	0.31	0.30	0.39	0.37	0.47	0.49	0.61	0.58	0.58	0.55
Age2	0.28	0.25	0.28	0.27	0.33	0.41	0.42	0.49	0.40	0.44	0.46
Age3	0.27	0.24	0.27	0.32	0.29	0.29	0.22	0.28	0.32	0.29	0.28
Age4	0.20	0.16	0.18	0.21	0.24	0.21	0.22	0.20	0.32	0.25	0.25
Age5	0.30	0.26	0.28	0.31	0.33	0.30	0.26	0.34	0.32	0.29	0.37
Age6+	0.30	0.26	0.28	0.31	0.33	0.30	0.26	0.34	0.32	0.29	0.37
%SPR	13.6	17.3	15.7	12.7	11.9	10.6	11.2	7.8	8.1	8.7	8.0

Abundance at age(thousands)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Age0	13,539	14,811	14,820	16,342	16,568	16,949	17,038	18,088	19,009	17,860	17,938
Age1	8,377	7,740	8,825	8,685	9,331	9,448	9,653	9,565	9,785	10,453	9,768
Age2	4,659	4,572	4,466	5,168	4,620	5,084	4,633	4,662	4,099	4,293	4,618
Age3	2,938	2,969	3,012	2,840	3,315	2,795	2,847	2,573	2,420	2,308	2,321
Age4	1,805	1,894	1,970	1,948	1,734	2,098	1,765	1,935	1,647	1,479	1,450
Age5	1,217	1,251	1,356	1,392	1,335	1,148	1,435	1,190	1,330	1,008	972
Age6+	2,014	2,020	2,124	2,224	2,226	2,164	2,061	2,265	2,077	2,085	1,950
Total	34,550	35,258	36,572	38,599	39,129	39,688	39,433	40,277	40,367	39,485	39,019

Biomass at age(tons)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Age0	1,041	1,139	1,139	1,256	1,274	1,303	1,310	1,391	1,462	1,373	1,379
Age1	1,687	1,559	1,777	1,749	1,879	1,903	1,944	1,927	1,971	2,105	1,968
Age2	1,643	1,612	1,575	1,822	1,629	1,793	1,634	1,644	1,445	1,514	1,628
Age3	1,569	1,586	1,609	1,517	1,771	1,493	1,520	1,374	1,293	1,233	1,240
Age4	1,325	1,391	1,446	1,430	1,273	1,540	1,296	1,421	1,209	1,086	1,065
Age5	1,177	1,209	1,311	1,346	1,291	1,111	1,388	1,151	1,286	975	940
Age6+	3,075	3,084	3,241	3,394	3,398	3,304	3,146	3,457	3,170	3,183	2,977
Total	11,517	11,580	12,100	12,516	12,516	12,447	12,239	12,363	11,836	11,468	11,197

SSB at age(tons)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Age0	0	0	0	0	0	0	0	0	0	0	0
Age1	0	0	0	0	0	0	0	0	0	0	0
Age2	0	0	0	0	0	0	0	0	0	0	0
Age3	785	793	804	758	885	746	760	687	646	616	620
Age4	1,325	1,391	1,446	1,430	1,273	1,540	1,296	1,421	1,209	1,086	1,065
Age5	1,177	1,209	1,311	1,346	1,291	1,111	1,388	1,151	1,286	975	940
Age6+	3,075	3,084	3,241	3,394	3,398	3,304	3,146	3,457	3,170	3,183	2,977
Total	6,362	6,477	6,804	6,929	6,848	6,701	6,590	6,715	6,312	5,859	5,602

Supplementary Table 2-4 (2). Stock analysis results for the central and western Seto Inland Sea stocks of Japanese seabream (1988 to 1998)

Catch at age in number(thousands)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Age0	3,062	3,063	3,207	2,477	3,323	2,983	3,082	2,477	3,330	2,785	4,314
Age1	4,198	3,913	3,921	3,041	3,839	3,448	3,447	2,916	3,857	3,271	1,560
Age2	1,642	1,275	1,150	1,281	1,050	805	764	731	855	814	804
Age3	640	624	509	548	654	683	640	661	664	701	952
Age4	339	366	341	324	503	572	538	559	538	565	632
Age5	222	240	296	247	313	340	329	342	315	328	351
Age6+	396	429	512	432	440	385	374	363	393	368	290
Total	10,498	9,909	9,936	8,350	10,122	9,215	9,174	8,050	9,951	8,832	8,903

Catch at age(tons)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Age0	235	235	247	190	255	229	237	190	256	214	332
Age1	845	788	790	613	773	695	694	587	777	659	314
Age2	579	449	406	452	370	284	269	258	301	287	283
Age3	342	334	272	293	349	365	342	353	355	374	509
Age4	249	269	250	238	369	420	395	411	395	415	464
Age5	214	232	286	239	302	329	318	330	305	317	339
Age6+	604	655	782	660	671	587	571	554	600	562	443
Total	3,069	2,962	3,032	2,684	3,091	2,908	2,827	2,684	2,988	2,828	2,684

Fishing mortality at age

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Age0	0.23	0.22	0.26	0.20	0.28	0.25	0.26	0.18	0.25	0.24	0.33
Age1	0.66	0.59	0.56	0.48	0.64	0.61	0.61	0.47	0.53	0.48	0.24
Age2	0.52	0.43	0.35	0.36	0.30	0.26	0.26	0.25	0.25	0.20	0.20
Age3	0.33	0.36	0.29	0.27	0.31	0.32	0.33	0.36	0.36	0.32	0.37
Age4	0.29	0.31	0.33	0.30	0.40	0.46	0.44	0.53	0.55	0.56	0.51
Age5	0.29	0.33	0.43	0.42	0.50	0.51	0.51	0.53	0.62	0.75	0.81
Age6+	0.29	0.33	0.43	0.42	0.50	0.51	0.51	0.53	0.62	0.75	0.81
%SPR	6.8	7.4	7.6	9.0	6.4	6.8	6.7	7.8	6.4	7.0	7.8

Abundance at age(thousands)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Age0	18,280	18,883	17,135	16,528	16,595	16,240	16,608	18,564	18,413	15,699	18,850
Age1	9,784	9,857	10,265	8,963	9,152	8,502	8,541	8,709	10,530	9,726	8,337
Age2	4,430	3,973	4,284	4,597	4,353	3,794	3,629	3,661	4,264	4,863	4,750
Age3	2,464	2,230	2,181	2,557	2,702	2,708	2,461	2,361	2,417	2,812	3,355
Age4	1,484	1,491	1,308	1,373	1,654	1,679	1,657	1,489	1,384	1,429	1,729
Age5	957	940	922	790	861	934	891	904	742	674	687
Age6+	1,708	1,681	1,598	1,383	1,210	1,056	1,013	960	925	756	568
Total	39,107	39,055	37,692	36,191	36,526	34,911	34,801	36,647	38,676	35,960	38,275

Biomass at age(tons)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Age0	1,405	1,452	1,318	1,271	1,276	1,249	1,277	1,427	1,416	1,207	1,449
Age1	1,971	1,985	2,068	1,805	1,843	1,712	1,720	1,754	2,121	1,959	1,679
Age2	1,562	1,401	1,510	1,621	1,535	1,338	1,280	1,291	1,504	1,715	1,675
Age3	1,316	1,191	1,165	1,366	1,443	1,446	1,315	1,261	1,291	1,502	1,792
Age4	1,090	1,094	960	1,008	1,214	1,232	1,217	1,093	1,016	1,049	1,269
Age5	926	909	891	764	832	903	862	874	718	652	664
Age6+	2,607	2,566	2,438	2,111	1,846	1,611	1,546	1,465	1,412	1,155	867
Total	10,876	10,600	10,350	9,946	9,990	9,492	9,216	9,166	9,477	9,239	9,395

SSB at age(tons)

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Age0	0	0	0	0	0	0	0	0	0	0	0
Age1	0	0	0	0	0	0	0	0	0	0	0
Age2	0	0	0	0	0	0	0	0	0	0	0
Age3	658	596	583	683	722	723	657	630	645	751	896
Age4	1,090	1,094	960	1,008	1,214	1,232	1,217	1,093	1,016	1,049	1,269
Age5	926	909	891	764	832	903	862	874	718	652	664
Age6+	2,607	2,566	2,438	2,111	1,846	1,611	1,546	1,465	1,412	1,155	867
Total	5,280	5,166	4,872	4,566	4,614	4,470	4,281	4,063	3,792	3,607	3,696

Supplementary Table 2-4 (3). Stock analysis results for the central and western Seto Inland Sea stocks of Japanese seabream (1999 to 2009)

Catch at age in number(thousands)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Age0	2,909	1,583	2,020	1,890	2,142	1,482	1,109	428	1,523	599	387
Age1	1,664	1,830	1,882	4,839	2,196	1,098	1,150	1,319	1,108	720	976
Age2	944	1,530	787	891	1,114	1,010	1,184	953	825	721	875
Age3	1,023	1,280	976	703	785	752	929	714	672	586	687
Age4	698	709	627	460	552	565	643	514	553	502	509
Age5	500	412	385	241	418	422	401	381	424	426	403
Age6+	267	176	295	180	316	437	408	387	479	561	460
Total	8,005	7,520	6,973	9,203	7,524	5,767	5,826	4,696	5,584	4,115	4,297

Catch at age(tons)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Age0	224	122	155	145	165	114	85	33	117	46	30
Age1	335	369	379	975	442	221	232	266	223	145	196
Age2	333	540	278	314	393	356	418	336	291	254	309
Age3	546	684	521	376	419	402	496	381	359	313	367
Age4	512	520	460	338	405	415	472	378	406	368	374
Age5	484	399	372	233	404	408	388	368	410	412	390
Age6+	408	269	450	275	483	667	623	590	731	857	703
Total	2,842	2,902	2,616	2,655	2,712	2,583	2,714	2,352	2,537	2,396	2,368

Fishing mortality at age

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Age0	0.26	0.14	0.13	0.15	0.20	0.15	0.12	0.05	0.19	0.08	0.05
Age1	0.23	0.30	0.29	0.59	0.31	0.17	0.19	0.24	0.21	0.15	0.20
Age2	0.22	0.34	0.21	0.22	0.25	0.23	0.29	0.23	0.24	0.21	0.27
Age3	0.42	0.51	0.37	0.28	0.30	0.26	0.33	0.27	0.25	0.25	0.31
Age4	0.49	0.55	0.49	0.28	0.35	0.35	0.37	0.29	0.34	0.29	0.35
Age5	0.97	0.59	0.64	0.33	0.44	0.49	0.44	0.37	0.40	0.46	0.38
Age6+	0.97	0.59	0.64	0.33	0.44	0.49	0.44	0.37	0.40	0.46	0.38
%SPR	7.6	7.4	9.7	10.7	11.1	13.6	12.5	16.0	13.6	16.2	14.7

Abundance at age(thousands)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Age0	15,207	14,267	20,645	16,094	14,131	13,031	11,546	10,139	10,558	9,637	9,093
Age1	9,212	7,902	8,358	12,315	9,342	7,805	7,603	6,905	6,512	5,895	6,033
Age2	5,175	5,771	4,593	4,905	5,396	5,400	5,166	4,961	4,261	4,140	3,999
Age3	3,269	3,499	3,463	3,152	3,320	3,529	3,629	3,270	3,310	2,837	2,830
Age4	1,956	1,818	1,776	2,026	2,013	2,080	2,286	2,208	2,104	2,175	1,855
Age5	878	1,009	883	922	1,287	1,191	1,236	1,338	1,390	1,267	1,374
Age6+	470	432	676	690	973	1,232	1,255	1,358	1,570	1,668	1,569
Total	36,166	34,699	40,393	40,104	36,462	34,269	32,721	30,179	29,704	27,620	26,753

Biomass at age(tons)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Age0	1,169	1,097	1,587	1,237	1,087	1,002	888	780	812	741	699
Age1	1,856	1,592	1,683	2,481	1,882	1,572	1,531	1,391	1,312	1,187	1,215
Age2	1,825	2,035	1,620	1,730	1,902	1,904	1,822	1,749	1,503	1,460	1,410
Age3	1,746	1,869	1,850	1,684	1,773	1,885	1,938	1,747	1,768	1,515	1,512
Age4	1,436	1,335	1,304	1,487	1,478	1,527	1,678	1,621	1,544	1,597	1,362
Age5	849	976	853	892	1,244	1,152	1,195	1,294	1,344	1,225	1,329
Age6+	717	660	1,031	1,053	1,486	1,881	1,916	2,073	2,396	2,546	2,394
Total	9,597	9,563	9,928	10,563	10,852	10,923	10,968	10,654	10,679	10,271	9,921

SSB at age(tons)

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Age0	0	0	0	0	0	0	0	0	0	0	0
Age1	0	0	0	0	0	0	0	0	0	0	0
Age2	0	0	0	0	0	0	0	0	0	0	0
Age3	873	935	925	842	887	943	969	874	884	758	756
Age4	1,436	1,335	1,304	1,487	1,478	1,527	1,678	1,621	1,544	1,597	1,362
Age5	849	976	853	892	1,244	1,152	1,195	1,294	1,344	1,225	1,329
Age6+	717	660	1,031	1,053	1,486	1,881	1,916	2,073	2,396	2,546	2,394
Total	3,875	3,906	4,113	4,274	5,095	5,503	5,758	5,862	6,168	6,126	5,841

Supplementary Table 2-4 (4). Stock analysis results for the central and western Seto Inland Sea stocks of Japanese seabream (2010 to 2019)

Catch at age in number(thousands)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Age0	63	76	33	16	13	79	181	353	408	351
Age1	316	1,022	865	987	975	559	907	928	556	608
Age2	645	826	720	861	992	558	881	952	836	691
Age3	617	614	634	683	684	445	867	880	775	633
Age4	493	469	472	510	487	422	609	540	600	530
Age5	429	372	335	332	318	410	311	311	408	424
Age6+	661	489	443	361	328	522	273	326	506	545
Total	3,224	3,868	3,501	3,750	3,797	2,996	4,029	4,290	4,089	3,782

Catch at age(tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Age0	5	6	3	1	1	6	14	27	31	27
Age1	64	206	174	199	196	113	183	187	112	122
Age2	227	291	254	304	350	197	311	336	295	244
Age3	330	328	338	365	365	238	463	470	414	338
Age4	362	345	346	375	357	310	447	397	441	389
Age5	415	360	324	321	307	397	301	300	395	410
Age6+	1,008	746	676	551	501	797	416	498	773	832
Total	2,411	2,281	2,115	2,115	2,078	2,057	2,135	2,215	2,460	2,362

Fishing mortality at age

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Age0	0.01	0.01	0.00	0.00	0.00	0.01	0.02	0.04	0.04	0.04
Age1	0.06	0.20	0.16	0.17	0.16	0.09	0.14	0.14	0.09	0.09
Age2	0.20	0.23	0.21	0.23	0.26	0.13	0.20	0.22	0.19	0.15
Age3	0.30	0.29	0.27	0.31	0.29	0.17	0.31	0.31	0.27	0.20
Age4	0.36	0.38	0.36	0.36	0.37	0.28	0.35	0.31	0.34	0.30
Age5	0.55	0.50	0.50	0.45	0.38	0.59	0.33	0.30	0.39	0.41
Age6+	0.55	0.50	0.50	0.45	0.38	0.59	0.33	0.30	0.39	0.41
%SPR	16.6	14.4	15.9	15.5	16.2	19.6	18.1	18.4	18.2	20.1

Abundance at age(thousands)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Age0	9,434	9,966	10,665	10,721	10,860	11,387	11,768	11,744	11,758	11660
Age1	5,838	6,335	6,684	7,194	7,246	7,342	7,645	7,818	7,661	7625
Age2	3,880	4,312	4,077	4,491	4,783	4,835	5,279	5,209	5,327	5533
Age3	2,570	2,681	2,879	2,779	2,998	3,125	3,566	3,645	3,520	3726
Age4	1,757	1,601	1,698	1,847	1,718	1,901	2,227	2,213	2,266	2259
Age5	1,098	1,029	920	1,000	1,090	1,002	1,216	1,320	1,370	1361
Age6+	1,690	1,351	1,217	1,089	1,125	1,275	1,065	1,387	1,699	1750
Total	26,266	27,276	28,142	29,120	29,820	30,867	32,767	33,336	33,602	33,914

Biomass at age(tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Age0	725	766	820	824	835	876	905	903	904	897
Age1	1,176	1,276	1,346	1,449	1,459	1,479	1,540	1,575	1,543	1,536
Age2	1,368	1,521	1,438	1,583	1,687	1,705	1,862	1,837	1,878	1,951
Age3	1,373	1,432	1,538	1,484	1,601	1,669	1,905	1,947	1,880	1,990
Age4	1,290	1,176	1,247	1,356	1,261	1,395	1,635	1,624	1,664	1,658
Age5	1,062	995	890	967	1,054	969	1,176	1,276	1,325	1,316
Age6+	2,579	2,061	1,857	1,662	1,718	1,947	1,625	2,118	2,593	2,671
Total	9,572	9,227	9,136	9,325	9,615	10,039	10,647	11,280	11,788	12,018

SSB at age(tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Age0	0	0	0	0	0	0	0	0	0	0
Age1	0	0	0	0	0	0	0	0	0	0
Age2	0	0	0	0	0	0	0	0	0	0
Age3	687	716	769	742	801	835	953	974	940	995
Age4	1,290	1,176	1,247	1,356	1,261	1,395	1,635	1,624	1,664	1,658
Age5	1,062	995	890	967	1,054	969	1,176	1,276	1,325	1,316
Age6+	2,579	2,061	1,857	1,662	1,718	1,947	1,625	2,118	2,593	2,671
Total	5,618	4,948	4,763	4,727	4,834	5,146	5,389	5,992	6,522	6,640

Supplementary Table 2-4 (5). Stock analysis results for the central and western Seto Inland Sea stocks of Japanese seabream (2020 to 2021)

Catch at age in number(thousands)

	2020	2021
Age0	313	112
Age1	817	695
Age2	822	824
Age3	712	812
Age4	506	669
Age5	354	459
Age6+	433	524
Total	3,957	4,096

Catch at age(tons)

	2020	2021
Age0	24	9
Age1	165	140
Age2	290	290
Age3	380	434
Age4	372	491
Age5	343	444
Age6+	661	801
Total	2,234	2,609

Fishing mortality at age

	2020	2021
Age0	0.04	0.01
Age1	0.13	0.12
Age2	0.18	0.19
Age3	0.21	0.26
Age4	0.24	0.31
Age5	0.32	0.35
Age6+	0.32	0.35
%SPR	21.5	19.9

Abundance at age(thousands)

	2020	2021
Age0	10,687	11,523
Age1	7,606	6,979
Age2	5,459	5,259
Age3	4,033	3,851
Age4	2,562	2,749
Age5	1,419	1,697
Age6+	1,734	1,937
Total	33,500	33,994

Biomass at age(tons)

	2020	2021
Age0	822	886
Age1	1,532	1,406
Age2	1,925	1,854
Age3	2,154	2,057
Age4	1,881	2,018
Age5	1,372	1,641
Age6+	2,647	2,956
Total	12,333	12,818

SSB at age(tons)

	2020	2021
Age0	0	0
Age1	0	0
Age2	0	0
Age3	1,077	1,029
Age4	1,881	2,018
Age5	1,372	1,641
Age6+	2,647	2,956
Total	6,977	7,644

Appendix 3 Proposed Reference Points and Proposed Fishing Ban Level

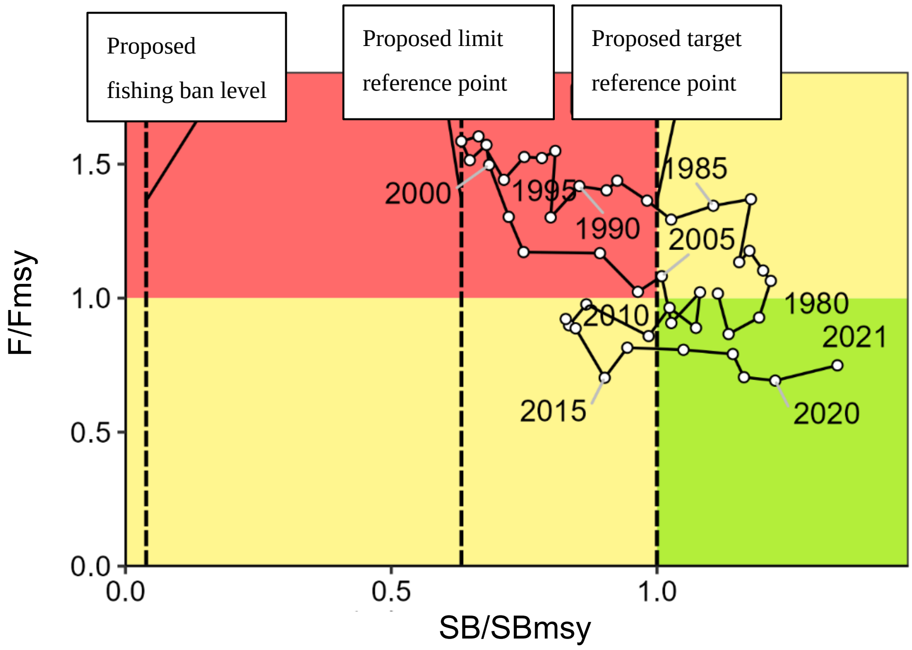
The Research Institute Meeting held in September 2021 proposed adoption of the following: SSB required for MSY (SBmsy: 57,000 tons) as a target reference point (SBtarget), Historic minimum SSB (SBmin: 3,607 tons) as a limit reference point (SBlimit), and SSB required for 10% MSY (SB0.1msy: 200 tons) as a fishing ban level (SBban) (Yamamoto et al. 2021, Supplementary Table 6-2).

The proposed target reference points and fishing pressure (F) required for MSY are shown in the Kobe plot in Supplementary Fig. 3-1. The SSB for 2021 (SB2021: 7,644 tons) obtained from the cohort analysis is above the proposed target reference point. Fishing pressure of this stock since 2005 was judged to be lower than the fishing pressure required for MSY (Supplementary Table 6-3).

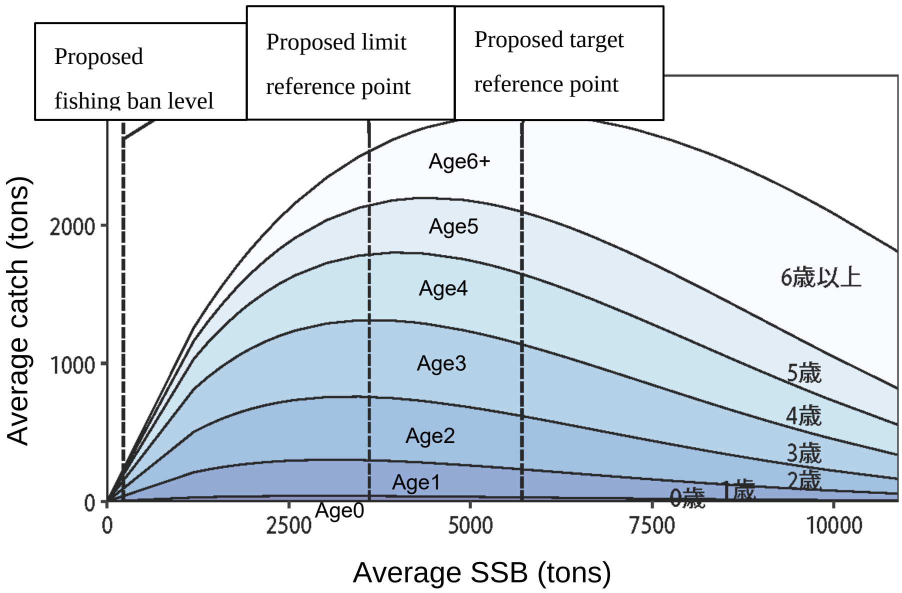
The relationship of average SSB and average catch in weight at age at equilibrium is shown in Supplementary Fig. 3-2. When average SSB is below the limit reference point, catches are dominated by age 1 to age 3 fish. However, the proportion of older fish tends to increase in correlation with increase of SSB.

References

Yamamoto, K., Katamachi, D., Yamashita, Y., and Suzuki, S. (2021) Materials for the Research Institute Meeting on Reference Points of Central and Western Seto Inland Sea Stocks of Japanese Seabream (Fiscal Year 2021). Japan Fisheries Research and Education Agency, 1-50. FRA-SA2021-BRP04-001 http://www.fra.affrc.go.jp/shigen_hyoka/SCmeeting/2019-1/20210928/ doc_madai_setonaikai-mw_RIM.pdf (last accessed 27 July 2022)



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



Supplementary Fig. 3-2. The relationship between the reference point plan, proposed fish ban level, and catch at age curve

The positional relationship between the average values for the catch at age for the average SSB in the future projection simulation and their proposed reference points are shown. The initial SSB (SB0) is 15,526 tons, assuming no fishing occurred.

Appendix 4. Future Projections Based on Proposed HCRs

(1) Setting Future Projections

Future projection calculations were performed for the 2022 to 2052 fishing seasons using a progression method for cohort analysis applied to estimates for stock abundance in 2021 (Appendix 5). Recruitment volume in future projections was predicted based on values for SSB in each year using the stock-recruitment relationship model. Calculations were replicated 10,000 times assuming errors which follow log-normal distribution to account for uncertainty in recruitment. Catch in weight in 2022 was assumed based on projected stock abundance and current fishing pressure (F2022). The current fishing pressure is the F value that give the %SPR corresponding to fishing pressure in 2021 in this assessment, under the same selectivity and biological parameters (average body weight, etc.) as the calculations for proposed reference points. Fishing pressure in 2023 and onwards was set as the fishing pressure established in the following proposed HCRs, which are based on SSB projections for each year.

Since this is a target species of stock enhancement, test calculations designed to take the released fish in population into consideration as recruitment of hatchery-reared fish (average stock population of age 0 hatchery-reared fish from 2017 to 2021 was 58,000) were performed in addition to the settings above (Supplementary Fig. 4-4, Supplementary Tables 4-2, 4-4, 4-6, 4-8, 6-5, and 6-7).

(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, which set fishing pressure (F) and other factors that correspond to SSB. The Harvest Control Rules and Basic Guidelines for ABC Calculation describe linear reduction of fishing pressure down to the proposed fishing ban level when SSB falls below the proposed limit reference point, and an upper limit for fishing pressure equal to Fmsy multiplied by adjustment coefficient β when SSB is above the limit reference point. Supplementary Fig. 4-1 and 4-2 show the HCRs from the Research Institute Meeting for this stock. This figure includes an example showing when the adjustment coefficient β is set to 0.8. The Research Institute Meeting proposals state that “when β is lower than 0.8, then there is a 50% or higher probability that values will exceed proposed target reference points in 10 years.”

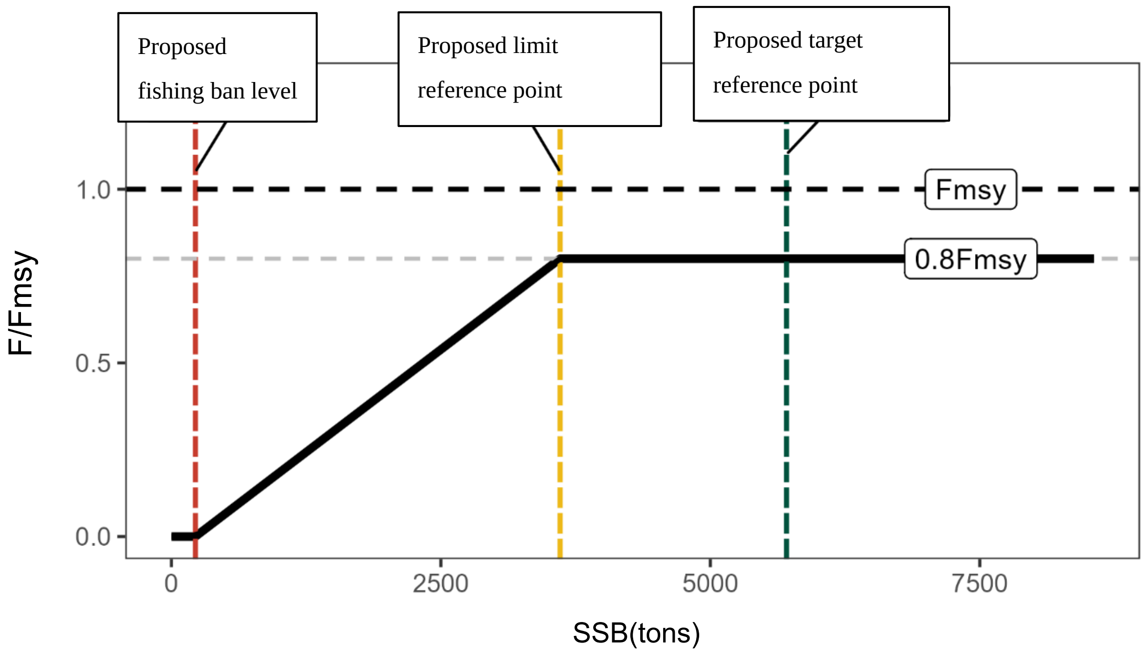
(3) Projected Values for 2023

The average catch in weight in 2023 calculated based on proposed HCRs was, when released stock was not assumed, 2,900 tons when β is 0.8, and 3,500 tons when β is 1.0 (Supplementary Table 6-4). When the current released stock was assumed, the average catch was 2,900 tons when β is 0.8 and 3,500 tons when β is 1.0 (Supplementary Table 6-5). Projected SSB in 2023 is projected to be an average of 7,600 tons, which exceeds limit reference points in replicated calculations using both values.

(4) Projections for 2024 and Onwards

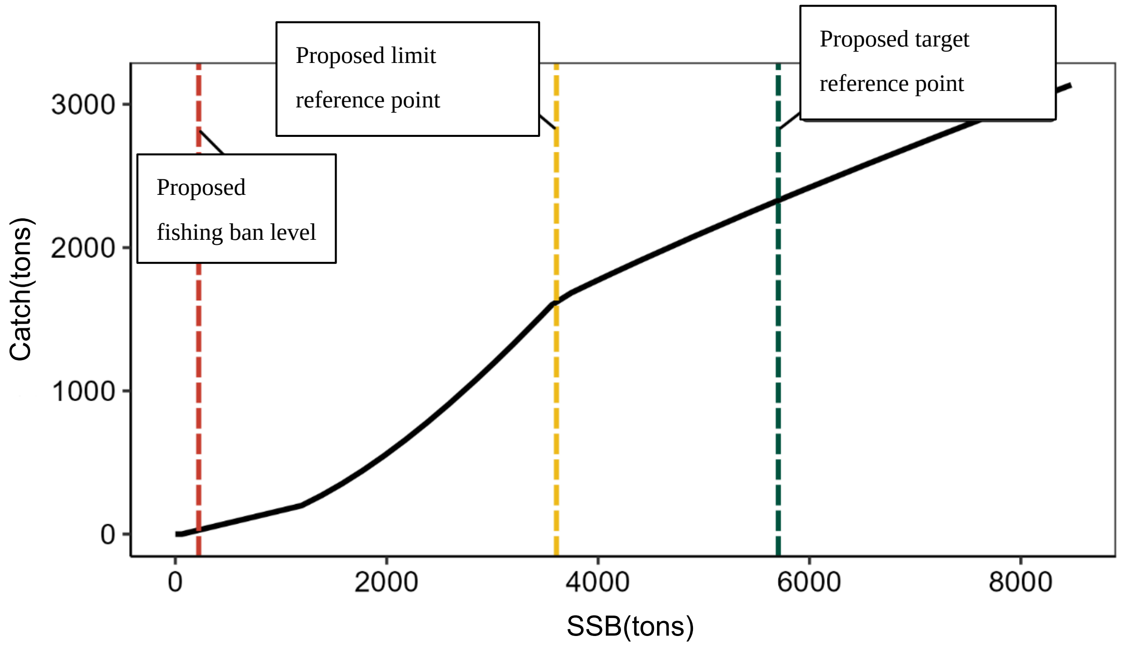
Similarly, results of future projections when released stock is not assumed, including for 2024 and onward, are shown in Supplementary Fig. 4-3 and Supplementary Tables 4-1, 4-3, 4-5, and 4-7. If management based on these proposed HCRs is continued for 10 years, then projected values for average SSB in 2033 will be 7,100 tons if β is set to 0.8 (90% prediction interval: 5,400 to 9,100 tons), and 5,800 tons if β is set to 1.0 (90% prediction interval: 4,200 to 7,600 tons) (Supplementary Table 6-6). 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. The probability of exceeding the proposed limit reference point is 100% when β is 0.9 or lower. If the current fishing pressure (F2022) is continued, then projected values for SSB in 2033 will be 7,600 tons (90% prediction interval of 5,900 to 9,600 tons), with a 97% probability that the value will exceed the proposed target reference point, and a 100% probability that it will exceed the proposed limit reference point.

Similarly, results of future projections, including for 2024 and onward, are shown in Supplementary Fig. 4-4 and Supplementary Tables 4-2, 4-4, 4-6, and 4-8. If management based on these proposed HCRs is continued for 10 years, then projected values for average SSB in 2033 will be 7,100 tons if β is set to 0.8 (90% prediction interval: 5,400 to 9,100 tons), and 5,800 tons if β is set to 1.0 (90% prediction interval: 4,300 to 7,600 tons) (Supplementary Table 6-7). 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. The probability of exceeding the proposed limit reference point is 100% when β is 1.0 or lower. If the current fishing pressure (F2022) is continued, then projected values for SSB in 2033 will be 7,700 tons (90% prediction interval of 5,900 to 9,700 tons), with a 97% probability that the value will exceed the proposed target reference point, and a 100% probability that it will exceed the proposed limit reference point.

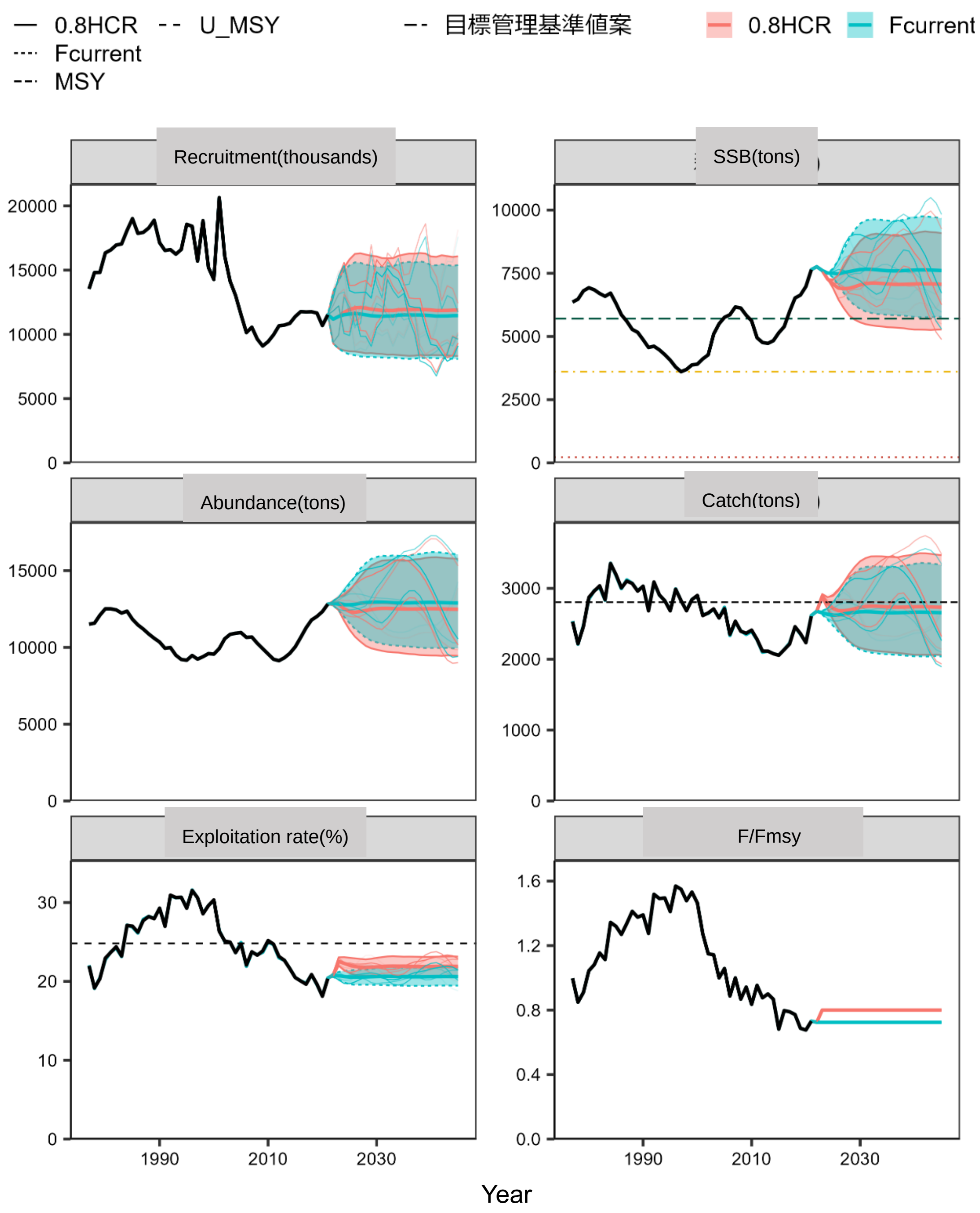


Supplementary Fig. 4-1. Proposed HCRs (F ratio)

The proposed target reference points (SBtarget) are the SBmsy values calculated based on a Ricker stock-recruitment model. The past minimum spawning stock biomass (SBmin) was used as the proposed limit reference point, and the standard value was used for the proposed fish ban level (SBban). An adjustment coefficient of β = 0.8, the standard value, was used. The black dashed line indicates Fmsy, the gray dashed line is 0.8 Fmsy, the black thick line is HCR, the red dashed line is proposed fish ban level, the yellow dashed line is proposed limit reference point, and the green dashed line is proposed target reference points.

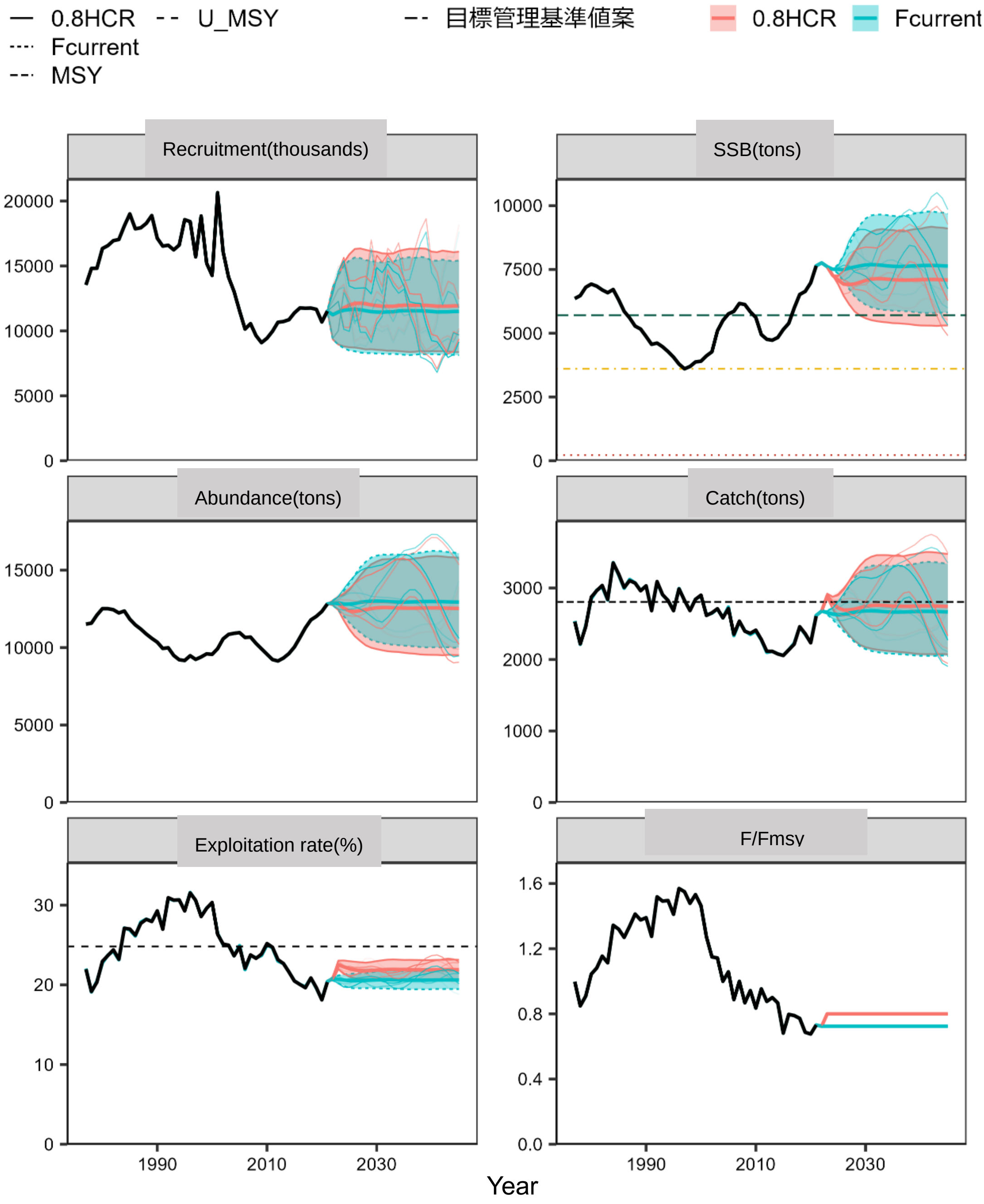


Supplementary Fig. 4-2. Proposed harvest control rules (catch in weight)
The proposed target reference points (SBtarget) are the SBmsy values calculated based on a Ricker stock-recruitment model. The past minimum spawning stock biomass (SBmin) was used as the proposed limit reference point, and the standard value was used for the proposed fish ban level (SBban). An adjustment coefficient of β = 0.8, the standard value, was used. The black dashed line indicates Fmsy, the gray dashed line is 0.8 Fmsy, the black thick line is HCR, the red dashed line is proposed fish ban level, the yellow dashed line is proposed limit reference point, and the green dashed line is proposed target reference points. While catch in weight varies slightly depending on the age composition of the catch year, the catch in weight for the average age composition at equilibrium is shown here.



Supplementary Fig. 4-3. Future projections based on proposed HCRs (red line), and future projections if the current fishing pressure is continued (green 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 3 future projections. In the SSB graph, the green dashed line is the proposed target reference point, the yellow dotted line is the proposed limit reference point, and the red dotted line is the proposed fishing ban level. In the exploitation rate graph, the dashed line indicates Umsy. The 2022 catch is based on predicted biomass and current fishing pressure

(F2022), while catches in 2023 onward follow the proposed HCRs (Supplementary Fig. 4-1). An adjustment coefficient of β = 0.8 was used.



Supplementary Fig. 4-4. The thick solid lines for future projections when using proposed HCRs assuming the current released stock (red) and the current fishing pressure (green) are the average values, while the shaded areas are the 90% prediction interval, which contain 90% of the simulation results, and the thin lines are examples of three future projections. In the SSB graph, the green dashed line is the proposed target reference point, the yellow dotted line is the proposed limit reference point, and the red line is the proposed fishing ban level. In the exploitation rate graph, the dashed line indicates Umsy. The 2022 catch is based on predicted biomass and current fishing pressure (F2022), while catches in 2023 onward follow the proposed HCRs (Supplementary Fig. 4-1). An adjustment coefficient of β = 0.8 was used. Recruitment of hatchery-reared fish from the current release is the average value of released fish from 2016 to 2020 (58,000 ind.) multiplied by survival to recruitment.

Supplementary Table 4-1. Probability that future SSB will exceed proposed target reference points

When assuming recruitment only from stock-recruitment relationships

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	100	100	100	100	100	40	30	34	40	45	48	50	**50**	50	50
0.9	100	100	100	100	100	98	82	73	72	73	74	74	**74**	72	71
0.8	100	100	100	100	100	100	100	97	94	92	91	91	**91**	89	88
0.7	100	100	100	100	100	100	100	100	100	99	99	98	**98**	97	97
0.6	100	100	100	100	100	100	100	100	100	100	100	100	**100**	100	99
0.5	100	100	100	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	**100**	100	100
0.3	100	100	100	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	**100**	100	100
0.1	100	100	100	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	**100**	100	100
現状の漁獲圧	100	100	100	100	100	100	100	100	99	98	98	97	**97**	96	95

Values in bold indicate the 10th year after starting management based on the HCRs.

Supplementary Table 4-2. Probability that future SSB will exceed proposed target reference points

Assuming released fish in population (58,000 ind.)

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	100	100	100	100	100	42	31	35	41	46	49	50	**51**	51	51
0.9	100	100	100	100	100	99	83	75	73	74	75	75	**75**	73	72
0.8	100	100	100	100	100	100	100	97	95	93	92	92	**91**	89	89
0.7	100	100	100	100	100	100	100	100	100	99	99	98	**98**	97	97
0.6	100	100	100	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	**100**	100	100
0.4	100	100	100	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	**100**	100	100
0.2	100	100	100	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	**100**	100	100
0.0	100	100	100	100	100	100	100	100	100	100	100	100	**100**	100	100
現状の漁獲圧	100	100	100	100	100	100	100	100	99	99	98	97	**97**	96	96

Values in bold indicate the 10th year after starting management based on the HCRs.

Supplementary Table 4-3. Probability that future SSB will exceed proposed limit reference points

When assuming recruitment only from stock-recruitment relationships

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	100	100	100	100	100	100	100	100	100	100	100	100	**99**	99	99
0.9	100	100	100	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	**100**	100	100
0.7	100	100	100	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	**100**	100	100
0.5	100	100	100	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	**100**	100	100
0.3	100	100	100	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	**100**	100	100
0.1	100	100	100	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	**100**	100	100
現状の漁獲圧	100	100	100	100	100	100	100	100	100	100	100	100	**100**	100	100

Values in bold indicate the 10th year after starting management based on the HCRs.

Supplementary Table 4-4. Probability that future SSB will exceed proposed limit reference points.

Assuming released fish in population (58,000 ind.)

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	100	100	100	100	100	100	100	100	100	100	100	100	**100**	99	99
0.9	100	100	100	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	**100**	100	100
0.7	100	100	100	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	**100**	100	100
0.5	100	100	100	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	**100**	100	100
0.3	100	100	100	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	**100**	100	100
0.1	100	100	100	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	**100**	100	100
現状の漁獲圧	100	100	100	100	100	100	100	100	100	100	100	100	**100**	100	100

Values in bold indicate the 10th year after starting management based on the HCRs.

Supplementary Table 4-5. Trends in future average SSB. When assuming recruitment only from stock-recruitment relationships

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	7,644	7,760	7,612	6,686	6,077	5,651	5,490	5,486	5,565	5,663	5,733	5,768	**5,777**	5,763	5,748
0.9	7,644	7,760	7,612	6,973	6,555	6,246	6,141	6,144	6,220	6,316	6,388	6,424	**6,432**	6,400	6,386
0.8	7,644	7,760	7,612	7,273	7,075	6,914	6,888	6,905	6,968	7,040	7,091	7,113	**7,112**	7,081	7,066
0.7	7,644	7,760	7,612	7,586	7,641	7,665	7,749	7,793	7,832	7,852	7,849	7,831	**7,806**	7,809	7,793
0.6	7,644	7,760	7,612	7,915	8,256	8,509	8,745	8,835	8,844	8,780	8,680	8,580	**8,504**	8,594	8,578
0.5	7,644	7,760	7,612	8,258	8,925	9,461	9,901	10,068	10,047	9,868	9,617	9,378	**9,205**	9,460	9,440
0.4	7,644	7,760	7,612	8,617	9,655	10,535	11,244	11,535	11,500	11,178	10,721	10,272	**9,933**	10,459	10,416
0.3	7,644	7,760	7,612	8,993	10,449	11,747	12,810	13,294	13,281	12,808	12,095	11,360	**10,766**	11,690	11,541
0.2	7,644	7,760	7,612	9,386	11,315	13,118	14,642	15,416	15,493	14,893	13,902	12,820	**11,878**	13,281	12,778
0.1	7,644	7,760	7,612	9,798	12,258	14,669	16,789	17,989	18,276	17,624	16,387	14,943	**13,591**	15,240	13,924
0	7,644	7,760	7,612	10,228	13,288	16,427	19,311	21,127	21,810	21,264	19,901	18,178	**16,449**	17,097	14,958
現状の漁獲圧	7,644	7,760	7,612	7,510	7,500	7,476	7,530	7,566	7,612	7,647	7,661	7,656	**7,638**	**7,629**	**7,613**

Values in bold indicate the 10th year after starting management based on the HCRs.

Supplementary Table 4-6. Trends in future average SSB. Assuming released fish in population (58,000 ind.)

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	7,644	7,760	7,612	6,686	6,082	5,663	5,508	5,508	5,589	5,687	5,757	5,792	**5,801**	5,786	5,771
0.9	7,644	7,760	7,612	6,973	6,560	6,259	6,160	6,168	6,246	6,342	6,413	6,449	**6,456**	6,424	6,409
0.8	7,644	7,760	7,612	7,273	7,080	6,928	6,909	6,932	6,997	7,069	7,118	7,139	**7,136**	7,106	7,090
0.7	7,644	7,760	7,612	7,586	7,646	7,679	7,772	7,822	7,864	7,884	7,880	7,859	**7,831**	7,835	7,818
0.6	7,644	7,760	7,612	7,915	8,261	8,525	8,770	8,868	8,880	8,816	8,714	8,610	**8,531**	8,622	8,605
0.5	7,644	7,760	7,612	8,258	8,931	9,478	9,927	10,104	10,088	9,909	9,655	9,412	**9,234**	9,491	9,470
0.4	7,644	7,760	7,612	8,617	9,660	10,552	11,273	11,575	11,547	11,226	10,766	10,312	**9,968**	10,494	10,449
0.3	7,644	7,760	7,612	8,993	10,455	11,766	12,842	13,339	13,334	12,864	12,149	11,409	**10,809**	11,731	11,576
0.2	7,644	7,760	7,612	9,386	11,321	13,138	14,676	15,466	15,554	14,959	13,969	12,882	**11,935**	13,326	12,814
0.1	7,644	7,760	7,612	9,798	12,265	14,690	16,826	18,046	18,346	17,702	16,469	15,025	**13,670**	15,281	13,961
0	7,644	7,760	7,612	10,228	13,295	16,450	19,352	21,190	21,892	21,358	20,004	18,285	**16,558**	17,121	15,020
現状の漁獲圧	7,644	7,760	7,612	7,510	7,505	7,490	7,552	7,595	7,643	7,678	7,690	7,683	**7,663**	7,654	7,638

Values in bold indicate the 10th year after starting management based on the HCRs.

Supplementary Table 4-7. Trends in future average catch in weight. When assuming recruitment only from stock-recruitment relationships

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	2,609	2,677	3,470	3,116	2,885	2,765	2,729	2,733	2,763	2,797	2,820	2,830	**2,833**	2,825	2,821
0.9	2,609	2,677	3,185	2,964	2,815	2,738	2,719	2,726	2,753	2,782	2,803	2,813	**2,814**	2,802	2,798
0.8	2,609	2,677	2,889	2,786	2,717	2,685	2,685	2,694	2,713	2,733	2,745	2,750	**2,748**	2,739	2,735
0.7	2,609	2,677	2,579	2,580	2,585	2,600	2,623	2,634	2,642	2,645	2,642	2,637	**2,630**	2,632	2,628
0.6	2,609	2,677	2,256	2,341	2,414	2,474	2,522	2,537	2,534	2,515	2,491	2,470	**2,455**	2,477	2,474
0.5	2,609	2,677	1,920	2,067	2,195	2,297	2,370	2,393	2,381	2,340	2,291	2,247	**2,218**	2,270	2,269
0.4	2,609	2,677	1,568	1,753	1,919	2,055	2,151	2,186	2,170	2,112	2,038	1,970	**1,922**	2,009	2,006
0.3	2,609	2,677	1,201	1,395	1,576	1,729	1,842	1,890	1,878	1,814	1,724	1,636	**1,569**	1,687	1,674
0.2	2,609	2,677	818	987	1,152	1,298	1,412	1,468	1,467	1,412	1,326	1,235	**1,159**	1,282	1,245
0.1	2,609	2,677	418	524	633	733	816	865	874	844	788	724	**666**	742	688
0	2,609	2,677	0	0	0	0	0	0	0	0	0	0	**0**	0	0
現状の漁獲圧	2,609	2,677	2,655	2,632	2,620	2,624	2,641	2,651	2,662	2,669	2,671	2,669	**2,664**	2,662	2,658

Values in bold indicate the 10th year after starting management based on the HCRs.

Supplementary Table 4-8. Trends in future average catch in weight. Assuming released fish in population (58,000 ind.)

β	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	**2033**	2043	2053
1.0	2,609	2,677	3,471	3,118	2,891	2,773	2,739	2,744	2,775	2,809	2,831	2,842	**2,844**	2,836	2,832
0.9	2,609	2,677	3,186	2,966	2,820	2,745	2,728	2,736	2,764	2,793	2,814	2,823	**2,824**	2,813	2,809
0.8	2,609	2,677	2,890	2,788	2,721	2,691	2,694	2,704	2,724	2,743	2,755	2,760	**2,758**	2,748	2,745
0.7	2,609	2,677	2,580	2,582	2,589	2,606	2,631	2,643	2,652	2,655	2,652	2,646	**2,639**	2,640	2,637
0.6	2,609	2,677	2,257	2,343	2,418	2,480	2,529	2,546	2,544	2,525	2,500	2,478	**2,462**	2,484	2,482
0.5	2,609	2,677	1,920	2,069	2,198	2,302	2,377	2,402	2,390	2,350	2,300	2,255	**2,225**	2,277	2,276
0.4	2,609	2,677	1,568	1,754	1,922	2,059	2,157	2,194	2,179	2,121	2,046	1,977	**1,928**	2,015	2,012
0.3	2,609	2,677	1,201	1,396	1,578	1,733	1,847	1,896	1,886	1,821	1,732	1,643	**1,575**	1,692	1,679
0.2	2,609	2,677	818	988	1,153	1,301	1,415	1,473	1,473	1,418	1,332	1,241	**1,164**	1,287	1,249
0.1	2,609	2,677	418	524	633	735	818	867	878	848	792	728	**670**	744	690
0	2,609	2,677	0	0	0	0	0	0	0	0	0	0	**0**	0	0
現状の漁獲圧	2,609	2,677	2,656	2,634	2,624	2,630	2,649	2,661	2,673	2,680	2,681	2,678	**2,673**	2,670	2,667

Values in bold indicate the 10th year after starting management based on the HCRs.

Appendix 5. Future Projection Methods

Future projections were performed using the stock-recruitment relationship used to estimate the F value that would achieve maximum sustainable yield (Fmsy) at the Research Institute Meeting held in September 2021 (Yamamoto et al. 2021) as well as the various settings shown in Supplementary Table 5-1 (natural mortality, maturity rate, average weight by age, and current fishing pressure) according to the harvest control rules for Stock Group 1 in the 2022 Harvest Control Rules and Basic Guidelines for ABC Calculation (FRA-SA2022-ABCWG02-01). The statistical software R (version 4.2.1) and the calculation package frasyr (version 2.2.0.3) were used to calculate projections for stock population and catch in weight based on the Technical Notes on Stock-Recruitment Relationship Estimates, Reference Point Calculations, and Future Projection Simulations (FRA-SA2022-ABCWG02-04).

This species is also a target species of stock enhancement, and its seeds are released continuously (Supplementary Table 2-2). When taking released stock into account in future projections, a recruitment volume of 58,000 fish, the average stock population for fish age 0 from 2016 to 2020, was added as the future recruitment of hatchery-reared fish.

The stock population of fish age 1 to 5 in future projections was obtained using the following equation.

$$N_{a,y} = N_{a-1,y-1}\exp\left(-M_{a-1} - F_{a-1,y-1}\right) \qquad (a = 1,\ldots,5)$$

The stock population of the plus group of fish age 6 and over was obtained using the following equation.

$$N_{6+,y} = N_{5,y-1}\exp\left(-M_{5,y-1} - F_{5,y-1}\right) + N_{6+,y-1}\exp\left(-M_{6+,y-1} - M_{6+,y-1}\right)$$

The catch in number at age was also obtained using the following equation.

$$C_{a,y} = N_{a,y}\left(1 - \exp\left(-F_{a,y}\right)\right)\exp\left(-\frac{M_a}{2}\right)$$

The biomass and catch in weight in future projections were obtained by multiplying the stock population or catch in number obtained here by the average weight in Supplementary Table 5-1, and SSB was calculated by multiplying this biomass by the maturity ratio.

References

Fisheries Resources Institute, Japan Fisheries Research and Education Agency (2022) Harvest Control Rules and Basic Guidelines for ABC Calculation (Fiscal Year 2022). FRA-SA2022-ABCWG02-01.

Stock Assessment Working Group (2022)Technical Notes on Stock-Recruitment Relationship Estimates, Reference Point Calculations, and Future Projection Simulations.FRA-SA2022-ABCWG02-04.

Yamamoto, K., Katamachi, D., Yamashita, Y., and Suzuki, S. (2021) Materials for the Research Institute Meeting on Reference Points of Central and Western Seto Inland Sea Stocks of

Japanese Seabream (Fiscal Year 2021). Japan Fisheries Research and Education Agency, 1-50. FRA-SA2021-BRP04-001
http://www.fra.affrc.go.jp/shigen_hyoka/SCmeeting/2019-1/20210928/ doc_madai_setonaikai-mw_RIM.pdf (last accessed 27 July 2022)

Supplementary Table 5-1. Future Projection Methods

	Selectivity (Note 1)	Fmsy (Note 2)	F2022 (Note 3)	Average weight (g)	Natural mortality coefficient	Maturity ratio
Age 0	0.28	0.04	0.03	77	0.39	0.0
Age 1	1.00	0.15	0.11	201	0.24	0.0
Age 2	1.61	0.24	0.17	353	0.17	0.0
Age 3	2.26	0.34	0.24	534	0.17	0.5
Age 4	2.79	0.41	0.30	734	0.17	1.0
Age 5	3.56	0.53	0.38	967	0.17	1.0
Age 6 and older	3.56	0.53	0.38	1,526	0.17	1.0

Note 1: Selectivity used to estimate the level required for MSY at the FY 2021 Research Institute Meeting (i.e., selectivity of Fcurrent in the FY2021 stock assessment).

Note 2: Fmsy estimated at the FY 2021 Research Institute Meeting (i.e., Fmsy/Fcurrent multiplied by Fcurrent in the FY2021 stock assessment).

Note 3: Under the selectivity above, an F value that gives the same fishing pressure as the F value by age in 2021 estimated in this stock assessment was calculated by conversion to %SPR. This F value was used as the assumed catch in weight for 2022.

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
Ricker model	Least squares method	Yes	7.31	2.05×10^{-4}	0.109	0.885

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. Reference points and MSY

Item	Value	Description
SBtarget	5,700 tons	A target reference point. SSB required for MSY (SBmsy).
SBlimit	3,600 tons	A limit reference point. SSB required for catch of 60% of MSY (SB0.6msy).
SBban	200 tons	Level for fishing ban. SSB required for catch of 10% of MSY (SB0.1msy).
Fmsy	Fishing pressure required for MSY (fishing mortality F) (Age 0, Age 1, Age 2, Age 3, Age 4, Age 5, Age 6 and older) = (0.04, 0.15, 0.24, 0.34, 0.41, 0.53, 0.53)	
%SPR (Fmsy)	13.6%	%SPR corresponding to Fmsy
MSY	2,800 tons	Maximum Sustainable Yield

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

Item	Value	Description
SB2021	7,644 tons	SSB in 2021
F2021	Fishing pressure in 2021 (fishing mortality F) (Age 0, Age 1, Age 2, Age 3, Age 4, Age 5, Age 6 and older) = (0.01, 0.12, 0.19, 0.26, 0.31, 0.35, 0.35)	
U2021	20%	Exploitation rate in 2021
%SPR (F2021)	19.9%	%SPR in 2021
Compared against reference points		
SB2021 / SBmsy (SBtarget)	1.34	B ratio required for MSY (target reference points) to SSB in 2021 fishing season
F2021 / Fmsy	0.75	F ratio required for MSY to fishing pressure in 2021*
Level of SSB	Over the level required for MSY	
Level of fishing pressure	Under the level required for MSY	
Changes in SSB	Increase	

*Ratio calculated based on F converted to %SPR, which gives the fishing pressure of Fmsy under the selectivity of 2021

Supplementary Table 6-4. Projected catch in weight and projected SSB Recruitment by stock-recruitment relationship only

SSB in 2023 fishing season (average projected value): 76,000 tons			
Item	Catch (hundred tons) in 2023	Ratio to current fishing pressure (F/F2022)	Exploitation rate in 2023 (%)
β = 1.0	35	1.38	27
β = 0.8	29	1.10	23
β = 0.6	23	0.83	18
β = 0.4	16	0.55	12
β = 0.2	8	0.28	6
β = 0	0	0	0
F2022	27	1.00	21

Supplementary Table 6-5. Projected catch in weight and projected SSB Hatching release taken into account (58,000 ind.)

SSB in 2023 fishing season (average projected value): 76,000 tons			
Item	Catch (hundred tons) in 2023	Ratio to current fishing pressure (F/F2022)	Exploitation rate in 2023 (%)
β = 1.0	35	1.38	27
β = 0.8	29	1.10	23
β = 0.6	23	0.83	18
β = 0.4	16	0.55	12
β = 0.2	8	0.28	6
β = 0	0	0	0
F2022	27	1.00	21

Supplementary Table 6-6. Results of future projections using various β Recruitment according to stock-recruitment relationship only

Uncertainty under consideration: Recruitment					
β	SSB in 2033 (hundred tons)	90% prediction interval (hundred tons)	Probability (%) that SSB will exceed the following proposed reference points in 2033		
			SBtarget (proposed)	SBlimit (proposed)	SBban (proposed)
β = 1.0	58	42 – 76	50	99	100
β = 0.9	64	48 – 83	74	100	100
β = 0.8	71	54 – 91	91	100	100
β = 0.7	78	60 – 98	98	100	100
β = 0.6	85	67 – 105	100	100	100
β = 0.5	92	74 – 112	100	100	100
β = 0.4	99	82 – 119	100	100	100
β = 0.3	108	90 – 127	100	100	100
β = 0.2	119	102 – 137	100	100	100
β = 0.1	136	119 – 154	100	100	100
β = 0	164	146 – 185	100	100	100
F2022	76	59 – 96	97	100	100

Supplementary Table 6-7. Results of future projections using various β Hatching release taken into account (58,000 ind.)

Uncertainty under consideration: Recruitment					
β	SSB in 2033 (tons)	90% prediction interval (tons)	Probability (%) that SSB will exceed the following proposed reference points in 2033		
			SBtarget (proposed)	SBlimit (proposed)	SBban (proposed)
β = 1.0	58	43 – 76	51	100	100
β = 0.9	65	48 – 83	75	100	100
β = 0.8	71	54 – 91	91	100	100
β = 0.7	78	61 – 98	98	100	100
β = 0.6	85	67 – 105	100	100	100
β = 0.5	92	74 – 113	100	100	100
β = 0.4	100	82 – 120	100	100	100
β = 0.3	108	91 – 127	100	100	100
β = 0.2	119	103 – 138	100	100	100
β = 0.1	137	120 – 155	100	100	100
β = 0	166	147 – 186	100	100	100
F2022	77	59 – 97	97	100	100

Supplementary Table 6-8. Summary of predicted SSB/catch in weight when recruitment of hatchery-reared fish is changed and the probability of SSB exceeding the proposed reference points

Hypothesized future recruitment	β	Probability of achieving the target in 10 years (%)	Projected average SSB (hundreds of tons)		Projected average catch in weight (hundred tons)		
		Probability of SSB exceeding the proposed target reference points	In 5 years	In 10 years	In 0 years	In 5 years	In 10 years
			2028	2033	2023	2028	2033
Recruitment according to stock-recruitment relationship only	1	50	55	58	35	27	28
	0.9	74	61	64	32	27	28
	0.8	91	69	71	29	27	27
	0.7	98	78	78	26	26	26
	0.6	100	88	85	23	25	25
	0.5	100	101	92	19	24	22
	F2022	97	76	76	27	27	27
Hatching release taken into account (58,000 ind.)	1	51	55	58	35	27	28
	0.9	75	62	65	32	27	28
	0.8	91	69	71	29	27	28
	0.7	98	78	78	26	26	26
	0.6	100	89	85	23	25	25
	0.5	100	101	92	19	24	22
	F2022	97	76	77	27	27	27

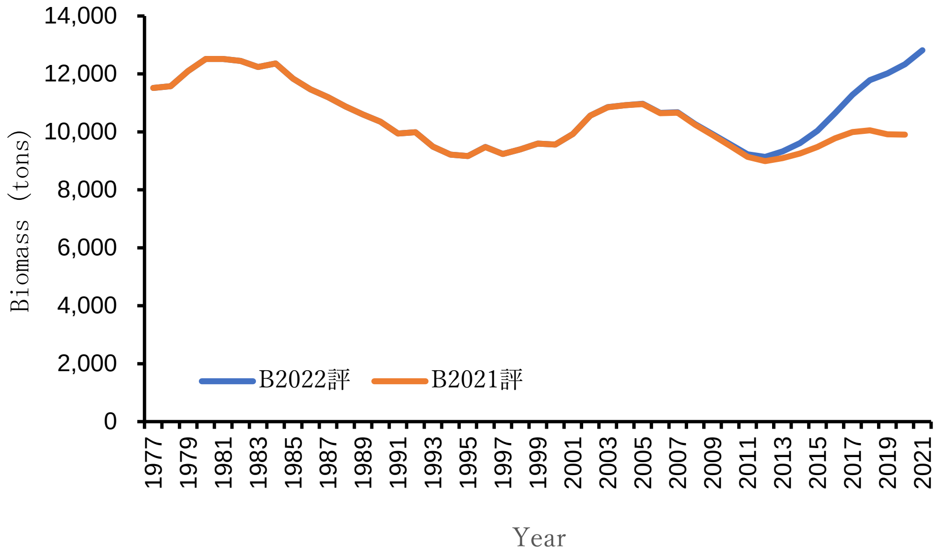
The results of changing the adjustment coefficient β in the proposed HCRs from 0.5 to 1.0 in increments of 0.1 are compiled here.

Values for 2023, the first year (year 0) of management under the proposed HCRs, are shown here along with values after 5 years and 10 years of management (2028 and 2033).

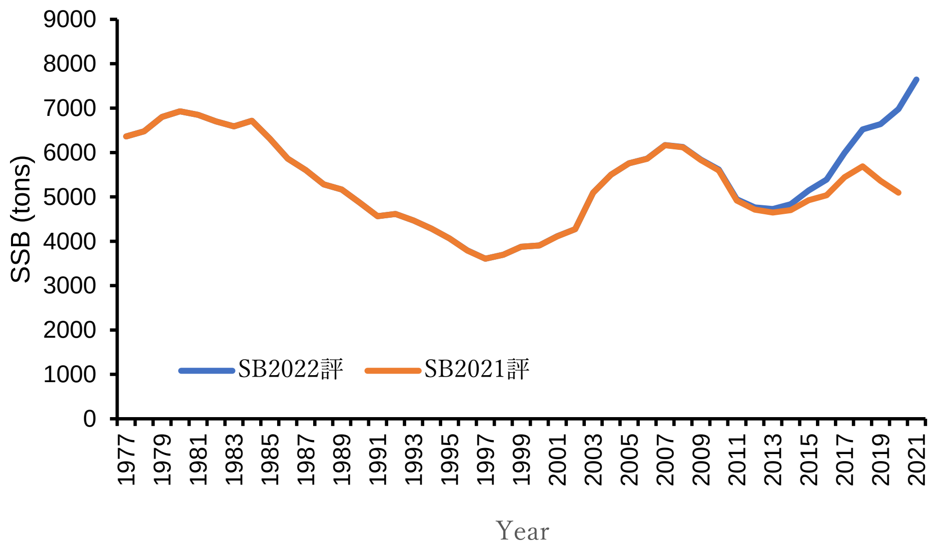
Hatching release taken into account: Average recruitment of hatchery-reared fish (2017 to 2021)

Appendix 7 Change in estimates from the assessment in the previous year

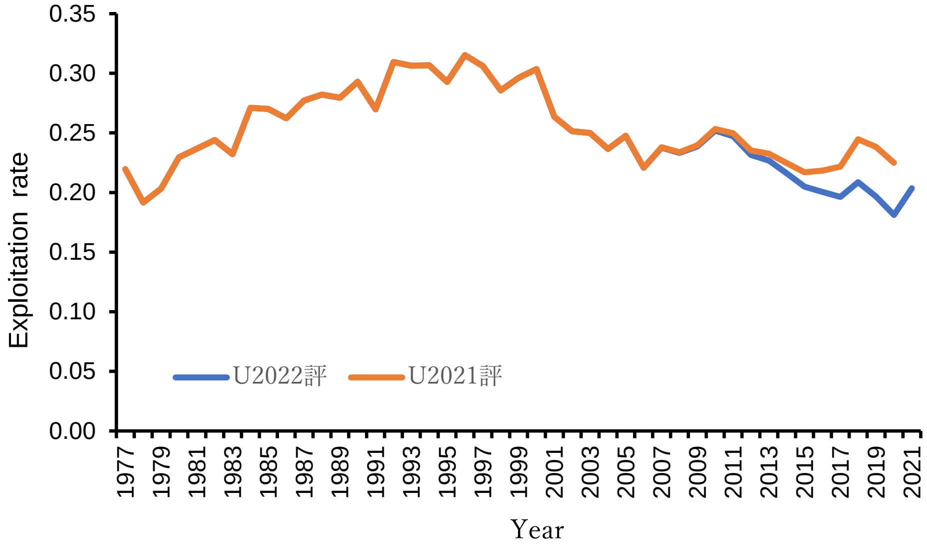
Estimated values are not significantly different from those prior to 2000 compared to the stock assessment of the previous fiscal year, but biomass and SSB from 2001 to 2020 have been revised upward (Supplementary Fig. 7-1, 7-2, and 7-3). This is due to a 15% increase in catch in 2021 over the previous year and a retroactive upward revision of recruitment volume.



Supplementary Fig. 7-1. Change in estimates (biomass)



Supplementary Fig. 7-2. Change in estimates (SSB)



Supplementary Fig. 7-3. Change in estimates (exploitation rate)