ISC/22/SHARKWG-3/2

Review of fishery data used in the benchmark stock assessment for North Pacific shortfin mako in 2018 [1]

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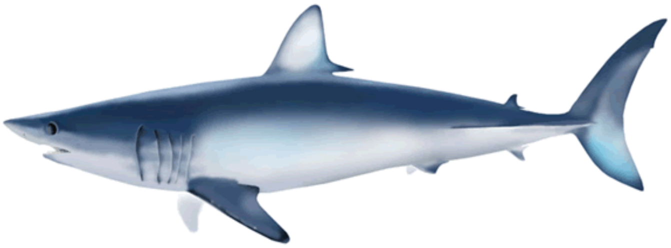

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Summary

This working paper reviews the fishery data used in the stock assessment for North Pacific shortfin mako, *Isurus oxyrinchus*, in 2018. The stock assessment was conducted using the Stock Synthesis 3 with three kinds of fishery data for 1975- 2016 which includes catch data, CPUE data, and size frequency data. Catch data comprises of annual catches of 18 fleets provided by four countries (Chinese Taipei, Japan, Mexico, and United States) and two Tuna-Regional Fisheries Management Organization (Western and Central Pacific Fisheries Commission, and Inter-American Tropical Tuna Commission). CPUE data comprises of annual abundance indices of 9 fleets and size frequency data comprises of 11 fleets provided by the above four countries. Finally, several recommendations are given for updating/revising the fishery data for the next stock assessment in 2024.

Introduction

Shortfin mako shark, *Isurus oxyrinchus*, is a highly migratory shark species and is widely distributed through tropical to temperate waters in the world Ocean (Compagno, 2001). This species is commonly caught by commercial fisheries targeting tunas and swordfish, *Xiphias gladius*, as bycatch or incidental catch (Kai et al., 2017). This species is well known to lower productivity compared to the other pelagic sharks due to slower growth, late maturity, and fewer offspring per adult female (Cortés et al., 2010). In the Pacific Ocean, this species is considered to have two stocks in the North and South Pacific Ocean (Sippel et al., 2011; Taguchi et al., 2015). The stock assessment of North Pacific shortfin mako was conducted in 2018 using Stock Synthesis (SS3; Methot and Wetzel, 2013) with fishery data including annual catch, catch per unit effort (CPUE) and size frequency data (ISC, 2018a) (**Table 1**, **Figure 1**). Fishery data is fundamental to conduct the stock assessment, and the accuracy of stock assessments largely depends on the quality and quantity of fishery data.

The purpose of this document paper is to review the fishery data used in the stock assessment for North Pacific shortfin mako in 2018, and to give recommendations for updating/revising the fishery data for the next stock assessment in 2024.

Review of catch data

Catch data (metric tons and numbers of sharks) comprises of annual catches of 17 fleets (F1_US_CA; F2_US_HI_SS; F3_US_HI_DS; F4_US_DGN; F5_US_REC; F6_TW_LRG_N; F7_TW_LRG_S; F8_TW_SML; F9_JPN_SS; F10_JPN_DS; F11_JPN_CST; F12_JPN_DFN; F13_JPN_OTH; F14_MEX_NOR; F15_MEX_SOU; F16_WCPFC; F17_IATTC) provided by Canada, Chinese Taipei (or Taiwan), Japan, Mexico, United States (US), Western and Central Pacific Fisheries Commission (WCPFC), and Inter-American Tropical Tuna Commission (IATTC) (**Figure 2**). The primary sources of catch were from longline and drift gillnet fishery, with smaller catches from purse seine, trap, troll and recreational fisheries. Most catches were provided by Japan, Taiwan, and Mexico. The provided catches are total dead removals composed of landings and discards because the catches of major fleets were estimated using annual CPUEs and total fishing efforts.

Since major fishing fleets of Japan and Taiwan had no species-specific information about the catches of shortfin mako prior to 1994, the fleet-specific annual catches of shortfin mako for 1975-1993 (F9_JPN_SS; F10_JPN_DS; F11_JPN_CST; F12_JPN_DFN; F8_TW_SML) were estimated from the fleet-specific annual catch of blue shark for the same period of time using fleet-specific mean catch ratio of shortfin mako to blue shark for 1994-2016 (Kai and Liu, 2018). The average catch of shortfin mako for 1975-1993 was 4,813 metric tons, and 5000 tons used as an initial equilibrium catch of shortfin mako in the stock assessment in 2018.

Chinese Taipei has two major fleets catching pelagic sharks including blue shark, *Prionace glauca*, and shortfin mako shark (Tsai et al., 2017a). The large-scale tuna longline fishery operates in the entire North Pacific Ocean targeting albacore tuna, *Thunnus alalunga*, in the temperate water and bigeye tuna, *Thunnus obesus*, in the tropical water, whereas the small-scale tuna longline fishery (F8_TW_SML) mainly operates in coastal water nearby Taiwan. Catch of shortfin mako caught by small scale longline fishery accounted for 90 % of the total catch. Annual trend of shortfin mako caught by small-scale longline fishery were stable from 1989 to 2016 except for 2004. The catch of shortfin mako shark caught by Taiwanese large-scale longline fisheries was separated into two regions (> 25°N and < 25°N) based on the difference in target species of the fisheries operating in these two regions (F6_TW_LRG_N; F7_TW_LRG_S).

Japan has four major fleets catching pelagic sharks including blue shark and shortfin mako shark (Kai and Semba, 2017; Kai and Yano, 2017). "The offshore and distant-water shallow-set longline fishery" (F9_JPN_SS) operates in the western and central North Pacific Ocean targeting swordfish and blue sharks in the temperate water, whereas "the offshore and distant-water deep-set longline fishery" (F10_JPN_DS) operates in the entire North Pacific Ocean targeting mainly bigeye tuna in the tropical water, but the shortfin mako shark is caught as bycatch. "The coastal longline fishery" (F11_JPN_CST) with smaller vessels less than 20 metric tons operates in the coastal area of Japan targeting tuna species including bluefin tuna (*Thunnus thynnus*), albacore, bigeye tuna, and yellowfin tuna, *Thunnus albacares*. "The large-mesh drift gill-net fishery" (F12_JPN_DFN) operated in the high-seas until 1993 caught swordfish and albacore and changed the operational area to the economic exclusive zone (EEZ) after 1993 due to the ban of high-seas driftnet fishery in 1993 (Ito et al., 1993). In addition, minor fisheries such as trap-net and bait fishing are categorized as a "trap and other fisheries" (F13_JPN_OTH). Catch of shortfin mako caught by high-seas driftnet fishery were remarkable in 1980s. The estimated catches of shortfin mako caught by shallow-set longline fishery gradually increased from 1992 to 2007, followed by decrease until 2016. The estimated catches of shortfin mako caught by deep-set longline fishery had decreased since 1992. The catches of "coastal fishery" as well as "trap and other fisheries" showed relatively stable trends over time.

United States has two major fisheries catching shortfin mako. Hawaii longline fishery which can separate the shallow-set longline fishery (F2_US_HI_SS) targeting swordfish and deep-set longline fishery (F3_US_HI_DS) targeting bigeye tuna, and US drift gillnet fishery (F4_US_DGN) targeting swordfish and thresher sharks within the US EEZ (Kinney et al., 2017; Carvalho, 2021). The Hawaii longline fishery displayed a generally increasing trend since 1995. The US drift gillnet fishery showed a large oscillation in the catches from 1975 to 2002, followed by decline, with the lowest catches recorded in 2015 and 2016.

Mexico has two distinct fisheries from northern and southern areas in the Mexico's Pacific waters. The northern fisheries (F14_MEX_NOR) from Baja California and Baja California Sur accounted for 72 % of shortfin mako catch, while the southern fisheries (F15_MEX_SOU) from Sinaloa, Nayarit, and Colima showed the remaining catch. Both fisheries indicated an increasing trend in catches over time (Sosa-Nishizaki et al., 2017).

Review of CPUE data

CPUE data (abundance indices) comprises of annual CPUEs of 9 fleets (S1_US_SS; S2_US_DS; S3_TW_LRG; S4_JPN_SS; S5_JPN_RTV; S6_JPN_OBS; S7_JPN_GEO; S8_MEX; S9_JPN_SS_I) provided by 4 countries (Chinese Taipei, Japan, Mexico, and United States) (**Figure 3**). All the standardized CPUEs were estimated using the catch and effort data of longline fisheries.

Since Japan had no species-specific information about the catches of shortfin mako prior to 1994, the nominal CPUEs for 1975- 1993 were estimated using annual catches of logbook data that estimated from the catch rates of shortfin mako to blue shark for 1994-2016 (Kai and Liu, 2018). The nominal CPUEs of shortfin mako caught by Japanese shallow-set longline fishery for 1975-1993 were standardized using generalized linear mixed model (GLMM) with spatiotemporal model (Kai and Kanaiwa, 2018). This index (S9_JPN_SS_I) was incorporated into the base-case model.

Standardized CPUEs for Japanese offshore and distant water shallow-set longline fishery for 1994-2016

(S4_JPN_SS) were estimated using delta two-step generalized linear model (GLM) with logbook data (Kai, 2017a). Based on the statistical soundness, long timespan, extensive spatial coverage, and relatively high catch rates, this index was considered as a high priority. However, further explorations showed that the steep increasing trend of this index was inconsistent with all the other indices available, as well as biologically implausible given the current understanding of SFM's population dynamics. Consequently, it was decided not to include this index in the base case model (ISC, 2018a).

Standardized CPUEs for Japanese research and training vessels operating mainly in the waters around Hawaii from 1992 to 2016 (S5_JPN_RTV) were estimated from a two-part model including binomial and Poisson GLMs (Kai, 2017b). Based on the statistical soundness, long timespan, extensive spatial coverage, and reliability of record, this index was considered as a high priority and therefore was included in the base case model (ISC, 2018a).

Standardized CPUEs for Hawaii longline fisheries for 2005-2016 were estimated separately for shallow-set and deep- set sectors using GLM with observer data (ISC, 2018a; Carvalho, 2021). The index of shallow- set (S1_US_SS) was included in the base case model due to the statistical soundness and 100 % observer coverage. Meanwhile, the index of deep-set (S2_US_DS) was not included in the base case model because the catch rates of shortfin mako for this fishery were much lower when compared to the shallow-set fishery.

Standardized CPUEs for Taiwanese large-scale longline fishery for 2005-2016 (S3_TW_LRG) were estimated using a zero-inflated negative binomial model with the logbook records (Tsai et al., 2017a). Based on the statistical soundness and extensive spatial coverage, this index was included in the base case model (ISC, 2018a).

Standardized CPUEs for Mexican pelagic longline fishery operating in the northwest Pacific Ocean for 2006-2016 (S8_MEX) were estimated using a GLM with observer data (Gonzalez-Ania et al., 2017). Based on the statistical soundness, and the fact that this is the only index available for the Eastern Pacific Ocean, this index was included in the base-case model.

Standardized CPUEs for Japanese observer data (S6_JPN_OBS) of longline fisheries operating in the western North Pacific Ocean from 2011 to 2016 (Kanaiwa et al., 2017) were estimated using a generalized additive mixed model (GAMM), however, this index was not included in the base case model due to the short span of this index (ISC, 2018a).

Standardized CPUEs for Japanese shallow- set longline fishery operating in the western and central North Pacific Ocean from 2006 to 2014 (S7_JPN_GEO) were estimated using a delta-GLMM framework with spatio-temporal and length composition data (Kai et al., 2017). This index was not included in the base case model because concern was raised on the dual inference of the length composition data incorporated into the SS model as a separate data source (ISC, 2018a).

Review of length composition data

Most length composition data were provided by Japan (90 %), followed by USA (7%), and Mexico (3%) (ISC, 2018a). All the length composition data were converted to Precaudal length (PCL) using the conversion equations if the other units (e.g., fork length or total length) were used in the observed measurement. Sex-specific length composition data for 8 fleets (F2_US_HI_SS; F3_US_HI_DS; F9_JPN_SS; F10_JPN_DS; F11_JPN_CST; F12_JPN_DFN; F14_MEX_NOR; F15_MEX_SOU) and sex-specific size composition data for one fleet (F4_USA_DGN) were used in the stock assessment (**Figure 4**), while length composition data for two fleets (F6_TW_LRG_N and F18_JPN_SSII) were not used due to the issue of the fit. Five cm length bins (40-330+ cm PCL) were used for all length composition data except for that of US drift gillnet which used 7 cm length bins due to aliasing of length data (40-341+ cm PCL) (Kinney et al., 2017).

Size data from longline gear comprised 91% of all Japanese size data, and they were divided into shallow-set longline (F9_JPN_SS), and deep-set longline (F10_JPN_DS) based on operational patterns (Semba, 2017). The size data of shallow-set longline were separated into two periods (i.e., 1994-2013; 2014-2016), however, the size data for 2014-2016 were not used in the stock assessment due to a large uncertainty in the sampling regulations for the small sized-fish. Size data of Japanese coastal fisheries (F11_JPN_CST) for 2006-2016 and drift gillnet fishery (F12_JPN_DFN) for 2005-2016 except in 2007 were used in the stock assessment.

Length composition data for the US drift gillnet fishery (F4_USA_DGN) were collected by onboard observers and port sampling (Kinney et al., 2017). Length composition data for US Hawaii shallow-set (F2_US_HI_SS) and deep-set (F3_US_HI_DS) longline fisheries were collected by onboard observers.

Length composition data for northern fisheries (F14_MEX_NOR) and southern fisheries (F15_MEX_SOU) in Mexico were collected by onboard observers in longline fisheries for 2006-2014 (Castillo-Geniz et al., 2017).

Length composition data of shortfin mako caught by small-scale (< 100 GRT) and large-scale (> 100 GRT) Taiwanese tuna longline fisheries in the North Pacific Ocean were provided (Tsai et al., 2017b), however, those were not used in the base case model due to a strong bimodal distribution. The length composition data of Taiwanese large-scale longline fisheries was attempted to use in the stock assessment after separating the data by northern and southern regions, however, those were finally not used in the base case model due to the issue of model fit (ISC, 2018b).

Recommendations about fishery data for the next stock assessment

It is recommended that all annual catch data of 18 fleets, all standardized CPUEs of 9 fleets except one fleet of geostatistical model, and all length composition data of 11 fleets used in the stock assessment in 2018 is updated/revised until 2021. Since the annual catch of North Pacific blue shark before 1994 had largely changed due to the implementation of stock assessment in 2022 (ISC, 2022), it is also recommended that the annual catch data of major fleets (F9_JPN_SS; F10_JPN_DS; F11_JPN_CST; F12_JPN_DFN; F8_TW_SML) from 1975 to 1993 are revised using the same method based on the catch ratio of shortfin mako to the blue shark. In addition, it is recommended to update the initial equilibrium catch based on the average of the estimated catches. For the standardized CPUEs estimated from the GLMs, it is recommended to use the spatio-temporal GLMM (e.g., VAST; Vector-Autoregressive Spatio-Temporal model; Thorson, 2019) to improve the quality of the annual abundance indices for all fleets.

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Table 1. Time series of catch, relative abundance, length composition data, and selectivity considered for the assessment of shortfin mako (SFM) in the North Pacific Ocean (NPO) in 2018.

Time series #	Symbol	Catch (metric tons) and abundance (numbers or biomass)	Name	Definition	Length composition availability (5 cm PCL bins, unless stated otherwise)	Selectivity
1	F1	Catch (metric tons)	F1_US_CA	US California longline	NA	Mirror F2
2	F2	Catch (numbers)	F2_US_HI_SS	US Hawaii longline shallow-set + California longline	(2005-2016)	Estimated
3	F3	Catch (in numbers)	F3_US_HI_DS	US Hawaii longline deep-set (Catch in 1000s fish)	(2005-2016)	Estimated
4	F4	Catch (metric tons)	F4_US_DGN	US Drift Gillnet	(1994-2016; 7 cm bin)	Estimated
5	F5	Catch (numbers)	F5_US_REC	US Recreational (Catch in 1000s fish)		Mirror F2
6	F6	Catch (metric tons)	F6_TW_LRG_N	TW longline large-scale (North)	(1994-2016; not fit)	Mirror F9
7	F7	Catch (metric tons)	F7_TW_LRG_S	TW longline large-scale (South)		Mirror F9
8	F8	Catch (metric tons)	F8_TW_SML	TW longline small-scale		Mirror F9
9	F9	Catch (metric tons)	F9_JPN_SS	JP offshore & distant water longline shallow-set	(2005-2013)	Estimated
10	F10	Catch (metric tons)	F10_JPN_DS	JP offshore & distant water longline deep-set	(2000-2016)	Estimated
11	F11	Catch (metric tons)	F11_JPN_CST	JP coastal longline	(2006-2016)	Mirror F9

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12	F12	Catch (metric tons)	F12_JPN_DFN	JP drift gillnet	(2005-2016)	Estimated
13	F13	Catch (metric tons)	F13_JPN_OTH	JP trap and others		Mirror F9
14	F14	Catch (metric tons)	F14_MEX_NOR	MX north all fisheries	(2007-2016)	Estimated
15	F15	Catch (metric tons)	F15_MEX_SOU	MX south all fisheries	(2006-2016)	Estimated
16	F16	Catch (metric tons)	F16_WCPFC	WCPFC observer other longlines		Mirror F2
17	F17	Catch (metric tons)	F17_IATTC	IATTC purse seine		Mirror F2
18	F18	Catch (numbers)	F18_JPN_SSII	JP F9 (last 3 years of size comp)	(2014-2016; not fit)	Mirror F9
19	S1	Relative abundance (numbers)	S1_US_SS	INDEX US Hawaii longline shallow-set		Mirror F2
20	S2	Relative abundance (numbers)	S2_US_DS	INDEX US Hawaii longline deep-set		Mirror F3
21	S3	Relative abundance (numbers)	S3_TW_LRG	INDEX TW longline large-scale		Mirror F6
22	S4	Relative abundance (numbers)	S4_JPN_SS	INDEX JP longline shallow-set (Primary index)		Mirror F9
23	S5	Relative abundance (numbers)	S5_JPN_RTV	INDEX JP research & training vessels		Mirror F9
24	S6	Relative abundance (numbers)	S6_JPN_OBS	INDEX JP observer		Mirror F9

25	S7	Relative abundance (numbers)	S7_JPN_GEO	INDEX JP longline shallow-set spatio-temporal model		Mirror F9
26	S8	Relative abundance (numbers)	S8_MEX	INDEX MEX longline		Mirror F14
27	S9	Relative abundance (numbers)	S9_JPN_SS_I	INDEX JP longline shallow-set (1975-1993)		Mirror F9

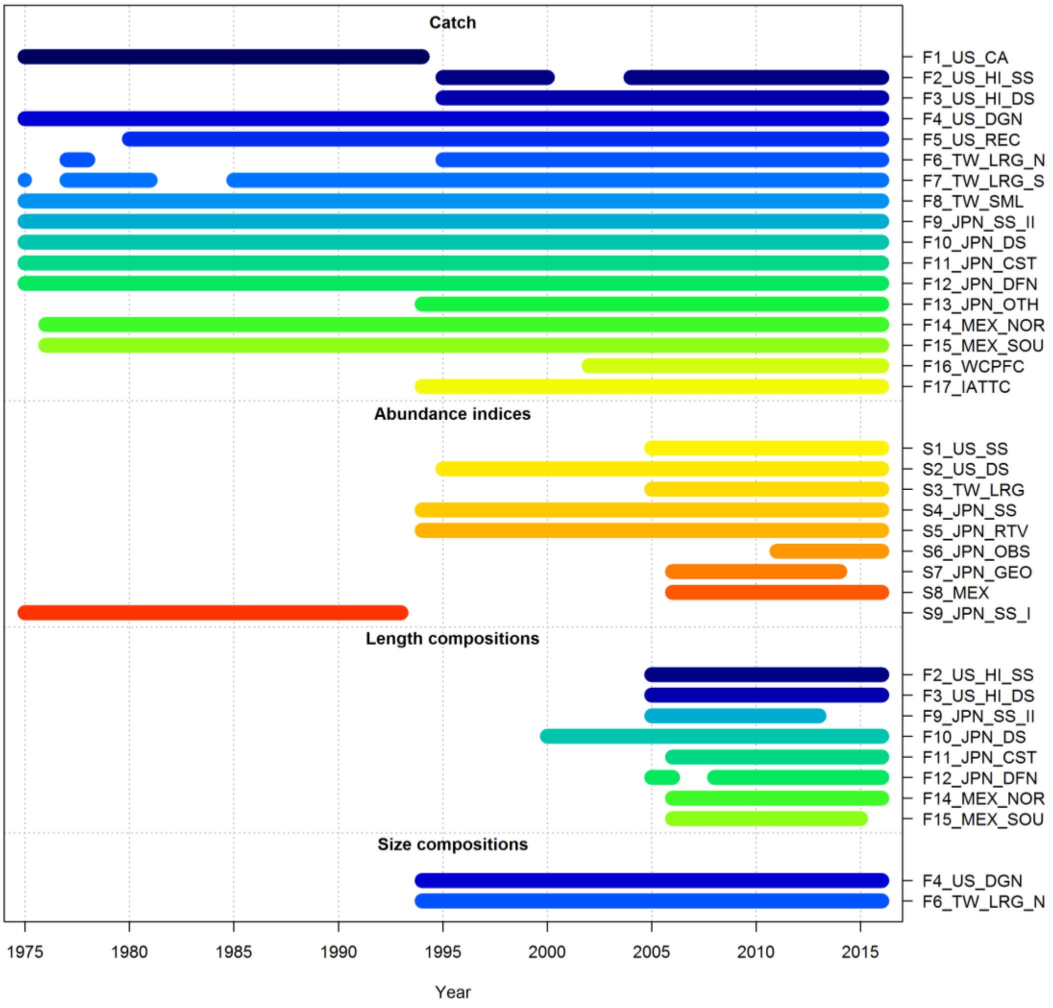

Fig. 1. Time series of catch, relative abundance, and length composition data of shortfin mako sharks in the North Pacific Ocean used in the stock assessment in 2018.

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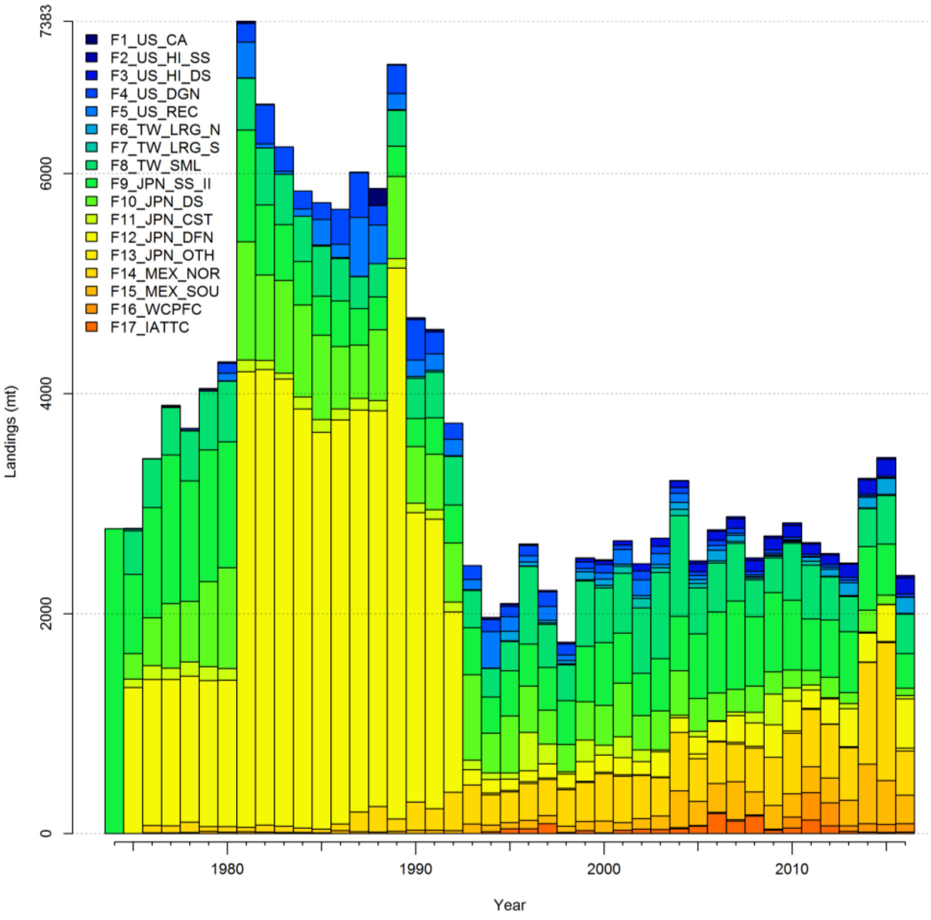

Fig. 2. Annual catch (total dead removals) of North Pacific shortfin mako shark by 17 fleets (1975-2016).

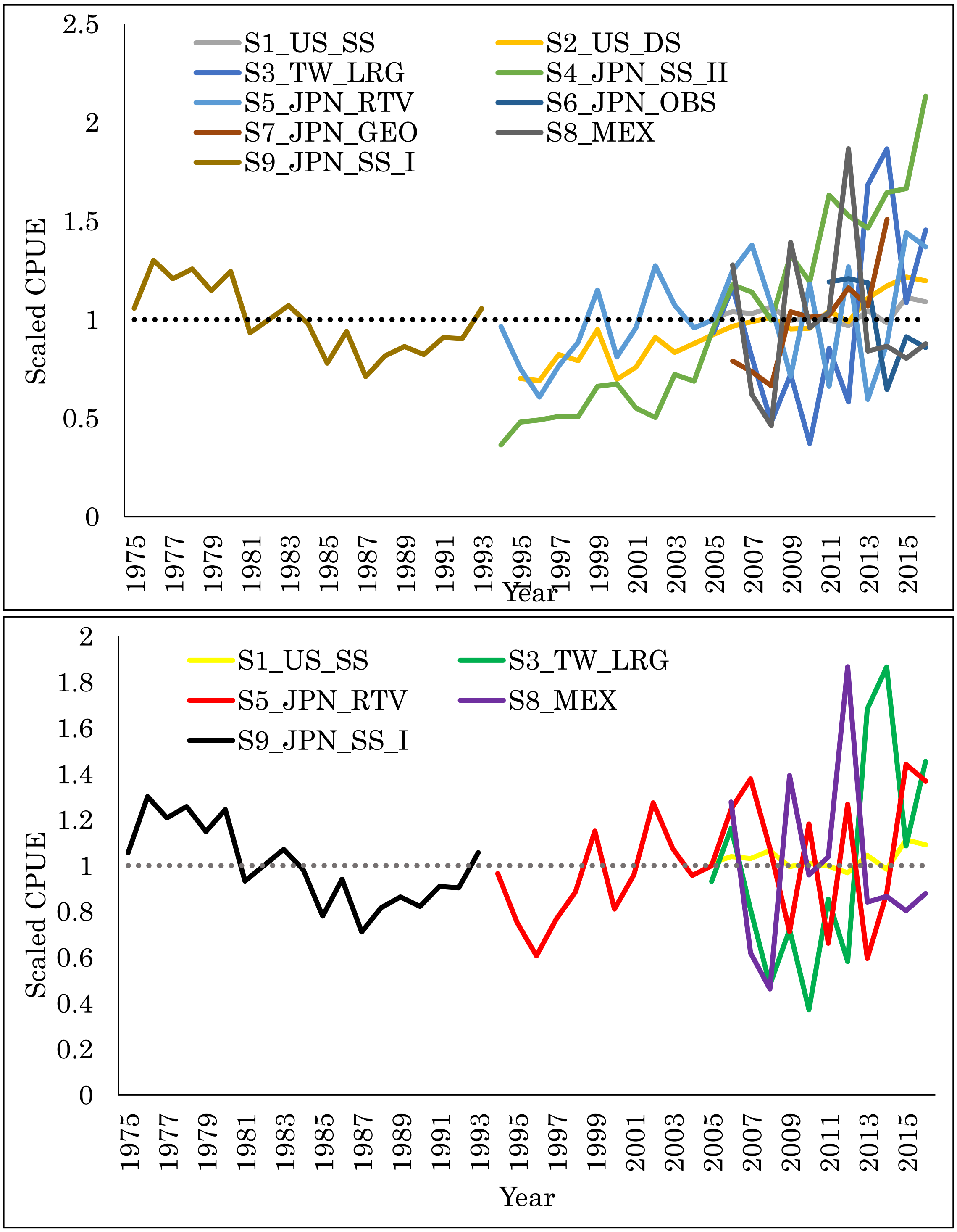

Fig. 3. Annual standardized CPUE of shortfin mako sharks in the North Pacific Ocean (1975-2016). All indices are normalized to a mean value of one (horizontal dotted line). Lower figure denotes abundance indices of base case model.

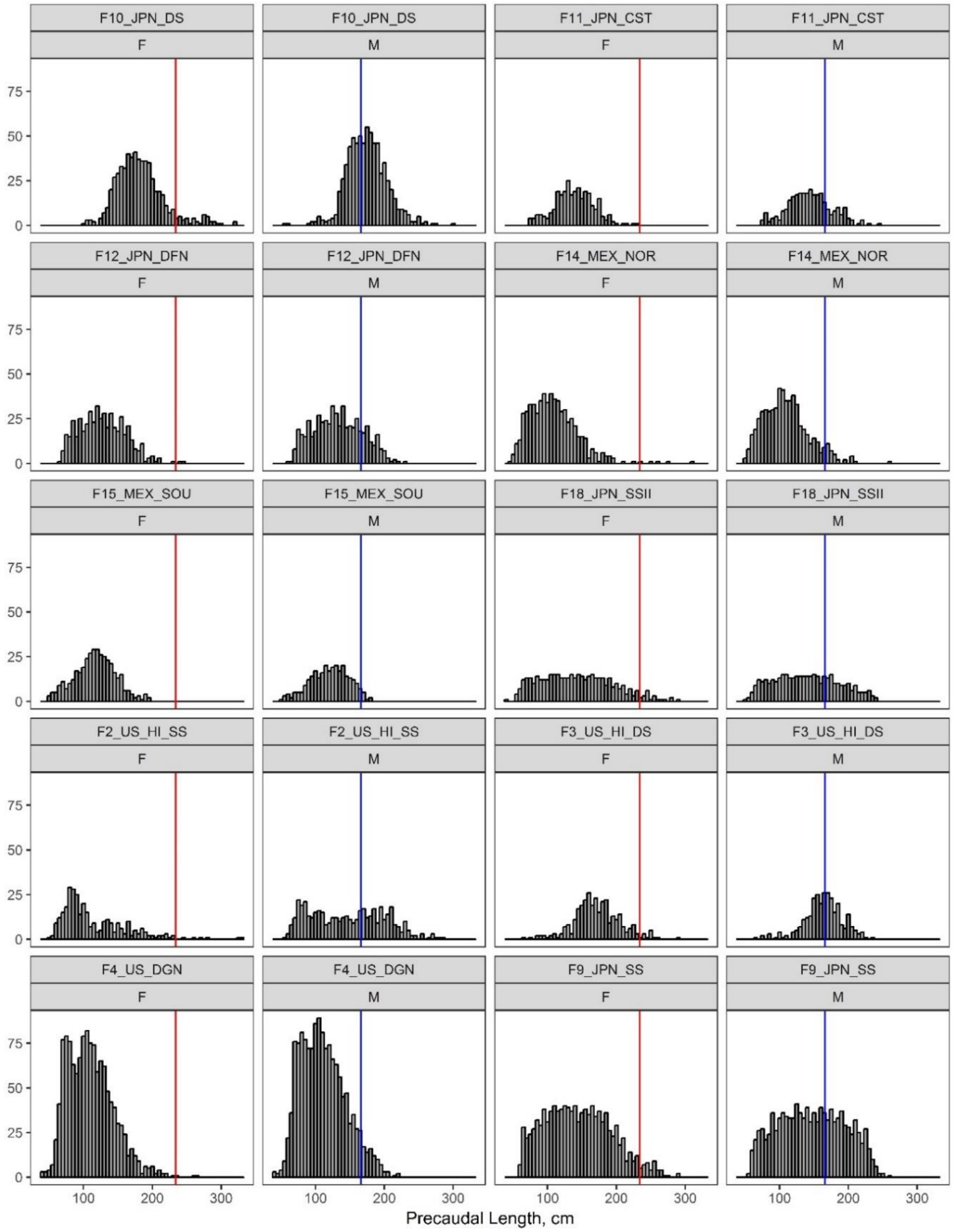

Fig. 4. Frequency of sex-specific size data (Pre-caudal length; PCL in cm) by fleet. Colored solid vertical lines indicate size-at-50% maturity. F and M denotes female and male, respectively.