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ANNEX 05

21st Meeting of the
International Scientific Committee for Tuna
and Tuna-Like Species in the North Pacific Ocean
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July 12-20, 2021

REPORT OF INDICATOR-BASED ANALYSIS FOR SHORTFIN MAKO SHARK IN THE NORTH PACIFIC OCEAN

REPORT OF THE SHARK WORKING GROUP WORKSHOP

July 2021

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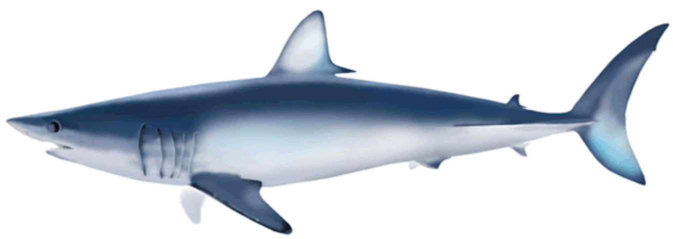

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EXECUTIVE SUMMARY

This document presents the results of the ISC Shark Working Group's (SHARKWG's) indicator-based analysis of shortfin mako shark (SFM, *Isurus oxyrinchus*) in the North Pacific Ocean (NPO) conducted in 2021. A benchmark stock assessment was completed in 2018 with the next full benchmark scheduled for 2024. In the interim, an indicator-based analysis was required to monitor key fisheries indicators for signs of potential changes in the stocks abundance or fisheries dynamics which could warrant a shift in the schedule for the next benchmark assessment. For the present analysis, key indicators included: time series of catch, indices of relative abundance (or CPUE; Catch Per Unit of Effort), and length-frequency data from multiple fisheries over the time period from 1957-2019.

Stock Identification and Distribution

SFMs are distributed throughout the pelagic, temperate waters of the NPO. Nursery areas are found along the continental margins in both the western and eastern Pacific Ocean (WPO and EPO), and larger subadults and adults are observed in greater proportions in the Central Pacific Ocean (CPO). A single stock of SFMs is assumed in the NPO based on evidence from genetics, tagging studies, and lower catch rates of SFM near the equator compared to temperate areas. However, within the NPO some regional substructure is apparent as the majority of tagged SFMs have been recaptured within the same region where they were originally tagged. Additionally, examinations of catch records by size and sex have demonstrated some regional and seasonal segregation across the NPO.

Data and indicator-based analysis

Annual trends of all available catch data (F1-F19) from 1957- 2019 and abundance indices (S1-S7) from 1992-2019 were visually inspected. Length frequency data were also used alongside the catch and the abundance indices as supplemental information for the indicator-based analysis.

Catch was estimated for multiple fleets and nations based on the best available information. Catch estimates for each fishery were made based on fishing effort, knowledge of the species composition of the catch, estimated CPUE, and scientific knowledge of the operations and catch history. Species-specific SFM catch was available for all major fisheries since 1993, however, catch for the early period, from 1957 up to 1993, is highly uncertain.

The four major abundance indices (S1, S3, S5, and S7) used in the base case benchmark stock assessment in 2018 were also used in this report as key indicators to determine whether the next benchmark stock assessment, scheduled for 2024, should be expedited.

A five-year moving average of CPUE, an approach used to reduce the effect of large fluctuations in CPUEs from year to year, was also used to examine trends in the abundance indices. Percent change (%) of the moving average of annual CPUE from long-term (i.e., the whole period for which CPUE data was avalibule) and short term (i.e., the most recent 5 years) were used to evaluate the historical and recent changes in the indices of relative abundance for the four major fleets.

Summary results of the indicator-based analysis

The highest catches came from Taiwan (F7-9), Japan (F10-14), and Mexico (F15-16) (**Figure ES1**). After 2016, the last year of data in the 2018 benchmark stock assessment, the catch amount in 2019 reached the 2nd highest value for the last decade. Recent increases in annual catchs from 2017-2019 may be a sign of an increase in population size, however, it may also indicate an increase in fishing pressure. The uncertainty surrounding this uptick in recent catch makes current catch data alone unsuitable for describing the stock status of SFM in the NPO.

The scaled CPUEs indicate a stable and slightly increasing trend in the four major fleets (**Figure ES2**).

The moving average of CPUE (**Figure ES3**) reflected the trends of annual CPUEs with more smoothing (**Figure ES2**). The moving average of CPUE for 3-surveys (S1, S3, and S5) showed an increasing trend throughout the period for which data were available. In contrast, the moving average of the S7 CPUE index showed a slight decrease up until 2018, followed by a large increase in 2019.

The percent change of the moving average of CPUE from long term (all years with data) for four major fleets indicated positive values, while the percent change from short term (the most recent 5-years) indicated slightly negative values for S3 and S7 (**Table ES1**). These results suggested that the indices of relative abundance of SFM in the NPO had no signals of population decline since the 1990s.

Conclusions of indicator-based analysis

Based on updated data for the abundance indices and length frequencies used in the base case benchmark assessment of SFM in 2018, no signs of shifts in the stocks abundance or fisheries dynamics are apparent. As such, the SHARKWG sees no reason to shift the schedule for the next benchmark stock assessment of SFM, currently scheduled for 2024.

Research needs

Threshold values of key indicators (i.e., indices of relative abundance) should be explored to help in determining when shifts may be needed in the benchmark stock assessments schedule.

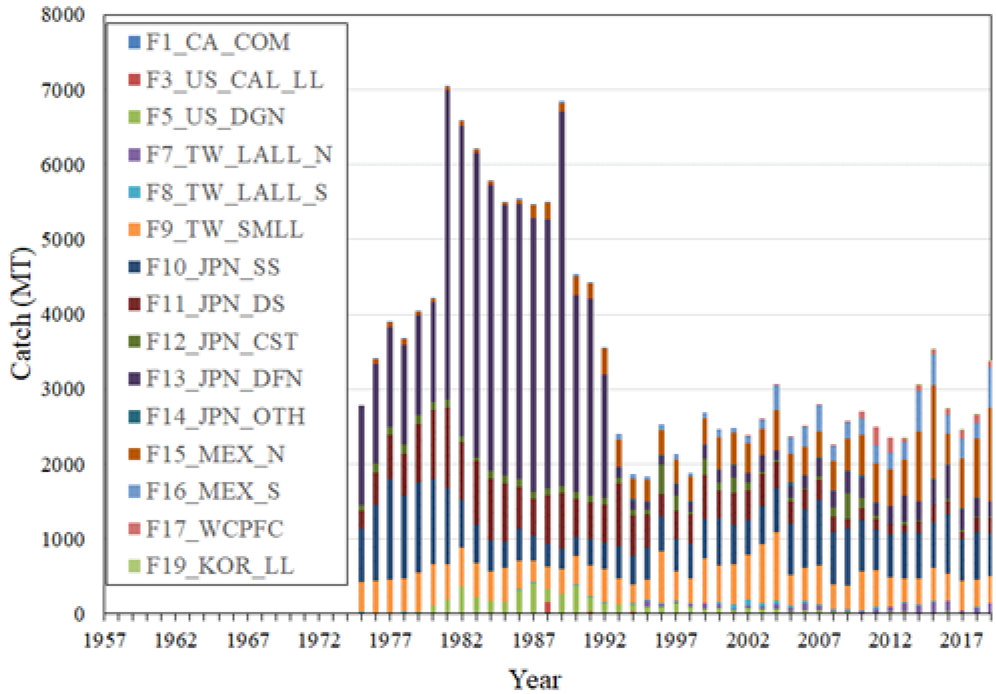

Figure ES1. Annual catch (MT) of shortfin mako in the North Pacific Ocean by fishery (fleet) from 1954 to 2019. Catch of some fleets are removed from this figure due to different units of catch.

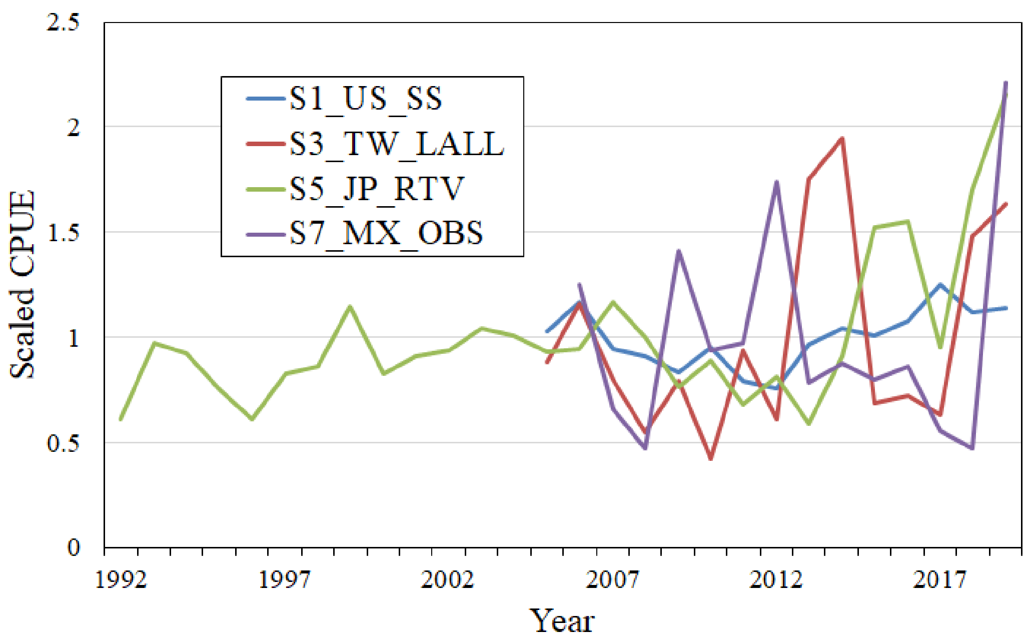

Figure ES2. Annual indices of relative abundance of shortfin mako in the North Pacific Ocean from 1992 to 2019 (CPUE of each year relative to average CPUE) for four major fleets (S1, S3, S5 and S7) used in the previous benchmark stock assessment in 2018. S1_US_SS (US Hawaii longline shallow-set), S3_TW_LALL (Taiwan longline large-scale), S5_JP_RTV (Japan research and training vessels), and S7_MX_OBS (Mexico observer for longline)

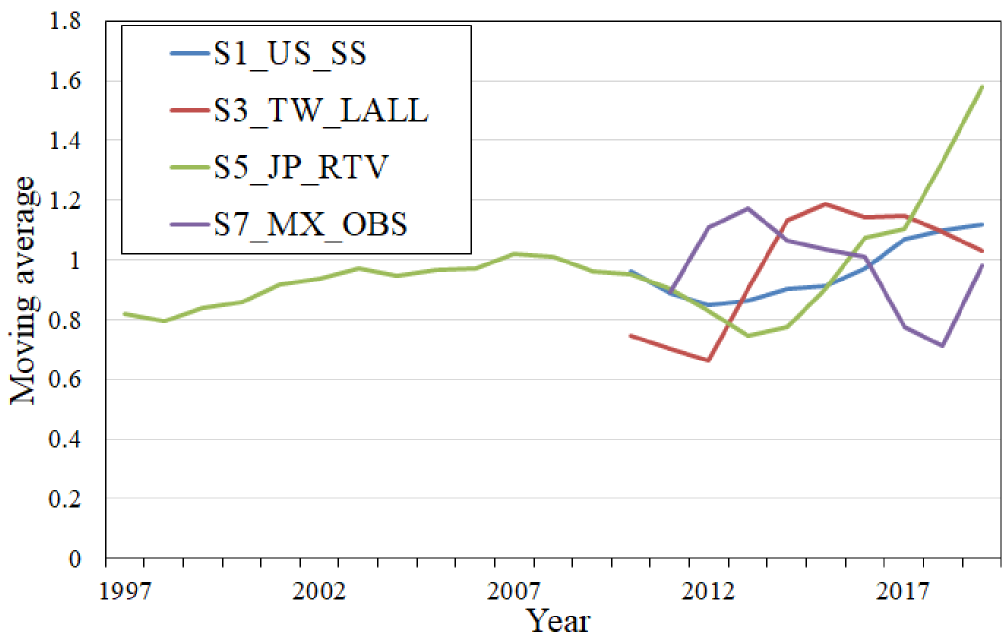

Figure ES3. Annual moving average (average CPUE of 5-year) of indices of relative abundance of shortfin mako in the North Pacific Ocean between 1997 and 2019 for four major fleets (S1, S3, S5 and S7) used in the base case previous benchmark stock assessment in 2018. See Table 1 for more information on survey names.

Table ES1. Percent change of moving average of CPUE for four major fleets (S1, S3, S5 and S7) used in the benchmark stock assessment in 2018. Moving averages were calculated using the mean value of CPUE for five years. The percentage indicates the positive and negative change in the moving average of CPUE between the start and end years from long term (all years with data) and short term (the most recent 5 years). The last year of S5 was removed from the calculation due to data from 2020 being preliminary. S1_US_SS (US Hawaii longline shallow-set), S3_TW_LALL (Taiwan longline large-scale), S5_JP_RTV (Japan research and training vessels), and S7_MX_OBS (Mexico observer for longline)

Period	**S1**	**S3**	**S5**	**S7**
Long term (all years with data)	16%	39%	93%	10%
Short term (the most recent 5 years)	23%	-13%	47%	-5%

1. INTRODUCTION

The Shark Working Group (SHARKWG) of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean (ISC) was established in 2010 and is responsible for providing regular stock assessments of pelagic sharks that interact with international tuna and billfish fisheries in the North Pacific Ocean (NPO). The focus of the SHARKWG to date has been on the two most commonly encountered pelagic sharks, the blue shark (BSH, *Prionace glauca*) and the shortfin mako shark (SFM, *Isurus oxyrinchus*). In order to assess population status, SHARKWG members have been collecting biological and fisheries information on these key shark species in coordination and collaboration with regional fishery management organizations, national scientists and observers.

The SFM is a highly migratory shark species and is one of the fastest of the pelagic sharks (Compagno 2001). Unlike commercially targeted species of higher value, such as tunas and swordfish, a greater portion of fishing intensity on sharks is the result of bycatch or incidental catch (Walker 1988; Bonfil 1994). Due to their lower reproductive potential as a result of slower growth, larger adult size, later reproduction, and fewer offspring, sharks are generally more susceptible to overfishing than teleosts and higher fecundity species (Branstetter 1990; Hoenig and Gruber 1990; Au et al. 2008). As largely non-targeted species, records of shark catches (retained and discarded) are often of lower quality and quantity than for targeted species.

The SHARKWG conducted its first assessment of SFM stock status in the NPO in 2015 using an indicator-based analysis (ISC 2015). The 2015 analysis used a series of fishery indicators, such as catch per unit of effort (CPUE) and average length (AL), to assess the response of the population to fishing pressure. After reviewing a suite of fishery indicators, the SHARKWG concluded that stock status (overfishing and overfished) of North Pacific SFM could not be determined in 2015 because information on important fisheries were missing, validity of indicators for determining stock status was untested, and there were conflicts in the available data.

The SHARKWG conducted its first benchmark stock assessment of SFM in the NPO in 2018 (ISC 2018; WCPFC 2018) using Stock Synthesis (SS) which is a length-based, age-structured, forward simulating population model (Methot and Wetzel, 2013). Time-series of catch, abundance indices (or CPUE), and sex-specific length composition from multiple fisheries were developed for the modeling period (1975 – 2016). In addition, new biological information, and research into parameterization of the Beverton-Holt stock recruitment relationship enabled the use of an integrated model. The results from the base case model showed that, relative to maximum sustainable yield (MSY), the shortfin mako in the NPO is not in an overfished condition and overfishing is not occurring. Based on future projections, spawning abundance (SA; number of mature female sharks) is expected to increase gradually if fishing intensity remains constant or is decreased moderately relative to 2013-2015 levels. However, given the uncertainty in fishery data and key biological processes within the model, especially the stock recruitment relationship, the models' ability to project into the future is limited and highly uncertain.

The International Union for Conservation of Nature and Natural Resources (IUCN) assessed the status of shortfin mako in 2019 and the global population of SFM was categorized as "Endangered" in the red list due to the declining population trends in some oceans around the world (Rigby et al. 2019). Based on the results from the IUCN, and the serious stock status of SFM in the North Atlantic Ocean (ICCAT 2018), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) listed the SFM in Appendix II in 2019 (CITES 2019). However, these global listings are likely of limited use, as shown by the contrast in stock status of SFM worldwide (FAO 2019). Despite its limited usefulness, the listing of SFM in Appendix II will undoubtable hamper future efforts to assess the stock status of this species by making biological samples less available, and incentivizing the discard or underreporting of this already non target species.

After the completion of the benchmark stock assessment for SFM in the NPO which indicated a healthy stock condition (ISC 2018), ISC 20 Plenary approved a schedule change for the benchmark stock assessments from 3 to 5 years to reduce the burden for stock assessment scientists, while also allowing more time to conduct research for the species between assessments (ISC 2020). As a condition of the approval, ISC 20 Plenary requested the SHARKWG conduct an indicator-based analysis to monitor key fisheries indicators (i.e., catch, CPUE, size frequency from the base case benchmark assessment) for changes that could warrant expediting the next scheduled benchmark assessments. The next benchmark assessment of SFM in 2024 is scheduled for one year after the next blue shark assessment (2022) to ensure an interval of at least two years between benchmarks.

2. BACKGROUND

2.1 Biology

2.1.1 Stock structure and movement

A single stock of SFM is assumed in the NPO based on evidence from genetics, tagging studies, and lower catch rates of SFMs near the equator relative to temperate areas (ISC 2018). All but one SFM tagged in the NPO and South Pacific Ocean (SPO) have been recaptured within the same hemisphere (Sippel et al. 2011; Bruce 2013; Urbisci et al. 2013; Wells et al., 2013), and there is a distinct signal in mitochondrial DNA heterogeneity between the NPO and SPO (Michaud et al. 2011; Taguchi et al. 2015). However, within the NPO, some regional substructure is apparent as the majority of tagged SFMs have been recaptured within the same region where they were originally tagged, and examination of catch records by size and sex demonstrates some regional and seasonal segregation across the NPO (Semba and Yokawa 2011; Sippel et al. 2015).

However, uncertainties remain about SFM stock structure. Microsatellite DNA analyses reveal no differentiation between the NPO and SPO, although the results are still being examined in order to determine the significance of the findings with respect to population connectivity (Taguchi et al. 2015). In addition, one SFM tagged in the southwestern Pacific Ocean (PO) off Australia was reportedly recaptured east of the Philippines (Bruce 2013). Given the preponderance of current evidence supporting limited connection of SFM populations between NPO and SPO, the SHARKWG assumes distinct North and South Pacific stocks, although stock structure should be reconsidered in the future, if there is further information supporting alternative hypotheses.

2.1.2 Habitat

SFM are distributed throughout the pelagic, tropical to temperate NPO, within which there are regions where young-of-the-year SFMs are more abundant, suggestive of pupping and/or nursery areas. These areas are distributed along the continental margins of the NPO, off the coast of U.S. and Mexico between about 27-35 degrees N in the eastern NPO (EPO, Holts and Bedford 1993; Wells et al., 2013; Sippel et al. 2015) and off the coast of Japan between about 30-40 degrees N (Semba and Yokawa 2011; Kai et al. 2015; Sippel et al. 2015; Kai et al. 2017). Larger subadults and adults are observed in greater proportions in the central NPO (CPO, Semba and Yokawa 2011; Sippel et al. 2015; Kai et al. 2017). However, these observations are based on fishery data and the effect of gear selectivity on the size composition of the catch is unclear. Nevertheless, the data are suggestive that larger sharks tend to use more oceanic habitats in the CPO, perhaps for mating purposes, and that large females move toward the coastal areas to pup. From the limited number of electronic tagging studies conducted in the NPO, SFMs appear to spend most of their time in epipelagic waters remaining predominately in the upper 100-150 m of the water column with occasional excursions below 500 m (Sepulveda et al. 2004; Vetter et al. 2008; Stevens et al. 2010; Abascal et al. 2011; Musyl et al. 2011; Nasby-Lucas et al. 2019). They exhibit diurnal behavior, generally remaining closer to the surface at night. The majority of individuals studied have been juveniles.

2.1.3 Reproduction and productivity

The occurrence of adult-sized SFMs in fishery catch is rare and studies of the reproductive biology of Pacific SFMs have therefore been few (Mollet et al. 2000; Joung and Hsu 2005; Semba et al. 2011). However, these studies have suggested SFMs reproduce every two to three years, with an estimated gestation of 12 to 25 months (Mollet et al. 2000; Juong and Hsu 2005; Semba et al. 2011), followed by a “rest period” before the next pregnancy begins. Combined Japanese and Taiwanese data suggested that females on average give birth to ~12 pups per litter (ISC 2017a). In the northern hemisphere, SFMs are thought to pup from late winter to mid spring (Cailliet and Bedford 1983; Mollet et al. 2000; Juong and Hsu 2005; Semba et al. 2011; Kai et al. 2015).

Productivity of SFM is assumed to be low compared to other pelagic sharks such BSH and silky sharks (*Carcharhinus falciformis*) due to its slow growth, late maturity at age and low fecundity (Compagno 2001). Yokoi et al. (2018) estimated a possible range of population growth rate using a two-sex age-structured matrix population model with multiple combinations of biological parameters. The estimated median value was 0.102 with a range of minimum and maximum values of 0.007 and 0.318. Kai (2020) developed a numerical approach which enable us to identify the most plausible combinations of the biological parameters as well as steepness. The estimated mean values and their standard deviation (SD) for steepness with the Beverton-Holt stock-recruitment relationship model were 0.353 (SD = 0.057) and 0.273 (SD = 0.046) for 2- and 3-year reproductive cycle, respectively. These biological parameters in consideration with the large uncertainties could be useful in the next benchmark stock assessment.

2.1.4 Growth

Pups are born at ~60 cm pre-caudal length (PCL), and adults reach a maximum length of between 232 – 244 cm PCL for males and 293 – 315 cm PCL for females (Takahashi et al. 2017). Sex-specific maturity ogives developed from a combined Japanese and Taiwanese dataset suggested that lengths at 50% maturity for male and female SFMs are 166 cm PCL and 233 cm PCL respectively (Semba et al. 2017).

Age determination for SFMs has been hampered by uncertainty in growth band pair deposition rates across regions, ages, and sexes. The periodicity of band pair deposition for SFM in the Northeast PO up to age five has been validated at two band pairs per year based on oxytetracycline tagging (Wells et al. 2013), and one per year for a single adult male shark after age five (Kinney et al. 2016). Validation studies based on radio-bomb carbon in the Atlantic suggest that one band pair is deposited in vertebrae per year (Ardizzone et al. 2006), but the data in the PO are not inconsistent with a deposition rate of two per year for a few years. Due to these uncertainties, a meta-analytic approach for estimating growth was adopted by the SHARKWG (Takahashi et al. 2017). This approach treated data from the western NPO (WPO) as having a constant band pair deposition rate and data from the EPO as having a band pair deposition rate that changes from 2 to 1 band pairs per year after age 5. This approach allowed the SHARKWG to produce a single growth model for the northern stock that included data collected from across the basin (ISC 2017).

2.2 Fisheries

For several decades, the primary source of known SFM fishing intensity has been oceanic longline fisheries targeting swordfish and tuna, including mostly shallow-set longline fisheries in temperate waters, and deep-set longline fisheries in more tropical area (ISC 2018). Sharks are targeted less often than tunas and swordfish by these fisheries, however, Asian shark markets, which have been developing for over a decade, provide economic value to SFM bycatch in these fisheries (Clarke et al. 2006).

3. MATERIALS AND METHODS

Available annual (Jan 1-Dec 31) time series of catch, indices of relative abundance (CPUE), and length composition data considered for use in this indicator-based analysis were assigned to "fleets" and "surveys" as summarized in **Table 1**. The time series of fishery data from 1957 to 2019 was used for this indicator-based analysis.

3.1 Data

3.1.1 Catch

Catches (metric tons; MT and/or numbers of sharks) were provided by ISC member nations and cooperating collaborators (**Table 2**; **Figure 1**). The primary sources of catch were from longline and drift gillnet fisheries, with smaller catches also estimated from purse seine, trap, troll, trawl and recreational fisheries. Catches are comprised of total dead removals, which include landings and discards. There is no catch record for SFM in Canada's fishery (F1_CA_COM).

USA

A multitude of US fisheries operating in the NPO, both along the US West Coast and out of Hawaii, catch SFM sharks (Kinney et al. 2017). These fisheries include: 1) Hawaiian shallow-set longline fishery targeting swordfish (F2_US_HI_SS); 2) California longline fishery (F3_US_CAL_LL); 3) Hawaiian deep-set longline fishery targeting bigeye tuna (F4_US_HI_DS); 4) US West Coast drift gillnets targeting swordfish and thresher sharks within the US EEZ (F5_US_DGN), and 5) Recreational fisheries and other fisheries that periodically catch SFM (F6_US_REC).

The majority of SFM catches in US fisheries are from the Hawaii longline and US West Coast drift gillnets. The catches of SFM from F5_US_DGN and F6_US_REC for 2017-2019 are not available in this indicator-based analysis.

Taiwan

Taiwanese fisheries data were obtained primarily from two sources (Liu et al. 2021a): 1) logbook data of the large-scale tuna longline fishery and 2) logbook data of the small-scale tuna longline fishery. The large-scale tuna longline fishery operates in two areas: north of 25°N (F7_TW_LALL_N) and south of 25°N (F8_TW_LALL_S), with F7_TW_LALL_N catching mainly albacore tuna, *Thunnus alalunga*, in more temperate waters, while F8_TW_LALL_S targets bigeye tuna, *Thunnus obesus*, in equatorial waters.

The small-scale tuna longline fishery operates mainly in coastal waters (F9_TW_SMLL) (Liu et al. 2021a). The large majority of SFMs from 2017 to 2019 are caught by F9_TW_SMLL (81%) followed by F7_TW__LALL_N (18%) and F8_TW_LALL_S (1%).

Japan

SFM is incidentally caught by Japanese coastal and high seas (i.e., offshore and distant waters) fisheries. The majority of SFM catch in Japanese fisheries is from either the high seas longlines or large mesh drift gillnet (ISC 2018). Offshore and distant water longline vessels were split into two fisheries based on vessel tonnage, with smaller vessels (20 -120 mt) designated as offshore, and larger vessels (>120 mt) deemed distant water (Kai 2021a). These two-longline fisheries were further categorized as shallow-set (SS) and deep-set (DS) based on the gear configuration (number of hooks between floats; HBF, with shallow-set - HBF ≤5 and deep-set - HBF ≥6). In 1993, the Japanese large-mesh drift gill-net fishery was banned in international waters (Miyaoka 2004). The Japanese large mesh drift gill-net fishery is however still operating within the economic exclusive zone (EEZ), and therefore is still considered part of the Japanese fisheries (Kai and Yano 2021).

Japan provided estimated catch for five sectors of their fisheries (**Figure 1b**), categorized by the vessel tonnage and gear configurations: 1) offshore and distant water longline shallow-set (F10_JPN_SS); 2) offshore and distant water longline deep-set (F11_JPN_DS); 3) coastal waters longline (F12_JPN_CST); 4) offshore and distant waters drift gillnet (F13_JPN_DFN); and 5) trap and other fisheries (F14_JPN_OTH) (Kai 2021a, Kai and Yano 2021). Note that after 1993 F13 has not operated in the distant water but the name is used in this report.

Estimated recent annual catches of SFM in Japanese fisheries from 2017 to 2019 were predominantly from F10_JPN_SS (58%), followed by F13_JPN_DFN (23%), F11_JPN_DS (16%), F12_JPN_CST (2%), and F14_JPN_OTH (1%).

Prior to 1994, shark catch data for Japanese and Taiwanese fisheries were reported in a single species-aggregated "sharks" category. SFM catches for these major fishing fleets during 1975 – 1993 were estimated using SFM to BSH catch ratios from the period 1994-2016 (Kai and Liu 2018).

Mexico

Aggregated shark catches from Mexico's Pacific waters were provided by the official Mexican fisheries agency, the National Commission for Aquaculture and Fisheries (CONAPESCA) for the states of Sinaloa, Nayarit and Colima, from 1976-2019. Since 2006 CONAPESCA has reported total catches of the main shark species. Catches were aggregated into two distinct fisheries: 1) the fisheries from States of Baja California and Baja California Sur as northern catches (F15_MEX_N), and 2) those from Sinaloa, Nayarit, and Colima as southern catches (F16_MEX_S). The northern fisheries were responsible for most of the SFM catches (73% during 2017 and 2019) (**Table 2**).

Western Central Pacific Fisheries Commission (WCPFC)

Fleet-specific catch statistics of SFM caught in the western and central Pacific Ocean (WCPO) from 1950 to 2020 (F17_WCPFC) were provided by SPC. The catch statistics provided by Republic of Kiribati, PNG, Republic of Palau, and Solomon Islands were not used as input data for the benchmark stock assessment (ISC 2018), but these data were included in this indicator-based analysis because they were deemed to be from the NPO.

Inter-American Tropical Tuna Commission (IATTC)

The number of SFMs caught in tuna purse seine fisheries (F18_IATTC) was available for the period between 1971-2019 and was estimated from observer bycatch data (see appendix A in ISC 2018). Some assumptions regarding the relative bycatch rates of SFMs were applied based on their temperate distribution, catch composition information, and estimates of SFM bycatch in tuna purse seine fisheries in the north EPO. Estimates were calculated separately by set type, year and area. Small purse seine vessels, for which there are no observer data, were assumed to have the same SFM bycatch rates by set type, year and area, as those of large vessels.

Republic of Korea

Major shark species were separately identified in catch statistics of Korean longline fishery in the NPO from 2013 to 2019 with 100% observer data coverage. These data (F19_KOR_LL) are considered to be reliable. The catch amount in recent years is near zero, due to conservation measures strengthened for Korean longline fisheries; sharks are now released prior to bringing on board the vessel. This is a new catch time series and was not included in the 2018 benchmark stock assessment. In future work, the estimation of blue shark catch will be conducted after reviewing and analyzing the data on the estimation method of catch because there is no information about the live release and dead discard.

3.1.2 Indices of relative abundance

Indices of relative abundance (CPUE) for SFM in the NPO was developed with fishery data from four nations (Japan, USA, Taiwan, and Mexico) (**Tables 1, 3**; **Figures 2, A1**).

Hawaii longline

Abundance indices for the Hawaii shallow-set and deep-set longline fisheries were developed with delta lognormal models using observer data (Carvalho 2021). The shallow-set fishery was impacted by closures from 2001-2004 due to bycatch concerns, but the deep-set fishery was not similarly affected.

Catch and effort data from the Hawaii-based pelagic longline fishery operating in the NPO were analyzed to estimate indices of relative abundance for the SFM between 1995 and 2019. The data came from the records of the Pacific Islands Regional Observer Program (PIROP) submitted to the Pacific Islands Fisheries Science Center (PIFSC). Standardized CPUEs were estimated separately for shallow-set (target: swordfish) (S1_US_SS) and deep-set (target: bigeye tuna) (S2_US_DS) sectors using Generalized Linear Models (GLM).

The index of relative abundance for S1_US_SS was considered high priority and therefore was included in the base case model (ISC 2018). This decision was based on the statistical soundness of the standardized CPUE, as well as the fact that this fishery has 100% observer coverage. The standardized CPUE for the deep-set fishery (S2_US_DS) was considered valuable because of its long timespan (1994-2019), and statistical soundness. However, the catch rates of SFM for this fishery were much lower when compared to the shallow-set fishery. This difference is probably associated with the spatial distribution and habitat preference of SFMs in the waters off the Hawaiian archipelago. Therefore, the index of relative abundance for S2_US_DS was not included in the base case model (ISC 2018).

Taiwan longline

The SFM catch and effort data from the logbook records of the Taiwanese large-scale tuna longline fishing vessels operating in the NPO from 2005 to 2019 were analyzed to create an index of relative abundance for Taiwanese longline fishery (S3_TWN_LALL) (Liu et al. 2021a). Due to the large percentage of sets with zero SFM catches, the nominal CPUE for SFM was standardized using a zero-inflated negative binomial model.

The S3_TWN_LALL index was considered high priority and therefore was included in the base case model (ISC 2018). This decision was based on the statistical soundness of the standardized CPUE, and the extensive spatial coverage of this fishery.

Japan longline

Offshore and distant water longline shallow-set

Set-by-set logbook data from Japanese offshore and distant water longline fishery was used to estimate the standardized CPUE over the period from 1994-2019 (Kai 2021b). Available data included information on catch number, amount of effort (number of hooks), number of branch lines between floats (hooks per basket: HPB) as a proxy for gear configuration, location (longitude and latitude) of set in a 1 × 1 degree square, vessel identity, fishery type (offshore or distant water), and the prefecture in Japan where the longline boats were registered. From this data, an index of relative abundance for Japan longline shallow-set (S4_JPN_SS) was estimated using delta 2 step GLM.

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, the SHARKWG decided not to include this index in the base case model (ISC 2018).

Research and training vessels

Japanese research and training vessels (JRTV) commonly operate in the waters around Hawaii. The catch data of SFM had been collected since 1992 and showed evidence of excess zeros. To account for the occurrence of excess zeros, a two-part model (Zuur et al. 2009) was used to standardize CPUE of SFM for the JRTV (Kai 2021c). A binomial GLM was used as the first stage and a Poisson model was used as the second stage to estimate an index of relative abundance for JRTV (S5_JP_RTV).

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 2018).

Observer data

Observer data of Japanese longline fisheries operating in the NPO from 2011-2019 were used to standardize CPUE for this fishery (S6_JP_OBS). This standardized CPUE was estimated using a Generalized Additive Mixed model (GAMM) (Kanaiwa et al. 2021). Given the short time span of this index, it was not included in the base case model.

Mexico longline

Standardized CPUE of SFM caught in Mexican pelagic longline fishery operating in the PO of northwestern Mexico was estimated for the period between 2006 and 2019 (S8_MX_OBS). The analysis used data obtained through the Mexican pelagic longline observer program and a GLM approach (González-Ania et al. 2021).

Based on the statistical soundness, and the fact that this is the only index available for the EPO, this index was considered as a high priority and therefore was included in the base case model (ISC 2018).

3.1.3 Size frequency data

Size frequency data of SFM in the NPO were provided by two nations (Japan and Taiwan).

Taiwan longline

The size frequency data of SFM caught by two Taiwan fisheries (the large-scale tuna longline fishery and the small-scale tuna longline fishery) were used (Liu et al. 2021b). The sizes of 11,173 individuals (sexes combined) recorded in the logbook of LTLL (F7_TW_LTLL and F8_TW_LTLL) from 2005-2019 ranged from 61 to 303 cm PCL (**Figure A2**). The size of shortfin mako caught by the F9_TW_STLL from 1989-2019 in the NPO ranged from 61 to 338 cm PCL for females (n = 116,281), and 60–262 cm PCL for males (n = 108,505) (**Figure A3**). Two modes (mostly 100 and 150 cm PCL) were observed in the size distribution of SFM caught by the STLL in the NPO. This also implied that the catches comprised mostly immature fish (female < 228, male < 172 cm PCL).

Japan observer

The size frequency data of SFM collected by the Japanese observer program between 2011 and 2019 were used (Semba 2021). Majority of size data was collected in the area north of 30°N and west of 175°E, which is part of main ground of shallow-set longline fishery targeting swordfish and BSH. The annual median and quartile percentiles of catch at size of shortfin mako in PCL indicated that remarkable temporal change of body size was not clearly observed and relatively stable in the main fishing ground of offshore shallow-set longline fishery where juvenile dominates (**Figure A4**). Although coverage of observer data is not high, combined with the abundance index estimated based on shallow-set logbook data and current result, it is suggested that population decrease is unlikely to occur after the last year (i.e., 2016) of stock assessment conducted in 2018.

3.2 Methodology of indicator analysis

The SHARKWG has no intention of updating the stock status of SFM in the NPO based on the indicator-based analysis because information of the indicators is insufficient to determine the stock status and the validity of indicators for determining the stock status is untested. The main goal is to review the historical time series of indicators and present their most recent trends in order to allow the SHARKWG to review relevant data in order to decide if an expedited schedule for the assessment of SFM is warranted.

3.2.1 Prioritization of data components

The SHARKWG reviewed the annual trends of all available catches (F1-F19) and CPUEs (S1-S7). The SHARKWG used four abundance indices (S1_US_SS, S3_TW_LALL, S5_JP_RTV, S7_MX_OBS) related to the data included in the benchmark stock assessment (ISC 2018) as key indicators. The four indices of relative abundance were used to determine whether the next benchmark stock assessment should be conducted earlier than the currently scheduled date of 2024. The size frequency data are used as supplementary information of the indicator-based analysis.

3.2.2 Visual inspection of indicators

The SHARKWG focused on the recent and historical annual trends of catches and CPUEs. The SHARKWG also used a 5-year moving average of CPUE (e.g., the moving average of CPUE in 2019 is a mean value of CPUEs between 2015 to 2019).

3.2.3 Percent change of annual CPUE

Percent change (%) of the moving average of CPUE from long term (i.e., the whole period of each CPUE index) and short term (i.e., recent 5 years from 2015-2019) are used to evaluate the historical and recent changes in the indices of relative abundance. The percent change is calculated for four major fleets (S1_US_SS, S3_TW_LALL, S5_JP_RTV, S7_MX_OBS). The moving average is calculated using the mean value of CPUE for five years. Regarding the percent change for JRTV (S5_JP_RTV), the SHARKWG decided not to use the most recent year's data for this analysis due to the preliminary nature of the data (i.e., data for all months of the year are unavailable at this time).

4. RESULTS OF INDICATOR-BASED ANALYSIS

4.1 Visual inspection of indicators

The SHARKWG visually examined the annual trends of catch (**Table 2; Figure 1**), indices of relative abundance (**Table 3; Figure 2**) and 5-year moving average (**Figure 3**).

4.1.1 Catch

Overall, the highest catches came from Taiwan (F7-9), Japan (F10-14), and Mexico (F15-16) (**Table 2**). After 2016, the last year of data from the benchmark stock assessment, the catch amount in 2019 reached the 2nd highest value for the last decade (**Figure 1b**). This remarkable increase in catch might be a signal of an increase in fishing pressure, or it may be the result of an increase in population size. For example, the trends of annual catch for four major fleets were not always synchronized with those of CPUE (**Figure A1**). The SHARKWG decided not to describe the stock status based on the increase of recent catch as previous work with indicators for this species (ISC 2015) highlighted the uncertainty of their use when attempting to describe stock status.

Catch number of SFM from F2_US_HI_SS and F4_US_HI_DS indicated a generally increasing trend since 1995. The F5_US_DGN showed a large oscillation in catches from 1975 to 2002, followed by a decline, with the lowest catches recorded in 2015. Estimated SFM catch from F7_TW_LALL_N and F8_TW_LALL_S ranged from 0 MT in 1973 to 156 MT in 2015, and it decreased thereafter, only to increased again to 142 MT in 2019. Annual trends of SFM catches by F9_TW_SMLL were relatively stable over-time with a peak in 2004 (917 MT). The recent catch of SFM for 2017-2019 was stable ranging from 356 to 393 MT. For F10_JPN_SS, the total catches of SFM gradually increased from 1992 to 2007, followed by a decrease until 2011 and thereafter stable around 600 MT. The estimated catches of F11_JPN_DS showed a decrease since 1992. F12_JPN_CST and F14_JPN_OTH had relatively stable catches over time. The total catches of Mexican fishery (F15_MEX_N and F16_MEX_S) had increased since the 1980s and both fisheries showed increaseing catches over time, with catches peaking in 2019 and 2014 for the northern and southern fisheries, respectively. The total catch of SFM in NPO from WCPO (F17_WCPFC) indicated a large oscillation with the highest catch in 2011. The estimated catch number of SFM from F18_IATTC was very small throughout the whole period. The catch amount of SFM from F19_KOR_LL in recent years was near zero.

4.1.2 Indices of relative abundance

Overall, the scaled CPUEs (CPUE of each year relative to average CPUE) indicate a stable and slightly increaseing trend for the major fleets used in the benchmark stock assessment except for S6_JP_OBS (**Table 3; Figure 2**). It should be noted however that the SHARKWG discussed that S6-JP_OBS has limited coverage and as such is a much smaller dataset compared to the major fleets used in the benchmark stock assessment.

The CPUE from S2_US_DS showed a stable trend from 1995 to 2016, followed by an increase in the last three years, while the CPUE from S1_US_SS showed a slow decrease up to 2012, followed by an increase in 2013. The CPUE from S3_TW_LALL showed an inter-annual fluctuation with two peaks (2013-2014 and 2018- 2019). The CPUE from S4_JP_SS indicated an increase until 2011, followed by a stable trend except in 2016. The CPUE from S5_JP_RTV slightly increased with large fluctuations until 2007, thereafter its gradually decreased until 2013, and then sharply increased. The CPUE from S6_JP_OBS showed a flat trend between 2011 and 2016 and slightly decreased after 2016. The CPUE from S7_MX_OBS also showed an interannual variability with three peaks (2009, 2011, and 2019).

4.1.3 Moving average of CPUE

Overall, the moving average of CPUE (**Figure 3**) reflected the trends of annual CPUEs with more smoothing (**Figure 2**). The moving average of CPUE for 5-survey (S1_US_SS, S2_US_DS, S3_TW_LALL, S4_JP_SS, and S5_JP_RTV) showed an increaseing trend throughout the whole period, while the moving average of CPUE for S6_JP_OBS showed a decreaseing trend. The moving average of CPUE for S7_MX_OBS showed a slight decrease up to 2018, followed by an increase in 2019.

4.2 Percent change of annual CPUE

The percent changes of the moving average of CPUE from long term (all years with data) for four major fleets indicated positive values, while the percent change from short term (the most recent 5-years) indicated slightly negative values for S3_TW_LALL and S7_MX_OBS (**Table 4**). These results suggested that the indices of relative abundance for SFM in the NPO had no signal of population decline since the 1990s.

4.3 Conclusions of indicator-based analysis

After conducting the indicator-based analysis as mentioned above, the SHARKWG concluded that there are no obvious signs of major shifts in the tracked indicators which would necessitate a revision to the current stock assessment schedule for SFM. As such, the SHARKWG plans to conduct the next benchmark stock assessment for SFM, on schedule, in 2024.

5. RESEARCH RECOMMENDATIONS

The SHARKWG recommends that threshold values of key indicators (i.e., indices of relative abundance) should be explored to help guide future interim indicator-based analysis in determining when shifts may be needed in the benchmark stock assessments schedule.

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8. TABLES

Table 1. Time series of catch, indices of relative abundance and availability of length frequency data for the indicator-based analysis of shortfin mako in the North Pacific Ocean.

Time series	Symbol	Indicator	Unit	Name	Definition	Length frequency availability
1	F1	Catch	MT	F1_CA_COM	Canada all fishery	
2	F2	Catch	Num.(1000s fish)	F2_US_HI_SS	US Hawaii longline shallow-set	
3	F3	Catch	MT	F3_US_CAL_LL	California longline	
4	F4	Catch	Num.(1000s fish)	F4_US_HI_DS	US Hawaii longline deep-set	
5	F5	Catch	MT	F5_US_DGN	US Drift Gillnet	
6	F6	Catch	Num.(1000s fish)	F6_US_REC	US Recrational	
7	F7	Catch	MT	F7_TW_LALL_N	Taiwan_longline large-scale (North)	(2005-2019)
8	F8	Catch	MT	F8_TW_LALL_S	Taiwan_longline large-scale (South)	
9	F9	Catch	MT	F9_TW_SMLL	Taiwan longline small-scale	(1989-2019)
10	F10	Catch	MT	F10_JPN_SS	Japan offshore and distant water longline shallow-set	
11	F11	Catch	MT	F11_JPN_DS	Japan offshore and distant water longline deep-set	
12	F12	Catch	MT	F12_JPN_CST	Japan coastal longline	
13	F13	Catch	MT	F13_JPN_DFN	Japan drift gillnet	
14	F14	Catch	MT	F14_JPN_OTH	Japan trap and others	
15	F15	Catch	MT	F15_MEX_N	Mexico all fishery (North)	
16	F16	Catch	MT	F16_MEX_S	Mexico all fishery (South)	
17	F17	Catch	MT	F17_WCPFC	WCPFC observer other longlines	
18	F18	Catch	Num.(1000s fish)	F18_IATTC	IATTC purse seine	
19	F19	Catch	MT	F19_KOR_LL	Korea longline fishery	
20	S1	CPUE	Num.	S1_US_SS	INDEX US Hawaii longline shallow-set	
21	S2	CPUE	Num.	S2_US_DS	INDEX US Hawaii longline deep-set	
22	S3	CPUE	Num.	S3_TW_LALL	INDEX Taiwan_longline large-scale	
23	S4	CPUE	Num.	S4_JP_SS	INDEX Japan longline shallow-set	
24	S5	CPUE	Num.	S5_JP_RTV	INDEX Japan research and training vessel	
25	S6	CPUE	Num.	S6_JP_OBS	INDEX Japan observer for longline	(2014-2019)
26	S7	CPUE	Num.	S7_MX_OBS	INDEX Mexico observer for longline	

Table 2. Catch time series of shortfin mako in the North Pacific Ocean from 1957 to 2019 assigned to "fleets" F1 – F19 as defined in Table 1. Each column indicates the fleet's catch either in numbers (1000s of fish) or metric tons (MT). See table 1 for catch unit.

Year	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19
1957	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1958	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1959	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1960	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1961	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1962	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1963	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1964	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1965	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1966	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1967	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1968	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1969	0	0.0	0	0.0	1	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1970	0	0.0	0	0.0	1	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1971	0	0.0	0	0.0	4	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1972	0	0.0	0	0.0	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1973	0	0.0	0	0.0	1	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0	0
1974	0	0.0	0	0.0	5	0.0	0	10	0	0	0	0	0	0	0	0	0	0.1	0
1975	0	0.0	0	0.0	7	0.0	0	15	396	721	232	75	1329	0	0	0	0	0.1	0
1976	0	0.0	0	0.0	1	0.0	0	0	443	1002	433	126	1329	0	66	7	0	0.1	0
1977	0	0.0	1	0.0	12	0.0	3	2	431	1351	588	103	1329	0	64	8	0	0.1	0
1978	0	0.0	2	0.0	17	0.0	2	4	454	1097	550	128	1329	0	92	11	0	0.1	0
1979	0	0.0	10	0.0	13	0.0	0	1	532	1200	774	123	1329	0	43	21	0	0.1	0
1980	0	0.0	14	0.0	91	2.7	0	3	551	1144	918	106	1329	0	51	14	0	0.1	0
1981	0	0.0	19	0.0	168	13.0	0	3	471	1013	1076	106	4142	0	38	19	0	0.1	0
1982	0	0.0	6	0.0	354	1.5	0	0	517	637	774	85	4142	0	61	15	0	0.1	0
1983	0	0.0	1	0.0	223	1.1	0	0	456	510	842	53	4064	0	58	10	0	0.0	0
1984	0	0.0	2	0.0	162	2.6	0	0	410	397	836	109	3810	0	40	10	0	0.0	0
1985	0	0.0	0	0.0	153	9.3	0	8	457	352	769	114	3607	0	35	7	0	0.0	0
1986	0	0.0	1	0.0	319	4.8	0	10	384	416	565	101	3674	0	57	29	0	0.0	0
1987	0	0.0	4	0.0	410	21.9	0	4	288	333	486	104	3655	0	177	19	0	0.0	0
1988	0	0.0	156	0.0	174	14.5	0	1	300	299	645	94	3595	0	231	16	0	0.1	0
1989	0	0.0	5	0.0	258	6.1	0	4	328	274	747	86	5007	0	114	20	0	0.1	0
1990	0	0.0	15	0.0	368	6.3	0	16	365	257	512	88	2630	0	257	30	0	0.0	0
1991	0	0.0	23	0.0	201	6.2	0	17	412	333	505	86	2630	0	198	30	0	0.0	0
1992	0	0.0	2	0.0	144	6.2	0	6	443	344	521	90	1639	0	350	26	0	0.0	0
1993	0	0.0	1	0.0	125	3.9	0	4	338	431	839	86	139	0	354	89	0	0.1	0
1994	0	0.0	21	0.0	111	13.6	0	1	262	374	546	69	123	21	274	61	0	0.0	0
1995	0	0.2	0	0.6	91	5.5	84	7	268	438	433	65	103	15	276	58	0	0.0	0
1996	0	0.1	0	0.3	94	2.2	36	3	707	454	303	399	101	17	337	76	0	0.0	0
1997	0	0.1	0	0.3	133	5.2	23	13	390	440	381	206	127	16	328	73	0	0.1	0
1998	0	0.1	0	0.4	99	1.9	31	10	325	472	394	21	130	13	332	56	0	0.0	0
1999	0	0.1	0	1.0	58	1.2	76	9	592	527	586	219	176	14	353	85	0	0.0	0
2000	0	0.3	0	1.0	75	2.4	56	24	498	621	376	104	156	15	431	108	0	0.0	0
2001	0	0.0	0	1.1	41	5.4	21	62	543	514	430	210	156	15	422	70	0	0.0	0
2002	0	0.0	0	1.9	82	5.8	25	88	592	456	397	120	122	5	392	96	0	0.0	0
2003	0	0.0	0	2.0	68	4.0	31	42	782	518	429	19	229	6	348	124	1	0.0	0
2004	0	0.1	0	1.7	53	3.3	64	57	917	576	354	26	134	1	530	334	13	0.0	0
2005	0	1.0	0	2.1	33	1.4	36	39	418	677	291	61	155	43	388	220	6	0.1	0
2006	0	0.6	0	2.3	45	1.7	99	20	444	776	277	10	178	6	380	260	13	0.2	0
2007	0	0.8	0	2.4	43	0.8	57	16	525	874	270	43	244	15	344	345	11	0.1	0
2008	0	1.0	0	2.7	32	0.6	12	18	334	686	213	121	212	14	400	209	9	0.2	0
2009	0	0.8	0	2.9	30	0.7	10	16	316	770	125	342	294	1	438	214	12	0.0	0
2010	0	0.9	0	3.0	21	0.4	12	13	518	685	151	151	272	20	550	211	100	0.1	0
2011	0	0.6	0	2.6	17	0.4	36	35	489	545	141	48	163	11	520	238	247	0.1	0
2012	0	0.4	0	2.5	22	0.9	63	6	392	568	142	10	229	2	488	226	208	0.1	0
2013	0	0.4	0	3.4	29	0.9	116	9	320	610	99	47	345	9	478	234	51	0.0	9
2014	0	0.6	0	3.6	16	0.6	98	6	345	609	160	7	263	3	925	542	76	0.0	8
2015	0	0.8	0	4.3	13	0.2	147	9	440	605	242	2	334	11	1253	400	72	0.0	2
2016	0	1.0	0	4.0	26	0.2	145	5	360	784	182	32	446	16	401	259	73	0.0	0
2017	0	1.1	0	4.4			37	3	393	564	99	23	271	10	672	264	117	0.0	0
2018	0	0.3	0	4.9			80	7	370	638	186	19	223	28	780	218	110	0.0	0
2019	0	0.2	0	4.9			132	10	356	571	215	16	195	2	1256	539	82	0.0	0

Table 3. Time series of indices of relative abundance from 1992 to 2019 (CPUE of each year relative to average CPUE) for shortfin mako in the North Pacific Ocean. The available abundance indices were assigned to "survey" S1-S7 (see Table 1) for use in the indicator-based analysis.

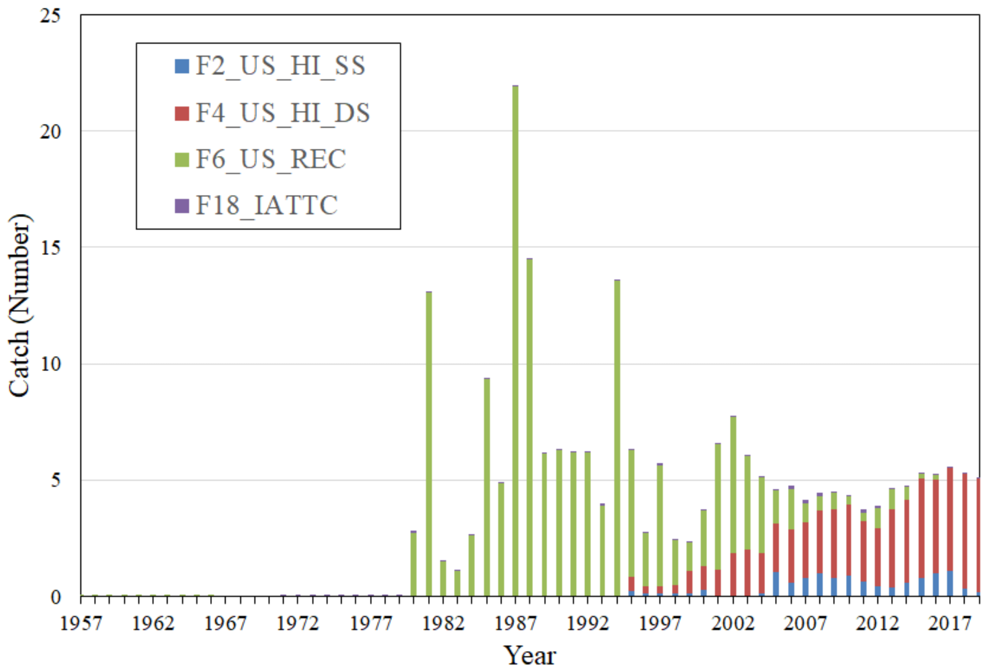
Year	S1	S2	S3	S4	S5	S6	S7
1992					0.61		
1993					0.97		
1994				0.35	0.92		
1995		1.47		0.43	0.75		
1996		0.59		0.49	0.61		
1997		0.71		0.49	0.83		
1998		0.51		0.51	0.86		
1999		1.11		0.58	1.15		
2000		0.60		0.64	0.83		
2001		0.65		0.53	0.91		
2002		0.78		0.48	0.94		
2003		0.72		0.67	1.04		
2004		0.59		0.68	1.01		
2005	1.03	0.80	0.88	0.94	0.93		
2006	1.17	0.83	1.16	1.06	0.95		1.25
2007	0.95	0.85	0.80	1.06	1.17		0.66
2008	0.91	1.13	0.55	0.94	1.00		0.47
2009	0.84	1.03	0.79	1.22	0.76		1.41
2010	0.95	0.82	0.42	1.10	0.89		0.94
2011	0.79	0.90	0.94	1.57	0.68	1.39	0.98
2012	0.76	0.78	0.61	1.42	0.81	1.39	1.74
2013	0.97	1.04	1.75	1.35	0.59	1.42	0.78
2014	1.04	1.01	1.94	1.45	0.91	0.69	0.88
2015	1.00	1.05	0.69	1.40	1.52	0.99	0.80
2016	1.08	0.99	0.72	2.16	1.55	0.96	0.86
2017	1.25	1.10	0.63	1.40	0.95	0.84	0.55
2018	1.12	1.27	1.48	1.54	1.71	0.74	0.47
2019	1.14	1.40	1.63	1.56	2.16	0.57	2.21

Table 4. Percent change of moving average of CPUE for four major fleets (S1, S3, S5 and S7) used in the benchmark stock assessment in 2018. Moving averages were calculated using the mean value of CPUE for five years. The percentage indicates the positive and negative change in the moving average of CPUE between the start and end years from long term (all years with data) and short term (the most recent 5 years). The last year of S5 was removed from calculations due to its preliminary nature. S1_US_SS (US Hawaii longline shallow-set), S3_TW_LALL (Taiwan longline large-scale), S5_JP_RTV (Japan research and training vessels), and S7_MX_OBS (Mexico observer for longline)

Period	**S1**	**S3**	**S5**	**S7**
Long term (all years with data)	16%	39%	93%	10%
Short term (the most recent 5 years)	23%	-13%	47%	-5%

9. FIGURES

(a)



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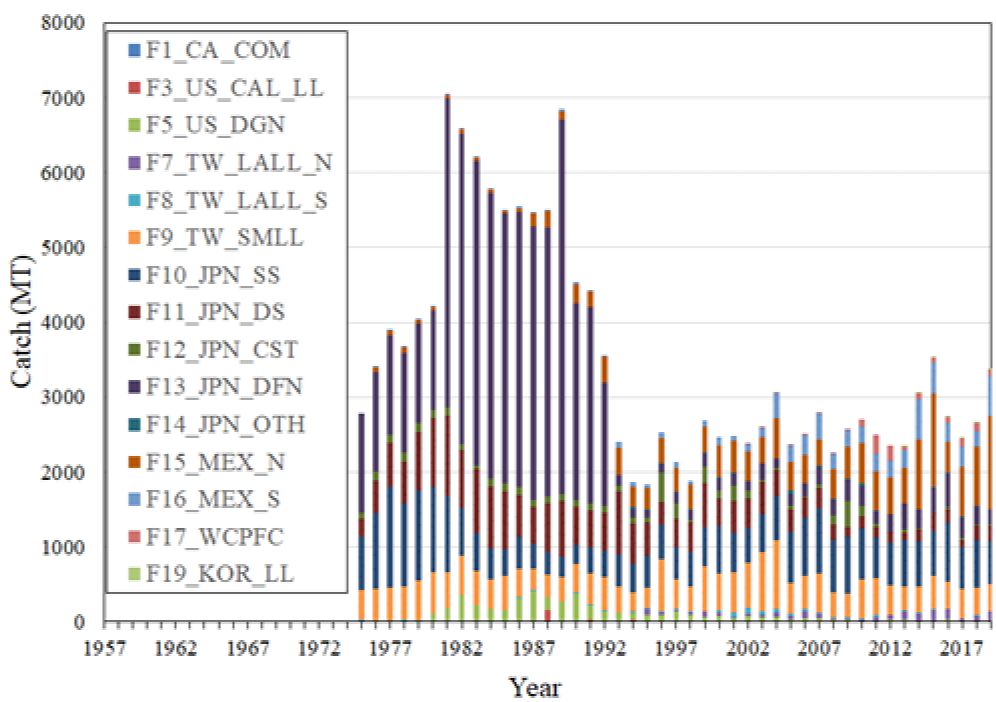
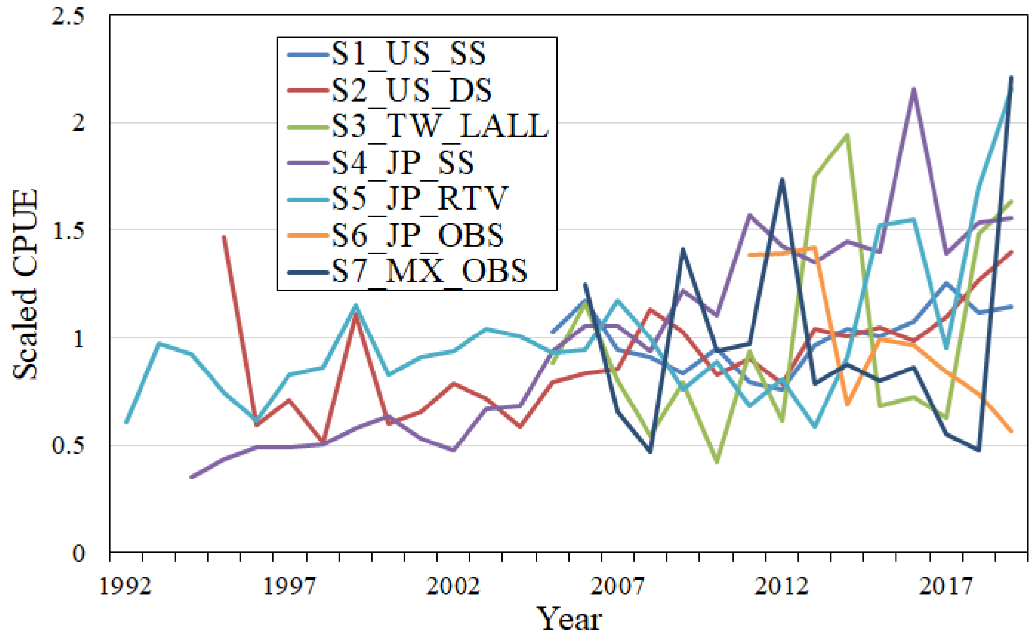


Figure 1. Annual catches of shortfin mako in the North Pacific Ocean by fishery (fleet) from 1954 to 2019 either in (a) numbers (1000s of fish) or (b) metric tons (MT). See table 1 for full fleet names.

(a)



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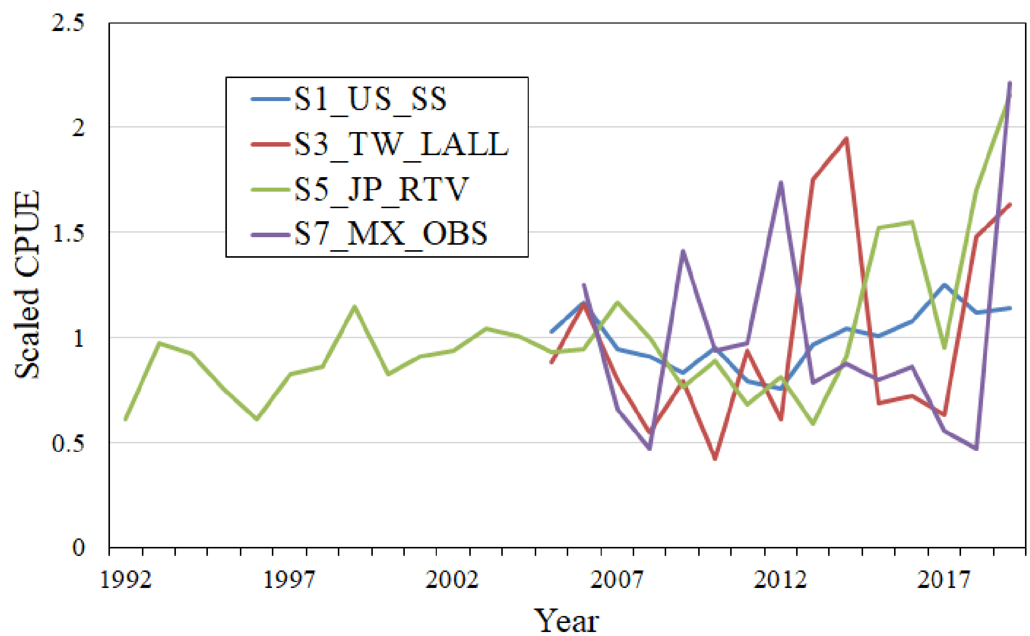
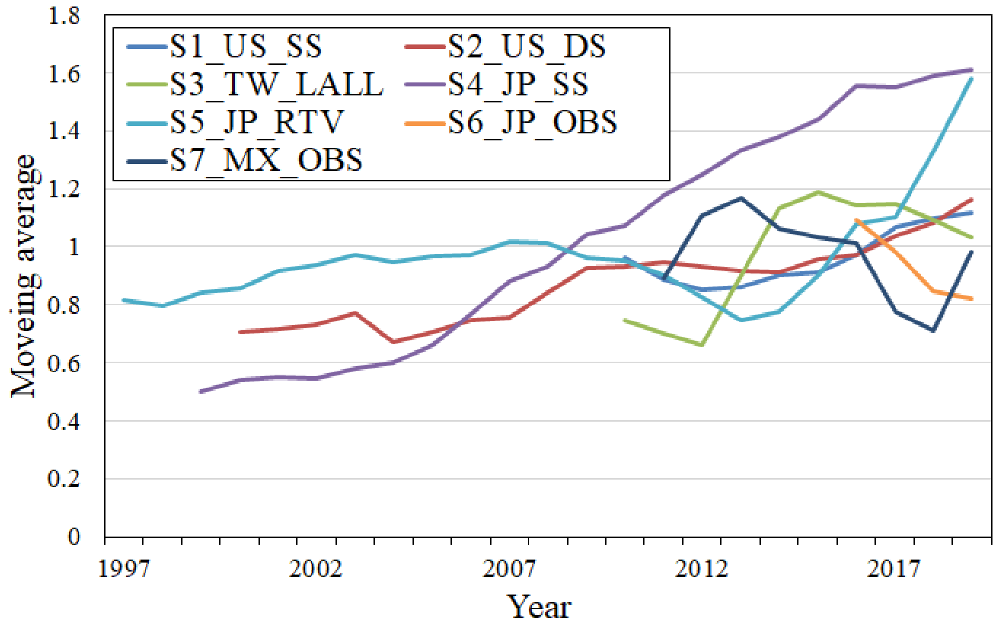


Figure 2. Annual indices of relative abundance of shortfin mako in the North Pacific Ocean from 1992 to 2019 (CPUE of each year relative to average CPUE) for (a) all fleets (S1-S7) available in the indicator-based analysis and (b) four major fleets (S1, S3, S5 and S7) used in the previous benchmark stock assessment in 2018. See Table 1 for more information on survey names.

(a)



(b)

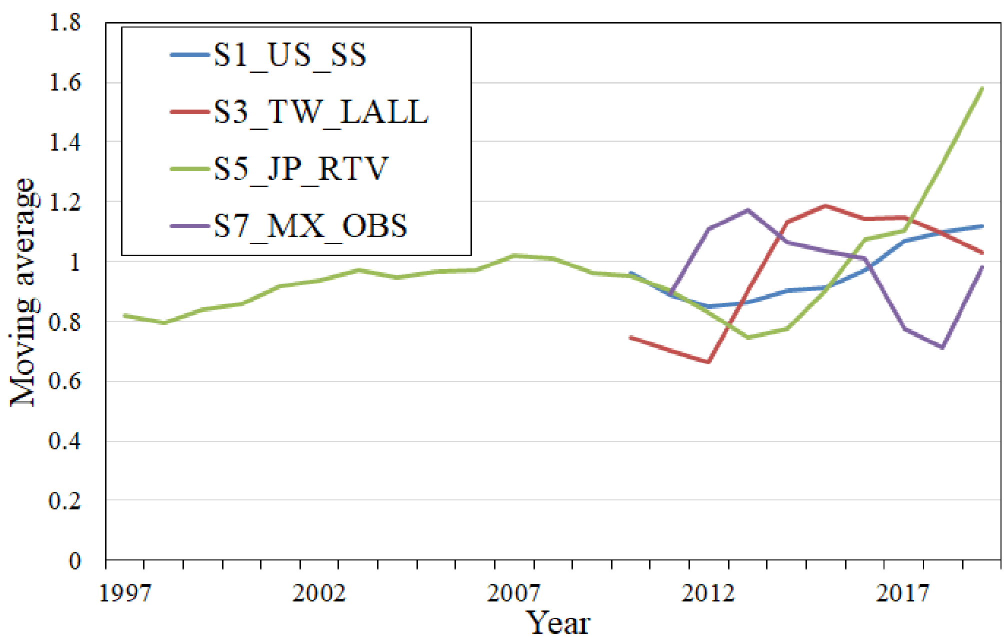


Figure 3. Annual moving average (average CPUE of 5-year) of indices of relative abundance of shortfin mako in the North Pacific Ocean between 1997 and 2019 for (a) all fleets (S1-S7) available in the indicator-based analysis and (b) four major fleets (S1, S3, S5 and S7) used in the base case previous benchmark stock assessment in 2018. See Table 1 for more information on survey names.

10. APPENDIX FIGURES

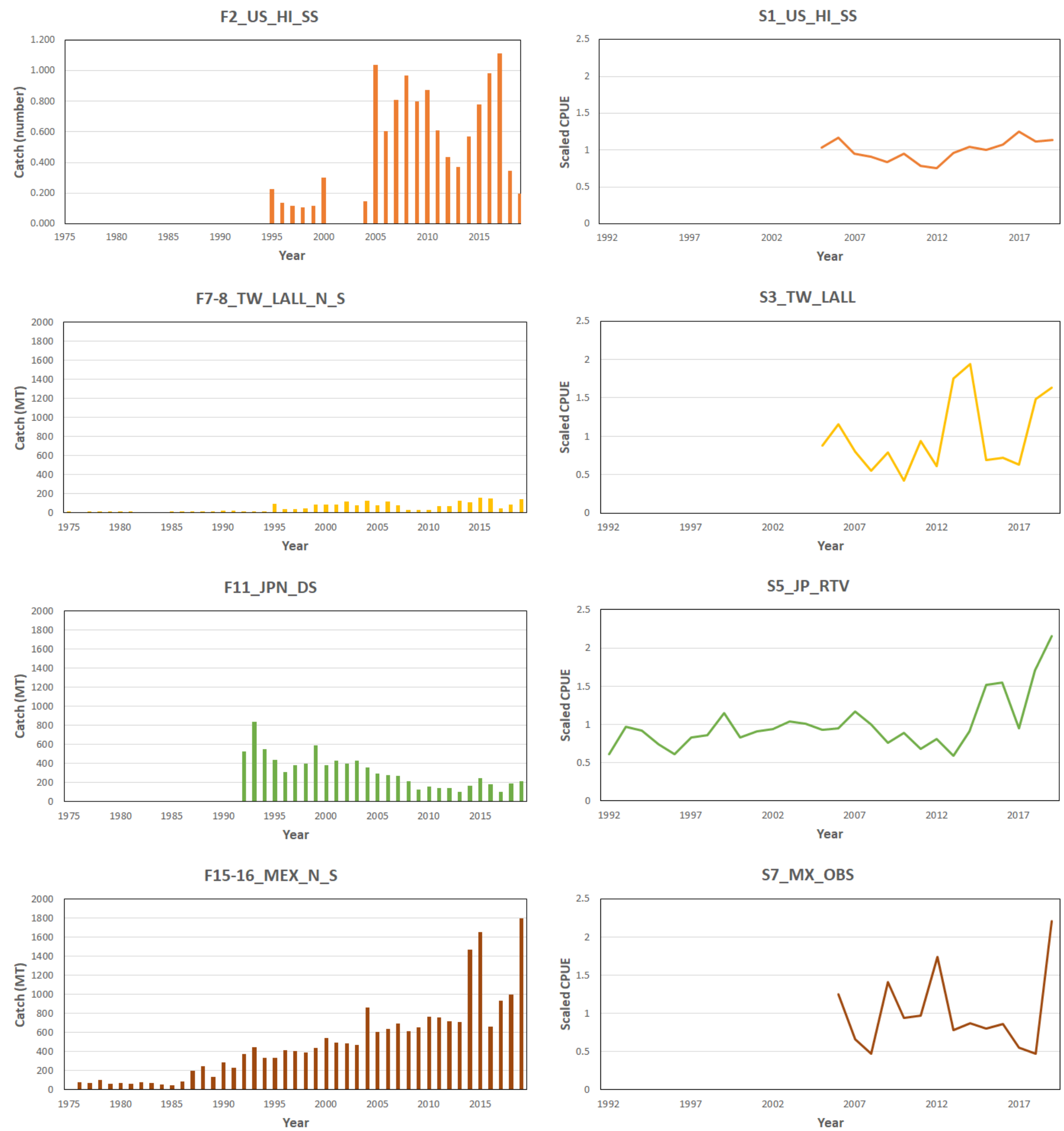
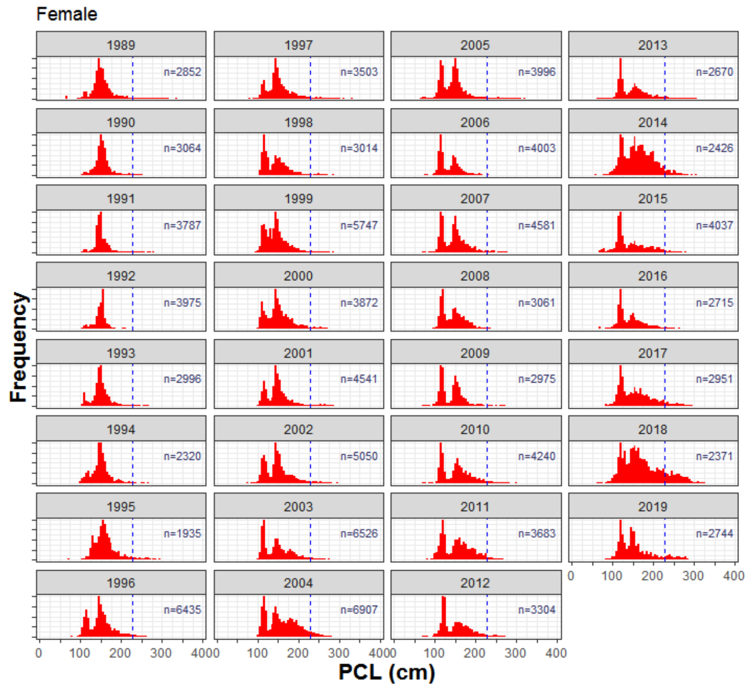


Figure A1. Annual catches (metric tons; MT) and indices of relative abundance (CPUE of each year relative to average CPUE) of shortfin mako in the North Pacific Ocean for four major fleets (F2, F7-8, F11 and F15-16 for catch and S1, S3, S5 and S7 for survey) used in the previous benchmark stock assessment in 2018. See table 1 for the reference of the catch and survey names.

(a)



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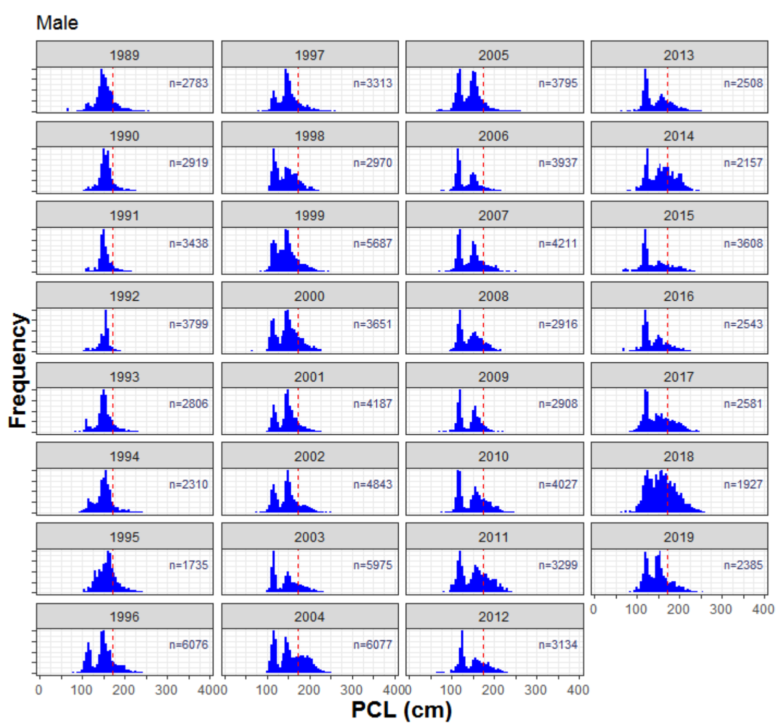

Figure A2. Annual length frequency of (a) female and (b) male shortfin mako caught by Taiwan small-scale tuna longline (F9) from 1989 to 2019. PCL is pre-caudal length (cm). The red-broken horizontal line denotes estimated length at 50% maturity.

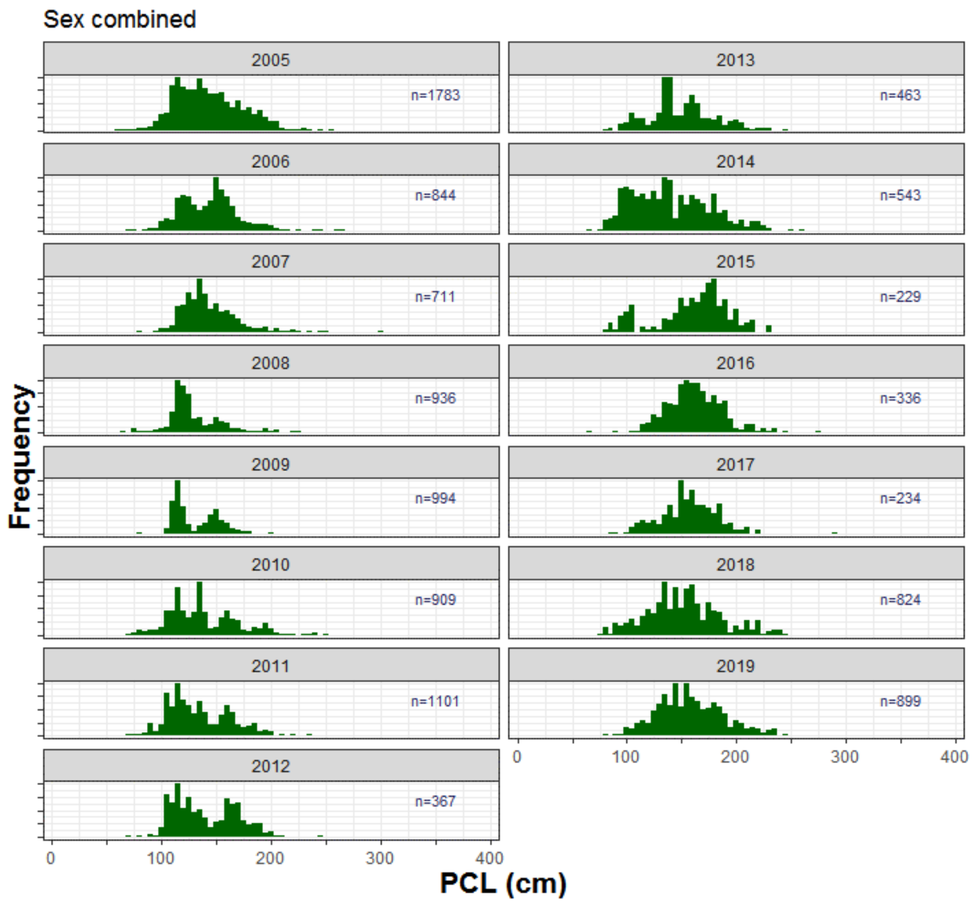

Figure A3. Annual length frequency of sex-combined shortfin mako caught by Taiwan large-scale tuna longline (F7-8) from 2005 to 2019. PCL is pre-caudal length (cm).

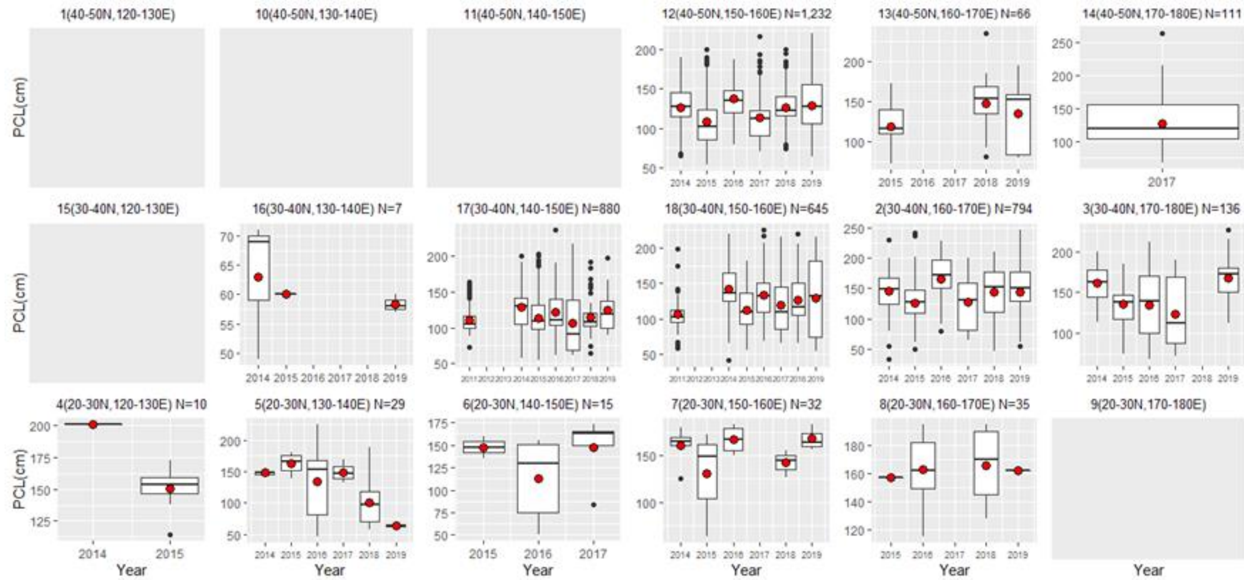

Figure A4. Annual median and quartile percentiles of catch at size of shortfin mako by 10 × 10 degrees in the northwestern Pacific Ocean from 2014 to 2019. The data was collected by Japanese observer and the shortfin makos were mainly caught by Japanese shallow-set longline (F10). Red circle denotes mean PCL (pre-caudal length; cm).