Stock Synthesis settings of data file for the stock assessment of blue shark in the North Pacific [1]

Mikihiko Kai[2], Steven L. H. Teo[3], Nicholas Ducharme-Barth[4], Yasuko Semba[2], Felipe Carvalho[4]

[2] Fisheries Resources Institute, Japan Fisheries and Education Agency,
5-7-1 Orido, Shimizu, Shizuoka, 424-8633, Japan
[3] NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, California USA
[4] NOAA Fisheries, Pacific Islands Fisheries Science Center, Honolulu, Hawaii USA

Email: kaim@affrc.go.jp

[1] Working document submitted to the ISC Shark Working Group Workshop, 19-22,26-28 March 2022, Web-meeting. **Document not to be cited without author's permission.**

Summary
This working paper summarizes the Stock Synthesis (SS3) dataset used in the stock assessment for blue sharks in the North Pacific Ocean in 2022. The SS3 dataset is available for 1971-2020 and is comprised of catch, CPUE and length composition data. These data were updated through 2019/2020 using newly available statistics for each ISC member, non-member countries and relevant international organizations. Some data used in the previous stock assessment in 2017 were also reconfigured and revised.

Introduction
Blue shark (*Prionace glauca*) is widely distributed from tropical to temperate waters around the globe and is the most abundant species of oceanic pelagic shark (Nakano and Steven, 2008). The stock assessment of blue shark in the North Pacific Ocean was conducted in 2017 by the ISC SHARK working group (WG) (ISC, 2017) using the Stock Synthesis (SS3) modeling platform (Method and Wetzel, 2013) and data from 1971 to 2015 (ISC, 2017). The SS dataset (i.e., data file) comprised of annual catch, annual abundance indices (CPUE; catch per unit effort) and length composition data.

The objective of this working paper is to summarize the SS3 dataset used in the stock assessment for blue sharks in the North Pacific Ocean in 2022. In addition, some data issues raised during model development are discussed.

Update and reconfiguration of the data file
The SS data file was updated using newly available annual catch, annual CPUEs, annual length composition data provided by ISC member countries, non-member countries, and relevant international organizations at the data preparatory meeting held in November 2021 (ISC, 2021). Almost all the data were updated through 2019/2020, and some data used in the previous stock assessment in 2017 were reconfigured and revised.

Annual catch
Annual catch data includes catches from 20 fleets of 7 countries (Canada, China, Chinese-Taipei/Taiwan, Japan, Mexico, the Republic of Korea, and US) and two international organizations (IATTC and SPC/Non-ISC countries) (**Table 1**). All the catch data were in whole weight (metric tons) except for three fleets with catch in 1000s of fish; small-mesh (high seas) squid driftnet fishery (F11: SM_MESH), Hawaii deep-set longline fishery (F17: US_HW_DP), and Hawaii shallow-set longline fishery (F18: US_HW_SH). The fleet definitions were changed from the 2017 assessment by separating the Japanese large-mesh driftnet fishery into two fleets (F8: JPN_LG_MESH_EARLY; F9: JPN_LG_MESH_LATE) and the Hawaii longline fleet into two fleets (i.e., F17 and F18) compared to the previous stock assessment (ISC 2017). Japan separated the large-mesh driftnet fishery into two fleets (F8 and F9) because the operation area of this fishery had changed from the high seas to coastal and offshore areas within the exclusive economic zone (EEZ) of Japan after the ban of the high-seas driftnet fishery in 1993 (Ito et al., 1993), and reconstructed the catch for the early period for 1973-1993 (F8) (Fujinami et al., 2021a). The separation of the Hawaii longline fleet into shallow- and deep- sets was motivated by the different target species of both fleets, with different operation time/area and gear configurations that resulted in the catch of different sizes of blue sharks. The US also reconstructed the catch of these longline fleets (F17 and F18) for 1992-2020 using a machine learning approach and rescaled the1971-1991 catch based on the historical bigeye tuna catch using a catch-ratio calculated from the recent period (Duchrme-Barth et al., 2021, 2022). For the annual catches of other fleets, Mexico reconstructed the catch for 1980-1993 in addition to the update of the recent catch for 2016-2020 (F1: MEX), Japan reconstructed the catch of four longline fleets (F4: JPN_KK_SH, F5: JPN_KK_DP, F6: JPN_ENY_SH, and F7: JPN_ENY_DP) for 1994-2020 and one coastal and other fleet for 1994-2019 (F10: JPN_CST_OTH). The annual catch of high seas squid driftnet fisheries for 1979-1992 (F11) was

reconstructed using the estimated catch of three countries; Japan (Fujinami et al., 2021b), the Republic of Korea and Chinese-Taipei (Kai et al., 2022a). The Republic of Korea reconstructed the catch of longline fishery from 1982 to 2020 (F13: KOREA). The catch of NON-ISC member countries (F14: NON-ISC) for 1997-2020 was reconstructed using the observed CPUE of longline fishery and reported total fishing effort in addition to the small catch of purse seine fishery (Kai et al., 2022b). The catches in 1995 and 1996 were replaced by the catch in 1997 to complement a lack of catch data for the periods. The catches of the other fleets were merely updated until 2020.

Annual CPUE

Annual CPUE data includes data from 10 fleets (**Table 2**) of 4 countries (Chinese-Taipei, Japan, Mexico, and US) and an international organization (SPC). In the previous stock assessment (ISC, 2017), 2 fleets (S5: JPN_EARLY and S6: JPN_LATE) were used as the base-case model and four alternative abundance indices (S1: HW_DP, S3: TAIW_LG, S9: SPC_OBS_TROPIC, and S10: MEX) for the late period were used in the sensitivity analysis. Since the issue of reporting rate post-2000 was resolved, the CPUE of Japanese research and training vessels (S7: JPN_RTV) was newly added as an alternative abundance index (Kai, 2021b). The annual CPUEs for S1 and S3 were normalized by the mean CPUE. The coefficients of variation (CVs) for all CPUEs were updated using the annual CV estimated in the CPUE standardization. Since there was no information about the CV of S9 (Rice and Harley, 2014), the WG calculated the CV for this fleet using the standard error (SE) and the mean value of standardized CPUE.

Annual length composition data

Annual length composition data includes data from 13 fleets (**Table 3**) of 5 countries (China, Chinese-Taipei, Japan, Mexico and US) and an international organization (SPC). China updated the size data until 2020 and also provided newly available size data from 1993 to 2008 (F3: CHINA). Japan updated the size data of three longline fleets (F4, F5 and F7) until 2020 (Semba, 2022) and large-mesh driftnet fleets (F8 and F9) until 2019. To align the fleet definition with catch data, Japan removed the size data of F5 for 2009-2015 from the previous data file and added those size data to F7. Japan also added newly available size data of F8 for 1979-1983, and F9 for 1994, 1996, and 1998 using observer and research survey data (Semba, 2021). Kai et al. (2022c) digitally extracted the length composition data in total length of blue sharks sampled by Canadian observers in the Japanese flying squid driftnet fishery in 1991 from a figure in McKinnell and Seki (1998). The size data was used as a newly available length composition data for F11. SPC provided newly available size data of longline fleets that mainly operated in the sub-tropical and tropical areas in the North Pacific Ocean for 1994-2020 (F14). The size data of Guam and Indonesia were removed from the size data of NON-ISC member countries. The US separated the size data of the Hawaii longline fleet into two fleets (F17 and F18) in association with the division of the catch and removed the size data for 1994-2002 from the previous size data. Chinese-Taipei provided newly available size data of small-scale longline fleets for 2012-2020 (F20: TAIW_SM) (Liu et al., 2021b).

Fleet-specific length composition data had 5 cm bins from 5 to 300 cm pre-caudal length (PCL) for each year and sex (male and female) except for F11. The size bin interval for F11 was set to 8.6 cm PCL between 22.3 and 160.9 cm PCL and the intervals of the remaining bins of both sides was set to 5 cm PCL between 5 and 175 cm PCL. The total number of samples by year was used as the input sample size for SS3. Since the birth size of blue shark is around 35 cm PCL (Fujinami et al. 2017), the data of blue shark less than 30 cm PCL (25 length bin) was removed from the size data.

Results

The data coverage of annual catch, annual CPUE and annual length composition data used in the stock assessment in 2022 were summarized in **Fig. 1**. The annual catch data is available from 1971 to 2020. The annual CPUE data is available from 1976 to 2020. The annual length composition data is available from 1979 to 2020. The length composition data for F5 and F11 was only available for five- and one-year, respectively. The area coverage of all fleets used in the stock assessment is shown in **Fig 2**. This map indicates the approximate operation area of all fleets and covers almost the entire distribution of blue shark in the North Pacific Ocean.

Annual catch by fleet indicated that most catches were made by F4, F7 and F20 throughout the assessment period (**Fig. 3**). The annual trends of catch increased in the1970s, reached a peak in 1981 and then decreased until 1992. After that, the catch increased until 2000 and gradually decreased until recent years. In the 1980s and the early 1990s, the driftnet fisheries (F8 and F11) had large amounts of catch. The catch of the Mexican fleet has been increasing since 1990 and the proportion of the catch in recent years to total catch has increased substantially. The annual catch of blue shark caught by ISC member/non-member countries indicated that most catches were by fleets from Japan and Chinese-Taipei (**Fig. 3**). The annual catch from the previous assessment had a similar trend in total catch to this assessment.

Annual CPUE of S5 was the only abundance index for the early period (**Fig. 4**). The CPUE indicated a declining trend until 1989 and then increased until 1993. The other six CPUEs were considered as abundance indices for the late period (**Fig. 4**). However, only two CPUE indices (S6 and S7) were available for the entire late period from 1994 to 2020. The CPUE trend of S6 was relatively stable throughout the period, while the CPUE trend of S7 was mixed and went down from 1994 to 2008 before increasing until 2020. The CPUE of S1 indicated a similar trend to that of S7, though the length of CPUE for S1 was shorter than S7. The CPUE of S3 indicated an increasing trend, whereas the CPUE of S10 indicated a slightly decreasing trend. The CPUE of S9 indicated a sharp increase until 1998 and then decreased until 2009.

Sex-specific length composition data indicated that the proportion of males tended to be higher than that of females for most of the fleets (e.g., F1, F4, F5, F7, F9, F15 and F20) (**Fig. 5**). The wider size ranges were observed for F8, F18 and F19, but the size range of F19 was clearly skewed to larger sizes compared to the other two fleets. The size range of the remaining fleets were mostly between 100 to 200 cm PCL (precaudal length) except for F15.

Sex-combined length composition data of F11 indicated a catch of small-sized blue shark (**Fig. 6**).

Discussions

This working paper summarized the Stock Synthesis (SS) data set used in the stock assessment for blue sharks in the North Pacific Ocean in 2022. We consider that this updated and reconfigured data file with revisions of annual catch, annual CPUE and annual length composition data by 2019/2020 represents the best available information for the stock assessment.

The revisions of annual catch for driftnet fisheries (i.e., F8, F9 and F11) and longline fisheries (i.e., F1, F4-F7, F14, F17, F18, F19 and F20) may improve the estimation of annual fishing mortality rates.

The updated annual CPUEs for the late time period may also contribute to improved estimations of trends in the annual abundance. The annual CPUE of the Japanese research and training vessel (S7) was newly available for the stock assessment. Although the annual trend of the CPUE for S7 is inconsistent with that of Japanese offshore and distant -water shallow longline (S6), the CPUE trend is consistent with those of Hawaii deep-set longline (S1) and Taiwanese large-scale longline (S3) (**Fig. 4**). We should therefore consider the possibility of the composite CPUE of these three as an alternative abundance index in the stock assessment since the nature of blue shark targeting in the Japanese offshore and distant -water shallow longline could result in un-modeled hyperstability. We note that in terms of geographic scope, the S1 and S7 indices are developed mainly from fishing effort in waters around the islands of Hawaii. Despite the more restricted spatial coverage, the trends of S1 and S7 are consistent with the S3 index, which covers a broad geographical range. The S3 index, however, is shorter compared to the S6 index. The CPUE of the

Mexican Pacific longline (S10) contains useful information about the annual trend of blue sharks in the eastern Pacific Ocean. However, the operation area is limited to the coastal and offshore waters of Mexico. The CPUE of SPC (S9) comes from a limited operation area (sub-tropical and tropical areas) and there is no data after 2009. The issues of these data conflicts in the late period could be considered in the model specification through the variance adjustment of CPUE or CV of CPUE. If multiple competing indices are fit to simultaneously, the CV of CPUE should be large for the data of non-representative CPUE time series.

The update/revision of annual length composition data may also contribute to improved estimations of age/length compositions of catch and abundance. The primary issues of length composition data are: 1) the small annual sample size for some fleets such as China (F3), NON-ISC (F14), US_HW_DP (F17) and US_HW_SH (F18); 2) the limited time period of annual length composition data such as JPN_KK_DP (F5), JPN_LG_MESH_EARLY (F8) and SM_MESH (F11); 3) the wide ranges of length composition data such as JPN_LG_MESH_EARLY (F8), US_HW_SH (F18) and TAIW_LG (F19). These issues should be considered in the model specification/conditioning and model diagnostics of the SS3 model. For example, F5 has only recent five years' length composition data while annual catch has a long time series from 1975 to 2020, so the limited number of data periods could have a large impact on the retrospective analysis.

References

Duchrme-Barth, N., Kinney, M., Carvalho, F. 2021. 2021 ISC North Pacific blue shark stock assessment: US domestic fishery data updates: Catch, CPUE and length frequency. ISC/21/SHARKWG-2/P-01.

Duchrme-Barth, N., Siders, Z., Ahrens, R. 2022. Blue shark catch and CPUE for the US Hawaii longline fleet. ISC/22/SHARKWG-2/02.

Fernández-Méndez, J.I., Castillo-Géniz, J.L., Ramírez-Soberón, G., Haro-Ávalos, H., González-Ania, L.V. 2021. Update on standardized catch rates for blue shark (*Prionace glauca*) in the 2006-2020 Mexican Pacific longline fishery based upon a shark scientific observer program. ISC/21/SHARKWG-2/15.

Fujinami, Y., Kanaiwa, M., Kai, M. 2021a. Blue shark catches in the Japanese large-mesh driftnet fishery in the North Pacific Ocean from 1974 to 1993. ISC/21/SHARKWG-2/08.

Fujinami, Y., Kanaiwa, M., Kai, M. 2021b. Estimation of annual catch for blue shark caught by Japanese high seas squid driftnet fishery in the North Pacific Ocean from 1981 to 1992. ISC/21/SHARKWG-2/07.

Fujinami, Y., Semba, Y., Okamoto, H., Ohshimo, S., Tanaka, S., 2017. Reproductive biology of the blue shark (*Prionace glauca*) in the western North Pacific Ocean. Mar. Freshw. Res. 68, 2018–2027

Hiraoka, Y., Kanaiwa, M., Yokawa, K., 2013a. Re-estimation of abundance indices and catch amount for blue shark in the North Pacific. ISC/13/SHARKWG-1/03.

Hiraoka, Y., Kanaiwa, M., Yokawa, K., 2013b. Summary of estimation process of abundance indices for blue shark in the North Pacific. ISC/13/SHARKWG-2/02.

ISC. 2017. Stock assessment and future projections of blue shark in the North Pacific Ocean through 2015. ISC Plenary report and documents. Annex 13.

ISC. 2021. http://isc.fra.go.jp/reports/shark/shark_2021_2.html

Ito, J., Shaw, W., and Burger, R.L., 1993. Symposium on biology, distribution and stock assessment of species caught in the High Seas driftnet fisheries in the North Pacific Ocean held by the standing committee on biology and research at Tokyo, Japan in 1991. Vancouver, Canada.

Kai, M. 2021a. Spatio-temporal model for CPUE standardization: Application to blue shark caught by Japanese offshore and distant water shallow-set longliner in the western North Pacific. ISC/21/SHARKWG-2/01.

Kai, M. 2021b. Spatio-temporal model for CPUE standardization: Application to blue shark caught by longline of Japanese research and training vessels in the western and central North Pacific. ISC/21/SHARKWG-2/03.

Kai, M. 2021c. Update of Japanese annual catches for blue shark caught by Japanese offshore and distant water longliner in the North Pacific Ocean from 1994 to 2020. ISC/21/SHARKWG-2/04.

Kai, M., Yano, T. 2021. Updated annual catches of blue shark caught by Japanese coastal fisheries in the North Pacific Ocean from 1994 to 2019. ISC/21/SHARKWG-2/05.

Kai, M., Ducharme-Barth, N., Fujinami, Y., Teo, S. 2022a. Reconstruction of catch for blue sharks caught by high seas squid driftnet fishery of Republic of Korea and Chinese Taipei in the North Pacific from 1980 to 1992. ISC/22/SHARKWG-2/01.

Kai, M., Semba, Y., Ducharme-Barth, N., Rice, J., Williams, P. 2022b. Reconstruction of catch for blue sharks caught by non-ISC countries in the western and central North Pacific from 1997 to 2020. ISC/22/SHARKWG-1/01.

Kai, M., Ducharme-Barth, N., Semba, Y., Teo, S. 2022c. Length frequency of blue sharks sampled by Canadian observers in the Japanese flying squid driftnet fishery. ISC/22/SHARKWG-2/02.

King, J.R. 2021. Updated (2020) blue Shark (*Prionace glauca*) bycatch statistics in Canadian fisheries. ISC/21/SHARKWG-2/06.

Kohin, S., Sippel, T., Carvalho, F. 2016. Catch and size of blue sharks caught in U.S. fisheries in the North Pacific. ISC/16/SHARKWG-2/15.

Lee, S.I., Kim, D.N., Lee, M.K., Kwon, Y. 2019. Estimation of blue shark catch by Korean tuna longline fishery in the North Pacific Ocean. ISC/19/SHARKWG-1/08.

Liu, K.M., Su, K.Y., Tsai, W.P., Chin, C.P. 2021a. Size and spatial distribution of the blue shark, Prionace glauca, caught by the Taiwanese large-scale longline fishery in the North Pacific Ocean. ISC/21/SHARKWG-2/13.

Liu, K.M., Su, K.Y., Tsai, W.P., Chin, C.P. 2021b. Catch, size and distribution pattern of the blue shark caught by the Taiwanese small-scale longline fishery in the North Pacific. ISC/21/SHARKWG-2/12.

Liu, K.M., Su, K.Y., Tsai, W.P., Chin, C.P. 2021c. Updated standardized CPUE and catch estimation of the blue shark from the Taiwanese large scale tuna longline fishery in the North Pacific Ocean. ISC/21/SHARKWG-2/14.

McKinnel, S., Seki, M.P. 1998. Shark bycatch in the Japanese High Seas squid driftnet fishery in the North Pacific Ocean. Fish. Res. 39, 127–138.

Method, R.D., Wetzel, C.R. 2013. Stock synthesis: a biological and statistical frame work for fish stock assessment and fishery management. Fish. Res. 142, 86–99.

Nakano, H., Stevens, J. D. 2008. The biology and ecology of the blue shark, *Prionace glauca*. In: Camhi, M. D., Pikitch, E. K., Babcook, E. A., editors. Sharks of the open ocean: biology, fisheries and conservation. Oxford: Blackwell Scientific. p. 140–51.

Rice, J., Harley, S. 2014. Standardization of blue shark catch per unit effort in the North Pacific Ocean based on SPC held longline observer data for use as an index of abundance. ISC/14/SHARKWG-2/04.

Semba, Y. 2021. Size distribution of blue shark (Prionace glauca) collected by Japanese fleet and research program in the North Pacific. ISC/21/SHARKWG-2/11.

Semba, Y. 2022. Revision of fleet definition of size data of blue shark (*Prionace glauca*) collected by Japanese commercial longline fishery and longline research program in the North Pacific. ISC/22/SHARKWG-1/03.

Sosa-Nishizaki, O., Castillo-Geniz, L., 2016. Blue shark catches estimations for the Mexican Pacific (1976-2014). ISC/16/SHARKWG-1/24. Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Busan, South Korea.

Table 1. Summary of catch data used in the stock assessment for North Pacific blue shark.

Fishery number	Reference Code	Fishing Countries	Gear Types	Units	Time series	Source
F1	MEX	Mexico	Mexican Pacific longline	Biomass	1971-2020	Sosa-Nishizak and Castillo-Geniz (2016), Castillo-Geniz, pers. Comm., Oct 1, 2021
F2	CAN	Canada	Troll, gillnet, seine fishery, foreign and joint-venture fisheries	Biomass	1979-2020	King (2021)
F3	CHINA	China	Longline	Biomass	2001-2020	Meng Xia, pers. comm., Nov 3, 2021
F4	JPN_KK_SH	Japan	Offshore shallow-set longline	Biomass	1971-2020	Hiraoka et al.(2013a); Kai (2021c)
F5	JPN_KK_DP	Japan	Offshore deep-set longline	Biomass	1975-2020	Hiraoka et al.(2013a); Kai (2021c)
F6	JPN_ENY_SH	Japan	Distant water shallow-set longline	Biomass	1971-2020	Hiraoka et al.(2013a); Kai (2021c)
F7	JPN_ENY_DP	Japan	Distant water deep-set longline	Biomass	1975-2020	Hiraoka et al.(2013a); Kai (2021c)
F8	JPN_LG_MESH_EARLY	Japan	High-sea large-mesh driftnet	Biomass	1973-1992	Fujinami et al. (2021a)
F9	JPN_LG_MESH_LATE	Japan	Coastal large-mesh driftnet	Biomass	1993-2019	Fujinami et al. (2021a); Kai and Yano (2021)
F10	JPN_CST_OTH	Japan	Coastal longline	Biomass	1971-2019	Kai and Yano (2021)
F11	SM_MESH	Japan, The Republic of Korea, Chinese Taipei	High-sea small-mesh driftnet	Number	1981-1993	Fujinami et al. (2021b); Kai et al. (2022a)
F12	IATTC	RFMO	Offshore longline, coastal longline, gillnet, harpoon, and others	Biomass	1971-2020	Lennert, pers. comm., Oct 14, 2021
F13	KOREA	Republic of Korea	Tuna longline, observer data	Biomass	1975-2020	Lee et al. (2019) and Lee, pers. Comm. Nov 11, 2021
F14	NON_ISC	Various flags	Longline	Biomass	1997-2020	Kai et al. (2022b)
F15	US_GIILL	USA (American Samoa)	Gill net	Biomass	1978-2020	Kohin et al. (2016) and Kinney, pers. Comm. Oct 23, 2021
F16	US_SPORT	USA (American Samoa)	Recreational fishing	Biomass	1971-2020	Kohin et al. (2016) and Kinney, pers. Comm. Oct 23, 2021
F17	US_HW_DP	USA (Hawaii)	Deep-set longline	Number	1971-2020	Duchrme-Barth (2022)
F18	US_HW_SH	USA (Hawaii)	Shallow-set longline	Number	1981-2020	Duchrme-Barth (2022)
F19	TAIW_LG	Chinese Taipei	Large-scale longline	Biomass	1971-2020	Liu et al. (2021a)
F20	TAIW_SM	Chinese Taipei	Small-scall longline	Biomass	1971-2020	Liu et al. (2021b)

Table 2. Summary of abundance indices data used in the stock assessment for North Pacific blue shark.

Fishery number	Reference Code	Fishery Description	Used	*n*	Time series	Source
S1	HW_DP	Hawaiian deep-set longline	Yes	19	2002-2020	Duchrme-Barth et al. (2021)
S2	HW_SH	Hawaiian shallow-set longline	No			
S3	TAIW_LG	Taiwanese large-scale longline	Yes	17	2004-2020	Liu et al. (2021c)
S4	TAIW_SM	Taiwanese small-scale longline	No			
S5	JPN_EARLY	Japanese offshore and distant-water shallow longline (early period)	Yes	18	1976-1993	Hiraoka et al. (2013b)
S6	JPN_LATE	Japanese offshore and distant-water shallow-setlongline (late period)	Yes	27	1994-2020	Kai (2021a)
S7	JPN_RTV	Japanese research and training vessels	Yes	27	1994-2020	Kai (2021b)
S8	SPC_OBS	SPC observer data	No			
S9	SPC_OBS_TROPIC	SPC hold longline observer data in the tropical area	Yes	17	1993-2009	Rice and Harley (2014)
S10	MEX	Mexican Pacific longlinn	Yes	15	2006-2020	Fernández et al. (2021)

Table 3. Summary of size data used in the stock assessment for North Pacific blue shark.

Fishery number	Reference Code	Used	Time series	Units	Bin	n	Source
F1	MEX	Yes	2006-2020	cm	5	15	Castillo-Geniz, pers. Comm., Oct 27, 2021
F2	CAN	No					
F3	CHINA	Yes	1993-2020 except for 2002	cm	5	26	Meng Xia, pers. comm., Nov 3, 2021
F4	JPN_KK_SH	Yes	2008-2020	cm	5	13	Semba (2021)
F5	JPN_KK_DP	Yes	2016-2020	cm	5	5	Semba (2021)
F6	JPN_ENY_SHL	No					
F7	JPN_ENY_DP	Yes	1992-2020	cm	5	30	Semba (2021)
F8	JPN_LG_MESH_ EARLY	Yes	1979-1983	cm	5	5	Semba (2021)
F9	JPN_LG_MESH_ LATE	Yes	1994,1996,1998, 2011-2019	cm	5	12	Semba (2021)
F10	JPN_CST_Oth	No					
F11	SM_MESH	No	1991	cm	5	1	Kai et al (2022b)
F12	IATTC	No					
F13	KOREA	No					
F14	NON_ISC	Yes	1994,1996-2008,2012,2016, 2018-2020	cm	5	19	Williams, pers. comm., Nov 19, 2021
F15	USA_GIILL	Yes	1990-2020	cm	5	31	Kohin et al. (2016) and Kinney, pers. Comm. Nov 27, 2021
F16	USA_SPORT	No					
F17	HW_DP	Yes	2003-2020	cm	5	18	Duchrme-Barth, pers. Comm., Jan 26, 2022
F18	HW_SH	Yes	2004-2020	cm	5	16	Duchrme-Barth, pers. Comm., Jan 26, 2022
F19	TAIW_LG	Yes	2004-2020	cm	5	17	Liu et al. (2021b)
F20	TAIW_SM	Yes	2012-2020	cm	5	9	Liu et al. (2021a)

Table 4. Time series of catch (total dead removals; metric tons) for different countries/data sources. "Previous" is total catch used in the previous assessment in 2017. The catch number for some fleets were converted to catch weight by each member country.

Year	Canada	China	IATTC	Japan	The Republic of Korea	Mexico	NON_ISC	Chinese Taipei	USA	Total	Previous
1971	0	0	7	23252	0	440	0	12070	30	35799	35799
1972	0	0	5	17977	0	440	0	15056	30	33508	33508
1973	0	0	5	22491	0	440	0	12025	30	34991	37828
1974	0	0	5	20075	0	440	0	10742	30	31292	34763
1975	0	0	7	27468	5	440	0	9392	33	37345	40153
1976	0	0	7	43154	32	374	0	10286	129	53982	53854
1977	0	0	6	59427	55	386	0	10045	225	70145	65861
1978	0	0	8	48717	17	561	0	10603	329	60235	60069
1979	1	0	10	55684	0	338	0	12360	466	68859	70368
1980	11	0	10	56952	114	336	0	12840	630	70894	74002
1981	0	0	9	59000	0	256	0	10961	669	70895	87805
1982	0	0	6	49538	317	306	0	12003	784	62954	71405
1983	25	0	6	50406	128	293	0	10586	954	62397	68554
1984	0	0	6	51117	117	263	0	9509	1112	62123	63265
1985	60	0	3	49600	95	227	0	10712	1291	61989	61054
1986	90	0	2	46924	91	407	0	9048	1496	58059	57025
1987	159	0	2	40837	174	351	0	6729	1508	49760	50758
1988	0	0	6	48754	147	509	0	6966	1783	58166	55553
1989	0	0	5	45883	83	280	0	7897	1607	55756	63407
1990	4	0	3	30323	80	1130	0	8885	460	40885	47603
1991	0	0	2	31490	103	1016	0	9619	1276	43507	50098
1992	0	0	3	27270	105	1636	0	7615	1209	37838	41735
1993	0	0	3	27242	52	2540	0	6919	1312	38068	40881
1994	0	0	2	36055	58	1758	0	5470	736	44080	44505
1995	0	0	10	34759	165	2100	52	10100	1353	48539	53117
1996	1	0	2	28564	294	3117	52	9917	1721	43667	45862
1997	1	0	4	30212	732	2948	52	13773	1945	49666	53716
1998	2	0	2	30499	427	3134	402	11640	2735	48841	50760
1999	1	0	1	33671	397	2261	947	14118	1608	53003	48973
2000	1	0	2	31257	406	2719	228	20391	1392	56395	57202
2001	5	340	0	33140	115	2587	318	9831	362	46698	45989
2002	5	334	3	29258	223	2524	347	11582	286	44562	44626
2003	17	305	1	27006	285	2307	225	10244	380	40772	43923
2004	4	282	1	25135	37	3781	770	12668	370	43047	50118
2005	0	343	0	25643	34	2721	564	14478	327	44112	51742
2006	20	201	3	22576	15	2765	472	14175	263	40489	46965
2007	9	234	2	20004	139	3324	986	13848	376	38923	46090
2008	6	134	3	16333	52	4355	625	14824	208	36539	42801
2009	8	298	2	17102	98	4423	479	16559	246	39215	44024
2010	7	357	1	17481	293	4469	532	13349	286	36774	44281
2011	13	613	1	9353	556	3719	424	16451	302	31432	45520
2012	9	758	2	11555	345	4108	597	16451	273	34097	39777
2013	26	598	2	12976	75	4494	474	7534	290	26468	33863
2014	9	251	0	13426	100	5502	409	11856	374	31927	37707
2015	23	627	0	11220	74	3985	361	10042	408	26741	32956
2016	12	258	2	11367	0	4973	388	12130	440	29570	
2017	25	764	0	11166	4	3384	1333	11676	526	28879	
2018	46	727	0	10388	2	2852	1488	11189	511	27204	
2019	78	856	0	9634	4	3772	1864	15743	569	32521	
2020	150	865	0	8231	0	3533	1158	12734	627	27297	

Table 5. CPUE time series (relative to its mean) for different fleets and the coefficient of variations (CV).

Year	JPN_EARLY, JPN_LATE		HW_DP		SPC_OBS_TROPIC		MEX		JPN_RTV		TAIW_LG	
	CPUE	CV	CPUE	CV	CPUE	CV	CPUE	CV	CPUE	CV	CPUE	CV
1976	1.35	0.02										
1977	1.40	0.01										
1978	1.21	0.02										
1979	1.27	0.01										
1980	1.36	0.02										
1981	1.13	0.01										
1982	1.11	0.01										
1983	1.05	0.01										
1984	0.91	0.01										
1985	0.78	0.01										
1986	0.91	0.01										
1987	0.68	0.01										
1988	0.71	0.01										
1989	0.64	0.01										
1990	0.67	0.01										
1991	0.85	0.01										
1992	0.89	0.01										
1993	1.07	0.01			0.87	0.15						
1994	0.84	0.15			0.96	0.14			1.48	0.10		
1995	0.90	0.15			0.46	0.14			1.44	0.12		
1996	0.85	0.14			0.87	0.14			1.39	0.10		
1997	1.04	0.13			1.18	0.14			1.44	0.10		
1998	1.03	0.13			1.80	0.14			1.39	0.12		
1999	1.09	0.12			1.50	0.14			1.44	0.19		
2000	1.06	0.12			1.35	0.14			1.24	0.12		
2001	1.22	0.10			1.37	0.15			1.17	0.10		
2002	1.03	0.11	1.04	0.63	1.06	0.15			1.09	0.10		
2003	1.08	0.09	1.43	0.45	0.85	0.17			1.05	0.11		
2004	1.03	0.10	1.34	0.43	1.05	0.14			0.96	0.10	0.24	0.12
2005	1.26	0.10	1.05	0.35	0.79	0.14			0.78	0.12	1.40	0.04
2006	1.06	0.10	0.90	0.42	0.85	0.14	1.32	0.07	0.72	0.12	0.80	0.05
2007	0.84	0.10	0.97	0.37	0.80	0.14	1.07	0.04	0.64	0.14	0.51	0.06
2008	0.73	0.12	0.57	0.30	0.69	0.14	1.26	0.05	0.41	0.13	0.69	0.06
2009	0.97	0.11	0.70	0.46	0.57	0.14	0.99	0.06	0.58	0.13	0.41	0.06
2010	1.04	0.13	0.81	0.32			0.83	0.05	0.79	0.15	0.97	0.07
2011	0.86	0.13	0.84	0.32			0.76	0.06	0.66	0.15	0.74	0.06
2012	0.88	0.14	0.71	0.39			1.23	0.11	0.59	0.15	1.03	0.05
2013	0.92	0.15	0.75	0.40			1.28	0.06	0.79	0.15	1.09	0.06
2014	1.04	0.15	0.97	0.37			1.10	0.06	1.04	0.16	0.70	0.07
2015	1.17	0.15	1.05	0.37			0.78	0.07	0.83	0.15	1.59	0.08
2016	1.14	0.15	1.05	0.30			1.05	0.07	1.09	0.13	1.21	0.07
2017	1.06	0.15	1.24	0.42			0.74	0.06	1.06	0.12	1.55	0.05
2018	1.04	0.15	1.12	0.39			0.91	0.07	0.98	0.13	1.22	0.07
2019	1.01	0.15	1.14	0.41			1.10	0.07	0.98	0.15	1.46	0.05
2020	0.81	0.17	1.35	0.47			0.57	0.09	0.97	0.17	1.39	0.06

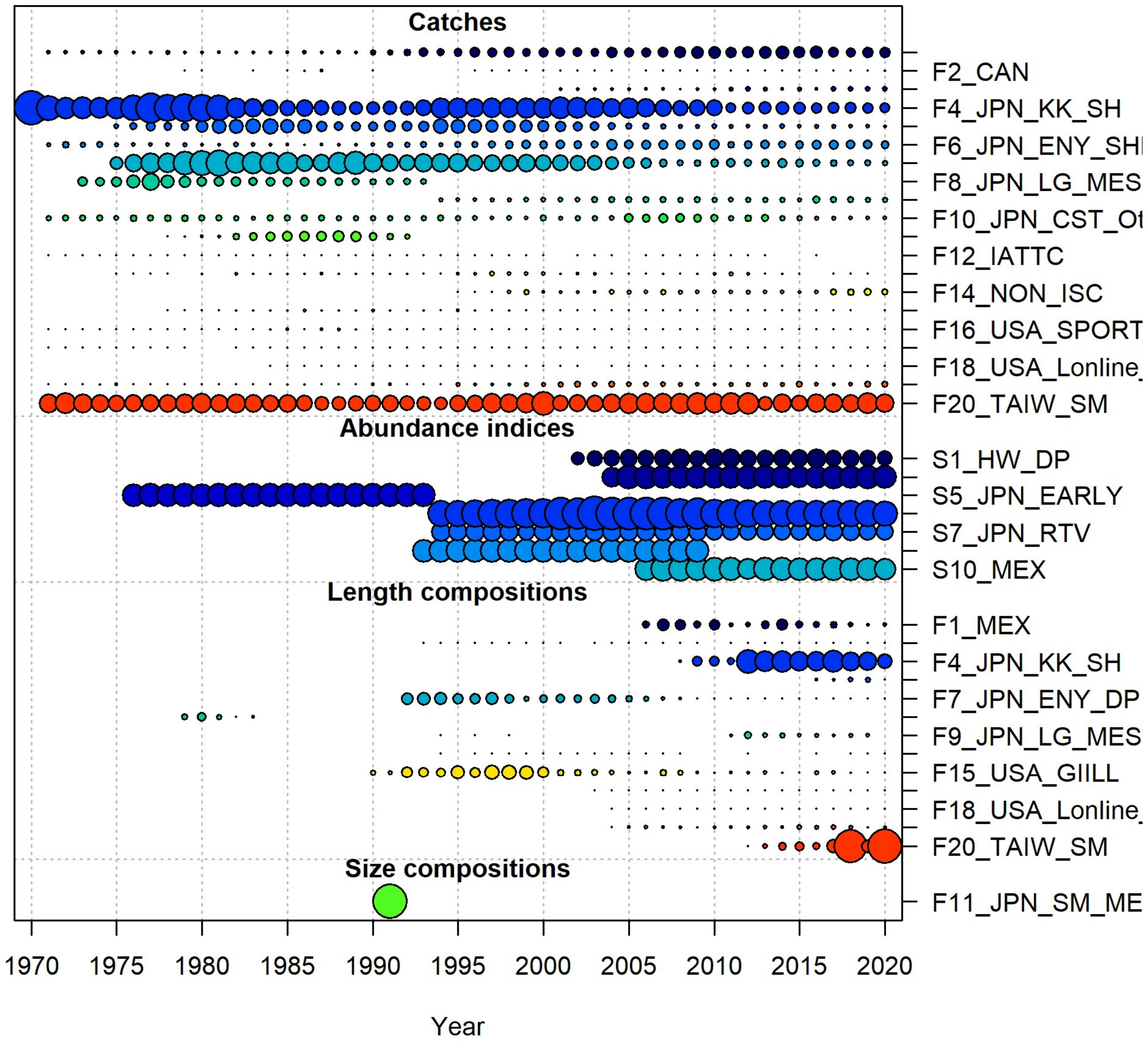

Figure 1. Coverage of catch, abundance indices, and length composition data by year for each fleet used in this stock assessment. Circle area is relative within a data type. Circles are proportional to total catch for catches; to precision for indices, and to total sample size for length compositions. Note that since the circle are scaled relative to maximum within each type, the scaling within separate plots should not be compared.

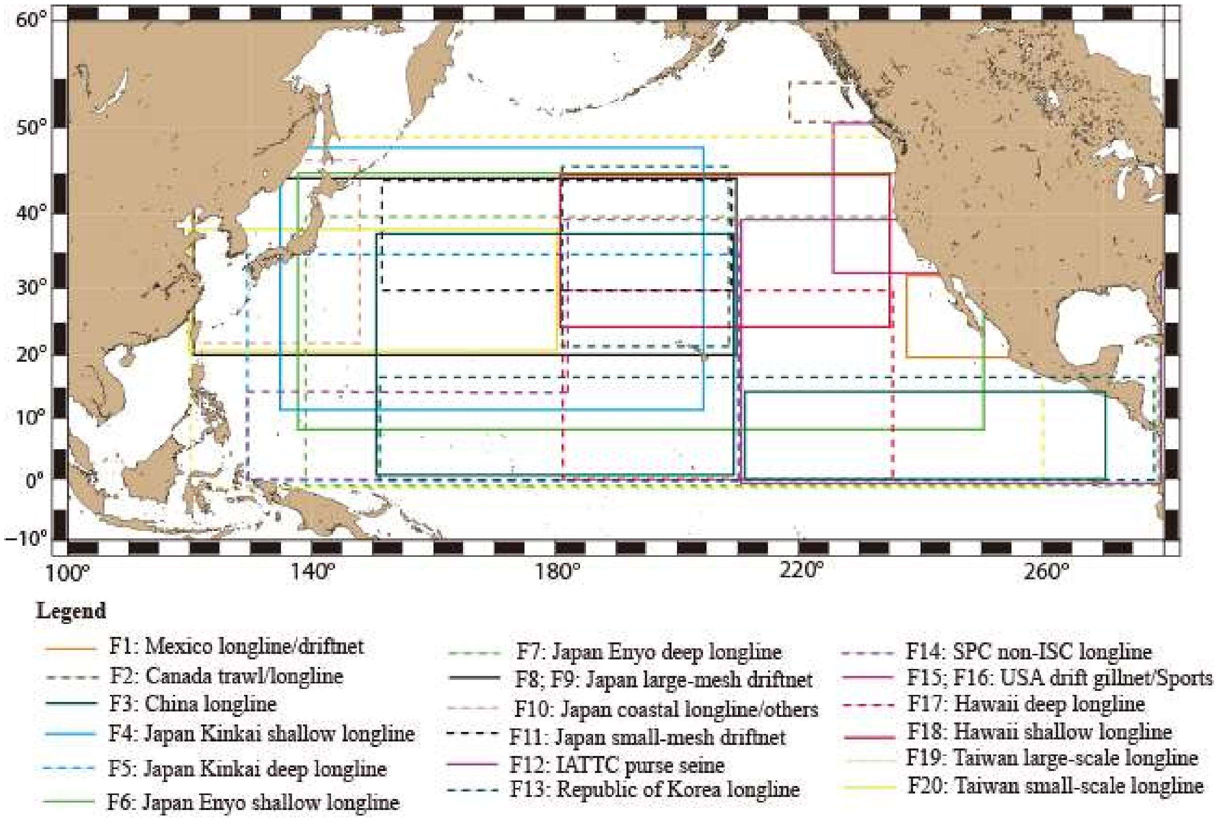

Figure 2. Blue shark (Prionace glauca) stock boundaries and approximate spatial extent of all fleets used in this stock assessment.

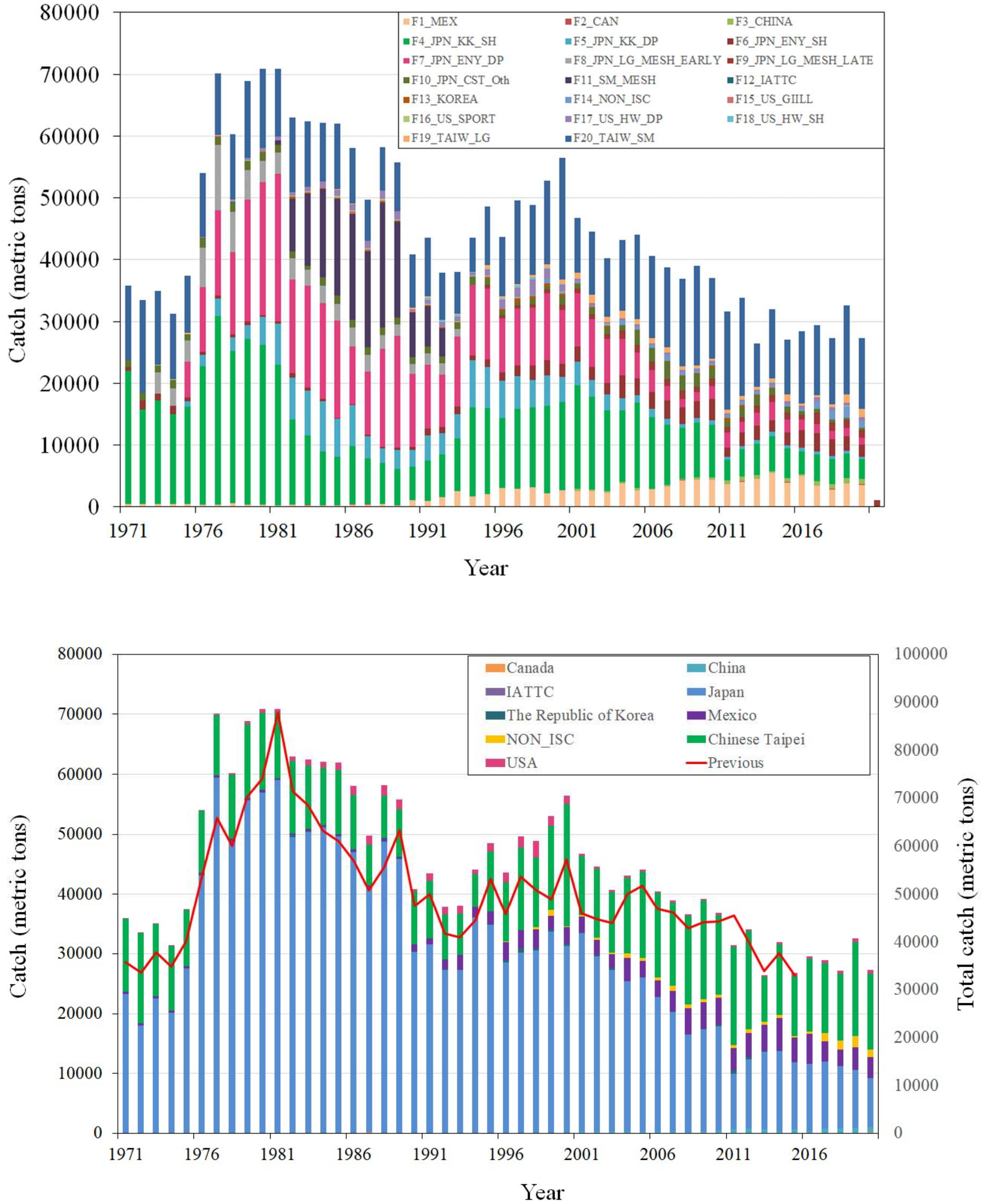

Figure 3. Annual catch (metric tons) of blue shark by fleet (upper panel) and by country (lower panel) for 1971-2020 used in this stock assessment. The red line of lower panel denotes total catch for 1971-2015 used in the previous assessment in 2017.

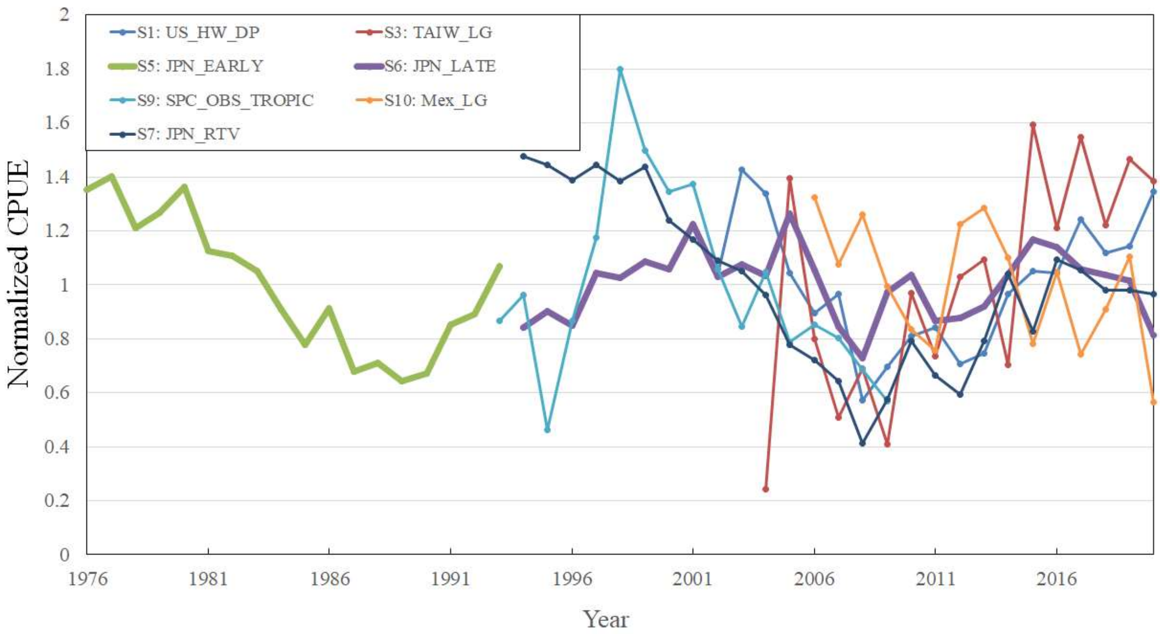

Figure 4. Annual abundance indices of blue shark used in this stock assessment by fleet for 1976-2020. Y-axis denotes CPUE relative to the mean CPUE.

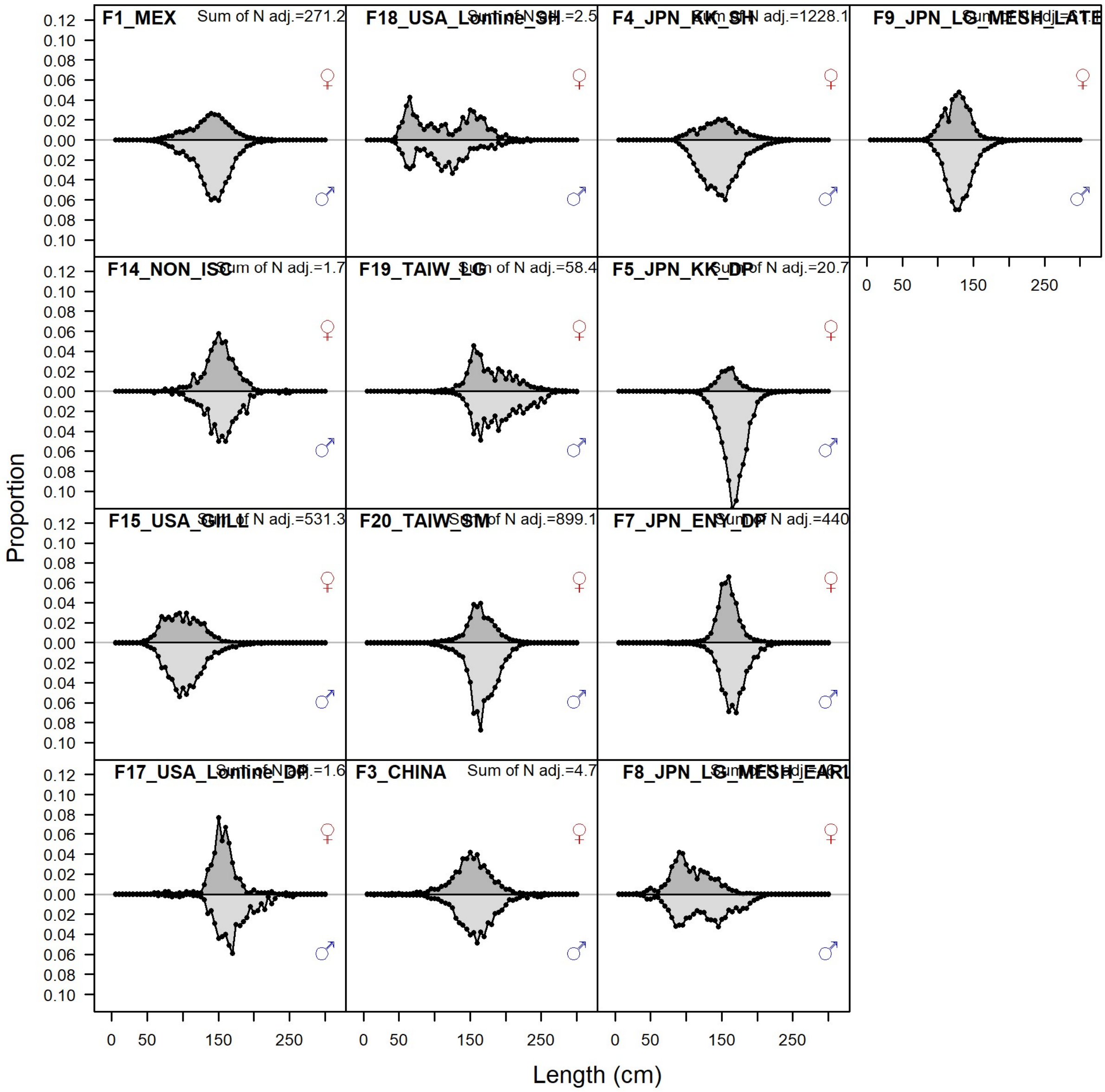

Figure 5. Sex-specific length composition data, aggregated across year by fleet, used in this stock assessment. Y- and X- axis denotes the proportion of sample at each bin and body length (PCL; cm), respectively.

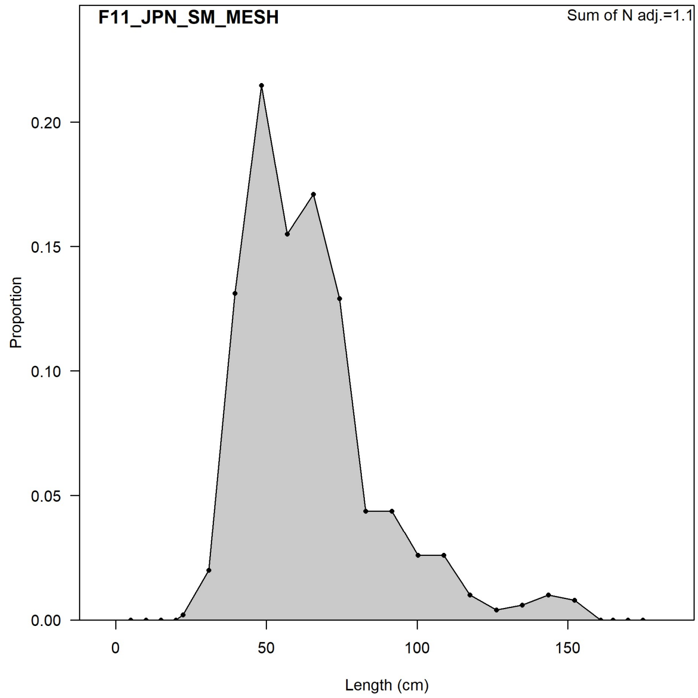

Figure 6. Sex-combined length composition data of high seas squid/small mesh driftnet fishery (F11) used in this stock assessment. Y- and X- axis denotes the proportion of sample at each bin and body length (PCL; cm), respectively.