

Catch, size and distribution pattern of the blue shark caught by the Taiwanese small-scale longline fishery in the North Pacific¹

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Abstract

This study presented the catch, size, and distribution pattern of the blue shark by the Taiwanese small-scale tuna longline (STLL) fishery in the North Pacific. Catch estimated was based on the landing data from the three major fishing ports for STLL fishery. The estimated annual catch of blue sharks by the Taiwanese small-scale tuna longline fisheries ranged from 6,983 MT in 2013 to 16,082 MT in 2009, with a mean of 11,685 MT in 2001-2020. The mean sizes were estimated to be 183 cm and 185 cm FL for females and males, respectively. Juvenile females were found in the tropical and subtropical area but adults were more often found in the temperate area. The smallest mean sizes for both sexes were found in season 2. The sex ratio was significantly different from 0.5 for every season except season 4.

1. Introduction

There are two types of Taiwanese small-scale tuna longline (STLL) fishing vessels. The vessels less than 50 tonnages operated in the coastal and offshore waters, western North Pacific. While those vessels between 50 and 100 tonnages often operate outside the Taiwan EEZ in the Pacific Ocean (Figure 1). These STLL vessels mainly target on tunas and sharks are the by-catch. Almost all sharks caught by these fleets in the North Pacific Ocean landed in Nanfangao, Chengkung and Tungkang fishing ports located at eastern and southwestern Taiwan. Nanfangao is the most important shark landing port in Taiwan, and the annual shark landings ranged from 2,651 MT to 5,841 MT with an average of 4,344 MT from 2001 to 2020 (Table 1). Tungkang is another important shark landing port in Taiwan, and its annual shark landings ranged from 4,263 MT to 8,563 MT with an average of 6,281 MT from 2009 to 2020 (Table 2). Annual shark landings in Chengkung ranged from 255 MT to 954 MT with an average of 500 MT from 2001 to 2020 (Table 3). According to the vessel monitoring system (VMS) data, the interview with the captain of longliners, and the logbook data, almost all the STLL vessels in Chengkung operated within the EEZ, however, large proportion of longliners in Nanfangao and Tungkang operated outside the EEZ.

The landing data indicated that the shark landings of these fisheries were dominated by the blue sharks of 72%, followed by shortfin mako shark, bigeye thresher shark, scalloped hammerhead shark and pelagic thresher shark, respectively (Figure 2). This study presents the catches estimate and distribution pattern of blue sharks caught by the Taiwanese small-scale tuna longline fishery in the North Pacific.

2. Material and Method

2.1 Data sources

The daily auction records of sharks for Taiwanese STLL fleet were detailed in species at Nanfangao fish market after 1989 and Chengkung fish market after 2001. There is no species-specific auction or landing record for sharks in Tungkang fish market until 2009. A total of 12 shark species were documented in the auction records at Nanfangao and Chengkung, and the blue shark was present in the auction records since 2001, while the other 11 species included shortfin mako shark were from 1989. In this study, we only presented the shark catch and composition at Nanfangao and Chengkung in 2001-2020. Because of the lack of the observer programs for small-scale longline vessels in Taiwan before 2014, the information of dead discarded and live released or escaped were not presented in this study.

2.2 Blue shark catch

The landing of blue shark was presented in the daily auction record of Nanfangao in 2001-2020, Tungkang in 2011-2020, and Chengkung in 2001-2008, 2014-2017 (**Figure 3**). The landing compositions of shark from 2001 to 2020 at Nanfangao were used to calculate the landing of blue shark at Tungkang in 2001-2010. According to daily auction records, all the blue shark landings at Chengkung were considered as whole fish, and 89.5% of blue shark landings at Nanfangao were frozen and processed on the sea, where the head, fins, and the internal organs of blue sharks were removed. The ratio between fresh and frozen landing of blue shark at Tungkang were assumed to equal to that at Nanfangao, because of similarity in operation distance.

For the proposal to convert frozen shark landing into total catch, 60 fresh blue sharks were sampled, processed and recorded the weight before and after processed by a local fisherman in Nanfangao. The results indicated that the processed weight is 41.08% of the whole body weight (20.11% – 56.11%, n=59). Therefore, the frozen landings were divided by 41.08% to be converted into total catch.

2.3 Size data collection

The observer program for the Taiwanese STLL fishery started from 2012. All the observers have been trained on identification of tuna and tuna like species and by-catch

species such as sharks, sea birds, and sea turtles. The operation area of the Taiwanese small-scale tuna longline fishing vessels in the North Pacific (2011-2020) (Figure 1) was based on the logbook data. The blue shark specimens caught by the Taiwanese STLL vessels in the North Pacific Ocean between 2012 and 2020 (Figure 4) were opportunistically collected by the on-board scientific observers. The fishing date, location, weight (in kg), and fork length (FL in cm) of the specimens were recorded, and the sex of each specimen was identified.

The mean sizes of specimens were compared between areas and sexes and among seasons using t-tests and analysis of variance (ANOVA) on the assumption of a normal distribution because of the large sample size. The annual variation of the mean catch-at-size was examined by ANOVA. The sex ratio was expressed as the number of females/the number of both sexes combined. Sex ratios were compared between areas and among seasons with a Chi-square test. A significance level of 0.05 was used in all statistical tests.

3. Results and Discussions

3.1 Blue shark catch

In total, 86.9% of the blue shark landings were frozen at Nanfangao in 2001-2020. After converting frozen blue shark landings into total catch, the annual estimated catches of blue sharks were the highest in 2005 (8,645 MT) and the lowest in 2015 (3,191 MT)(Table 4). The estimated annual catch of blue shark had an increasing trend from 4,694 tons in 2001 to 8,645 tons in 2005, and constantly around 7,500 tons per year since 2005 to 2011, decreased to 3,779 tons in 2012, and increased from 2015 to 2019 in Nanfangao (Figure 5). Under the assumption that the percentage of blue shark were the same in the Nanfangao and Tungkang, and also frozen blue shark ratio as well, the blue shark catch at Tungkang was estimated from 2,607 MT to 7,745 MT, with an average landing being 5,000 MT in 2001-2020 (Table 4; Figure 5).

A total of 62% of total large shark landings at Chengkung was occupied by blue shark, which ranged from 136 MT to 689 MT, with an average of 343 MT in 2001 to 2008 and 2014 to 2017 (Table 3). Species-specific landing data were not available for Chengkung fish market in 2009 to 2013 and 2018-2020. Therefore, large shark landing and blue shark ratio (62%) were used to calculate the catch of blue shark, which ranged from 144 MT to 338 MT (Table 4; Figure 5). Overall, estimated annual catch of blue sharks by the Taiwanese small-scale tuna longline fisheries ranged from 6,983 MT in 2013 to 16,081 MT in 2009, with a mean of 11,483 MT in 2001-2020 (Table 4; Figure

5).

3.2 Size and sex variation by season

The size information of 52,578 blue shark specimens, including 36,008 males and 16,570 females caught by the Taiwanese STLL vessels in the North Pacific Ocean were collected by the on-board scientific observers (Table 5). The sizes ranged from 78 to 288 cm FL and 72 to 283 cm FL for males and females, respectively. The mean size of females was 183 cm TL and that was 185 cm TL for males (Table 5). Significant difference on mean length was found between sexes. The sizes of the 44,114 specimens in the area A ranged from 80 to 288 cm TL and 72 to 283 cm FL for males and females, respectively (Figure 6). The sizes of the 8,464 specimens in the area B ranged from 78 to 266 cm FL and 79 to 274 cm FL for males and females, respectively (Figure 6). Significant difference in mean length of female blue shark was found between areas, but no significant difference on mean length between areas was found for males. Juvenile females were found in the area B but adults were more often found in the area A (Figure 4). This finding was comparable to those data collected by the observers of Taiwanese LTLL fishing vessels (Liu et al. 2021) but was contradict to the migration pattern of blue shark in the North Pacific (Nakano 1994).

As the observer program for Taiwanese STLL started in 2012 and the observation only limited to certain areas, more size data are needed to improve our results. The estimated mean sizes of both sexes in this study were smaller than those estimated from the Taiwanese LTLL fishing vessels. Different operation depth and operation area are the two possible reasons causing this result. The LTLL mainly operated in central western North Pacific while the STLL mainly operated in the western North Pacific. The smallest mean sizes for both sexes of blue sharks were found in season 2. The sex ratios were significantly less than 0.5 in area A for every season (0.24-0.43)($P < 0.05$). The sex ratios were significantly larger than 0.5 in area B for seasons 2 and 3 (0.58-0.60)($P < 0.05$), but it was less than 0.5 in season 1 (0.41)($P < 0.05$).

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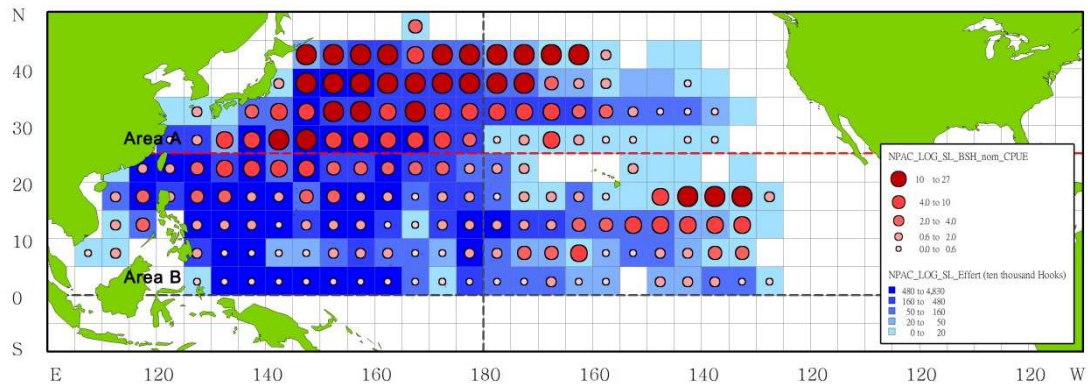


Figure 1. Fishing effort and CPUE of the blue shark (BSH) recorded by logbook of the Taiwanese small-scale longline fishing vessels operating in the North Pacific from 2011 to 2020. The color scale within grid cells represents fishing effort, with darker blue representing more hooks and lighter blue representing fewer hooks. The size of the red dots indicates the CPUE of blue sharks categorized using 20th percentiles of the data.

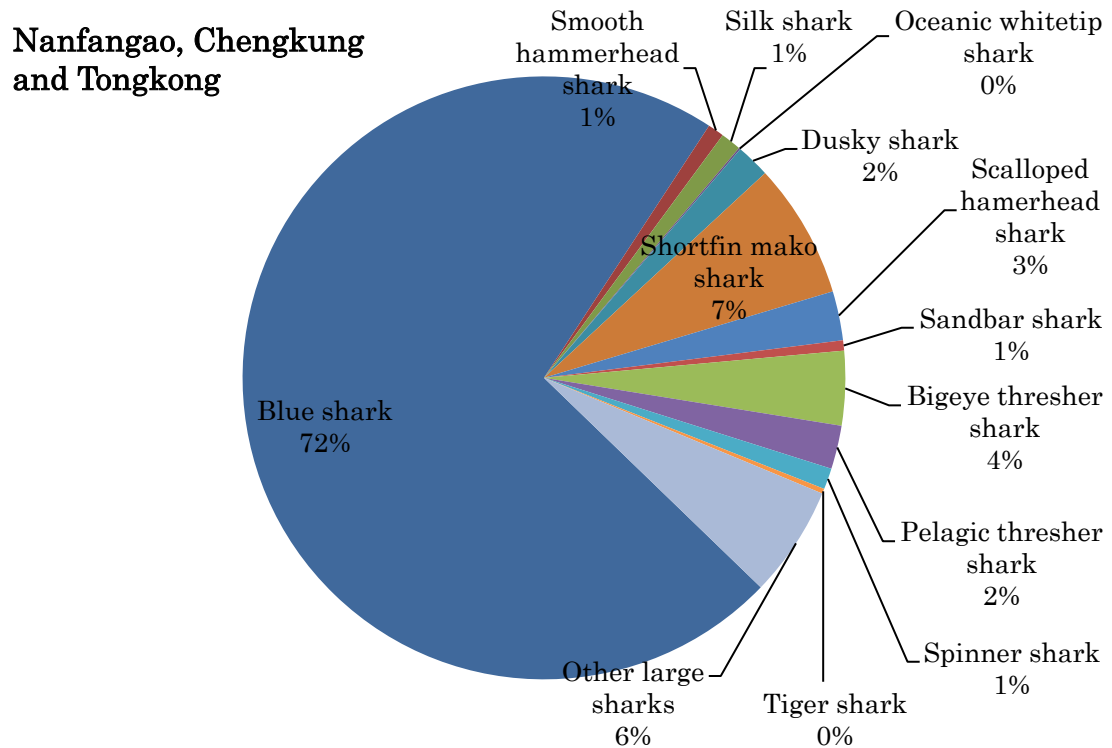
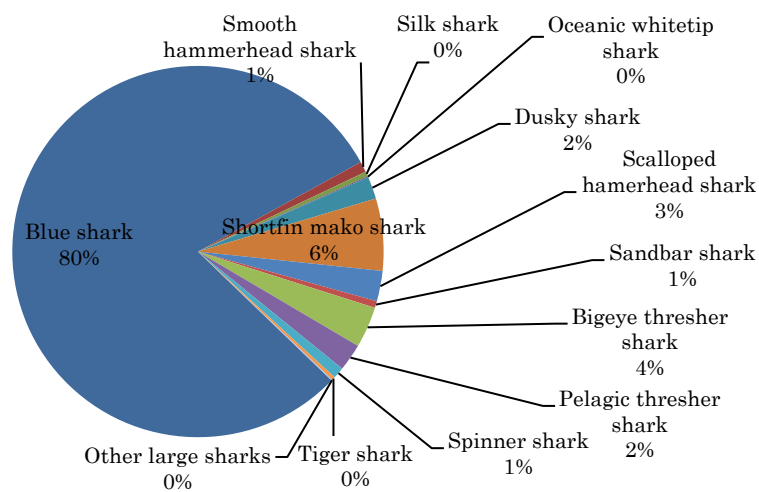
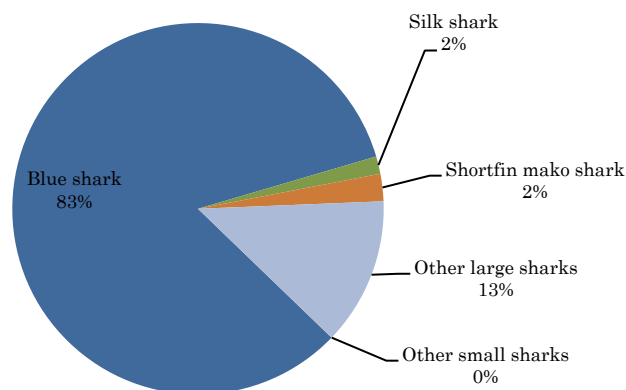


Figure 2. Species composition of sharks by the Taiwanese STLL fishing vessels from 2001 to 2020.

Nanfangao



Tongkong (2009-2020)



Chengkung (2001-2008, 2014-2017)

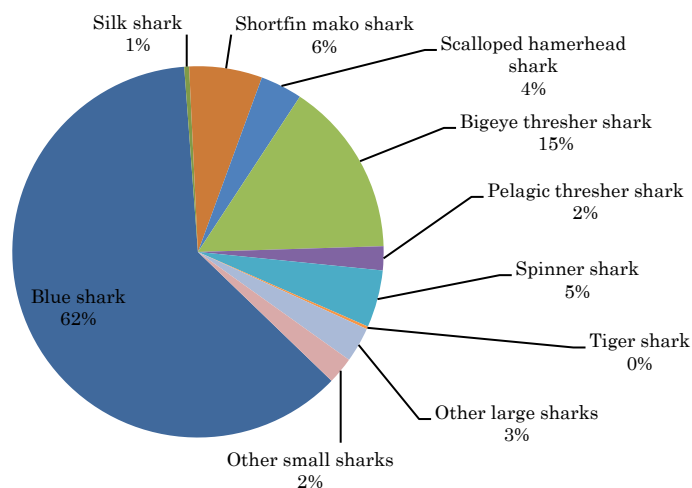


Figure 3. Species composition of sharks by the Taiwanese STLL fishing vessels at Nanfangao, Tongkong and Cgengkung fishing ports.

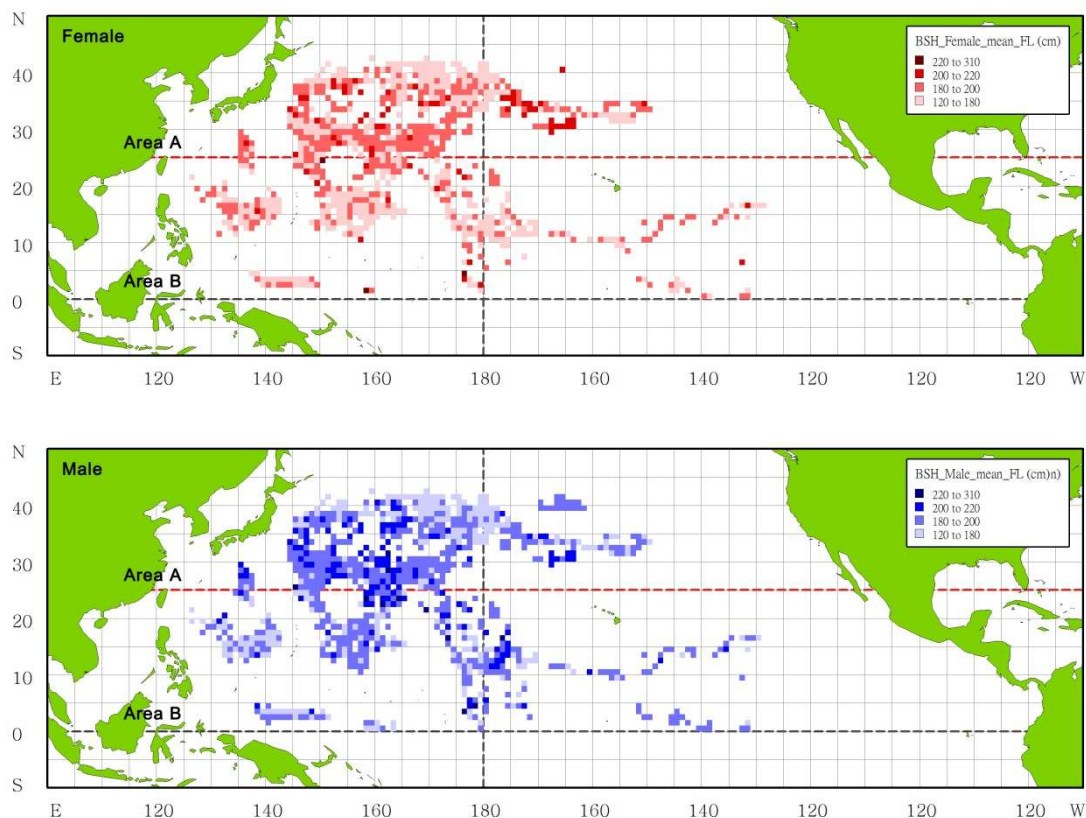


Figure 4. The size distribution of the blue sharks caught by the Taiwanese small-scale longline fishing vessels in the North Pacific. The color scale within grid cells represents the mean FL categorized using 25th percentiles of the data, with darker red or blue representing larger size of females or males and lighter blue representing smaller size.

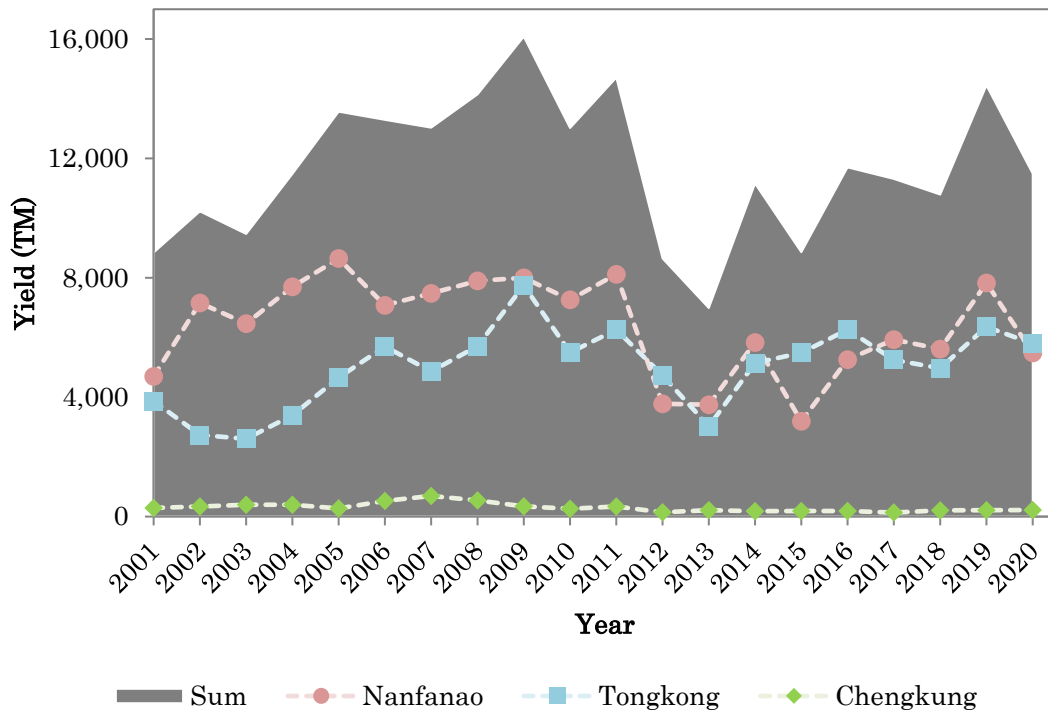


Figure 5. Estimated blue shark catch caught by the Taiwanese small-scale longline fishery from 2001 to 2020.

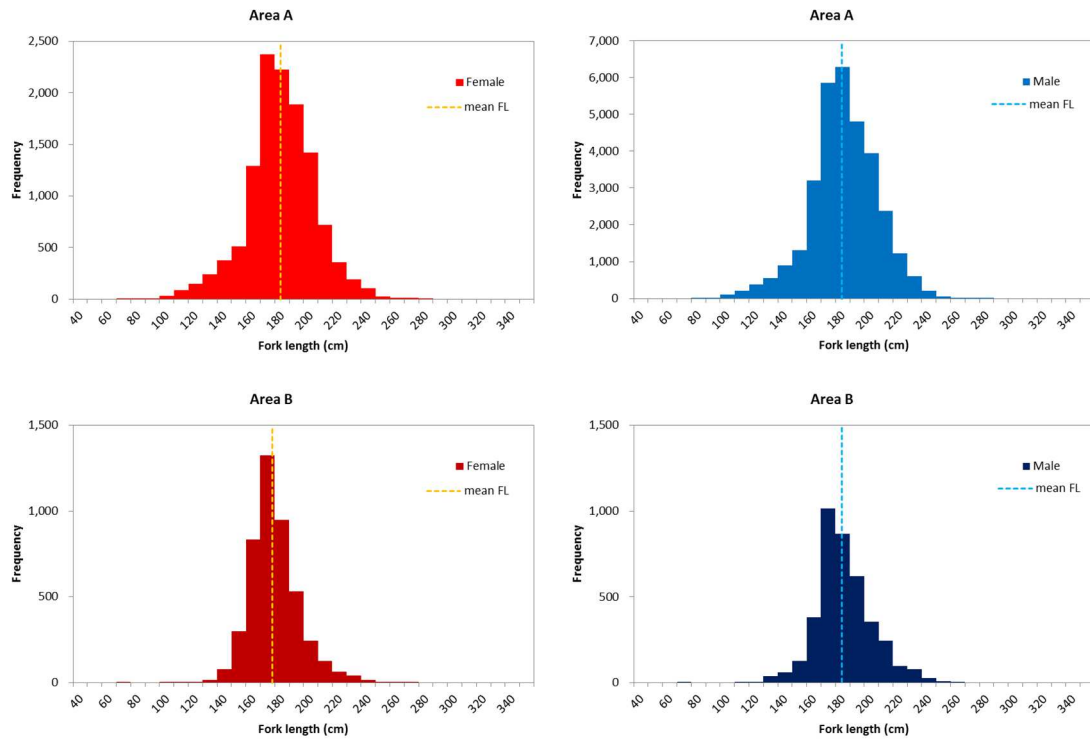


Figure 6. Length frequency distribution of the blue shark by sex and area caught by the Taiwanese small-scale longline fishery in the North Pacific.

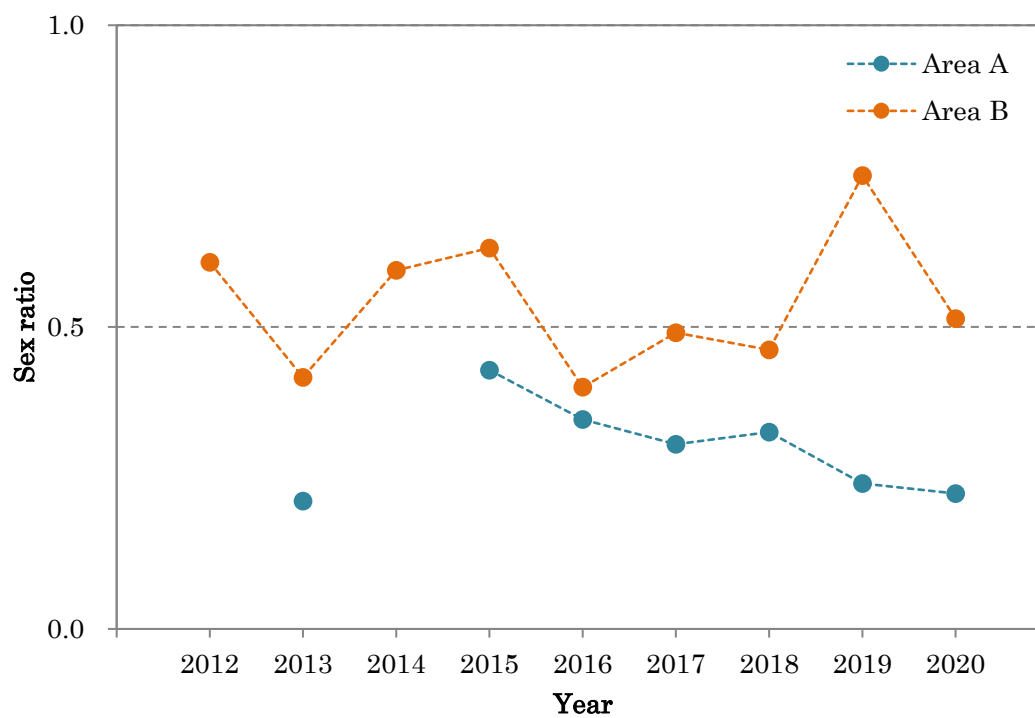


Figure 7. Annual variation of the sex ratio of the blue shark caught by the Taiwanese small-scale longline fishery in the North Pacific from 2012 to 2020.

Table 1. Species-specific shark landings (MT) at Nanfangao fishing port from 2001 to 2020.

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Blue shark	2,049	3,124	2,756	3,268	3,794	3,016	3,658	3,560	3,320	2,988	3,431	1,599	1,635	2,510	1,404	2,210	2,476	2,334	3,248	2,281
Smooth hammerhead shark	92	96	124	79	58	64	65	57	82	57	78	53	43	72	88	60	61	76	98	77
Silk shark	62	137	63	61	64	51	45	54	44	40	21	14	12	10	6	—	—	—	—	—
Oceanic whitetip shark	46	24	23	10	8	8	7	6	6	5	2	1	—	—	—	—	—	—	—	—
Dusky shark	174	193	339	358	181	227	188	141	131	170	124	125	138	36	54	61	73	103	142	121
Shortfin mako shark	806	572	760	919	385	399	501	325	286	492	602	393	295	362	467	374	490	496	596	508
Scalloped hammerhead shark	246	273	385	368	213	261	194	160	255	198	167	149	152	137	126	117	151	190	234	229
Sandbar shark	71	98	122	87	47	57	50	32	63	33	31	22	19	20	39	31	25	21	28	37
Bigeye thresher shark	296	367	405	321	297	222	208	242	228	216	293	237	234	270	285	281	339	346	326	292
Pelagic thresher shark	319	233	188	156	166	146	168	238	173	184	204	96	208	252	115	161	174	176	284	150
Spinner shark	97	138	140	171	86	105	63	56	97	82	68	62	47	42	55	38	35	45	88	62
Tiger shark	26	41	62	43	19	23	43	39	22	13	13	13	9	5	9	9	10	9	14	7
Other sharks	4	3	0	0	7	16	8	22	7	8	3	20	4	23	3	0	4	13	6	20
Sum	4,288	5,299	5,367	5,841	5,325	4,595	5,198	4,932	4,714	4,486	5,037	2,784	2,796	3,739	2,651	3,342	3,838	3,809	5,064	3,784

Table 2. Species-specific shark landings (MT) at Tongkang fishing port from 2009 to 2020.

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Blue shark	5,376	4,117	6,259	4,724	3,022	5,144	5,482	6,260	5,245	4,970	6,356	5,787
Large sharks	2,331	1,425	2,125	1,714	1,178	459	176	165	76	15	3	2
Silk shark	164	116	161	406	31	29	11	27	85	18	43	50
Shortfin mako shark		6	17	46	32	26	30	126	260	301	466	489
Other sharks			0	5	0	0	1	0	2	1	3	9
Sum	7,870	5,663	8,563	6,895	4,263	5,658	5,700	6,578	5,668	5,305	6,871	6,337

Table 3. Species-specific shark landings (MT) at Chengkung fishing port from 2001 to 2020.

Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Blue shark	288	336	396	392	268	520	689	540						179	183	184	136			
Hammerhead shark	23	20	27	17	17	20	22	5						30	23	17	23			
Silk shark	4	5	9	3	6	1.1	0.16	0.1						—	—	—	—			
Shortfin mako shark	36	40	45	36	33	45	49	14						30	41	31	24			
Bigeye thresher shark	78	93	119	87	109	66	122	49						82	79	81	54			
Pelagic thresher shark	10	14	14	3	11	7	11	5						17	16	15	16			
Spinner shark	30	31	34	35	54	58	43	7						18	11	5	7			
Tiger shark						9	3	1						1	1	—	1			
Other large sharks	9	6	12	1	31	4	8	109	511	394	531	231	341	4	5	8	6	332	330	343
Small sharks	32	13	17	14	14	9	7	30	38	42	100	24	74	8	4	4	5	25	8	8
Sum	510	558	673	588	543	739	954	760	549	436	631	255	415	369	363	345	272	357	338	351

Note: Species specific landing data were not available in 2009-2013 and 2018-2020.

Table 4. Estimated blue shark catch (MT) by Taiwanese STLL fishing vessels in the North Pacific from 2001 to 2020.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Nanfangao	4,694	7,157	6,464	7,697	8,645	7,077	7,480	7,895	7,999	7,262	8,114	3,779	3,747	5,833	3,191	5,256	5,928	5,612	7,827	5,483
Tongkong	3,866	2,733	2,607	3,390	4,649	5,695	4,861	5,709	7,745	5,493	6,259	4,724	3,022	5,144	5,482	6,260	5,245	4,970	6,356	5,787
Chengkung	288	336	396	392	268	520	689	540	338	260	334	144	214	179	183	184	136	205	209	217
Sum	8,847	10,225	9,467	11,479	13,563	13,291	13,030	14,144	16,081	13,015	14,707	8,647	6,983	11,156	8,856	11,700	11,309	10,787	14,445	11,487

Table 5. The size range and mean length of the blue shark by area and season based on the Taiwanese small-scale longline observer's data.

Area	Season	Female			Male			Total		
		n	mean FL (cm)	range of FL (cm)	n	mean FL (cm)	range of FL (cm)	n	mean FL (cm)	range of FL (cm)
Area A	1	1,049	188	102-254	1,396	185	102-256	2,445	186	102-256
	2	4,157	186	72-283	13,140	183	80-284	17,297	184	72-284
	3	2,979	186	115-260	10,380	187	103-288	13,359	187	103-288
	4	3,844	179	87-260	7,169	186	103-266	11,013	184	87-266
	Sum	12,029	184	72-283	32,085	185	80-288	44,114	185	72-288
Area B	1	580	177	124-232	844	186	78-262	1,424	182	78-262
	2	1,283	178	129-268	936	187	127-266	2,219	182	127-268
	3	1,584	179	108-274	1,047	183	126-249	2,631	180	108-274
	4	1,094	182	79-260	1,096	185	135-254	2,190	184	79-260
	Sum	4,541	179	79-274	3,923	185	78-266	8,464	182	78-274
Total		16,570	183	72-283	36,008	185	78-288	52,578	184	72-288