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Update of sex-specific size frequency of shortfin mako (*Isurus oxyrinchus*) collected by Japanese commercial vessel and research program.

Yasuko Semba

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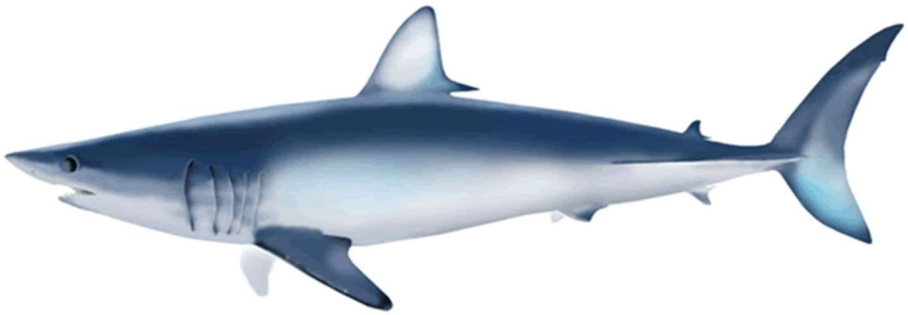
Fisheries Resources Institute, Japan Fisheries Research and Education Agency, 2-12-4 Fukuura, Kanazawa, Yokohama, Kanagawa, 236-8648, Japan

Email: semba_yasuko25@fra.go.jp



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Abstract

In this document, size frequency and annual trend of mean size of shortfin mako (*Isurus oxyrinchus*) were described by Japanese fishery and research data with consideration of area effect in some data sources. Port sampling data comes from offshore shallow-set longline, small-scale longline (mostly coastal) and driftnet fishery, while research data comes from shallow-set and deep-set longline survey, research and training vessel, and observer program. Generally, coastal fisheries including driftnet fishery, shallow-set longline research, and small-scale longline operated in the west of the dateline catch larger amount of juveniles (< 150 cm PCL) compared to deep-set longline research mainly operated in the area east of the dateline.

Regarding juvenile ratio, 86-95% of males and almost 100% of females were juveniles in these coastal fishery, while 58% of males and 4.7% of femeles were adults in deep-set longline research. Kinkai-shallow commercial fishery also catch mainly juveniles smaller than 150 cm PCL, but 20% of males were adults with juveinles dominated in females.

Different size structure was also observed, depending on data sources even if the same fishery and operation type were used in the same area. Difference in the pattern of landing and reporting between commercial vessel and research and less overlap of the operation area between them in more fine-scale may explain this difference.

It is suggested that Japanese fishery can be divided into shallow-set longline, deep-set longline and driftnet fishery as in past and no continuous trend of mean size was observed in Kinkai-Shallow commercial landing data, deep-set longline research data and driftnet fishery if the possible artificial effect was excluded. From the perspective of data availability, Kinkai-Shallow commercial fishery has provided good amount of size data as representative fleet in Japan, while that of deep-set longline research becomes getting worse by year.

Introduction

Shortfin mako (*Isurus oxirinchus*, hereafter indicated as SMA) is a wide-ranging shark distributed from tropical to temperate oceans throughout the world. It is a common, extremely active, and highly migratory species, with occasional inshore movements (Compagno 2001). In Japan, SMA has been caught mainly as bycatch in the longline fishery targeting for tunas and billfish and coastal driftnet fisheries targeting for billfish in the North Pacific and landing by longline dominated (80% of total shortfin mako landed) and the ratio of catch by driftnet fishery is 17% (Semba and Kai 2023), in the domestic fishing port.

In Japan, Kesen-numa is the largest fishing port where SMA is landed in fresh state by various fisheries such as offshore longline, small-scale longline and driftnets. National Research Institute of Far Seas Fisheries (current organization name: Fisheries Resources Institute (FRI)) launched the system to collect size and sex information of this population from the catch by these fisheries since 2005. FRI has also collected sex-speific size data from several research programs including research and training vessel (indicated as “RTV” hereafter), FRI longline research, and observer program. The fishing area, opeartion type and data collection system are variable depending on the fishery or data sources.

For the stock assessment of shortfin mako in the North Pacific, size composition of catch by various fishery is important information to categorize “fleet” and estimate selectivity in the size or age-based stock assessment model such as “Stock Synthesis”. Regarding the distribution of this species, segregation by ontogenetic stage and/or sex has

been proposed to occur (Mucientes *et al*. 2009, Semba 2011). Given the possibility that North Pacific population may exhibit this distributional pattern, description of size distribution by fishery is necessary to improve the accuracy of stock assessment of this population.

In past, Taguchi and Yokawa (2011), Shiozaki *et al*. (2013), Semba and Shiozaki (2013) and Semba (2017) summarized size data of SMA from Japanese fishery. The purpose of this documment is to update Semba (2017) focusing on annual changes of size frequency with summarization of the available SMA length composition information caught by Japanese commercial fishery and research program in Japan.

Materials and methods

Data

Data sources from which individual size and sex data of SMA in the North Pacific was extracted, were same with that described in Semba (2017). The sources include port sampling (hereafter, 'Port sampling data') and research data including RTV database, longline research survey conducted by FRI, and observer program. The details of data used for each source are described below and number of individual are shown by "fishery type and data source" and sex in Table1.

1) Port-sampling data

Size data between 2005 and 2022 was available for this work. All size data of SMA was obtained from port-sampling program in Kesen-numa fishing port.

Regarding longline fishery, offshore longline fishery (larger than 119 ton) treated in this document has deployed shallow and night setting style and thus was categorized as "shallow-set longline". This fishery corresponds to Kinkai-shallow in CPUE standardization of Japanse data and thus indicated as Kinkai-shallow hereafter. At least after 2005, this fishery mainly targets swordfish and blue shark seasonally (Yokawa 2009) and according to this target shift, fishing area also changed seasonally. Most of small-scale longline vessel used in this document is smaller than offshore longline vessel and their target is suggested to be variable depending on its registry or independent vessel. As detailed information such as operation area and gear configuration is not available, size data from this fishery was treated as "small-scale (coastal) longline". Driftnet fishery is developed in coastal area of Japan and mainly targets swordfish, billfish, and sharks.

Spatial resolution (i.e., location of catch) of these size data is variable such as 1 degree by 1degree, 5 degrees by 5 degrees, and 10 degrees by 20 degrees (latitude by longitude), because the sharks are landed by cruise. Therefore, level of operation area has been assigned considering the operation area of corresponding cruise based on logbook data. All sharks are landed without head and gut, therefore, dorsal length (distance between the origin of first and second dorsal fin) are measured to the nearest cm and converted to precaudal length (PCL) using the conversion equation (Semba *et al*. 2009). As small individuals (approximately <100 cm PCL) are landed in lumped state, measurement and sex determination are conducted for a few individuals from each lump.

Port sampling data was filtered by removing the data without location and unreliable data with unrealistic size.

2) RTV data

The size data with sex from RTV research was available for 1992-2023 (only first quarter for 2023). In most operation, the main target of RTV research is bigeye tuna and/or yellowfin tuna, and deep-set (hooks per basket: mostly ≥12) with daytime setting has been adopted. But data before 2000, most of operation was categorized as "unknown-type longline" due to the lack of gear information. Following the discussion in the past data preparatory meeting, size data from unknown-type longline was removed and thus data between 2000 and 2023 was included here. Spatial resolution of this data is 1 degree by 1 degree and PCL is measured to the nearest cm for all individuals as much as possible. RTV data with deep set was included in the category of "Research deep longline".

3) Longline research survey data

The size data with sex from longline research survey conducted by FRI was available for 1999-2023. In this program, fishing vessels were chartered and either shallow-set longline (hooks per basket: 4-6) or deep-set longline were operated. Thus, the survey data was divided into shallow-set ("Research shallow longline") or deep-set category ("Research deep longline"). Spatial resolution of this data is 1 degree by 1 degree and PCL is measured to the nearest cm for all individuals as much as possible. Estimated size data (visual estimation before release) was removed from the analysis.

4) Observer data

In the North Pacific, observer program began in 2008 but size data of SMA has been avairable since 2011. Spatial resolution of this data is 1 degree by 1 degree and PCL is measured to the nearest cm for all individuals as much as possible. Observer data consists both shallow-set (hooks per basket: 3-4) and deep-set (hooks per basket: 13-24) longline operation and can be divided into each operation type ("observer_ShallowLL" or "observer_DeepLL"). Some operation for which operation pattern is unknown was categorized as "unknown-type longline".

Analysis

Data available in this document was summarized by "fishery type and data source" and sex. In addition, size data was divided into five areas following area stratification (Fig. 1) cited from Sippel *et al*. (2015). This area stratification roughly reflects fishing ground of each fishery from related countries.

For comparison of size frequency, quantile of PCL was calulated by "fishery type and data source" and histogram was also plotted by "fishery type and data source" and sex (year was aggregated).

Annual trend of mean PCL of SMA was plotted by "fishery type and data source" and sex. For data-rich sources, (i.e., Kinkai-shallow port sampling data and deep-set longline research data), annual trend of mean PCL of SMA was also calculated and plotted by areas.

Based on the revised maturity size (Semba *et al*. 2018), number of juveniles/adults and the ratio of juvenile was calculated by sex and fishery type and data sources.

Results

In this document, size and sex data of SMA from total of 8 different sources was summarized. Size data from

port sampling was divided into Kinkai-shallow (comercial shallow-set longline), small-coastal longline (commercial), or driftnet (commercial), while data from research program (RTV, and FRI survey, observer) and observer data were divided into shallow-set, deep-set, respectively (Table 1). Considering the effect of area on the size frequency, data was divided into five area (Table 2).

Size frequency of SMA by fishing type and data sources

1) Driftnet fishery and small-scale longline fishery (commercial port-sampling data)

Size data from these fishery were exclusively collected in Area1 located near Japan. In both fisheries, 75% of sharks measured was smaller than 150cm PCL and thus was juvenile sharks (Table 3, Fig. 2). In the driftnet fishery, the largest mode was located between 110 and 130 cm PCL in both sexes, while the mode in the small-coastal longline was much wider ranging from 100 to 150 cm PCL. Slight difference was observed in the median, mean and 3rd quartile (larger size in driftnet) but the maximu size was similar between them (Table 3).

2) Shallow-set longline (commercial port-sampling data, observer data, and research data)

Size data from Kinkai-shallow was collected in Area1, Area2, Area3 and Area4 while that from research program and observer data with shallow-set longline was mostly collected in Area1(Table 2). Clear difference was observed in size frequency among data sources even though the same gear was used (Fig. 3 and Table 3). Both mean and median was largest in the commercial landing, followed by observer shallow-set data and shallow-set research data (Table 3). In Kinkai-shallow landing data, clear modes were observed between around 130 and 150 cm PCL, while mode in obsererver data was seen around between 100 and 120 cm (Fig. 3). In research data, the largest mode located between 60 and 70 cm PCL and the second largest mode was seen between 100 and 120 cm PCL (Fig. 3). Small mode between 70 and 100 cm was only observed in research data, but not clear in the commercial data (landing and observer data).

3) Deep-set longline (research data and observer data)

Size data from deep-set longline research data was collected from Area1, Area2, Area3, and Area4 (mostly Area 3 and Area 4: east of the dateline), while size data collected in observer data was collected in Area 1 and Area 2 (west of the dateline) (Table 2). In both dataset, minimum size was same but another quantile and median in research data was larger than that in observer data (Table 3). In the research data, the largest mode located between 150 and 190 cm PCL (Fig. 4). Several modes were seen in the observer data but there is uncertainty in the interpretation of its size frequency due to low sample size.

Annual trend of mean size by fishing type and data sources

Annual trend of mean size was shown by fishing type and data sources in Fig. 5. Mean size of commercial driftnet fishery was stable around 120 to 140 cm PCL between 2005 and 2022, and similar trend was indicated in commercial small-coastal longline between 2005 and 2021 with fluctuation in some years (especially for unknown sex). In commercial Kinkai-Shallow, mean PCL was stable around 130 and 150 cm PCL between 2005 and 2013 and then it decreased to around 130 cm in 2014, which was continued until 2018 in both sexes. From 2014 to 2018, mean

PCL increased to the level before 2013 in both sexes. Mean PCL of observer data of shallow-set longline fluctuated between 100 and 130 cm PCL in both sexes during the period calculated. Regarding research data with shallow-set longline, mean size of males decreased from 1999 and 2002 and then it fluctuated around 100 cm PCL, while mean size of females fluctuated between 75 and 130 cm PCL. Mean size from research deep-set data showed stable trend between 2000 and 2016/2017 around 175 cm PCL in both sexes, followed by rapid decrease and increase between 2017 and 2022.

Annual trend of mean size by area

1) Comparison of annual trend of mean size for commercial shallow-set longline by area

As described previously, size data of commercial shallow-set was available in Area 1 – 4, but majority was recorded in Area 1 and Area 2 (Table 2). Considering the effect of spatial segregation by size and sex, annual trend of mean PCL was shown by area (Fig. 6). Trend in Area 1 was almost same with area-aggregated trend shown in Fig. 2 and mean PCL fluctuated between 130 and 150 cm PCL. In Area 2, annual mean PCL fluctuated between 140 and 160 cm PCL in both sexes. In Area 3, mean PCL of females fluctuated between 140 and 155 cm PCL, while that of males fluctuated between 150 and 180 cm. In Area 4 which is most distant from Japan, size data is only avaibalbe between 2006 and 2010 and interpretation of the trend is difficult due to the limited data.

2) Comparison of annual trend of mean size for deep-set research longline by area

As described previously, size data of deep-set research longline was available in Area 1 – 4, but majority was recorded in Area 3 and Area 4 (Table 2). With same reason above, annual trend of mean PCL was shown by area in Fig. 7. Large fluctuation observed in Fig. 2 was observed only in Area 1. In Area 3, mean PCL of males fluctuated between 170 and 200 cm PCL without any continuous trend, while that of females between 2003 and 2007 (larger than 200 cm PCL) was higher than that in other years. In Area 4, mean PCL was relatively stable between 165 and 185 cm PCL between 2000 and 2011, followed by fluctuation between 130 amd 190 cm after 2012 in both sexed.

Ratio of juvenile by fishing type and data sources

The ratio of juvenile was calculated by sex and fishery type (Table 4). Juvenile was defined as sharks < 166 cm PCL for male and < 233 cm PCL for female, based on the 50% maturity size estimated in Semba *et al*. (2018).

For males, the ratio of juvenile was the highest in the Shallow-set longline reserch data (95.4 %), followed by driftnet fishery (92.0%) and observer shallow-set longline data (89.3%).The ratio was lowest in the Deep-set longline research data (41.8%), which indicate that majority of catch is adult. Juvenile male also dominated in Kinkai-shallow but not so high as other coastal fisheries described above. .

For females, almost 100% of catch was juveniles in all fishery type and data sources except for deep-set longline research data, in which, 4.7 % of SMA measured was adult. Juvenile ratio in observer data with deep-set longline was 100%, and the data was collected in Area 1 and Area 2 (Table 2), west of Area 3 and Area 4.

Discussion

In this document, size frequency and annual trend of mean PCLof SMA were described by fishery type and data

sources with consideration of area effect in some data sources. As indicated in previous document, coastal fisheries including driftnet fishery, FRI shallow-set longline survey, and small-scale longline operated in the west of the dateline catch larger amount of juveniles (< 150 cm PCL) compared to deep-set longline research mainly operated in the area east of the dateline, in general. Kinkai-shallow commercial fishery also catch mainly juveniles smaller than 150 cm PCL, but 20% of males were adults with juveinles dominated in females. In deep-set longline research, 58% of males and 4.7% of females were adult, which are highest percentage of adult among data sources compared.

As discussed in the previous document (Semba 2017), different size structure was also observed, depending on data sources even if the same fishery and operation type were used. In case of Shallow-set longline, commercial vessel land larger size compared to data from observer and research. As a possible cause for this difference, release of small individuals in commercial vessel and different operation area are suggested. For shallow-set research, the operation was mostly conducted between April and June which overlap with pupping season of this species in the area where does not overlapped with fishing area of commercial vessel (i.e., more coastal area).

Annual comparison of mean PCL for Kinkai-shallow landing data indicated small decline of mean PCL between 2014 and 2018 and increase after 2018. In 2014, FRI launched survey to collect size data from small sharks which has been usually released in the operation. This survery changed landing pattern of commercial vessel and lasted few years. Around 2015, the Management Plan for Longline Fisheries Targeting Shaks developed for the offshore surface longline fleets based at Kesennuma fishing port was implemented under CMM2014-05 (JAPAN 2015), which request release of juvenile sharks (< 150 cm PCL). Therefore, this change may be caused by such artificial effect.

Regarding the deep-set longline survery, size data from Area 3 and Area 4 would be better to be referred as the size data of Japanese deep-set longline fleet, considering that main operation area was east of dateline. This data source provides both index and size data for subadult and adult SMA, but recently, sample size decreased rapidly since around 2011 and available sample size after 2020 is less than 10 per year (Table 1). Therefore, caution is necessary to interprete the fluctuation observed after 2010s. It is unlikely that the data collection would be improved in future, because of several regulations implemented.

In conclusion, no continuous trend of mean PCL was observed in Kinkai-Shallow commercial landing data, deep-set longline survey data and driftnet fishery if excluding the possible artificial effect described above.

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Table 1. Annual number of length data of SMA in the North Pacific between 1999 and 2022 by the type of fishing gear and sex. Processing of data in 2023 has been undertaken and not included in this summarization.

Year	Kinkai-Shallow LL			Small-coastal LL			Driftnet			Shallow LL			Deep LL			Shallow LL			Deep LL		
	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U
1999										0	2	3	107	145	6						
2001										1	1	0	95	129	4						
2002										26	22	9	116	114	2						
2003										38	23	8	119	142	4						
2004										39	33	1	113	169	7						
2005	1,613	2,268	1,154	1	0	0	4	11	7	13	12	0	119	174	13						
2006	3,796	5,066	1,032	7	13	7	9	7	7	16	11	3	103	150	25						
2007	3,510	4,412	1,522	20	12	6				12	16	0	91	146	5						
2008	2,968	4,018	1,045	81	113	30	355	421	169	5	11	3	68	107	7						
2009	1,782	2,727	809	64	62	8	282	345	106	10	13	4	37	47	12						
2010	1,747	2,465	664	156	118	45	403	536	166	5	8	0	27	46	6				0	0	2
2011	907	1,060	274	23	28	3	58	96	29	1	0	0	18	31	7	108	86	2			
2012	2,913	3,648	682	60	56	0	762	780	198	26	20	3	3	16	1				0	0	2
2013	2,788	2,944	307	68	58	1	323	326	142	5	5	0	2	5	1				0	0	1
2014	6,532	7,618	6	47	39	1	613	568	174	51	35	3	7	4	0	261	248	34	0	0	5
2015	5,512	5,648	247	61	59	2	329	380	107	23	23	0	5	9	0	622	638	49	0	0	17
2016	7,121	6,320	449	51	45	5	254	192	85				1	15	2	117	137	1			
2017	6,611	5,455	180	256	239	50	165	170	192	29	22	5	2	8	4	208	211	1	15	11	3
2018	6,979	6,739	12	220	227	68	226	244	249				7	7	1	292	264	11	10	19	1
2019	4,240	3,666	1,955	157	169	101	142	142	324	7	9	1	7	6	1	198	203	1	21	13	4
2020	2,911	2,842	893	61	68	14	41	67	24	17	12	2	2	2	1				6	5	0
2021	2,837	2,602	471	12	3	4	16	35	0	3	4	0	3	3	1						
2022	2,520	2,824	82				23	37	0	0	1	1	0	4	0						
Total	67,287	72,322	11,784	1,345	1,309	345	4,005	4,357	1,979	223	202	25	502	780	87	1,806	1,787	99	52	48	35
Total by data source	151,393			2,999			10,341			450			1,369			3,692			135		
Percentage (%)	89			2			6			0			1			2			0		

Table 2. Number of length data of SMA in the North Pacific between 1999 and 2022 by Area and Sex.

			Area				
Source	Fishery type	Sex	1	2	3	4	5
Port sampling	ShallowLL	F	59,719	5,950	732	227	0
		M	63,733	5,955	1,610	426	0
		U	11342	289	125	23	0
	Small-coastalLL	F	1,327	0	0	0	0
		M	1,289	0	0	0	0
		U	345	0	0	0	0
	Driftnet	F	4,005	0	0	0	0
		M	4,357	0	0	0	0
		U	1,979	0	0	0	0
Research	ShallowLL	F	298	29	0	0	0
		M	264	19	0	0	0
		U	40	5	0	0	1
	DeepLL	F	16	2	128	907	0
		M	11	7	358	1,106	0
		U	3	1	19	87	0
Observer	ShallowLL	F	1,908	28	0	0	0
		M	1,877	22	0	0	0
		U	105	1	0	0	0
	DeepLL	F	44	8	0	0	0
		M	32	16	0	0	0
		U	25	10	0	0	0
	Total by area		152,719	12,342	2,972	2,776	1
	Percentage (%)		89	7	2	2	0

Table 3. Quantile and median of PCL of SMA by data source. Sex was aggregated.

source	Minimum	1st quartile	Median	Mean	3rd quartile	Max.
Driftnet	60.4	114.5	132.7	132.9	149.3	243.1
Smallcoastal	62.2	111.4	123.2	124.9	139.1	247.2
ps_Kinkai Shallow	55.7	113.6	134.1	135.9	155.2	296.3
obs_Kinkai Shallow	33	100	120	123.3	145	265
res_Shallow	55	70	105	99.73	118	200
res_Deep set	54	158	173	175	190	320
obs_Deep set	54	87	118	118.3	151.5	209

Table 4. Number of juvenile and adults with the ratio of juvenile by fishery type and data sources and sex. LL is abbreviation of “longline”.

Male	No. of Juvenile (<= 166.36 cm PCL)	No. of Adult (>166.36 cm PCL)	Ratio of juvenile (%)
ps_Driftnet	5,230	456	92.0
ps_Small-coastalLL	1,281	202	86.4
ps_ShallowLL	58,888	14,333	80.4
Observer_ShallowLL	1,695	204	89.3
Res_ShallowLL	270	13	95.4
Observer_DeepLL	42	6	87.5
Res_DeepLL	619	863	41.8

Female	No. of Juvenile (<= 233.65 cm PCL)	No. of Adult (> 233.65 cm PCL)	Ratio of juvenile (%)
ps_Driftnet	5,140	2	100.0
ps_Small-coastalLL	1,460	2	99.9
ps_ShallowLL	67,940	178	99.7
Observer_ShallowLL	1,931	5	99.7
Res_DeepLL	1,003	50	95.3
Observer_DeepLL	52	0	100.0
Res_ShallowLL	327	0	100.0

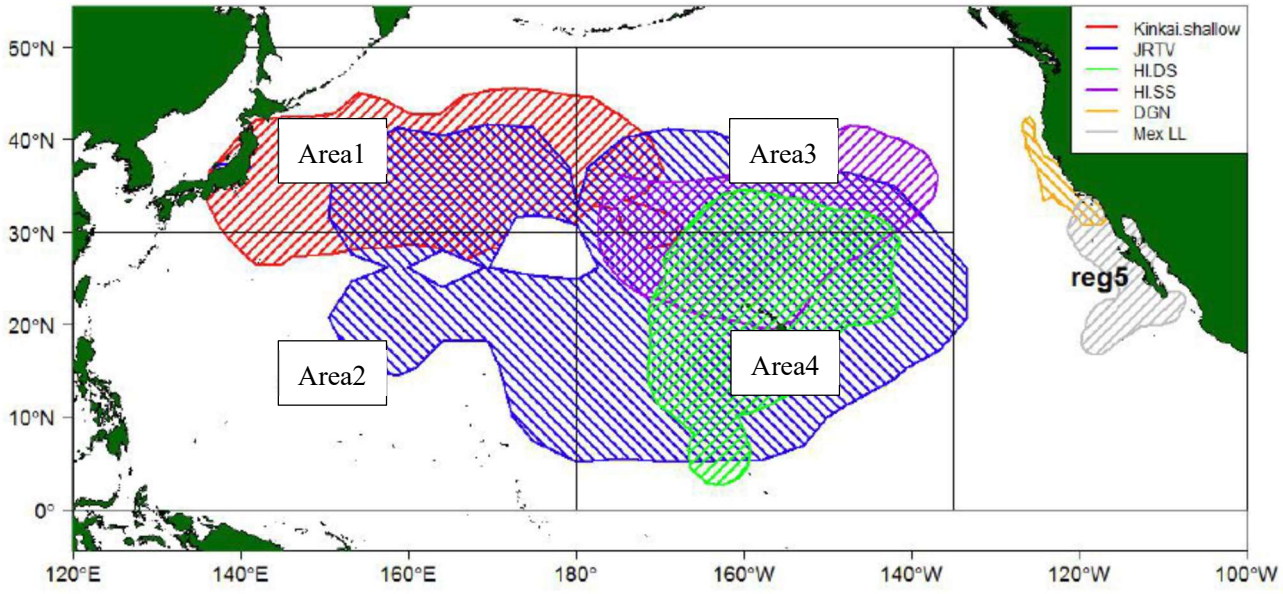

Fig. 1. Area stratification used in this document. Cited from Sippel *et al*. (2015).

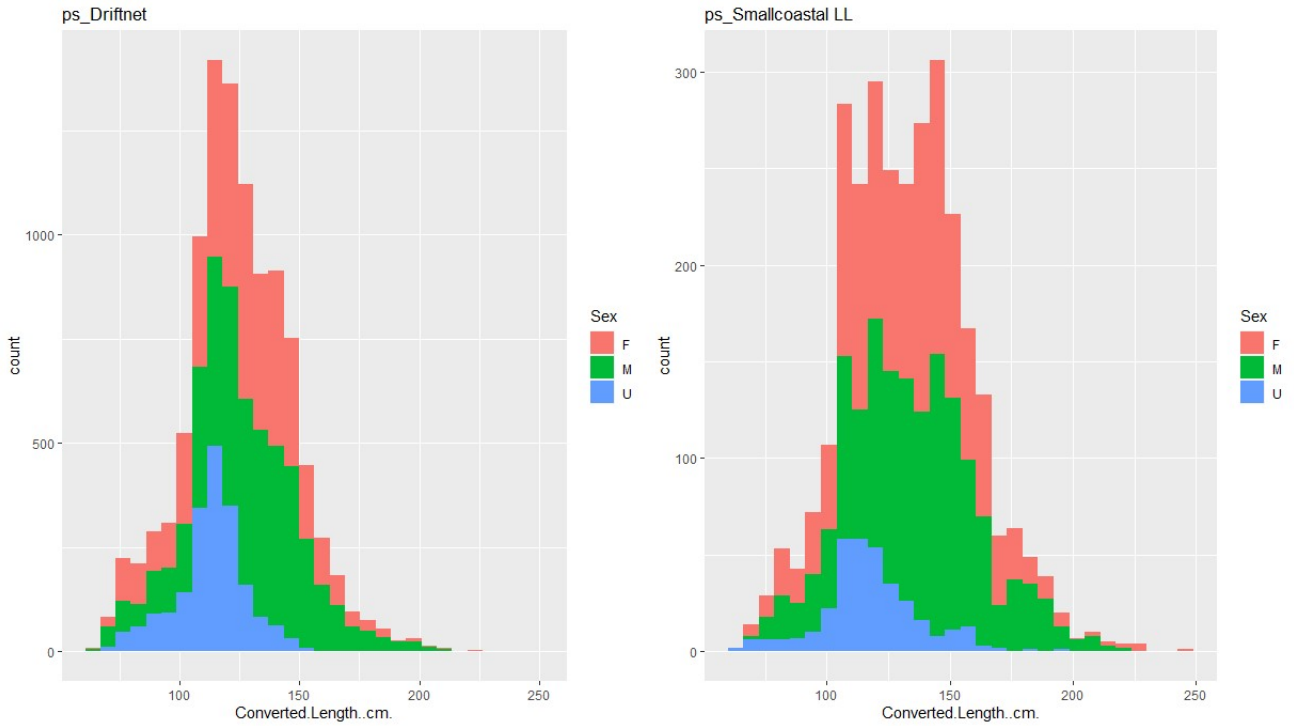

Fig. 2 Size frequency of SMA caught by driftnet fishery (left) and small-scale longline fishery (right) by sex. Definition of F, M, and U in Sex denote females, males, and unknown, respectively.

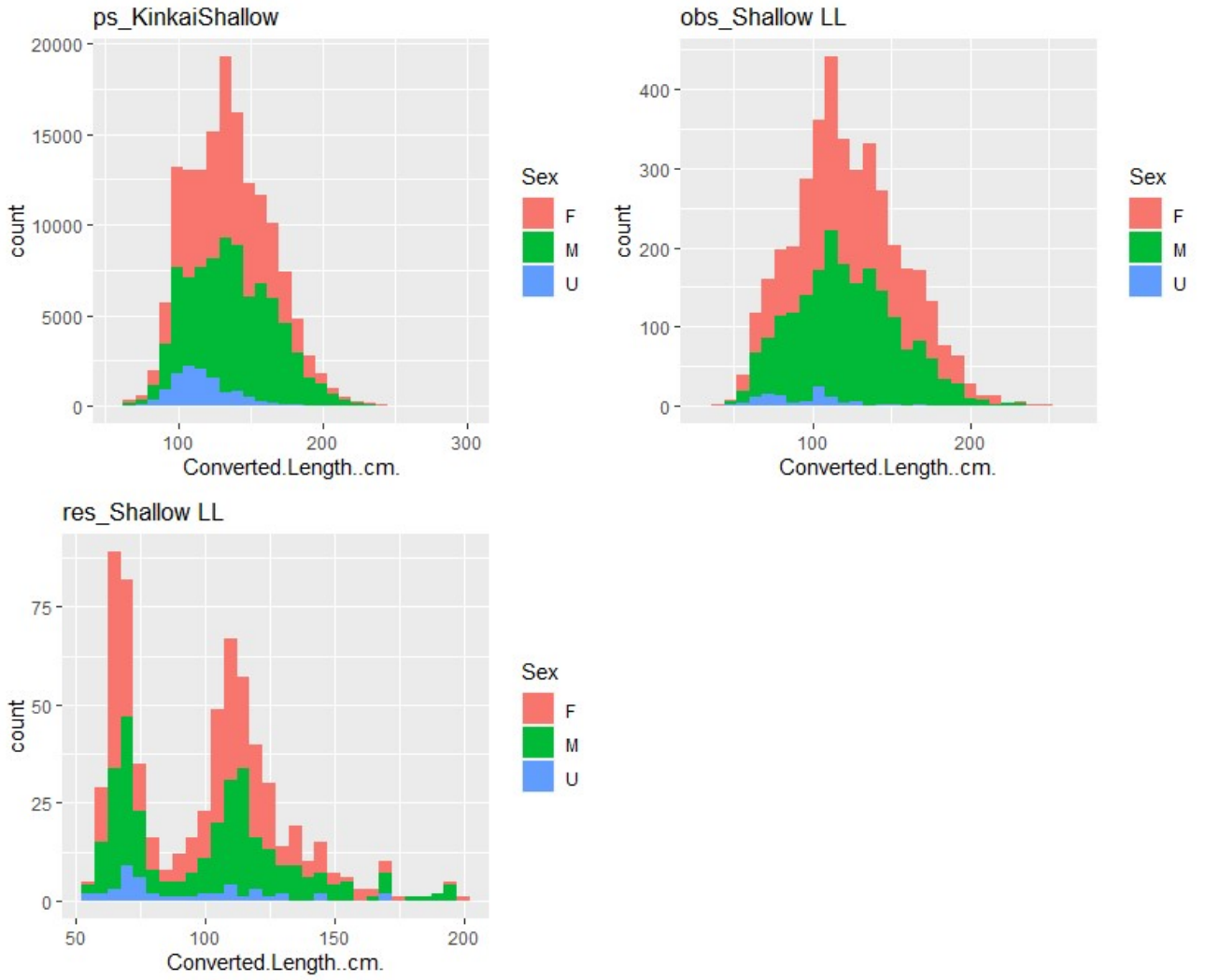

Fig. 3 Size frequency of SMA collected by Kinkai-Shallow longline (top left: port sampling), observer data from Kinka-Shallow longline (top right) and shallow-set longline research (bottom left). Definition of F, M, and U in Sex denote females, males, and unknown, respectively.

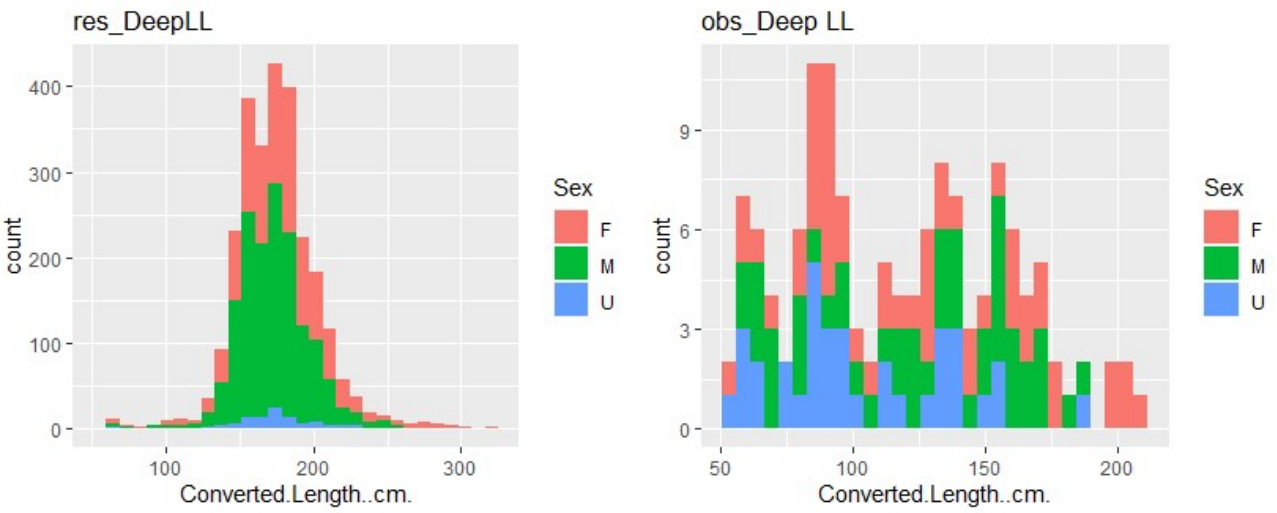

Fig. 4 Size frequency of SMA collected by deep-set longline research (left) and observer data with deep-set longline (right). Definition of F, M, and U in Sex denote females, males, and unknown, respectively.

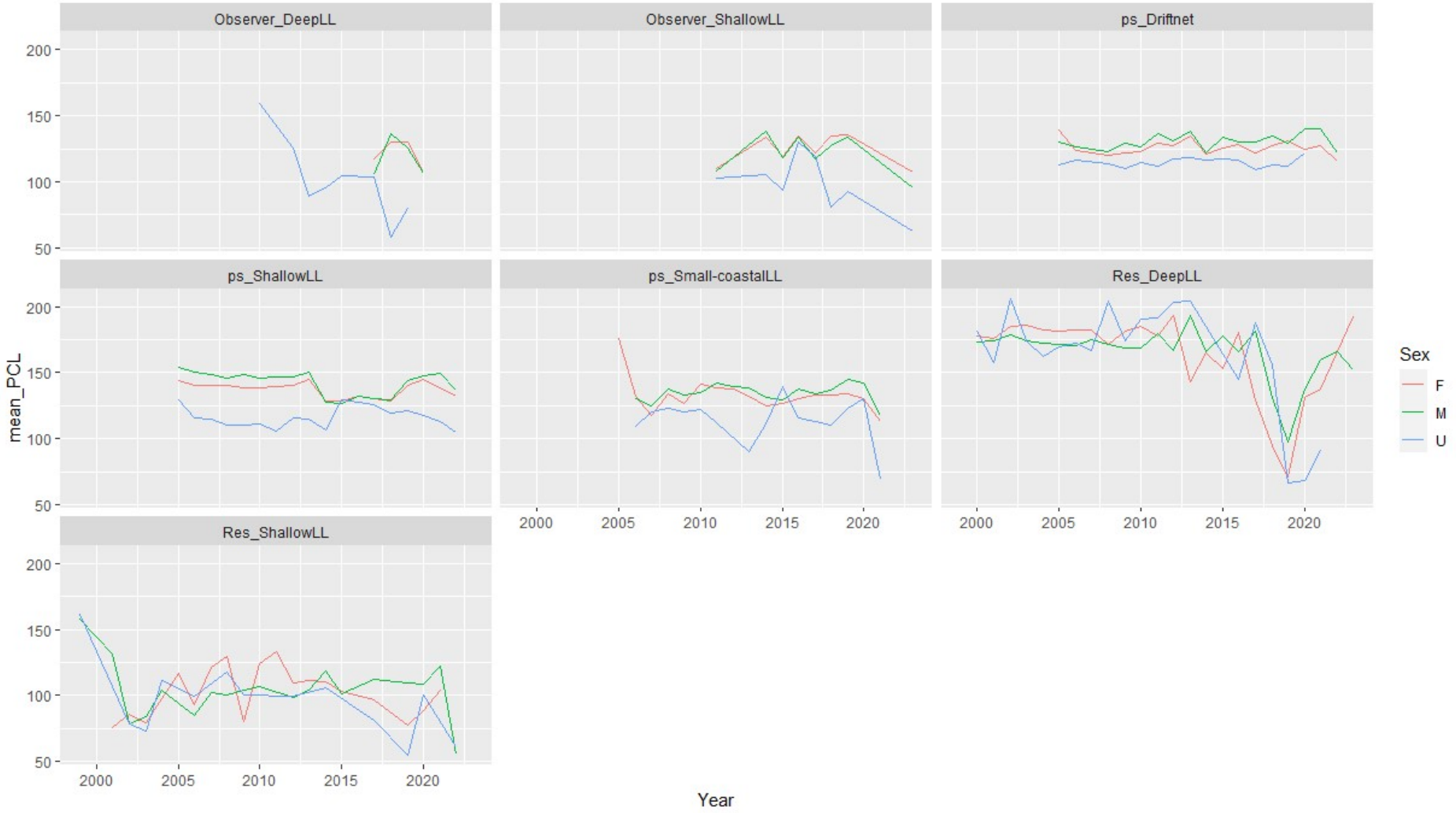

Fig. 5. Annual trend of mean PCL of SMA by fishery type and data sources and sex.

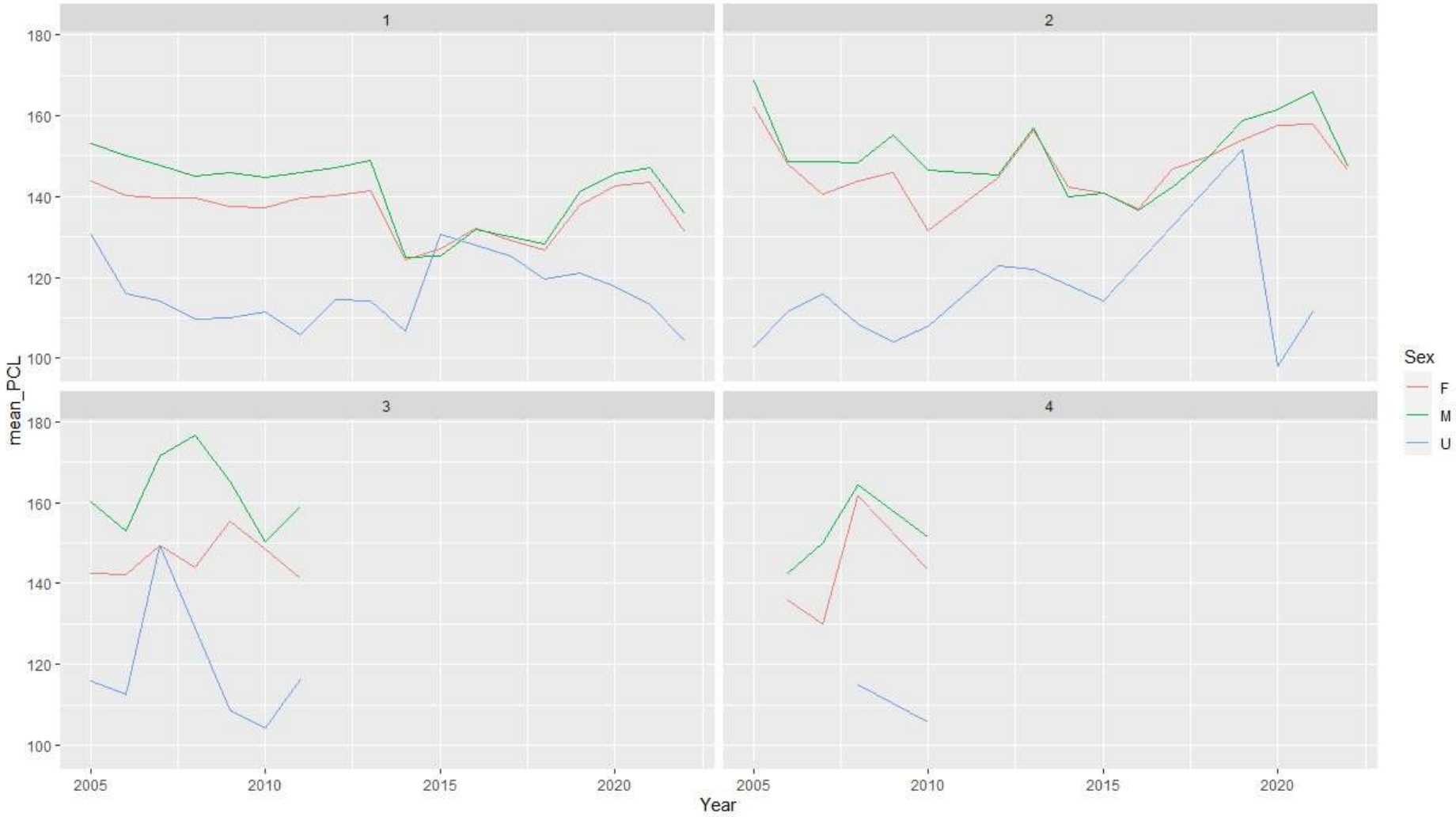

Fig. 6. Annual trend of mean PCL of SMA calculated from commercial landing data of Kinkai-Shallow longline by area and sex.

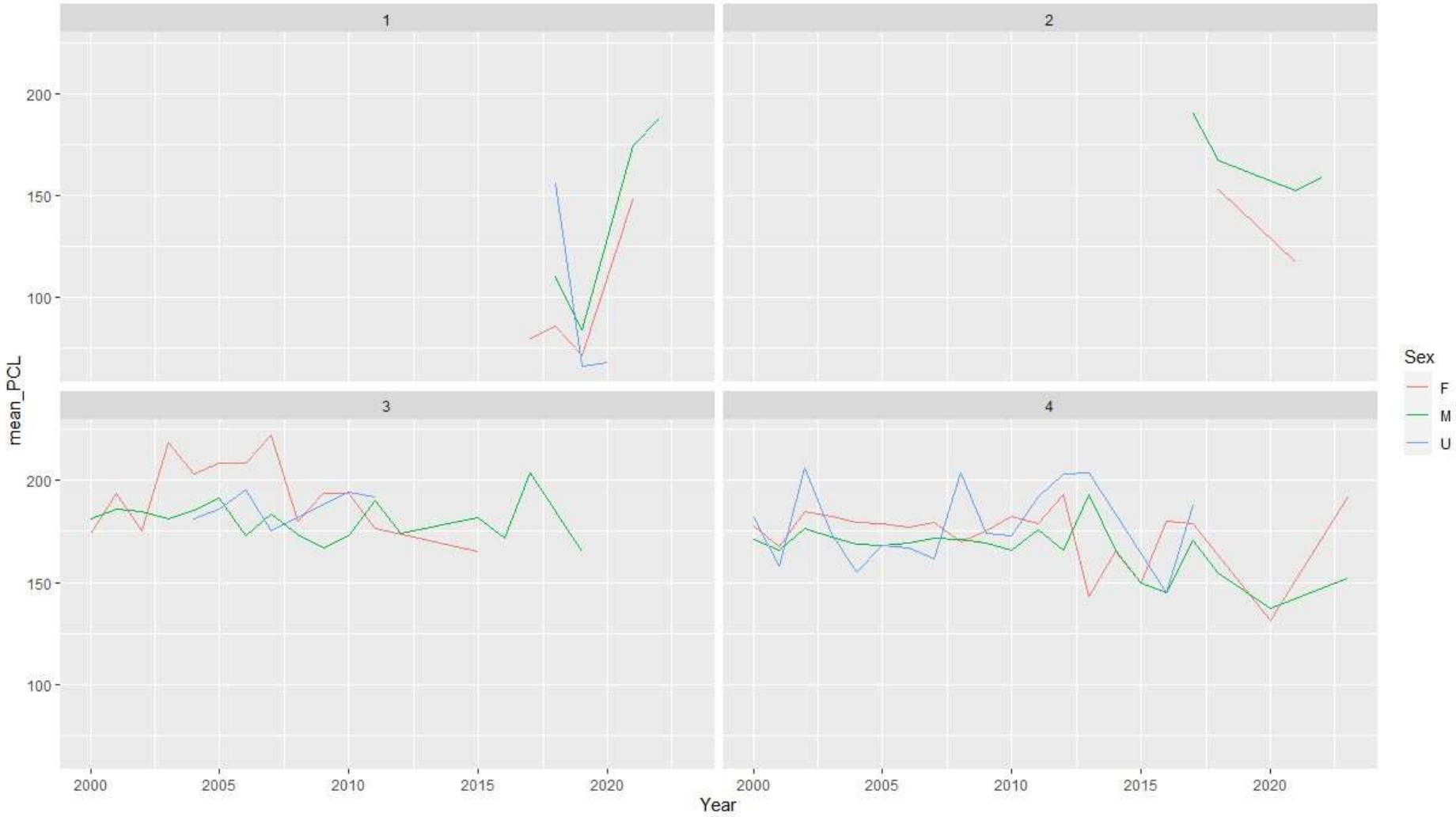

Fig. 7. Annual trend of mean PCL of SMA calculated from deep-set research longline by area and sex.