The size composition and age structure of shortfin mako *(Isurus oxyrinchus)* caught by Japanese commercial fisheries in the North Pacific[1]

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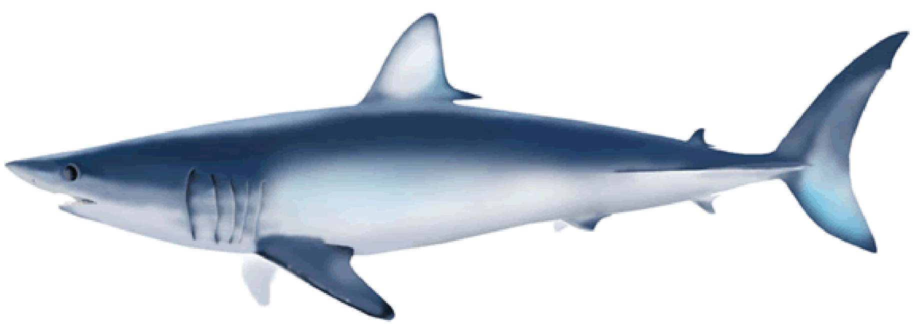

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Summary

Size composition of a total of 96,000 length data of shortfin mako caught by Japanese commercial fisheries, coastal, offshore, distant-water longline and drift net, in the North Pacific during the years 2005 - 2009 was examined for their stock analysis. The frequencies were depicted by quarter and area using the size data obtained from the offshore longliners because of the largest number of available size data. Overall, the frequencies were not so different among years and quarters but among areas, which indicated that shortfin mako in the eastern North Pacific was larger than western. The length frequencies were converted into the age to examine the age structure of catch by the offshore longliners, which suggested that shortfin makos caught by Japanese offshore longliners were composed of juveniles aged 1 to 2 years, and adult female was quite few.

Introduction

The scientific committee of Western and Central Pacific Fisheries Commission (WCPFC) made recommendation with regards to research plan and stock assessment of pelagic sharks at the Fifth Regular session of the Scientific Committee of WCPFC in August 2009. The scientific committee of WCPFC also requested discussion on feasibility of stock assessment by the international scientific committee for tuna and tuna-like species in the North Pacific Ocean (ISC) for key shark species in the North Pacific, especially for shortfin mako and blue shark. In response to the recommendation, ISC established the shark working group in the last year, and entrusted the stock assessments of blue shark and shortfin mako in the North Pacific to the working group.

The size composition and age structure of shortfin mako caught by Japanese commercial fisheries in the North Pacific were examined for their stock analysis in the present study.

Materials and methods

A total of 96,000 size data was mainly recorded as dorsal length (DL) in cm, distance between the origin of the first dorsal fin and that of the second dorsal fin, of shortfin mako caught from second quarter in 2005 to 2009 by distant-water, offshore, coastal longliners and the coastal drift netters based on Kesennuma was used (Table 1) in the present study. DLs were converted to PCLs, precaudal length, using the following formula by sex (Semba *et al*., 2009). However, the DLs unrecorded the sexual data were converted with formula for male.

Male $PCL = 2.04DL + 12.1$
Female $PCL = 2.18DL + 7.79$

Age structure was calculated with cohort slicing method by year, quarter and area. Following growth equations of the shortfin mako in the central and western North Pacific (Semba *et al*., 2009) were used in this analysis.

Male $L_t = 60 + 171.3\{1 - \exp(-0.156t)\}$
Female $L_t = 60 + 248.6\{1 - \exp(-0.090t)\}$

Where L is PCL in cm and t is age of shark. Size classes for age were calculated by following criterion. However, the parturient season of shortfin mako was set in May which estimated by Semba *et al*. (2009), and age was counted on January 1 in the present study.

$$\begin{cases} L_0 \leq L_t < L_{\frac{2}{3}} & (t = 0) \\ L_{\frac{t+1}{3}} \leq L_t < L_{\frac{t+2}{3}} & (t \geq 1) \end{cases}$$

Additionally, annual average product weight of shortfin mako was calculated by quarter and by area in 1994 - 2009, using the log-book data of offshore longline, and their trends were estimated by GLM.

In the present study, the North Pacific was divided into 3 areas to analyze the length distribution and age structure of shortfin mako as shown in Fig. 1.

Results and discussion

All size data used in the present study were collected at Kesennuma fishing port where located in the Pacific coastal side of the northeastern Honsyu, Japan. The amount of landing for shortfin mako in Kesennuma fishing port can be considered the Japanese landing because it account for more than 80% of the total of their landing in Japan (Fig. 2). Most size data used in this analysis was obtained from the offshore longliners (Table 1). Their annual coverage by quarter and by subarea, dividing by 10 degrees latitude and 20 degrees longitude, were more than 80% in each stratum except a few strata whose coverage is less than 30%. Moreover, the collection of the size data from drift netters was started in 2008, and they have been mainly collected in area 1.

Figure 3 showed frequency distributions in PCL of shortfin mako by the type of fishery, coastal, offshore, distant-water longlines and drift net. Annual length distributions of shortfin mako caught by offshore longliners with the largest sample size of all fisheries were shown by quarter and by area in Figs. 4a - e. Additionally, the length frequency of sharks caught by drift netters is also shown by year and by quarter (Fig. 5). Shortfin mako landed in Kesennuma fishing port were ranged between 60 and 220 cm as shown in Fig. 2. The position of peaks were slightly different among types of fishery, which showed the highest peak between 105 and 110 cm in the offshore longline, and between 110 and 125 cm in drift net. However, the seasonal changes in the position of the peak were not observed in length frequencies of both the drift net and offshore longline in area 1 in 2008 - 2009 (Figs. 4d and e). Moreover, the offshore longliners landed shortfin mako on a year-around (Table 1), but most of catch by drift netters was obtained in second and third quarters. Given these observations, the difference in frequencies between the offshore longline and drift net could be related to difference in their fishing season. Furthermore, the length distributions of shortfin mako caught by offshore longliners also suggested that larger fishes were caught in eastern North Pacific than western, and the size compositions by year were rather similar (Figs.

4a - e). However, the length frequencies of shortfin mako in area 1 in second and third quarters were slightly larger than other quarters.

Catch at age of shortfin mako caught by the offshore longliners shown in Table 3 indicated that the shortfin mako landed in Kesennuma were composed of juveniles aged one and two years, and no adult sharks more than fifteen years old were caught. Shortfin mako in the central and western North Pacific attain sexual maturity at an age of 5 years for male and 17 years for female (Semba *et al.*, 2011), which means that few mature females were caught by Japanese offshore longliners. Given rather stable catch of juvenile shortfin mako by Japanese offshore longliners at least since 1994 (Table 3), the relatively stable recruitment should occur in that period. Semba and Yokawa (2011) indicated that the main distribution areas of the juvenile and adult shortfin mako are in the xx and tropical Pacific area, respectively. The fishing ground of the longliners based on Kesennuma overlaps with the juvenile distribution area rather than the adult. This would be one of the reasons for a lack of adult catch in the present study. The observed relatively stable catch of juvenile shortfin mako, the largely overlapping between their distribution area and fishing ground of Japanese longliners, and high coverage of size data should give a good indicator of their recruitment. Additionally, considering high maturity age and reproduction with small number of pups for shortfin mako, they should be quite vulnerable to the fishing pressure. Although, the Japanese surface offshore longliners based on Kesennuma fishing port have operated using similar style in same area for more than 30 or 40 years with some large amount of landing of shortfin mako. If one compares this reproductive character with the long history of catch and relative stable catch of juveniles in the recent 15 years, we should have a interest in the mechanisms to ensure stable recruitment for longer period. The clarification of such mechanism should provide important information for the management of this stock.

Annual average product weights of shortfin mako from Japanese offshore longliners by operation between 1994 and 2009 were plotted in Fig. 6 by landing port, by quarter and by area. The interannual trends in Kesennuma fishing port were estimated by GLM, which showed statistically-significant negative correlation between year and average product weight in all quarters of areas 1 and 2 except the fourth quarter in area 2 (Fig. 6a), whereas positive correlations were estimated in all quarters of area 3. Although, the observed interannual change were quite small, and dramatically change in average product weight of shortfin mako caught by offshore longliners have not been found since 1994.

The sex ratio in relation to the length class of shortfin mako caught by offshore longliners was shown by area and by quarter in Fig. 7. In area 1, no apparent difference in the sex ratio was observed, and female accounted for 40 - 60 % of all size data, identified sexually, in less than 140 cm through the year. On the other hand, the sex ratio of shortfin mako larger than 140 cm was changed by quarter, which showed that the female ratio increased in relation to length in second and third, and decreased in first and fourth quarters. Additionally, the observed trends of sex ratio were not so different among areas, but the ratios of female tends to be higher in area 1 than area 2, which indicated that more male sharks were caught in the eastern North Pacific than western. These observations would indicate the sex and size specific distribution of shortfin mako in the central and western North Pacific. Although, most sex information of shortfin mako less than 100 cm, which was majority of size data used in the present study, was not recorded. Given the results of the present study, the sexual information should be collected in combination with length data in all size classes in further researches.

References

Semba, Y., H. Nakano and I. Aoki (2009) Age and growth analysis of the shortfin mako, Isurus oxyrinchus, in the western and central North Pacific Ocean. Environmental Biology of Fishes 84:377-391

Semba, Y., I. Aoki and K. Yokawa (2011) Size at maturity and reproductive traits of shortfin mako, Isurus oxyrinchus, in the western and central North Pacific. Marine and Freshwater Reserach 62:20-29

Semba, Y. and K. Yokawa (2011) Preliminary analysis of sex-specific distributional pattern of shortfin mako, Isurus oxyrinchus, in the western and central North Pacific. ISC Document submitted to this WG meeting, 30pp.

Table 1 Annual number of length data by type of fishery for shortfin mako caught by Japanese commercial fisheries

Year	Quarter	Distant-water	Off shore	Coastal	Drift net	Total
2005	1	0	0	0	0	0
	2	0	3238	0	80	3318
	3	0	1954	1	0	1955
	4	0	6332	0	0	6332
	Unrecorded	0	38	0	0	38
	Total	0	11562	1	80	11643
2006	1	188	4628	61	0	4877
	2	218	5041	0	81	5340
	3	0	3753	1	0	3754
	4	0	6329	1	0	6330
	Unrecorded	0	142	0	0	142
	Total	406	19893	63	81	20443
2007	1	0	7498	70	0	7568
	2	1	4728	0	0	4729
	3	0	4400	1	0	4401
	4	202	7643	0	0	7845
	Unrecorded	0	461	0	0	461
	Total	203	24730	71	0	25004
2008	1	0	7460	23	61	7544
	2	0	5649	298	1183	7130
	3	0	2740	54	969	3763
	4	0	4407	95	186	4688
	Unrecorded	0	0	4	0	4
	Total	0	20256	474	2399	23129
2009	1	0	5219	44	12	5275
	2	0	2964	132	501	3597
	3	0	2379	5	982	3366
	4	0	3446	27	204	3677
	Unrecorded	0	0	0	111	111
	Total	0	14008	208	1810	16026
Total		609	90449	817	4370	96245

Table 2 Annual number of length data by sex, area and quarter for shortfin mako caught by offshore longline in Japan

Year	Quarter	Sex	Area 1	Area 2	Area 3	Total
2005	1	Male	0	0	0	0
		Female	0	0	0	0
		Unrecorded	0	0	0	0
	2	Male	173	406	104	683
		Female	145	305	41	491
		Unrecorded	976	1023	65	2064
	3	Male	82	254	39	375
		Female	88	251	24	363
		Unrecorded	101	1056	59	1216
	4	Male	154	869	250	1273
		Female	214	474	85	773
		Unrecorded	810	3081	395	4286
	Unrecorded	Male	0	10	0	10
		Female	0	5	0	5
		Unrecorded	0	23	0	23
	Total		2743	7757	1062	11562
2006	1	Male	478	423	32	933
		Female	480	190	21	691
		Unrecorded	2045	959	0	3004
	2	Male	433	599	152	1184
		Female	551	442	122	1115
		Unrecorded	2281	427	34	2742
	3	Male	242	853	54	1149
		Female	320	567	38	925
		Unrecorded	532	1127	20	1679
	4	Male	347	1219	180	1746
		Female	348	642	59	1049
		Unrecorded	826	2604	104	3534
	Unrecorded	Male	12	0	0	12
		Female	19	0	0	19
		Unrecorded	111	0	0	111
	Total		9025	10052	816	19893
2007	1	Male	745	278	0	1023
		Female	892	133	0	1025
		Unrecorded	5040	410	0	5450
	2	Male	496	528	103	1127
		Female	584	338	39	961
		Unrecorded	1983	657	0	2640
	3	Male	573	432	67	1072
		Female	491	233	37	761
		Unrecorded	2001	541	25	2567
	4	Male	558	695	30	1283
		Female	533	392	8	933
		Unrecorded	3079	2291	57	5427
	Unrecorded	Male	31	90	0	121
		Female	22	82	0	104
		Unrecorded	222	14	0	236
	Total		17250	7114	366	24730
2008	1	Male	805	312	57	1174
		Female	768	216	30	1014
		Unrecorded	4331	855	86	5272
	2	Male	595	647	23	1265
		Female	575	456	20	1051
		Unrecorded	2203	1118	12	3333
	3	Male	332	388	41	761
		Female	296	235	6	537
		Unrecorded	940	502	0	1442
	4	Male	75	940	34	1049
		Female	61	439	15	515
		Unrecorded	604	2239	0	2843
	Unrecorded	Male	0	0	0	0
		Female	0	0	0	0
		Unrecorded	0	0	0	0
	Total		11585	8347	324	20256
2009	1	Male	453	125	0	578
		Female	393	43	0	436
		Unrecorded	3871	334	0	4205
	2	Male	215	308	22	545
		Female	200	197	10	407
		Unrecorded	1697	313	2	2012
	3	Male	183	244	262	689
		Female	142	226	109	477
		Unrecorded	580	574	59	1213
	4	Male	205	669	22	896
		Female	157	325	3	485
		Unrecorded	755	1310	0	2065
	Unrecorded	Male	0	0	0	0
		Female	0	0	0	0
		Unrecorded	0	0	0	0
	Total		8851	4668	489	14008
Total			49454	37938	3057	90449

Table 3 Annual age structure of shortfin mako caught by offshore longline

Age	2005					2006					2007					2008					2009					Total
	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total	1	2	3	4	Total	
0	N.D.	100	0	0	100	128	218	221	71	637	61	82	177	86	406	62	465	219	354	1100	149	152	193	317	812	3055
1	N.D.	1457	66	663	2186	961	189	221	1229	2600	1611	208	134	1918	3870	1348	278	87	1182	2896	1462	528	199	999	3188	14739
2	N.D.	858	330	231	1419	523	973	522	405	2422	1179	1107	809	291	3385	598	1842	350	251	3041	1229	2102	545	343	4218	14485
3	N.D.	120	264	1010	1393	262	479	288	693	1722	286	421	451	529	1687	295	378	231	431	1335	226	286	397	448	1357	7495
4	N.D.	200	198	652	1050	189	552	270	423	1433	258	449	381	241	1329	198	478	172	201	1049	203	265	278	242	988	5850
5	N.D.	40	264	421	725	110	653	301	339	1402	125	270	332	172	900	94	262	102	203	660	70	147	278	211	706	4394
6	N.D.	20	396	189	605	61	348	166	178	753	61	142	144	114	460	64	135	54	117	370	37	84	152	116	388	2577
7	N.D.	0	264	147	411	18	145	68	75	306	28	81	58	60	227	24	72	22	57	175	23	36	59	46	163	1282
8	N.D.	0	0	63	63	6	160	37	57	260	10	48	23	27	108	19	23	18	30	89	11	17	49	27	104	625
9	N.D.	0	0	63	63	6	58	49	32	145	3	19	21	19	63	5	15	12	17	49	5	10	17	12	44	364
10	N.D.	0	0	32	32	6	15	6	11	38	0	10	10	11	31	3	8	6	13	30	3	9	16	8	35	166
11	N.D.	0	0	21	21	6	0	0	2	8	3	4	16	9	31	1	4	3	5	13	2	0	10	5	17	90
12	N.D.	0	0	21	21	0	0	6	9	15	0	5	2	3	10	1	1	3	1	7	1	0	7	3	11	64
13	N.D.	0	0	11	11	0	0	0	2	2	0	1	2	3	6	1	2	0	1	5	1	1	1	2	5	29
14	N.D.	0	66	21	87	6	0	0	2	8	0	1	2	1	4	1	0	0	3	3	1	1	7	0	10	113
15	N.D.	0	0	0	0	0	0	6	5	11	0	0	0	0	0	0	0	0	1	1	0	0	2	1	3	15
16	N.D.	0	0	0	0	0	0	0	2	2	0	0	2	2	4	1	1	0	1	4	0	0	0	3	3	13
17	N.D.	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	1	2
18	N.D.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	1	2	1	0	1	0	2	5
19	N.D.	0	0	0	0	0	15	0	0	15	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	15
20	N.D.	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	1	2	0	0	0	0	0	4
21	N.D.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
22	N.D.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1
23	N.D.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	N.D.	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	1	0	0	1	4
25	N.D.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26+	N.D.	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1
Total	N.D.	2794	1847	3545	8186	2282	3803	2160	3537	11782	3628	2850	2566	3487	12531	2717	3965	1279	2872	10833	3423	3641	2211	2783	12058	55390

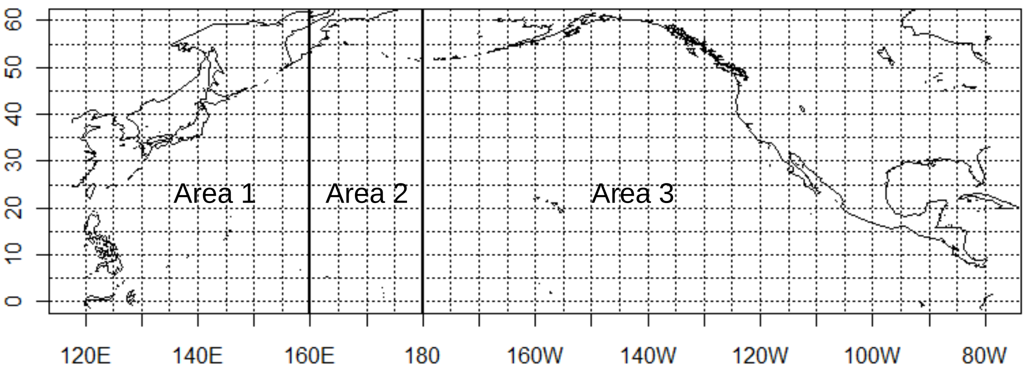

Fig. 1 Area stratification used in the present working paper

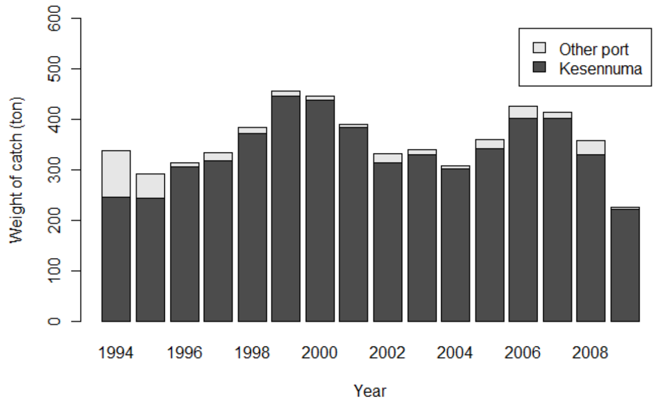

Fig. 2 Annual weight of catch for shortfin mako caught by Japanese longline

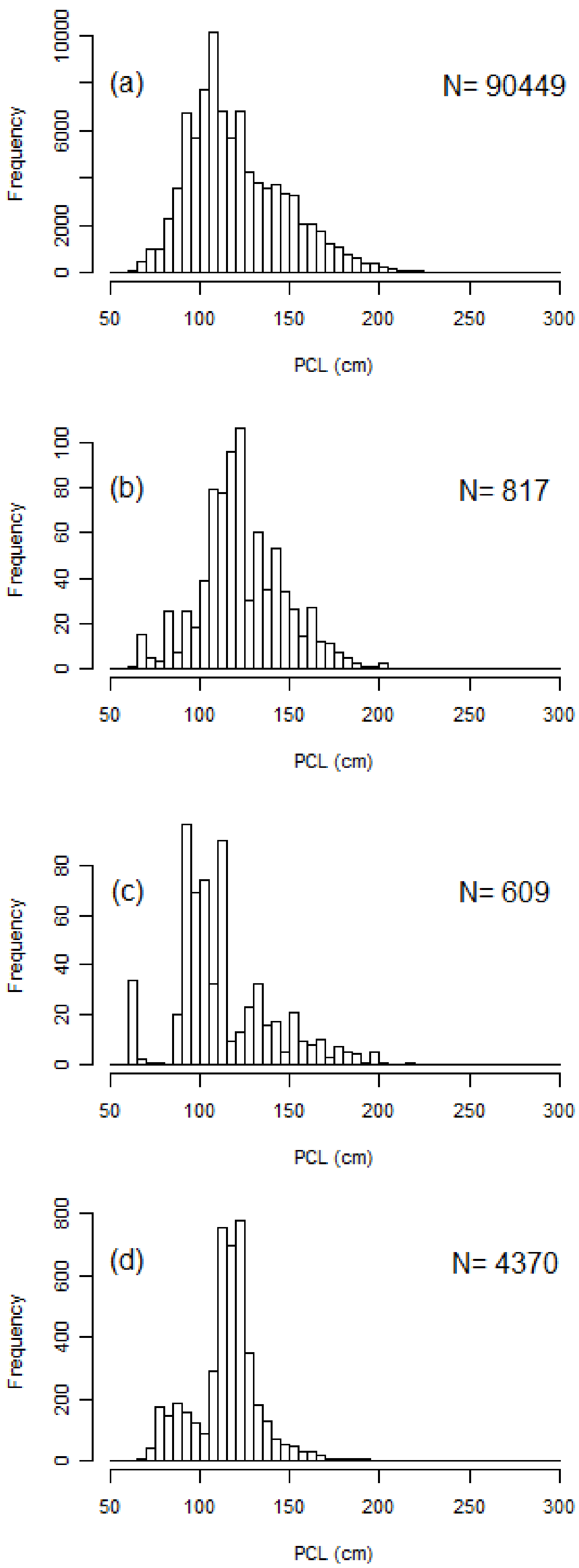

Fig. 3 Frequency distributions in PCL by type of fishery for shortfin mako caught by Japanese commercial fisheries. (a) offshore longline, (b) coastal longline, (c) distant-water longline and (d) drift net

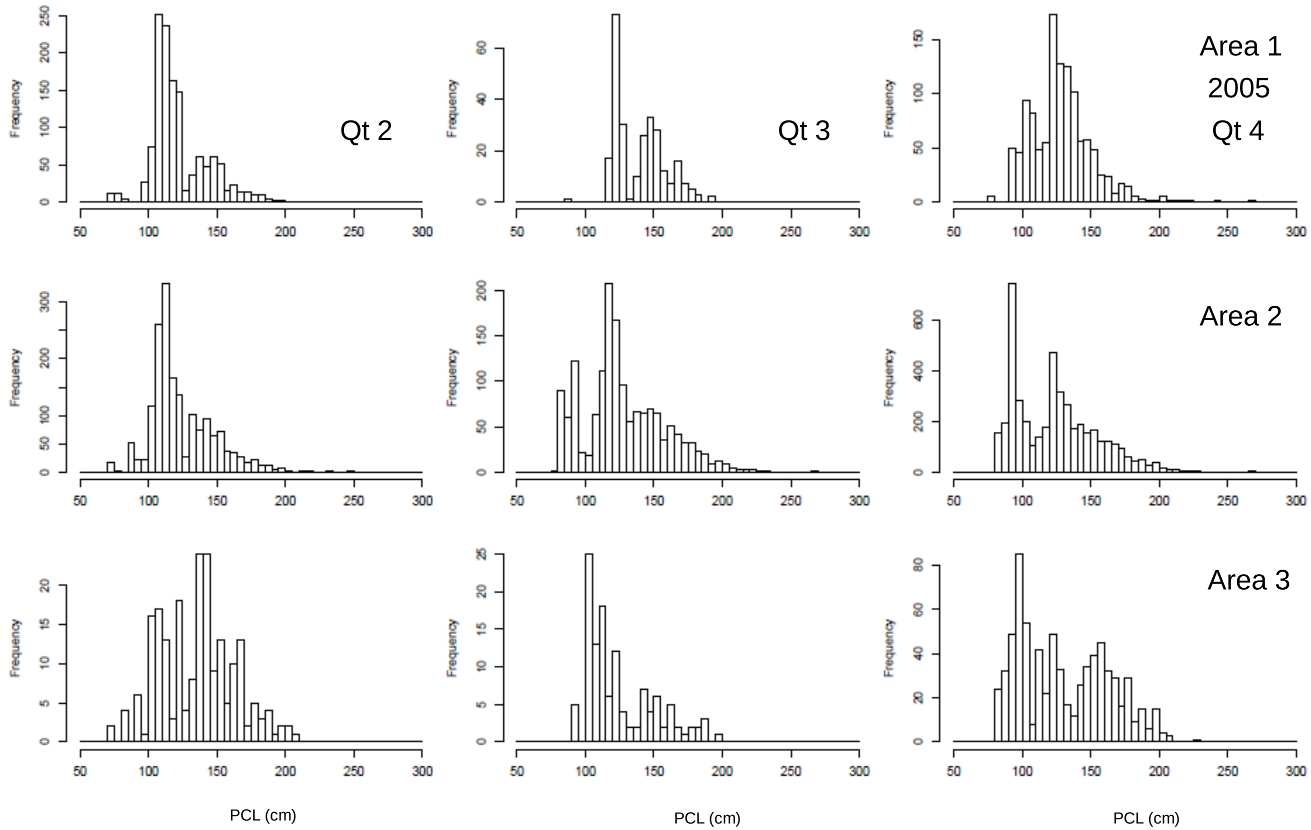

Fig. 4a Quarterly frequency distributions in PCL by area for shotfin mako caught by Japanese offshore longline in 2005. Sample size can be found in table 2.

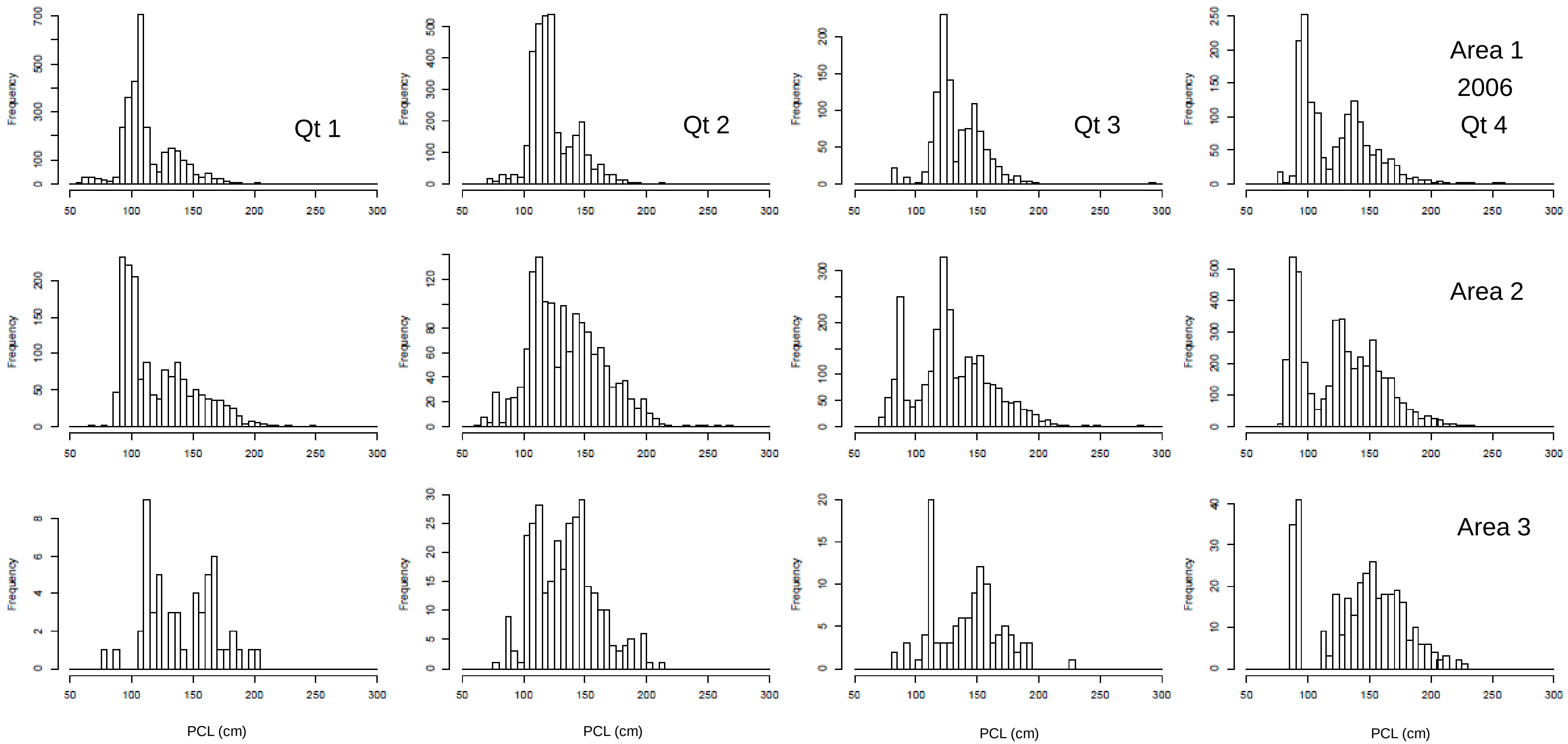

Fig. 4b Quarterly frequency distributions in PCL by area for shotfin mako caught by Japanese offshore longline in 2006. Sample size can be found in table 2.

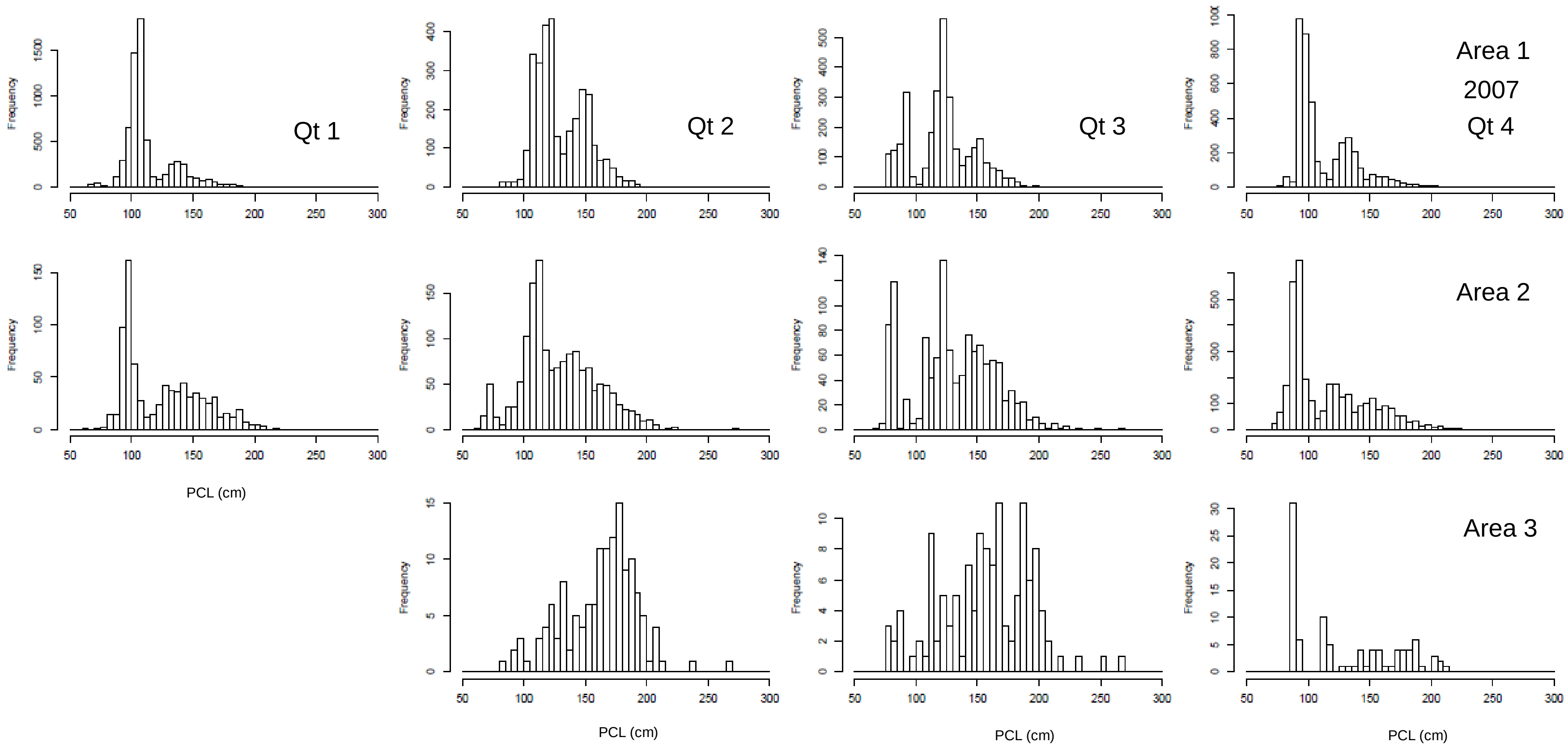

Fig. 4c Quarterly frequency distributions in PCL by area for shotfin mako caught by Japanese offshore longline in 2007. Sample size can be found in table 2.

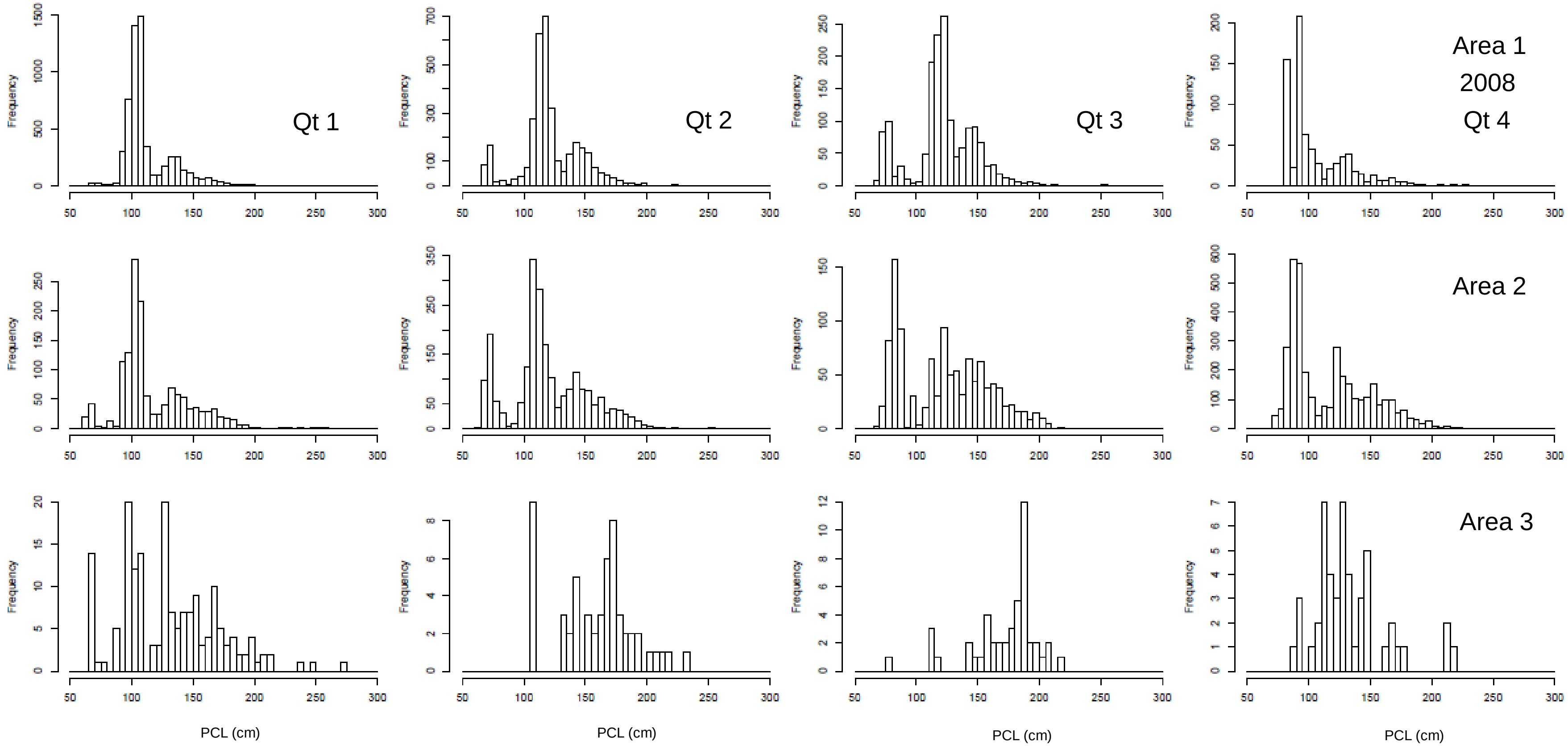

Fig. 4d Quarterly frequency distributions in PCL by area for shotfin mako caught by Japanese offshore longline in 2008. Sample size can be found in table 2.

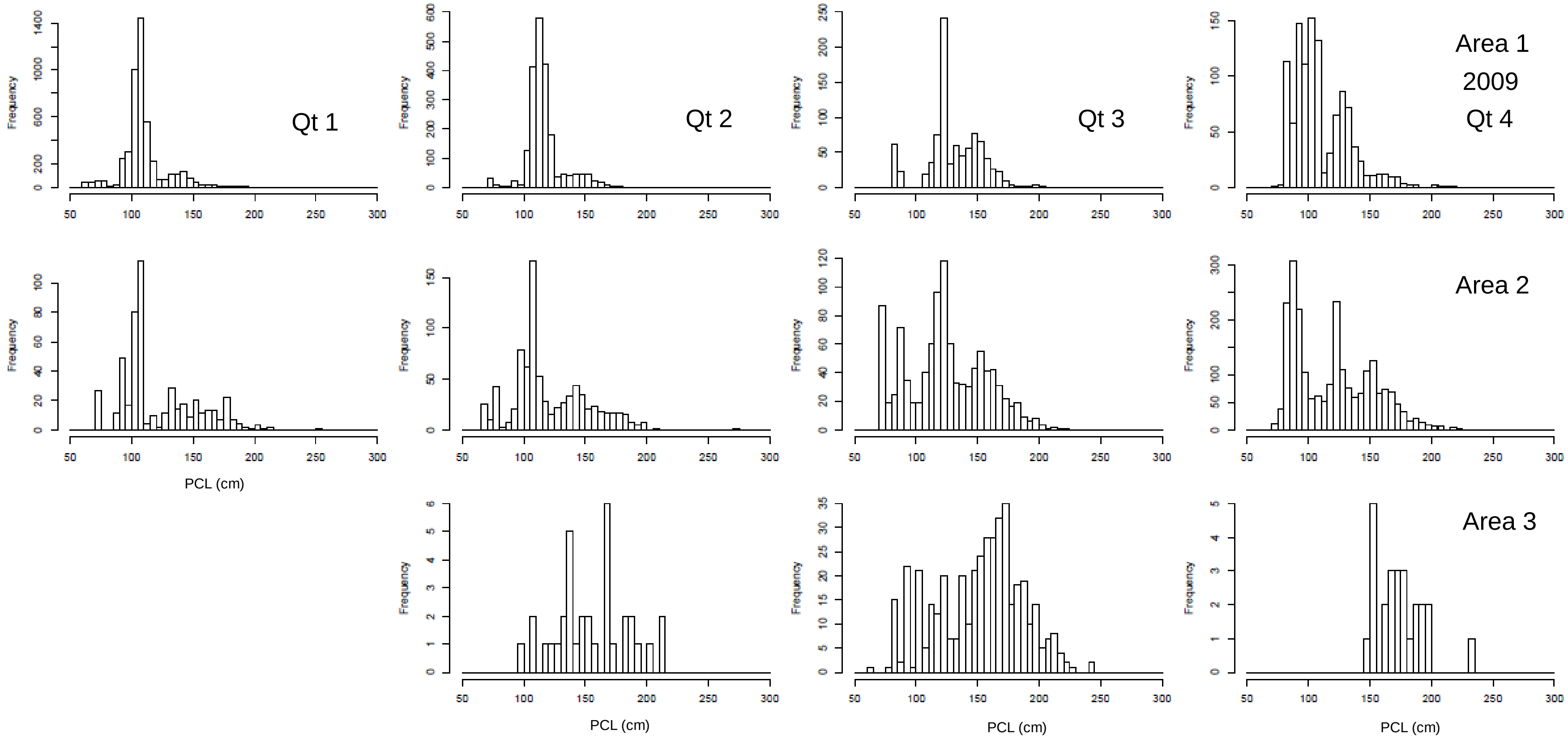

Fig. 4e Quarterly frequency distributions in PCL by area for shotfin mako caught by Japanese offshore longline in 2009. Sample size can be found in table 2.

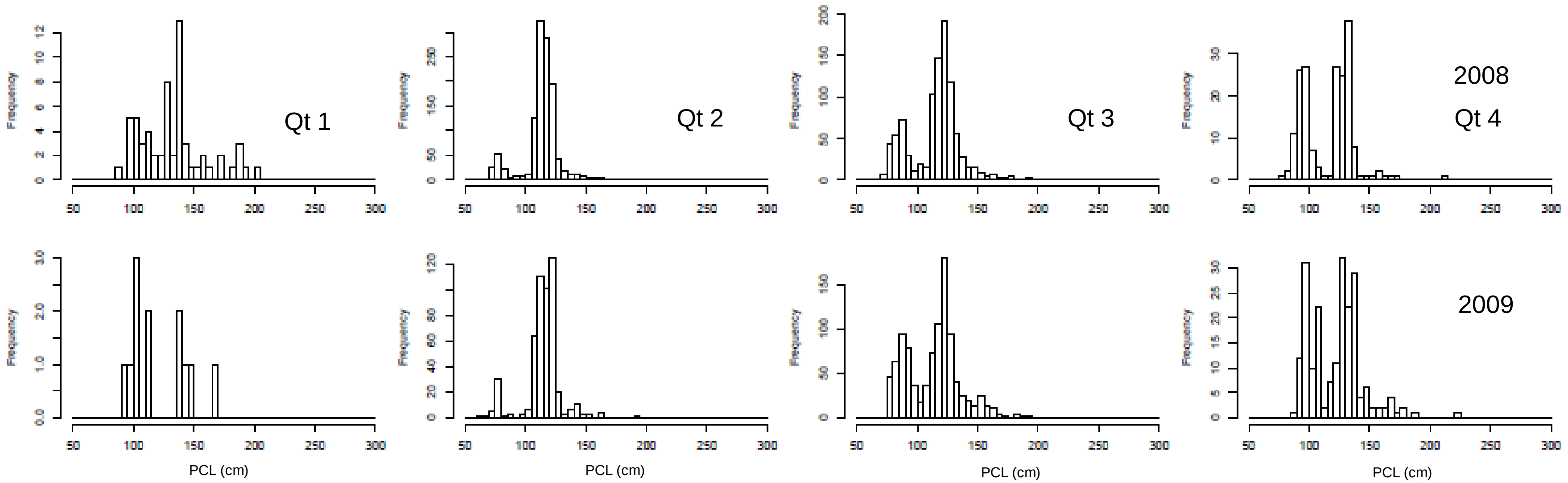

Fig. 5 Annual frequency distributions in PCL by quarter for shotfin mako caught by Japanese drift net between 2008 and 2009. Sample size can be found in table 1.

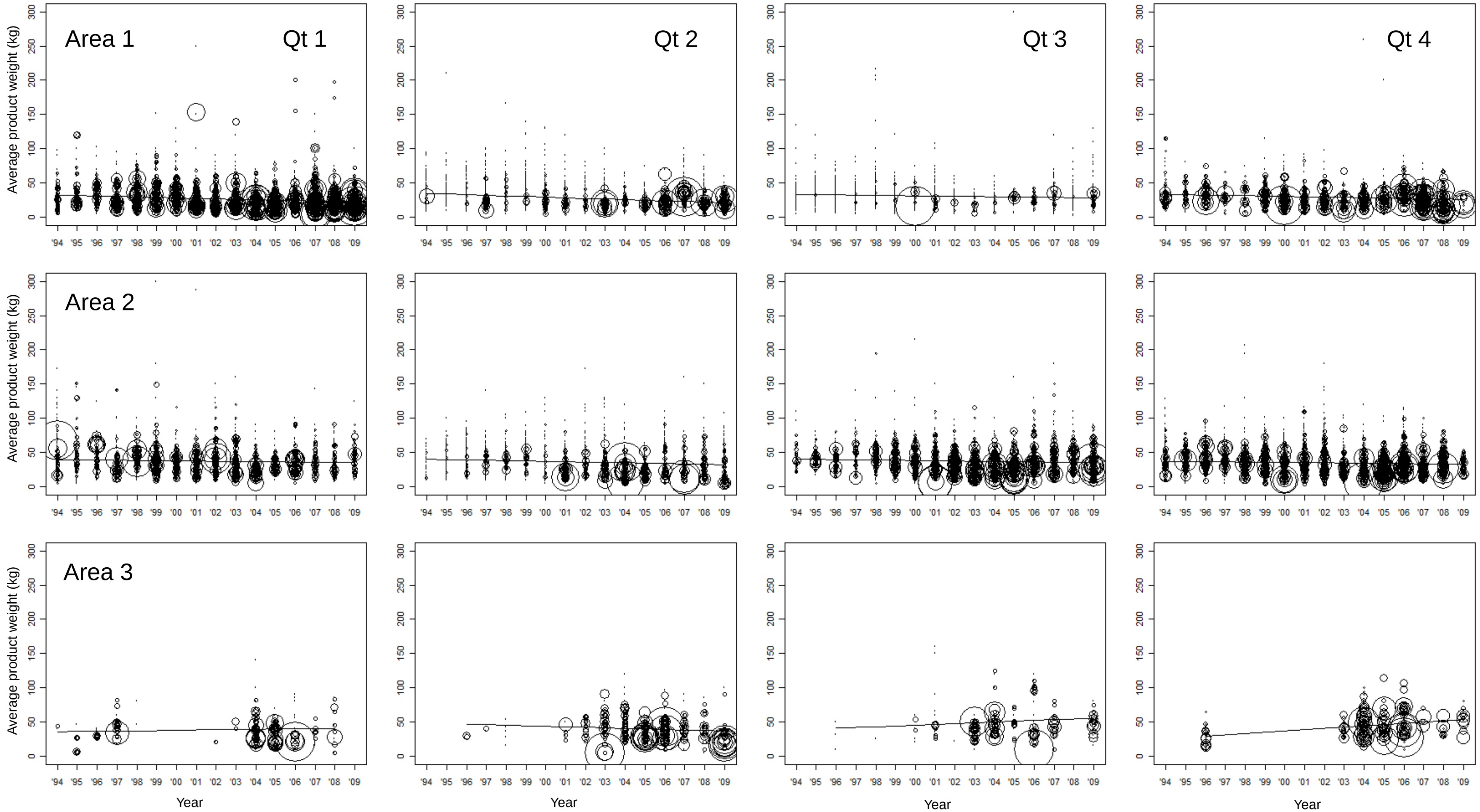

Fig. 6a Annual change of average product weight for shortfin mako caught by offshore longline vessels based on Kesennuma port between 1994 and 2009. Circle size reflected a number of shortfin mako.

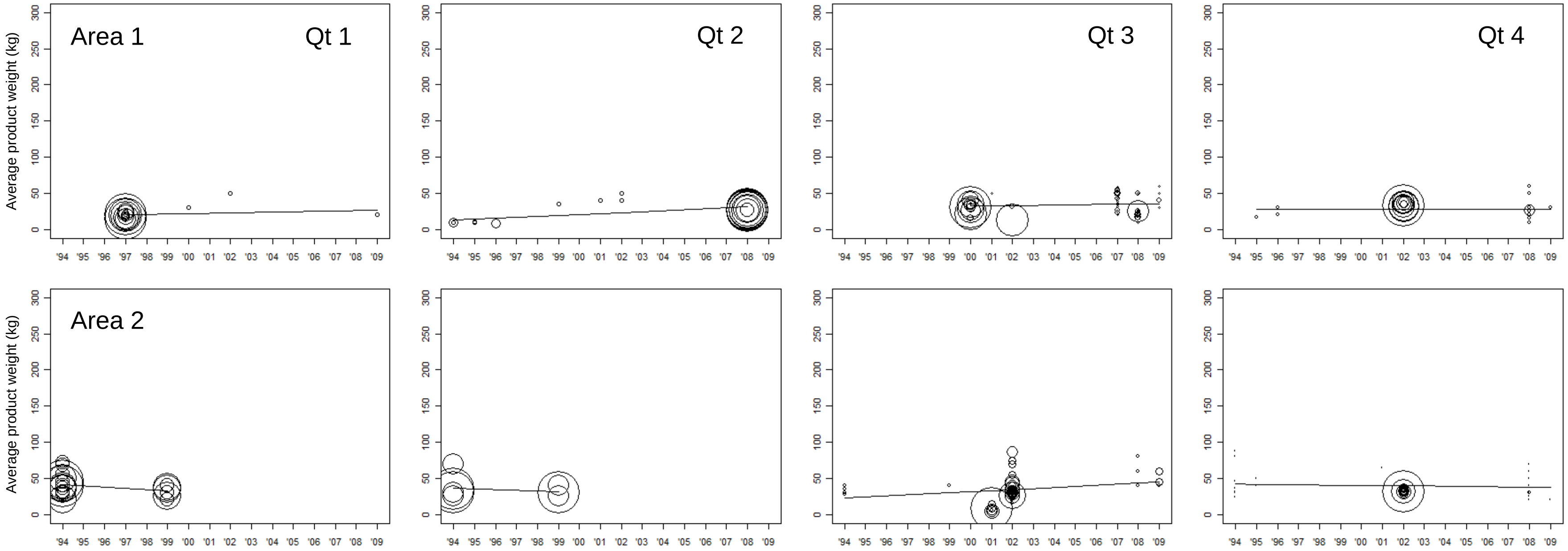

Fig. 6b Annual change of average product weight for shortfin mako caught by offshore longline vessels based on port other than Kesennuma between 1994 and 2009. Circle size reflected a number of shortfin mako.

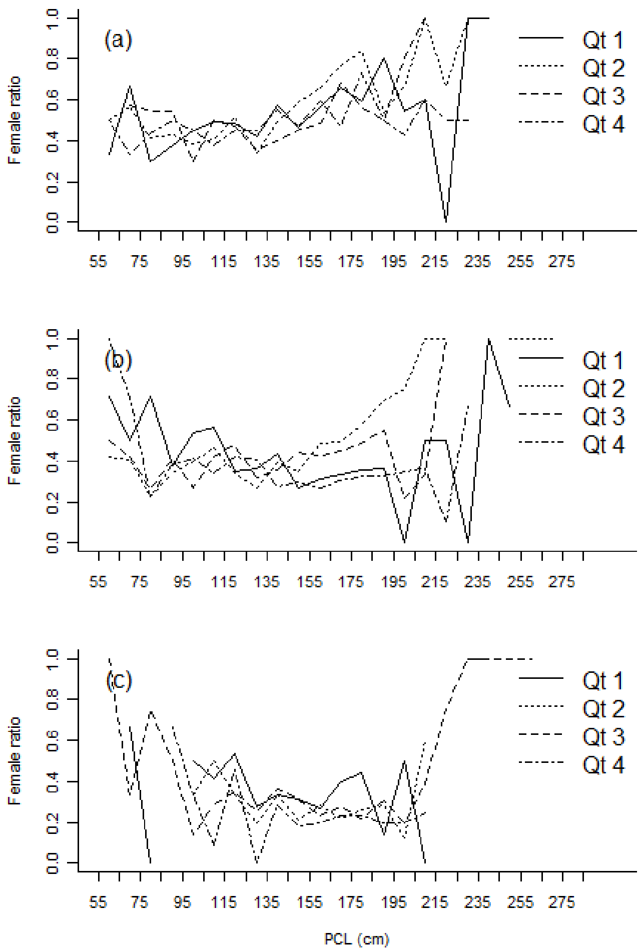

Fig. 7 Sex ratio of shortfin mako caught by offshore longline in relation to growth by area and quarter. (a) Area 1, (b) Area 2 and (c) Area 3