Estimation of catch at size of Pacific bluefin tuna caught by Japanese set net fisheries: Updated up to 2014 fishing year

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November 2015

Information paper submitted to the ISC Pacific bluefin tuna Working Group, International Scientific Committee for Tuna and Tuna-Like Species in the North Pacific Ocean (ISC), 18-25 November 2015, Kaohsiung, Taiwan.

Summary

The catch at size data for Japanese set-net fishery was updated using revised method which was approved by ISC PBF WG in April meeting in 2015; the estimation was based on multi-stratified raising of size-measurement data using the catch amount. In the revised method, excessive estimation was avoided by the introduction of broad size category stratum (i.e. Small/Medium/Large) and limitation of over-strata calculation. After separating the "North area (Hokkaido and Aomori)", this document proposes the following options for the fleet definition based on the results of the catch-at-size estimation by area and quarter; 1) combine the catch-at-size data for all prefectures (except for Hokkaido and Aomori), 2) combine all prefectures but divides by the 2nd quarter and the other quarters (1st, 3rd, and 4th), 3) make two groups of prefecture ("Tohoku area" and "South area") which have similar catch-at-size. The "North area" cannot be combined with the other areas because weight frequency is used in this area.

Introduction

Various sized Pacific bluefin tuna (PBF) has been caught incidentally by set-net fishery along the Japanese coast (Chikuni 1985). The set-net have been deployed in the variety of places of Japanese coast, and their catch at size information for PBF were collected through a "Research project on Japanese bluefin tuna (RJB)" at fishing port and market since 1994. However, the size sampling at some local area and seasons has been insufficient, thus we need to raising the size measurement data using the catch in the corresponding strata; e.g. the strata of year, month, quarter, prefecture, area, brand name etc. (Kai and Takeuchi 2012, Hiraoka et al. 2015).

In previous ISC PBF WG workshop (2015 April), a revised method to estimate the catch-at-size was proposed (Hiraoka et al. 2015). In the new method, the assumption about the random sampling was kept as much as possible, and the bias such as spikes of the length frequency was reduced. In the procedure, some problems contained in previous method were resolved: the previous method (Kai and Takeuchi 2012) sometimes used the size data over-strata excessively (e.g. year stratum) to estimate the catch-at-size when corresponding strata have no size measurement. On the other hand, the new method solved it due to the application of the maximum strata (size, quarter, and area) for the data pooling (Hiraoka et al. 2015). Moreover Hiraoka et al. (2015) introduced three size categories (**S**mall, **M**edium, **L**arge (S/M/L)) for the estimation process, which worked to reduce the biased estimation of catch-at-size relating to the data-poor size strata. The WG considered the revised method more accurately reflects the catch-at-size, and agreed to use this method to prepare the catch-at-size of Japanese set-net for the upcoming stock assessment in next February (ISC 2015).

In order to incorporate the set-net information for the stock assessment using stock synthesis (SS3), ISC PBF WG defined four fleets (Fleet 7–10) in previous assessment (ISC 2014). This fleet definition is based on the area and quarter: The Fleet 7 is set-net fishery in "North area" of Japan (Hokkaido and Aomori prefecture) of which size composition data are based on weight because weight data is more abundant than length data in this area (ISC 2012, Fujioka et al. 2012). The size composition data of the other fleets (Fleet 8, 9, and 10) are based on the length data. The Fleet 8 is the set-net fishery in quarter 3-4 (calendar year) of "West area" (15 prefectures which are faced to

the Sea of Japan). The Fleet 9 is those in quarter 1 of "West area" and quarter 1, 3, 4 of "East area" and "South area". The Fleet 10 is those in quarter 2 of "West area", "East area", and "South area" (Fig. 1-a). This fleet definition should be re-considered because the area grouping was different between the previous method (Kai and Takeuchi 2012) and the revised method (Hiraoka et al. 2015). Hiraoka et al. (2015) suggested the possibility of new fleet definition using the size categories (S/M/L), but this idea would be difficult to apply because we don't have any catch-at-size before 1994 which is essential to divide the catch amount into each size category. Another option suggested in the April meeting is to combine all set-net fisheries. This would be beneficial to simplify the structure of assessment model, but we need more exploration the possibility of other fleet combinations.

This document provides some options of fleet definition of set-net fishery in the context of above discussion. The catch-at-size information is updated using the revised method (Hiraoka et al. 2015) including the most recent size measurement data available for the Japanese set-net fishery up to the 2014 fishing year (up tp June 2015).

Materials and Methods

Data sources

1) Data from "Research project on Japanese bluefin tuna (RJB data)"

RJB has been conducted to collect the catch amount and size data for PBF since 1994. In this document, we used sales slips at main landing ports in 21 prefectures to aggregate the catch amounts (Table 1). In the RJB database, year, month, date, prefecture, landed port, brand name, product status (e.g. round or gilled and gutted), fishing gear, fishing area, weight, and number (if available) are included.

Size measurement of PBF landed from Japanese set-net fishery was conducted at the main ports of 20 prefectures (Table 2). Fork length (FL) was directly measured by 1cm intervals using caliper in principle. Body weight (BW) was recorded by either 1kg or 0.1kg precision. Year, month, date, prefecture, landed port, brand name, product status (e.g. round or gilled gutted), fishing gear, fishing area, FL and/or BW data are included in the database. When fish BW (or FL) was not measured for the size measurement, the FL (or BW) of measured fish was estimated using existing weight-length relationship (Kai 2007a).

2) Data from "Japan Fisheries Agency (JFA data)"

Monthly catch data by landing ports has been collected under the "Survey on Catch of Bluefin tuna in Japan's coastal areas" implemented by Japan Fishery Agency (JFA), Ministry of Agriculture, Forestry and Fisheries (MAFF), the government of Japan, since April 2008. This data collection system has been used for the official catch management since 2014. In the database, year, month, fishing gear, landing port, and landing weight are included.

3) Data from "Statistics Department (SD report)"

The annual report of catch statistics of fishery and aquaculture has been published by the Statistics Department of MAFF (SD report, formerly referred to as "SID report") since 1952. This dataset

has yearly inconsistency in available information; for example, temporal resolution (monthly or yearly) and spatio resolution (prefectural or national) are different between past and present. This inconsistency is also found in size category (nothing or including) and fishing category (separated by large-scale, small scale, and salmon set-net, OR only large scale set-net). Therefore the annual catch by prefecture was estimated by available information according to Hiraoka et al. (2015). The detailed information for the estimation was described by Kai (2007b) and Kai and Takeuchi (2012).

Estimation process

In this document, the revised method by Hiraoka et al. (2015) was used for the estimation of catch-at-size based on the size measurement data of RJB and three different catch statistics (RJB data, JFA data, and SD report) from 1994 to 2015 calendar year. The estimation process is as follows in principle;

1) Definition of stratum

Define the size-strata, temporal-strata, and spatio-strata as follows. These strata have high and low resolution;

	High resolution	Low resolution
Size-strata	Brand-name[1]	Size category (S/M/L)[2]
Temporal-strata	Month	Quarter
Spatio-strata	Prefecture	Area[3]

*1: There are a lot of brand names for PBF in Japan, and their definition is different among the prefectures. Therefore, all brand names were classified into three size categories (S/M/L) based on size measurement data. The detailed information was described by Hiraoka et al. (2015).

*2: The definition of size category for each brand-name is based on the median FL in each quarter of calendar year as follows. If the FL data is not available, median BW is used as an alternative (mainly in Hokkaido and Aomori). Three size categories correspond approximately to age-0 (“S” category), age-1&2 (“M” category), and over age-3 (“L” category).

	“S” category	“M” category	“L” category
Quarter 1	<64.0 cmFL or <5.51 kg	≥64.0 & <119.0 cmFL or ≥5.51 & <35.51 kg	≥119.0 cmFL or ≥35.51 kg
Quarter 2	<41.0 cmFL or <1.46 kg	≥41.0 & <101.0 cmFL or ≥1.46 & <21.67 kg	≥101.0 cmFL or ≥21.67 kg
Quarter 3	<46.0 cmFL or <2.06 kg	≥46.0 & <107.0 cmFL or ≥2.06 & <25.79 kg	≥107.0 cmFL or ≥25.79 kg
Quarter 4	<62.0 cmFL or <5.01 kg	≥62.0 & <114.0 cmFL or ≥5.01 & <31.21 kg	≥114.0 cmFL or ≥31.21 kg

*3: There are some prefectures with the missing or few size measurement data. Area definition covers such prefectures appropriately in the revised method (Hiraoka et al. 2015). We used same "5 area" definition with Hiraoka et al. (2015) which was decided by using GLM analysis based on the tentative catch-at-size only from RJB data except for those of Hokkaido and Aomori (Fig. 1-b). We also conducted the same GLM analysis using updated tentative data, and confirmed that it produces the same results (Table 3).

Area	Prefecture	Note
"North area"	Hokkaido, Aomori	BW frequency
Area 1	Iwate, Miyagi, Fukushima, Ibaragi	FL frequency. Area definition was decided by GLM analysis.
Area 2	Akita, Yamagata, Niigata	
Area 3	Chiba, Tokyo, Kanagawa, Shizuoka, Mie,	
Area 4	Toyama, Ishikawa,	
Area 5	Fukui, Kyoto, Hyogo, Wakayama, Tottori, Shimane, Yamaguchi, Tokushima, Ehime, Kochi, Fukuoka, Saga, Nagasaki, Kumamoto, Ooita, Miyazaki, Kagoshima, Okinawa	

2) Data pooling and estimation

When size measurement data exists in the higher resolution stratum, the size frequency is raised by relative weight of measured fish to total catch amount in corresponding stratum. If there are no size measurement data or very few in the stratum, the estimation is conducted after data pooling—this means to use lower resolution stratum. In this document, we used corresponding stratum if the number of measurement was more than 10 fish or the coverage of measurement was more than 50%. We used the same order of the data pooling with Hiraoka et al. (2015) which was decided by using GLM as was the case in area definition. We also conducted the same GLM analysis using updated tentative data, and confirmed that it produces the same results (Table 4).

	Strata
1st step	Brand-name, Month, Prefecture
2nd step	Brand-name, Month, Area
3rd step	Brand-name, Quarter, Prefecture
4th step	Brand-name, Quarter, Area
5th step	S/M/L, Month, Prefecture
6th step	S/M/L, Month, Area
7th step	S/M/L, Quarter, Prefecture
8th step	S/M/L, Quarter, Area

For the prefecture with no size measurement for RJB data, their catch-at-size is estimated by 6th and 8th steps without using "Prefecture" stratum.

3) Adjustment to "SD report" and "JFA data"

The catch-at-size estimated by RJB data is adjusted the catch amount of "SD report" for

1994-2007 and "JFA data" for 2008-2015. Because there is a difference in the resolution of catch data between the "SD report" and "JFA data", the corresponding catch-at-size data are adjusted to the minimum strata for each data source. Some prefectures don't have any size measurement data (no "RJB data"). The catch-at-size data for those prefectures are assumed that they have average size frequency of the corresponding area.

4) Fleet construction

Firstly, the "North area (Hokkaido and Aomori)" was separated because the catch-at-size in this area is based on the BW data. Then the options for fleet definition for the rest of prefectures were considered. Through the above process, the catch-at-size of set-net fisheries in each prefecture can be estimated in each year and quarter. Using these results, we tried to make some option to define the set-net fleet as follows;

a) Combine all prefectures,
b) Combine all prefectures but divides by quarter,
c) Combine some prefectures which have similar catch-at-size.

The updated catch-at-size of "North area" (previous Fleet 7) is also presented independently of the above combine options.

Results and Discussion

The ratios of catch amount whose size compositions was able to be estimated using the above method against to total landing recorded in RJB were 95.0 % in "North area" (Hokkaido and Aomori prefecture), and 87.2 % in the other areas (Table 5). Higher coverage was shown for "North area" and this is because of using "sales slip" data as the body weight information (Fujioka et al. 2012). The BW frequency of set-net fishery in "North area" (Fig. 2) shows; 1) small PBF are caught in all quarters, 2) their catch-at-size has no drastic changes from 1994 to 2015, and 3) There are some catch records in the smallest weight bin; corresponding to the catch of 0-1 kg fish (i.e. Qt4 in 1994 and 1996, Qt2 in 2011). This smallest bin would not provide good fitting for the "Double normal" selectivity which was used for this fishery (Fleet 7) in previous assessment (ISC 2014). These results should be noted to consider the model setting for the upcoming stock assessment.

Fig. 3-8 shows the catch-at-size using length frequency for the other areas (Area 1-5, except for "North area"). Approximate trends shown by yearly aggregated catch-at-size (Fig. 4-5) indicate that, 1) set net fisheries in area 1 and 2 tend to catch somewhat larger sized PBF (mainly larger than 50cm FL) than those of area 3-5, 2) smaller fish (< 50cm FL) tend to be caught in area 3-5 especially in quarter 3 and/or 4, but not found during quarter 2 in all area, 3) the catch amount is different among the areas. Those broad trends suggest that we can aggregate them by area and/or quarter as with Kai and Takeuchi (2012). Based on these results, we propose the following options for the fleet definition after separating the "North area";

[Option 1]: Combining the catch-at-size for all prefectures

This provides the simplest fleet structure which was already proposed by some participants in

April WG meeting. In this option size range caught by the fleet will become wider. In particular, there are variations of catch-at-size among the quarters, thus it would be challenging to have accurate selectivity (Fig. 5). The WG suggested in April the possibility to use "time-varying selectivity" to follow the yearly changes of catch-at-size (Fig. 6).

[Option 2]: Combining all prefectures but divides by quarter

In this option, the catch-at-size data for all prefectures are combined, but it is divided in two between quarter 2 and the other quarters. This is reflecting the difference of catch-at-size by quarter; as mentioned above, size range of quarter 2 is larger than those of the other quarters, and small sized PBF (< 50cmFL) is rarely observed in quarter 2 (Fig. 5). This fleet definition is similar to previous Fleet 10 (see ISC 2014).

[Option 3]: Make two groups of prefectures which have similar catch-at-size

This option is reflecting the difference of catch-at-size by area. The area 1 and 2, which are northern part of Honshu (it is called Tohoku area), size of PBF caught by set-net is larger than southern area (Fig. 4). In this option, we aggregated the set-net fisheries in area 1-2 and 3-5 as the fleet X1 and X2, respectively. In this fleet definition, the size difference in quarter 3 and 4 between fleets was able to divide clearly, but there is still overlap in quarter 1 and 2 (Fig. 7 and 8). This is different from the previous fleet definition (Kai and Takeuchi 2012), thus it would be essential to re-calculate catch amount before 1994.

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Table 1 Total catch amount (ton) of Japanese set-net by year, prefecture, and data sources.

1) Data from "Research project on Japanese bluefin tuna (RJB data)"

	#1	#2	#3	#4	#5	#6	#7	#8	#12	#13	#14	#15	#16	#17	#18	#22	#24	#26	#28	#30	#31	#32	#35	#36	#38	#39	#40	#41	#42	#43	#44	#45	#46	#47
	Hokkaido	Aomori	Iwate	Miyagi	Akita	Yamagata	Fukushima	Ibaragi	Chiba	Tokyo	Kanagawa	Nigata	Toyama	Ishikawa	Fukui	Shizuoka	Mie	Kyoto	Hyogo	Wakayama	Tottori	Shimane	Yamaguchi	Tokushima	Ehime	Kochi	Fukuoka	Saga	Nagasaki	Kumamoto	Ooita	Miyazaki	Kagoshima	Okinawa
1994	46.1	24.3	103.0	20.1	-	0.5	0.0	0.0	-	-	4.8	161.8	73.1	0.0	-	0.0	5.7	-	-	0.6	0.4	19.0	0.8	-	0.1	3.3	-	-	0.0	-	-	0.0	1.1	0.0
1995	239.4	142.5	499.8	100.0	-	0.0	0.0	0.0	-	-	34.8	139.8	90.6	127.7	-	0.0	2.3	-	-	1.4	0.2	37.2	8.4	-	0.2	6.7	-	-	0.0	-	-	0.0	2.3	0.0
1996	57.4	46.4	116.8	56.0	-	0.1	0.0	0.0	-	-	11.9	80.9	86.5	80.6	-	3.7	2.4	-	-	2.1	0.0	16.2	4.3	-	0.3	6.3	-	-	4.9	-	-	0.0	2.6	0.0
1997	11.4	16.1	89.9	38.6	-	0.2	0.0	0.0	-	-	7.8	45.0	40.9	77.8	-	0.7	1.4	-	-	4.7	0.0	25.1	0.4	-	2.4	8.1	-	-	17.3	-	-	0.0	7.2	0.0
1998	35.4	32.2	60.4	22.3	-	0.0	0.0	0.0	-	-	25.7	140.6	45.7	103.0	-	5.0	5.3	-	-	1.8	0.0	9.9	0.3	-	0.2	2.8	-	-	0.0	-	-	0.0	1.4	0.0
1999	13.3	38.1	66.6	33.8	-	0.0	0.0	0.0	-	-	4.5	111.8	95.4	130.4	-	1.1	1.0	-	-	1.2	0.0	8.9	0.0	-	0.5	3.7	-	-	0.0	-	-	0.1	2.0	0.0
2000	70.5	41.6	162.9	121.6	-	0.0	0.0	0.0	-	-	19.3	54.3	205.9	113.8	-	1.6	3.2	-	-	6.2	0.0	19.6	0.2	-	0.4	5.8	-	-	0.0	-	-	0.0	1.0	0.0
2001	31.6	47.3	146.7	63.2	-	0.0	0.0	59.5	-	-	12.9	52.9	161.4	102.2	-	2.8	6.9	-	-	2.8	0.0	5.4	6.4	-	1.0	2.9	-	-	0.0	-	-	0.2	1.2	0.0
2002	17.4	46.3	68.6	105.6	-	0.0	0.1	18.1	-	-	15.0	30.3	79.9	103.9	-	9.6	6.5	-	-	1.5	0.0	3.0	0.6	-	1.5	5.8	-	-	0.0	-	-	0.3	0.9	0.0
2003	4.7	183.7	56.3	41.3	-	0.0	0.0	9.7	-	-	4.7	65.2	66.7	30.4	-	8.1	5.0	-	-	1.0	0.0	2.1	0.4	-	0.5	5.4	-	-	0.0	-	-	0.8	0.3	0.0
2004	1.7	114.2	91.3	65.2	-	0.0	0.0	1.7	-	-	3.3	130.4	114.9	74.8	-	2.1	6.0	-	-	2.8	0.0	2.2	2.5	-	0.4	2.0	-	-	0.0	-	-	1.0	0.9	6.6
2005	12.4	249.4	124.6	115.6	-	0.0	0.0	8.8	-	-	16.7	336.0	133.3	87.0	-	10.2	31.4	-	-	6.3	0.0	111.2	6.8	-	0.8	20.5	-	-	0.0	-	-	3.5	0.9	5.4
2006	2.4	193.4	189.8	189.9	-	0.0	0.2	0.0	-	-	6.7	159.5	171.1	98.4	-	7.9	6.9	-	-	2.8	0.0	4.8	3.8	-	0.3	4.5	-	-	0.0	-	-	0.6	1.8	3.2
2007	1.0	367.4	114.3	54.5	-	0.0	0.1	0.0	-	-	30.7	102.1	262.4	119.5	-	23.3	13.2	-	-	5.7	0.0	2.8	2.2	-	0.2	2.1	-	-	0.0	-	-	0.3	1.0	0.0
2008	2.0	406.7	254.8	232.8	-	0.0	0.0	0.0	-	-	38.0	318.6	413.8	298.5	-	19.8	14.8	-	-	2.1	0.0	25.4	31.2	-	0.8	4.1	-	-	0.0	-	-	0.1	1.2	0.0
2009	7.0	408.5	245.0	220.8	-	0.0	0.3	0.0	-	-	4.6	293.3	230.7	138.4	-	4.7	9.0	-	-	4.8	0.0	17.8	20.6	-	0.5	4.4	-	-	0.0	-	-	0.3	9.4	0.0
2010	0.6	245.4	145.1	114.4	-	0.0	0.0	0.0	-	-	20.7	226.1	160.5	158.7	-	20.1	7.4	-	-	2.3	0.0	26.6	20.8	-	0.2	3.2	-	-	0.0	-	-	0.0	2.1	0.1
2011	1.1	412.8	55.7	2.1	-	0.0	0.0	0.0	-	-	31.1	194.5	194.5	100.1	-	15.1	12.2	-	-	5.8	0.0	16.0	10.4	-	0.3	5.8	-	-	0.0	-	-	0.5	3.0	0.2
2012	1.7	382.9	115.2	108.9	-	0.0	0.0	0.0	-	-	22.7	213.7	128.4	148.0	-	8.9	9.3	-	-	4.0	0.0	42.4	23.1	-	0.4	8.6	-	-	0.0	-	-	2.7	4.0	0.0
2013	1.6	288.1	153.9	124.1	-	0.0	0.0	0.0	-	-	2.9	96.2	73.8	61.6	-	3.1	11.0	-	-	2.7	0.0	11.8	15.0	-	0.0	3.0	-	-	0.0	-	-	1.4	9.1	0.1
2014	2.2	351.6	205.5	129.7	-	0.0	0.0	0.0	-	-	3.9	301.0	105.8	79.1	-	4.7	12.2	-	-	8.9	0.0	15.5	29.9	-	0.1	3.6	-	-	1.2	-	-	0.0	2.4	0.0
2015	0.5	202.0	104.1	25.3	-	0.0	0.0	0.0	-	-	0.6	122.3	10.1	29.6	-	35.7	9.8	-	-	9.5	0.0	9.5	5.4	-	0.2	7.2	-	-	0.3	-	-	1.3	1.3	0.0

2) Data from "Japan Fisheries Agency (JFA data)"

	Hokkaido	Aomori	Iwate	Miyagi	Akita	Yamagata	Fukushima	Ibaragi	Chiba	Tokyo	Kanagawa	Nigata	Toyama	Ishikawa	Fukui	Shizuoka	Mie	Kyoto	Hyogo	Wakayama	Tottori	Shimane	Yamaguchi	Tokushima	Ehime	Kochi	Fukuoka	Saga	Nagasaki	Kumamoto	Ooita	Miyazaki	Kagoshima	Okinawa
2008	45.1	463.9	278.1	230.3	0.0	0.0	0.0	0.0	27.9	0.0	41.4	266.3	135.2	206.3	36.6	19.0	12.3	0.0	0.0	10.9	0.0	49.0	27.1	0.0	0.2	3.1	0.0	0.9	61.9	0.0	0.0	0.3	14.9	0.0
2009	116.6	444.7	264.0	218.0	0.0	0.0	0.0	0.0	12.1	0.0	3.6	279.7	170.9	135.6	44.4	5.8	31.2	0.0	0.0	9.0	0.0	89.2	41.3	0.0	0.4	7.3	0.0	3.5	98.4	0.0	0.0	0.0	39.2	0.0
2010	42.5	273.1	146.5	0.2	0.6	1.1	0.0	0.4	20.3	0.6	20.6	227.1	60.3	47.2	51.7	21.0	2.5	35.0	0.5	11.5	1.0	47.5	20.0	0.0	0.1	6.1	0.1	0.2	54.3	0.2	0.0	0.1	9.2	0.0
2011	81.3	350.9	6.7	0.0	28.9	1.5	0.0	0.1	18.8	1.9	29.5	177.3	0.0	0.0	24.4	15.1	0.0	32.7	1.6	20.2	4.0	28.2	10.3	3.0	0.2	15.6	0.0	0.5	71.7	2.3	1.4	0.1	11.0	0.0
2012	258.1	409.0	129.3	0.0	40.6	0.2	0.0	0.8	8.1	0.4	22.7	166.9	0.0	0.0	33.2	9.1	0.0	64.1	3.3	18.0	1.6	58.6	23.5	2.8	0.1	21.3	2.2	4.8	87.8	0.8	1.2	0.0	18.0	0.0
2013	252.5	188.3	153.3	0.0	4.8	0.7	0.0	2.4	7.4	2.5	2.6	118.4	0.0	0.0	26.9	4.2	0.0	43.6	2.8	17.1	0.1	19.9	25.9	9.4	4.4	32.6	1.0	1.4	112.3	1.5	5.7	2.6	41.6	0.0
2014	191.0	399.0	210.5	8.4	9.1	0.3	0.0	0.6	3.4	4.3	1.7	303.5	10.0	4.4	28.8	5.6	9.3	62.0	4.8	14.4	0.4	14.5	37.7	6.8	0.1	22.3	0.3	0.5	64.5	0.6	5.0	0.7	6.4	0.0
2015	92.8	280.8	121.2	5.7	41.2	0.0	0.0	0.4	1.9	0.0	0.3	140.3	10.6	32.3	13.6	3.2	31.2	12.1	0.1	10.3	0.3	16.8	5.4	3.3	0.0	25.5	0.1	0.0	12.5	0.6	1.6	4.7	2.6	0.0

3) Data from "Statistics Department (SD report)"

	Hokkaido	Aomori	Iwate	Miyagi	Akita	Yamagata	Fukushima	Ibaragi	Chiba	Tokyo	Kanagawa	Nigata	Toyama	Ishikawa	Fukui	Shizuoka	Mie	Kyoto	Hyogo	Wakayama	Tottori	Shimane	Yamaguchi	Tokushima	Ehime	Kochi	Fukuoka	Saga	Nagasaki	Kumamoto	Ooita	Miyazaki	Kagoshima	Okinawa
1994	74.0	9.0	104.0	19.0	3.0	0.7	1.0	6.8	17.0	0.0	2.0	200.0	109.0	272.0	80.0	4.0	28.0	118.0	5.0	0.0	0.0	63.2	2.0	0.5	0.0	8.9	0.0	0.0	21.3	0.0	0.0	0.0	10.0	0.0
1995	279.8	161.0	539.0	87.0	5.0	0.0	13.0	17.3	0.0	0.0	42.2	147.0	120.0	170.0	41.9	19.5	12.7	33.0	4.0	4.6	0.0	97.9	34.7	0.0	0.0	5.6	0.0	0.0	15.3	0.0	0.0	0.0	8.8	0.0
1996	210.1	57.0	129.0	51.0	3.0	0.0	2.0	6.8	0.0	2.8	21.0	92.0	158.0	115.0	42.0	37.9	22.8	50.0	4.0	9.8	0.0	83.2	12.9	2.0	0.0	24.7	0.0	1.0	0.0	0.0	0.0	0.0	11.3	0.0
1997	58.0	21.0	110.0	39.6	1.0	0.0	3.0	0.0	10.5	1.1	0.0	55.0	78.0	77.3	41.4	8.3	12.0	20.8	8.0	10.3	0.0	107.4	34.7	0.0	0.0	55.5	0.0	1.0	30.3	0.0	11.0	1.0	7.2	0.0
1998	74.0	39.0	75.0	23.0	14.0	0.0	2.0	3.8	34.4	1.7	33.0	149.0	81.0	125.0	29.0	22.0	22.5	31.6	0.0	8.8	0.0	46.8	9.9	1.0	0.0	12.7	0.0	1.0	17.2	0.0	10.0	0.0	7.2	0.0
1999	44.0	51.0	95.0	33.0	13.0	0.7	0.0	2.3	48.0	0.6	1.3	140.0	106.0	151.3	222.9	4.0	6.0	51.3	3.0	14.3	0.0	61.5	7.9	1.0	0.0	14.9	0.0	2.0	11.6	0.0	0.0	1.0	9.5	0.0
2000	116.0	48.0	201.0	114.0	8.0	0.0	0.0	0.0	26.4	1.0	24.0	0.0	203.0	140.0	60.0	10.0	14.9	43.3	4.0	18.4	0.0	20.5	39.6	2.0	0.0	27.8	0.0	0.0	2.8	0.0	0.0	0.0	0.0	0.0
2001	379.0	73.0	170.0	48.3	15.0	0.0	0.0	0.0	14.0	0.5	5.5	77.0	314.0	107.1	29.7	8.0	7.5	20.4	5.0	18.3	0.0	13.7	27.7	2.0	0.0	20.0	0.0	0.0	4.2	1.0	0.0	2.0	2.8	0.0
2002	478.0	14.0	89.0	76.0	3.0	0.0	0.0	0.0	18.0	0.0	0.0	0.0	111.0	99.0	0.0	24.6	18.0	21.8	1.0	2.0	0.0	17.2	37.7	1.0	0.0	69.2	1.0	0.0	4.5	0.0	0.0	2.0	12.0	0.0
2003	184.3	231.0	0.0	36.2	5.7	0.0	0.0	0.0	13.4	0.0	3.9	63.8	53.8	30.3	6.0	9.1	11.5	13.4	0.0	7.3	0.0	0.0	0.0	0.0	0.0	30.6	0.0	0.0	124.2	0.0	0.0	2.0	11.9	0.8
2004	60.3	139.0	108.3	61.9	7.8	1.0	0.0	0.0	2.0	0.0	3.1	155.8	95.1	84.5	22.5	5.0	15.8	0.0	0.0	12.8	0.0	0.0	0.0	0.0	0.0	19.8	0.0	0.0	84.6	0.0	0.0	3.0	12.9	0.8
2005	95.8	374.8	247.7	34.9	12.3	1.6	0.0	0.0	47.6	0.0	28.6	123.9	231.8	146.1	57.2	50.8	109.6	0.0	0.0	63.5	0.0	0.0	0.0	0.0	0.0	166.7	0.0	0.0	330.3	0.0	0.0	4.8	49.2	4.8
2006	116.1	422.0	141.0	54.2	0.0	0.0	0.0	0.0	17.4	0.0	11.9	100.9	174.6	192.0	24.9	19.5	39.1	18.4	0.0	7.6	0.0	0.0	3.3	0.0	0.0	24.9	0.0	0.0	48.8	0.0	0.0	1.1	3.3	0.0
2007	122.8	446.3	149.2	57.4	0.0	0.0	0.0	0.0	18.4	0.0	12.6	106.7	184.7	203.1	26.4	20.7	41.3	19.5	0.0	8.0	0.0	0.0	3.4	0.0	0.0	26.4	0.0	0.0	51.6	0.0	0.0	1.1	3.4	0.0
2008	41.5	480.4	367.5	252.3	0.0	0.0	0.0	0.0	42.6	0.0	32.3	399.7	42.6	327.1	46.1	26.5	24.2	109.4	0.0	13.8	0.0	0.0	19.6	0.0	0.0	36.9	0.0	0.0	81.8	0.0	0.0	5.8	8.1	0.0
2009	112.3	452.5	307.2	256.5	42.9	0.0	0.0	0.0	18.7	0.0	5.5	383.1	15.4	178.4	49.5	7.7	17.6	110.1	11.0	4.4	0.0	87.0	19.8	0.0	0.0	45.1	0.0	0.0	90.3	0.0	0.0	1.1	19.8	0.0
2010	36.2	270.8	171.0	119.5	11.0	0.0	0.0	0.0	41.7	0.0	12.1	261.0	66.9	179.8	81.1	28.5	29.6	99.8	8.8	11.0	0.0	54.8	19.7	0.0	0.0	28.5	0.0	0.0	59.2	0.0	0.0	2.2	9.9	0.0
2011	67.6	436.9	68.7	160.8	38.8	0.0	0.0	0.0	27.7	0.0	45.5	290.5	65.4	122.0	47.7	22.2	42.1	36.6	2.2	14.4	0.0	35.5	7.8	0.0	0.0	33.3	0.0	0.0	75.4	0.0	0.0	0.0	10.0	0.0
2012	241.2	421.0	83.8	112.8	44.7	0.0	0.0	0.0	12.3	0.0	29.0	260.2	129.5	166.4	61.4	14.5	23.5	67.0	3.4	15.6	0.0	55.8	16.8	0.0	0.0	36.9	0.0	0.0	118.4	0.0	0.0	1.1	16.8	0.0

Table 2 Total number of size data caught by Japanese set-net used for the Catch-at-size data, which was based on RJB database. Data was aggregated by region (prefecture) and measurement quality (only length, weight, or both length & weight data) in 1994-2015 calendar year.

a) Only weight measurement data

	Hokkaido	Aomori	Iwate	Miyagi	Yamagata	Ibaragi	Chiba	Kanagawa	Nigata	Toyama	Ishikawa	Shizuoka	Mie	Wakayama	Tottori	Shimane	Yamaguchi	Ehime	Kochi	Miyazaki	Kagoshima
1994	0	1559	0	0	0	0	0	0	0	0	0	0	0	1	13	0	0	0	0	0	3
1995	2	17860	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	41
1996	0	4652	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
1997	0	1302	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
1998	0	2604	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0
1999	141	6442	0	0	0	0	0	0	21	2	0	0	0	47	0	0	0	0	0	0	0
2000	229	5739	0	0	0	0	0	0	4	0	0	0	0	51	0	35	0	0	0	0	0
2001	2840	7679	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0
2002	2965	4038	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	390	10442	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	127	4947	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	1409	13254	0	0	0	0	0	0	1431	0	0	0	0	0	0	0	0	0	0	0	0
2006	137	12162	0	0	0	0	0	0	479	0	0	0	0	0	0	0	0	0	0	0	0
2007	75	11428	0	0	0	0	0	0	733	0	0	0	0	0	0	0	0	0	0	0	0
2008	287	19277	0	0	0	0	0	0	3633	4	0	0	0	0	0	0	0	0	0	0	0
2009	878	7670	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
2010	62	0	0	0	0	0	0	0	2576	0	7	0	0	0	0	0	0	0	0	0	0
2011	169	2	0	0	0	0	0	0	1609	0	0	0	0	0	0	0	0	0	0	0	0
2012	129	3	0	0	0	0	0	0	2843	1	334	0	0	0	0	0	0	0	0	0	1
2013	158	0	0	0	0	0	0	0	1522	33	81	0	0	0	0	0	0	0	0	0	1
2014	318	32	0	0	0	0	0	0	3267	0	41	0	0	8	0	0	0	0	0	0	0
2015	42	0	0	0	0	0	0	0	503	0	0	0	0	0	0	0	0	0	0	0	0

b) Only weight measurement data

	Hokkaido	Aomori	Iwate	Miyagi	Yamagata	Ibaragi	Chiba	Kanagawa	Nigata	Toyama	Ishikawa	Shizuoka	Mie	Wakayama	Tottori	Shimane	Yamaguchi	Ehime	Kochi	Miyazaki	Kagoshima
1994	40	0	316	702	134	0	0	0	0	1552	0	0	0	4	0	0	0	0	0	0	0
1995	40	0	1929	2321	0	0	0	0	0	709	0	0	0	47	0	0	0	0	0	0	1
1996	16	0	1028	1637	0	0	0	0	0	183	0	0	0	3	0	0	0	0	0	0	0
1997	0	0	670	1186	0	0	0	99	0	420	0	0	0	99	0	0	0	0	0	0	0
1998	0	0	763	1078	0	0	0	2	0	1244	0	0	58	0	0	12	0	0	0	0	0
1999	0	0	0	1037	0	0	0	0	0	1922	0	0	2	34	0	0	0	0	0	0	0
2000	0	0	0	3299	0	0	0	1	0	1997	0	0	0	7	0	0	0	0	0	0	0
2001	0	0	0	997	0	13	0	15	0	756	0	0	59	0	0	0	0	0	0	0	0
2002	0	0	0	2497	0	0	0	4	0	527	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	1254	0	0	0	38	0	1026	0	0	53	0	0	0	0	1	0	0	0
2004	0	0	0	855	0	0	0	21	0	1423	0	0	88	11	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	75	0	1384	0	0	894	9	0	0	0	0	0	0	0
2006	0	0	0	219	0	0	0	3	0	1943	0	0	177	87	0	0	0	0	0	0	0
2007	0	0	15	8	0	0	0	305	0	1340	0	0	206	6	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	89	0	929	0	0	198	0	0	0	265	0	0	0	0
2009	0	0	1	0	0	0	0	39	0	432	0	0	24	0	0	0	163	0	0	0	0
2010	0	0	0	105	0	0	6	73	0	1920	593	0	162	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	205	0	38	1064	0	1	0	0	0	0	0	0	0	2
2012	0	0	0	242	0	0	0	18	0	2207	563	0	49	0	0	0	0	0	0	0	0
2013	0	0	86	116	0	0	0	3	0	1310	568	0	14	0	0	0	0	0	0	0	0
2014	0	0	0	143	0	0	0	0	0	1406	370	0	76	0	0	0	0	0	9	0	0
2015	0	0	3	0	0	0	0	0	1	103	18	0	0	0	0	0	0	0	0	0	0

Table 2 Cont.

c) Both length and weight measurement

	Hokkaido	Aomori	Iwate	Miyagi	Yamagata	Ibaragi	Chiba	Kanagawa	Nigata	Toyama	Ishikawa	Shizuoka	Mie	Wakayama	Tottori	Shimane	Yamaguchi	Ehime	Kochi	Miyazaki	Kagoshima
1994	212	0	119	158	1	0	0	15	759	236	0	0	0	4	0	0	33	3	0	0	10
1995	230	0	191	87	0	0	0	16	3283	275	0	0	0	3	0	0	181	0	0	0	42
1996	50	0	136	297	4	0	0	2	1426	82	0	0	0	1	0	0	75	3	0	0	11
1997	34	0	86	216	44	0	0	184	1185	61	0	0	4	30	0	0	30	2	0	0	33
1998	0	0	157	159	1	0	0	47	521	450	0	0	0	6	0	0	17	2	0	0	0
1999	0	0	1010	118	0	0	0	50	834	233	0	0	0	1	0	0	0	0	0	0	0
2000	119	0	1698	369	0	0	0	25	973	162	0	0	12	11	0	0	20	0	0	0	0
2001	146	0	1096	251	0	0	0	40	908	98	0	4	14	9	0	0	55	1	0	0	0
2002	157	0	1083	509	0	0	0	16	451	0	0	0	0	0	0	0	15	23	0	0	0
2003	72	0	900	240	0	0	0	11	560	0	0	0	10	0	11	0	36	3	0	0	0
2004	4	2	610	846	0	0	0	9	886	1	0	0	49	1	0	0	46	0	0	0	0
2005	0	19	1018	1419	0	0	0	26	1481	15	0	0	67	12	0	0	149	148	47	0	0
2006	4	63	2551	845	0	0	0	3	972	44	0	0	17	0	0	0	114	20	0	0	0
2007	0	35	1425	1244	0	0	0	4	943	112	0	0	20	1	0	0	86	0	0	0	0
2008	12	116	2686	2196	0	0	0	36	873	286	0	0	2	0	0	0	354	0	0	0	0
2009	9	0	2101	1456	0	0	0	2	633	186	0	0	1	0	0	0	360	0	0	0	55
2010	2	192	1119	1026	0	0	0	1	357	470	162	0	10	0	0	0	290	0	0	0	9
2011	5	197	399	148	0	0	0	14	757	53	114	0	0	0	0	0	279	0	0	0	9
2012	61	1362	2346	1295	0	0	0	43	527	358	341	0	15	25	0	0	778	9	0	0	424
2013	32	486	1054	1413	0	0	0	91	302	456	624	0	0	21	0	0	538	0	1	0	371
2014	24	1829	1258	1454	0	0	0	0	578	68	568	0	26	4	0	0	705	4	3	0	144
2015	4	426	513	183	0	0	0	0	344	64	148	0	26	1	0	0	218	0	0	16	28

Table 3 The result of combination of prefectures using AIC values of the tentative GLM analysis. This analysis is used to decide the area stratum for size estimation. We used "step 9" as the area stratification according to Hiraoka et al. (2015).

	Step											
	Prefecture	1	2	3	4	5	6	7	8	9	10	11	12
3	Iwate	1	1	1	1	2	2	2	2	2	2	2	2
4	Miyagi	2	2	2	2	2	2	2	2	2	2	2	2
14	Kanagawa	3	3	3	3	3	3	3	4	8	10	10	12
24	Mie	4	4	4	4	4	4	4	4	8	10	10	12
30	Wakayama	5	5	5	5	5	6	8	8	8	10	10	12
38	Ehime	6	6	6	6	6	6	8	8	8	10	10	12
46	Kagoshima	7	8	8	8	8	8	8	8	8	10	10	12
35	Yamaguchi	8	8	8	8	8	8	8	8	8	10	10	12
17	Ishikawa	9	9	10	10	10	10	10	10	10	10	10	12
16	Toyama	10	10	10	10	10	10	10	10	10	10	10	12
15	Nigata	11	11	11	12	12	12	12	12	12	12	12	12
6	Yamagata	12	12	12	12	12	12	12	12	12	12	12	12
	AIC	860140.2	860240.3	860757.2	861614.3	862715.4	864158.1	864701.7	871512.8	888522.7	911966.2	911966.2	1237683

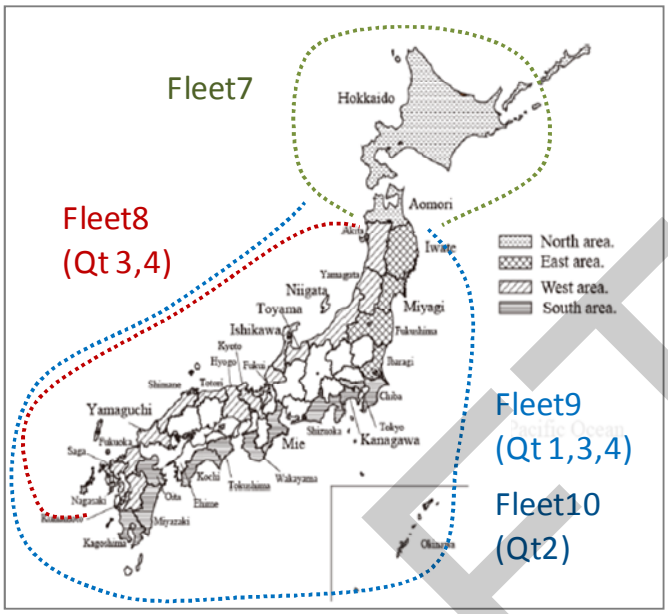
Table 4 The result of definition for data pooling order using AIC values of the tentative GLM analysis. Each model includes the estimation strata as explanatory variables. Estimated order is based on the AIC values according to Hiraoka et al. (2015).

GLM to decide the order of data pooling		df	AIC	Order
Highest resolution model				
Model 0	log(FL)= (intersept)+(Brand name)+ (Month)+ (Prefecture)+ error	78	-32022.0	1st
One of three criteria pooled model				
Model 1	log(FL)= (intersept)+ (S/M/L)+ (Month)+ (Prefecture)+ error	33	-22593.7	5th
Model 2	log(FL)= (intersept)+ (Brand name)+ (Quarter)+ (Prefecture)+ error	70	-27671.5	3rd
Model 3	log(FL)= (intersept)+ (Brand name)+ (Month)+ (Area)+ error	64	-30044.5	2nd
Two of three criteria pooled model				
Model 4	log(FL)= (intersept)+ (S/M/L)+ (Quater)+ (Prefecture)+ error	25	-15987.5	7th
Model 5	log(FL)= (intersept)+ (S/M/L)+ (Month)+ (Area)+ error	19	-21958.4	6th
Model 6	log(FL)= (intersept)+ (Brand name)+ (Quater)+ (Area)+ error	56	-25703.2	4th
Lowest resolution model (All criteria pooled model)				
Model 7	log(FL)= (intersept)+ (S/M/L)+ (Quater)+ (Area)+ error	11	-14941.8	8th

Table 5 Rate of estimated catch amount of catch-at-size against to total catch amount recorded by RJB database. At the final step (8^{th} step), about 90% of catch was estimated their size in both "North area" and the other areas.

Step	strata	Rate	
		North area (Hokkaido and Aomori)	The other areas
1st	Brand-name, Month, Prefecture	60.4%	63.4%
2nd	Brand-name, Month, Area	65.2%	69.5%
3rd	Brand-name, Quarter, Prefecture	66.9%	74.2%
4th	Brand-name, Quarter, Area	69.7%	74.9%
5th	S/M/L, Month, Prefecture	89.0%	79.1%
6th	S/M/L, Month, Area	89.1%	85.0%
7th	S/M/L, Quarter, Prefecture	93.0%	83.2%
8th	S/M/L, Quarter, Area	95.0%	87.2%

a) Previous definition (Kai and Takeuchi 2012)



b) New definition (Hiraoka et al. 2015)

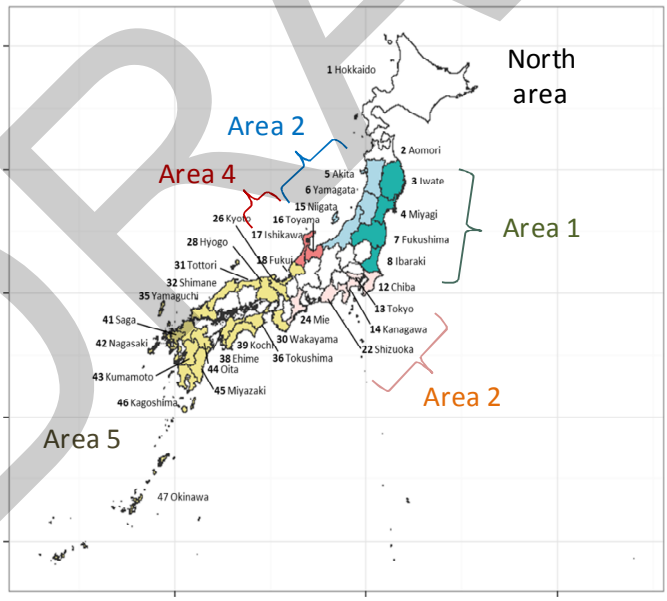


Fig. 1 Area definition used for the estimation of catch-at-size in previous study (upper panel; Kai and Takeuchi 2012) and current study (lower panel; Hiraoka et al. 2015). The fleet definition in previous assessment is also indicated in the map of previous definition (ISC 2014). In this document, "North area" and five other areas are used for the estimation of catch-at-size, and some options for the fleet grouping are discussed based on this area definition.

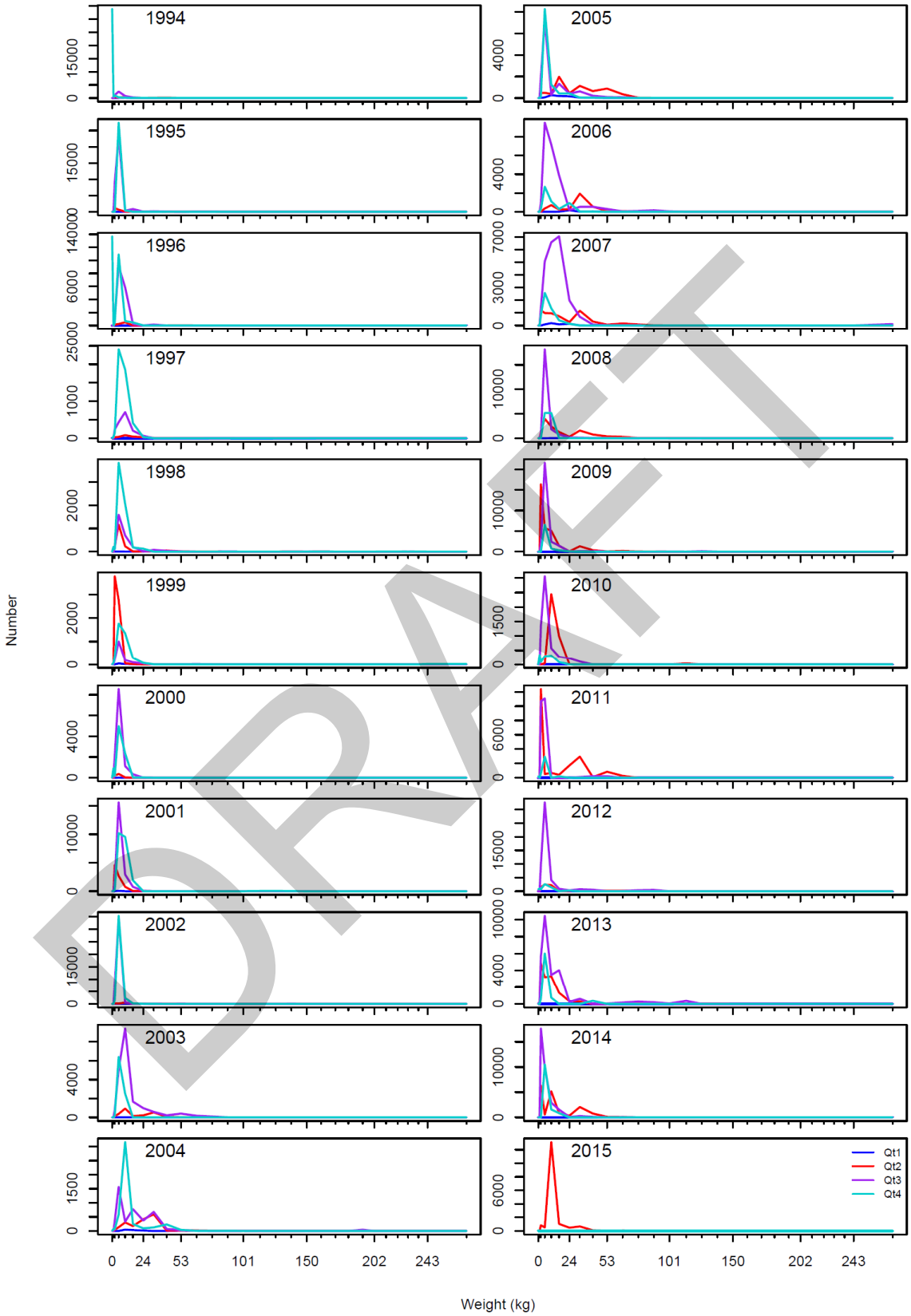


Fig. 2 Estimated catch-at-size (weight frequency) of PBF caught by Japanese set-net in "North area" (Hokkaido and Aomori) by quarter of calendar year.

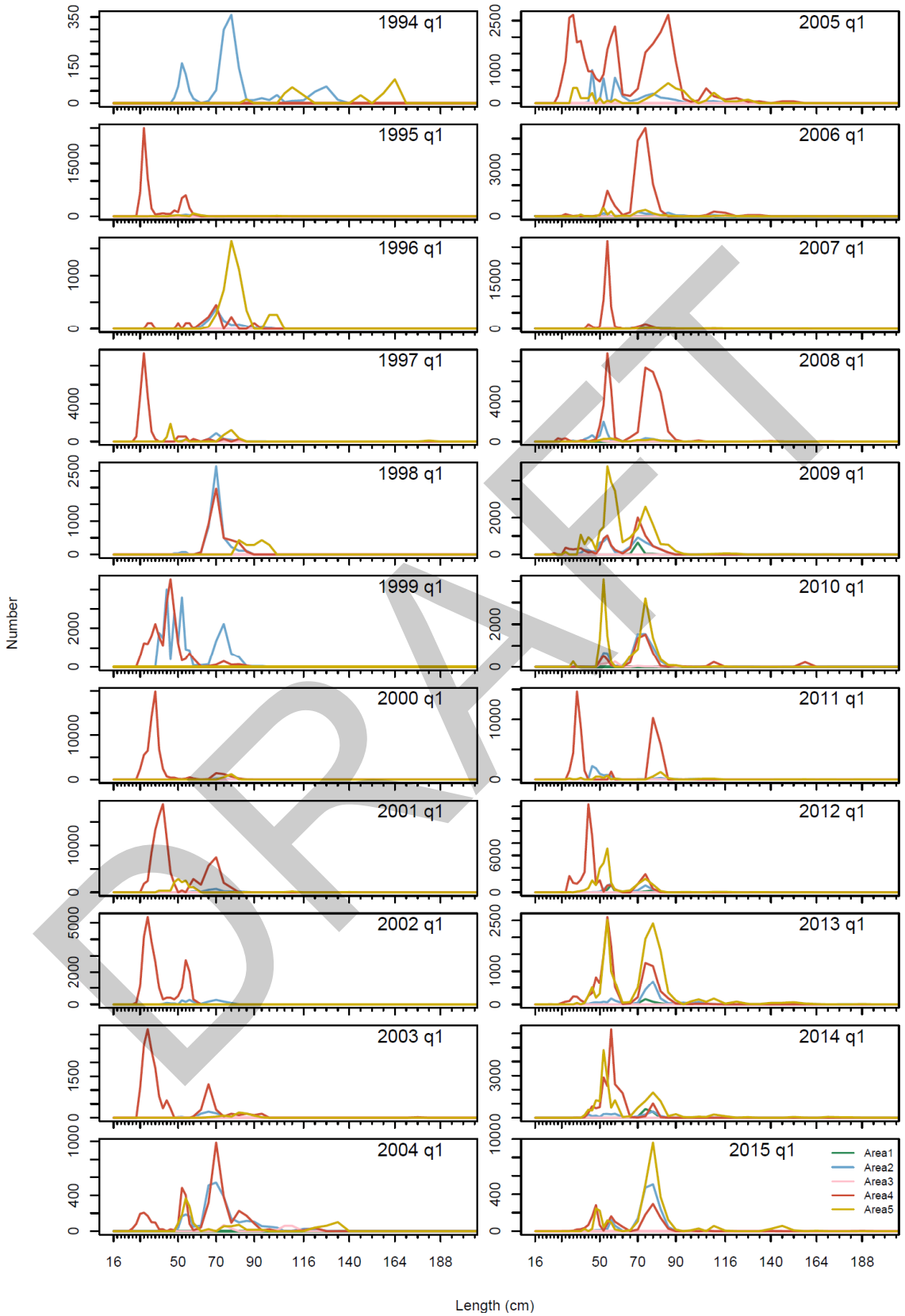


Fig. 3a Estimated catch-at-size (length frequency) of PBF caught by Japanese set-net in Area 1-5 (except for "North area") by quarter 1 (Jan-Mar) of calendar year.

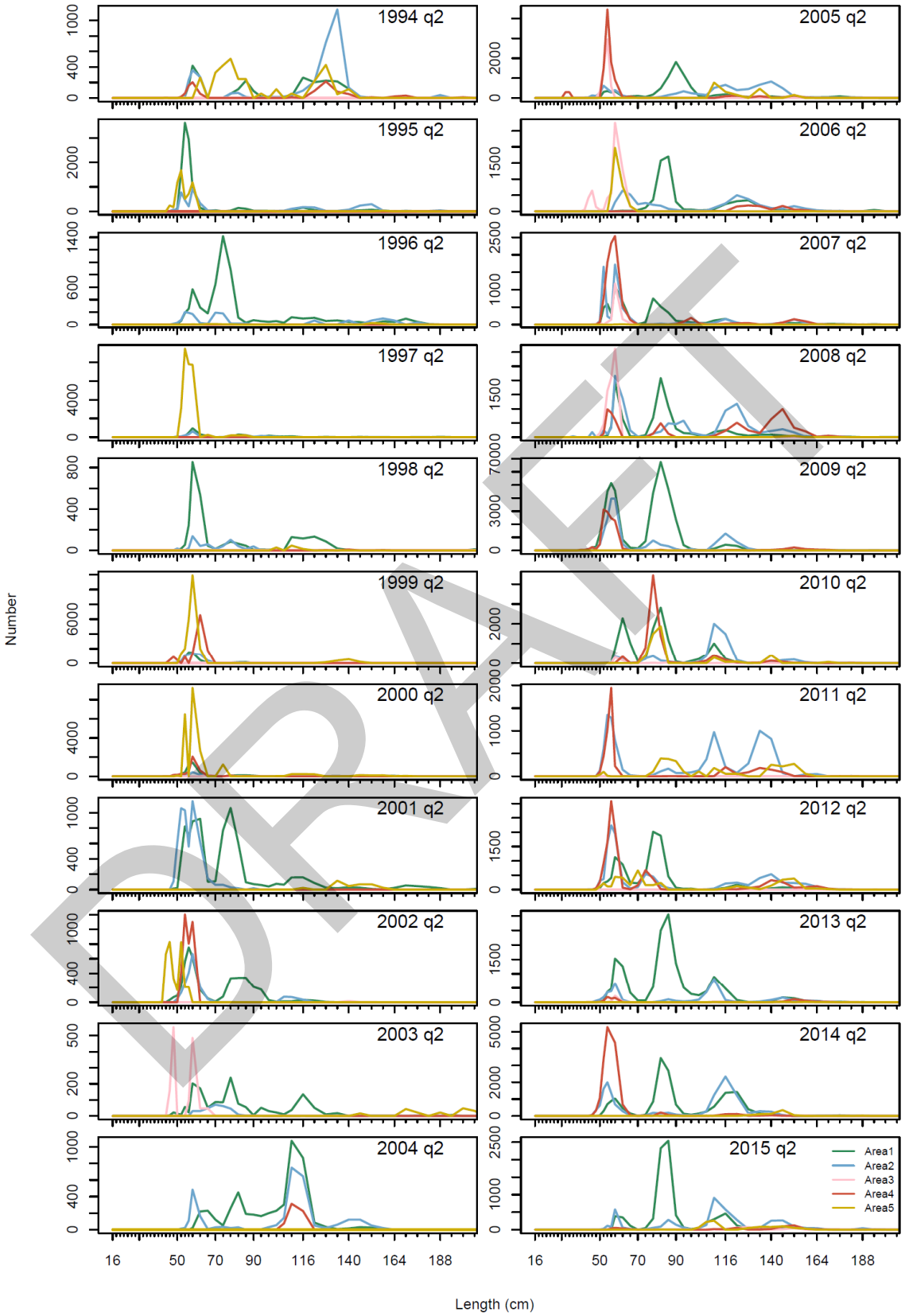


Fig. 3b Estimated catch-at-size (length frequency) of PBF caught by Japanese set-net in Area 1-5 (except for "North area") by quarter 2 (Apr-Jun) of calendar year.

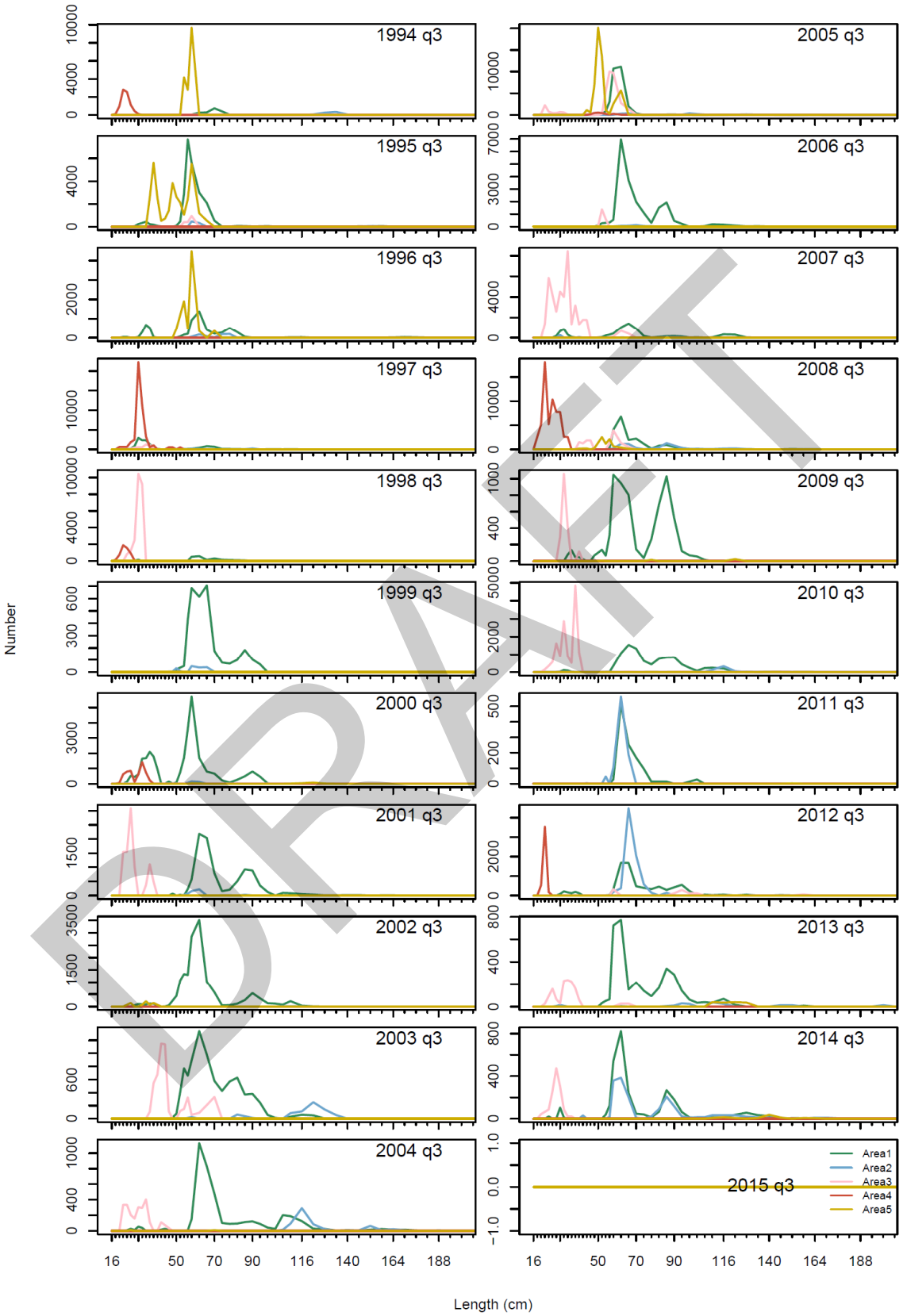


Fig. 3c Estimated catch-at-size (length frequency) of PBF caught by Japanese set-net in Area 1-5 (except for "North area") by quarter 3 (Jul-Sep) of calendar year.

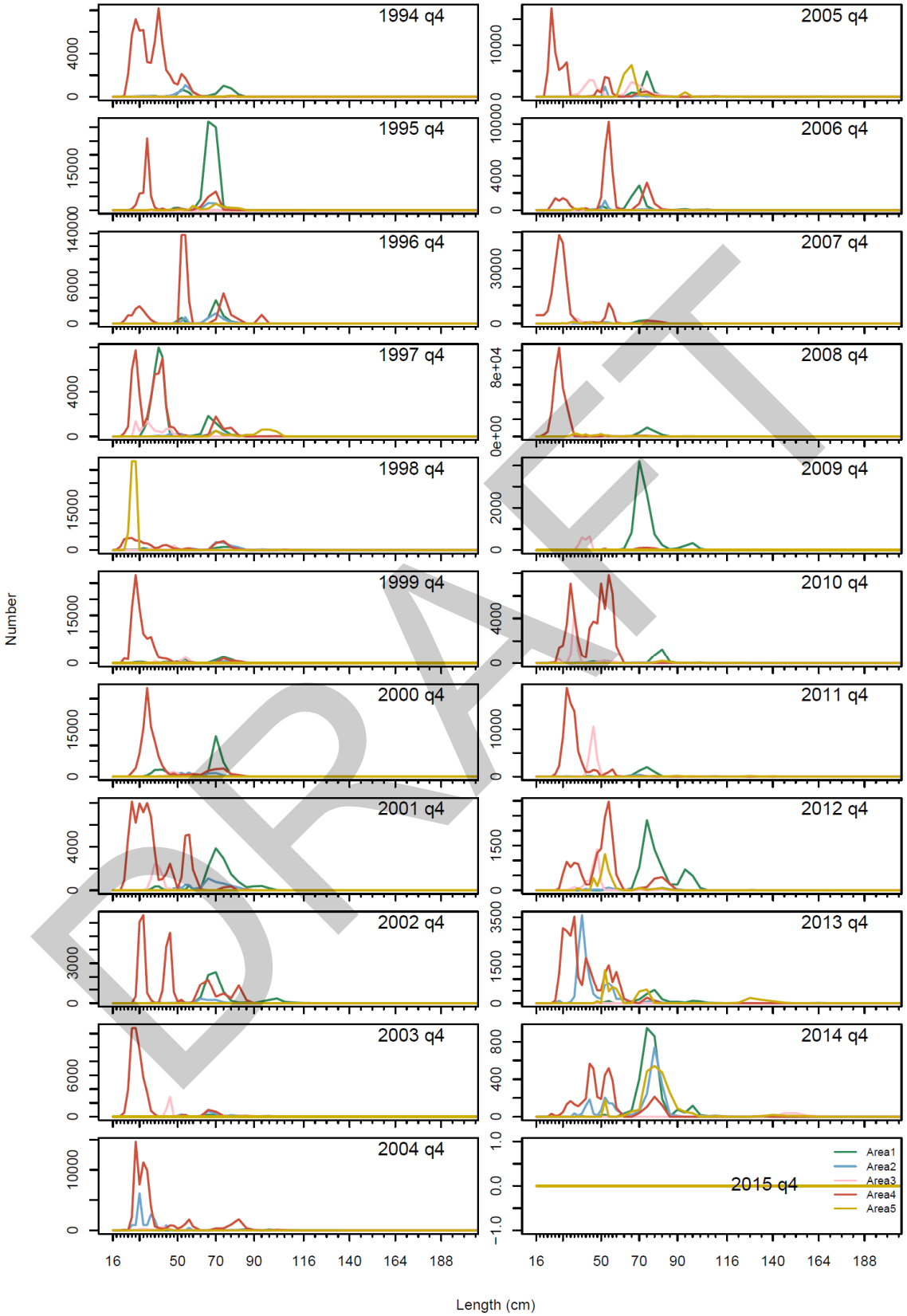


Fig. 3d Estimated catch-at-size (length frequency) of PBF caught by Japanese set-net in Area 1-5 (except for "North area") by quarter 4 (Oct-Dec) of calendar year.

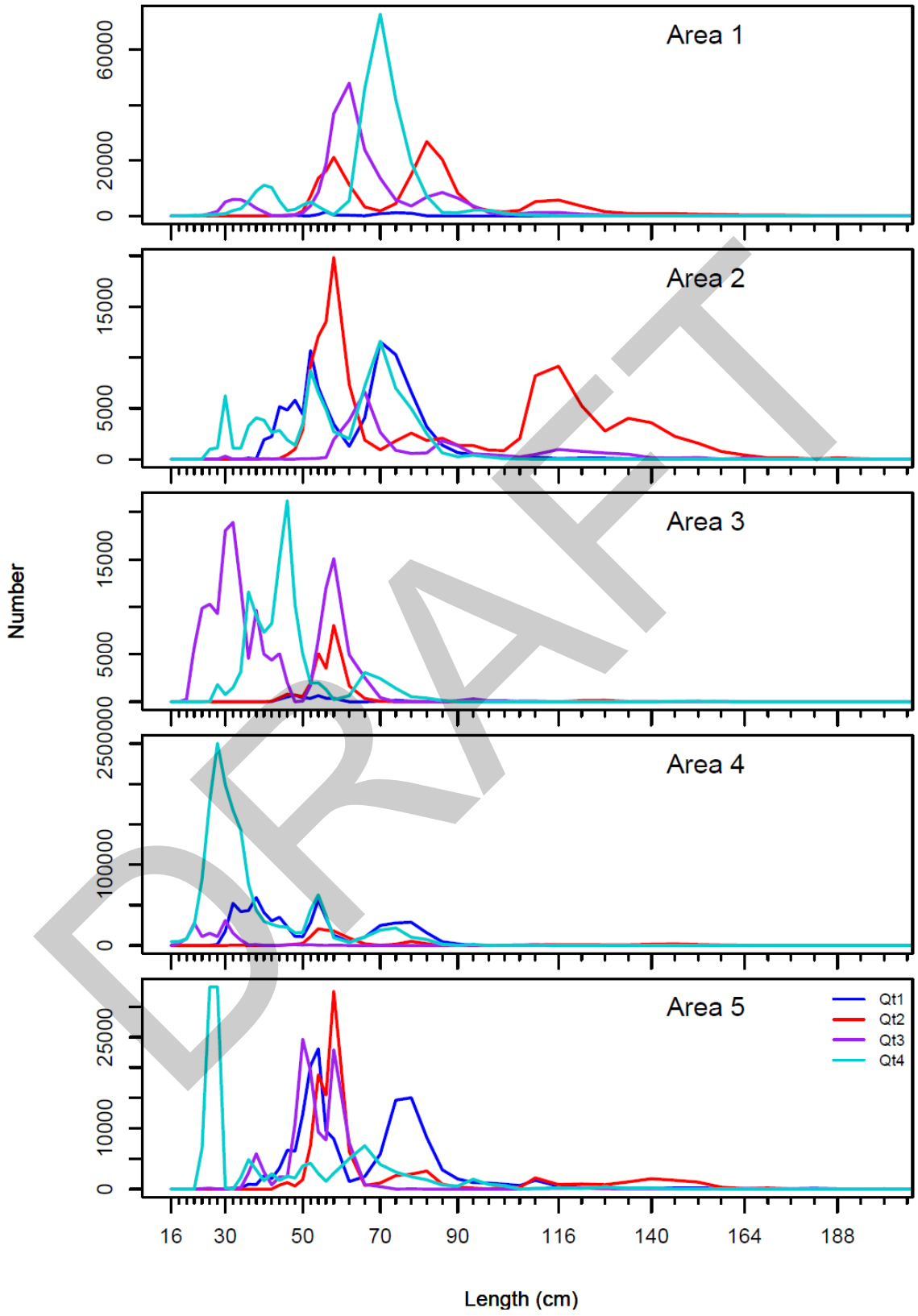


Fig. 4 Estimated length frequency of PBF caught by set-net in area 1-5 by quarter. All data from 1994 to 2015 are aggregated.

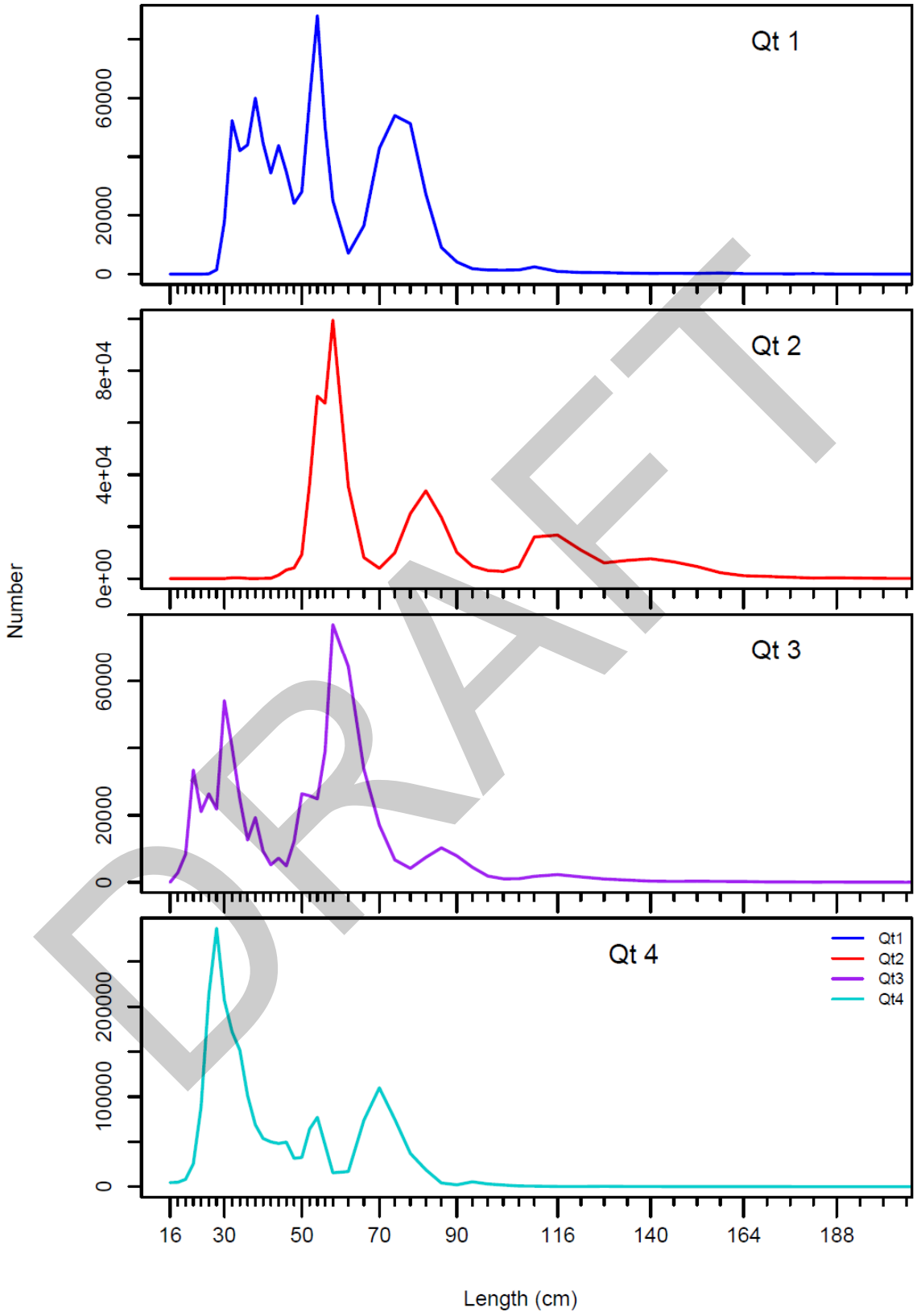


Fig. 5 Estimated length frequency of PBF caught by set-net in area 1-5 by quarter. The data of area 1-5 from 1994 to 2015 are aggregated.

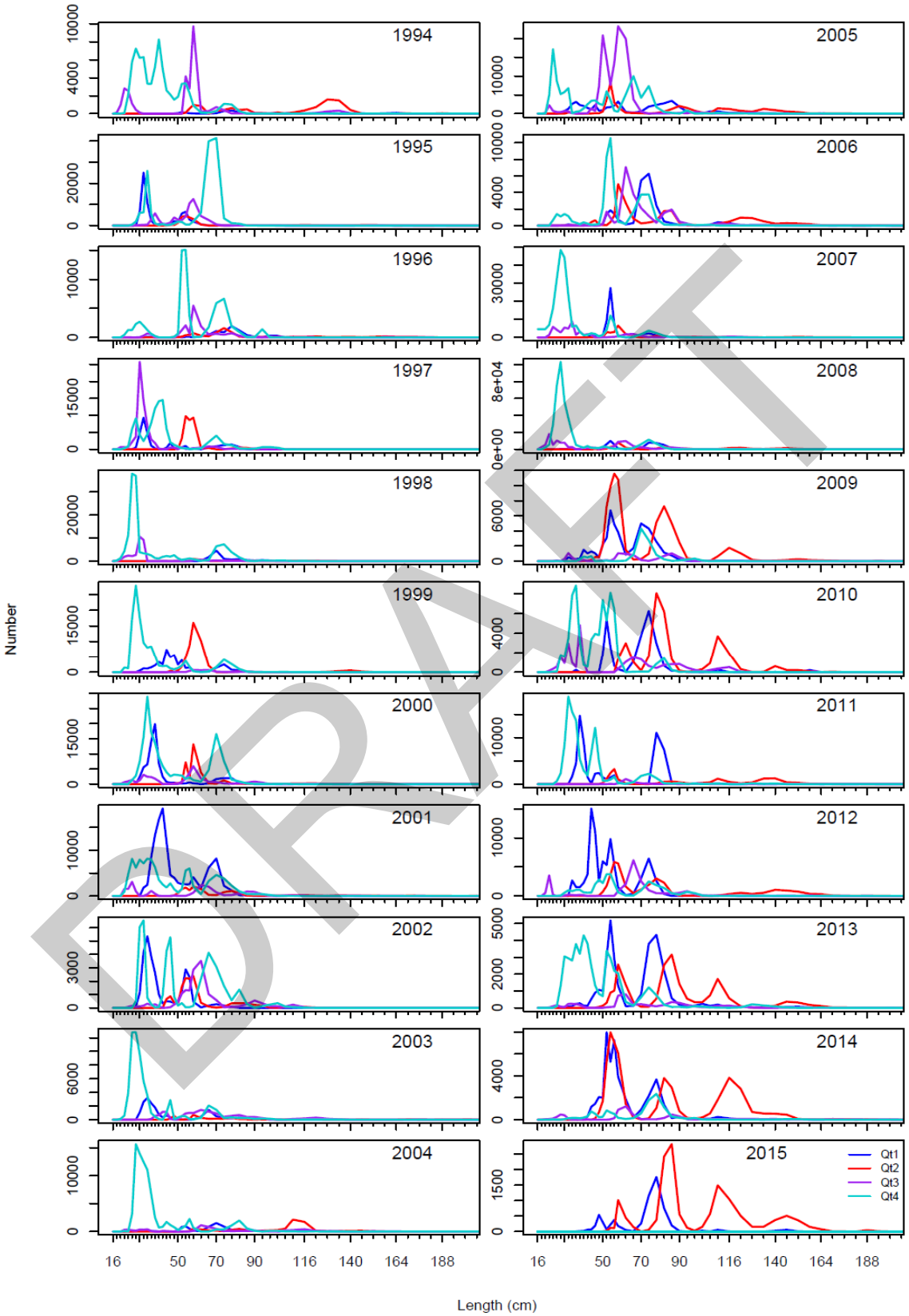


Fig. 6 Estimated length frequency of PBF caught by set-net in area 1-5 by quarter. The data of area 1-5 are aggregated.

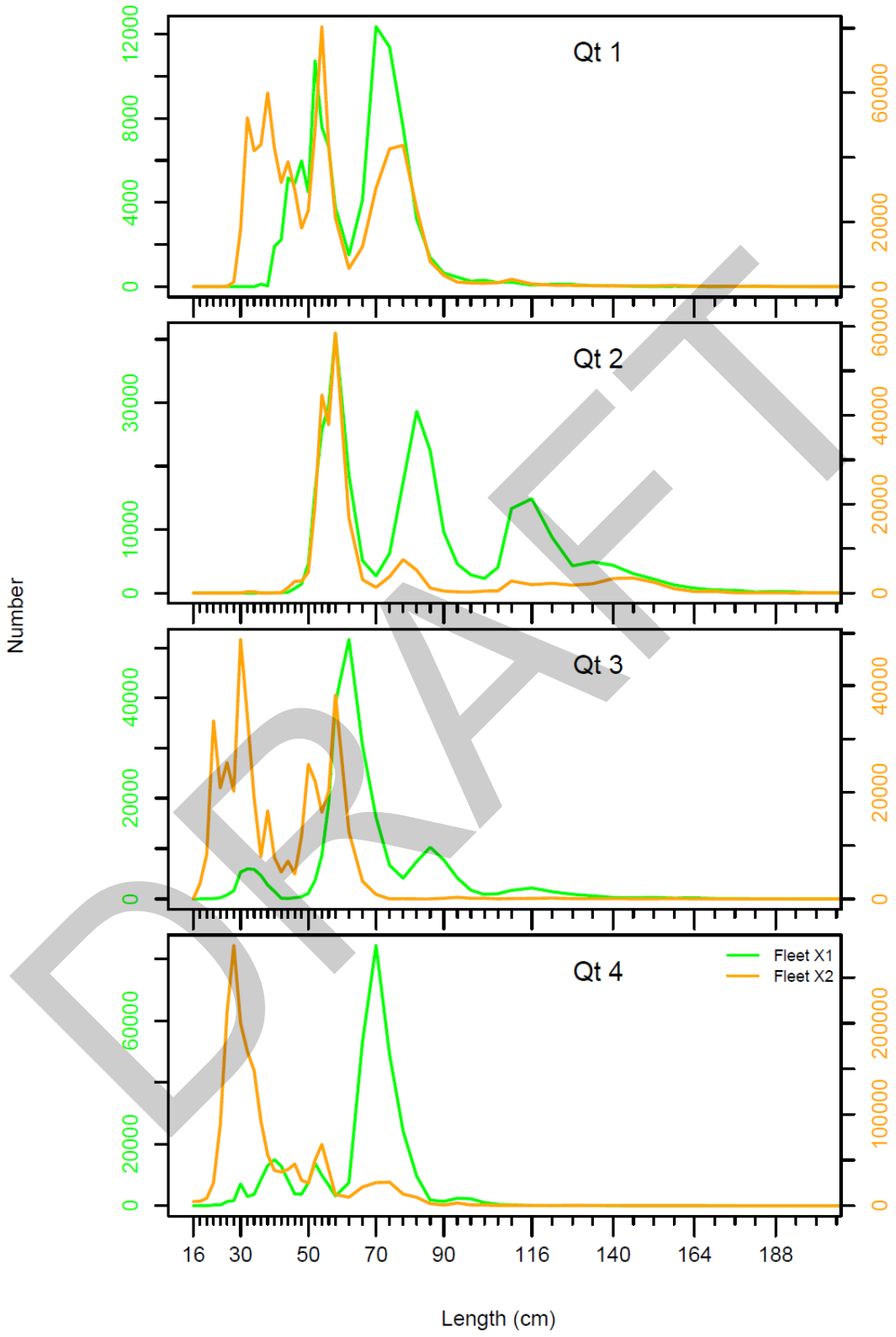


Fig. 7 Estimated length frequency of PBF caught by set-net by quarter. The data of area 1, 2 and 3-5 are aggregated as fleet X1 and X2, respectively. All yearly data are aggregated.

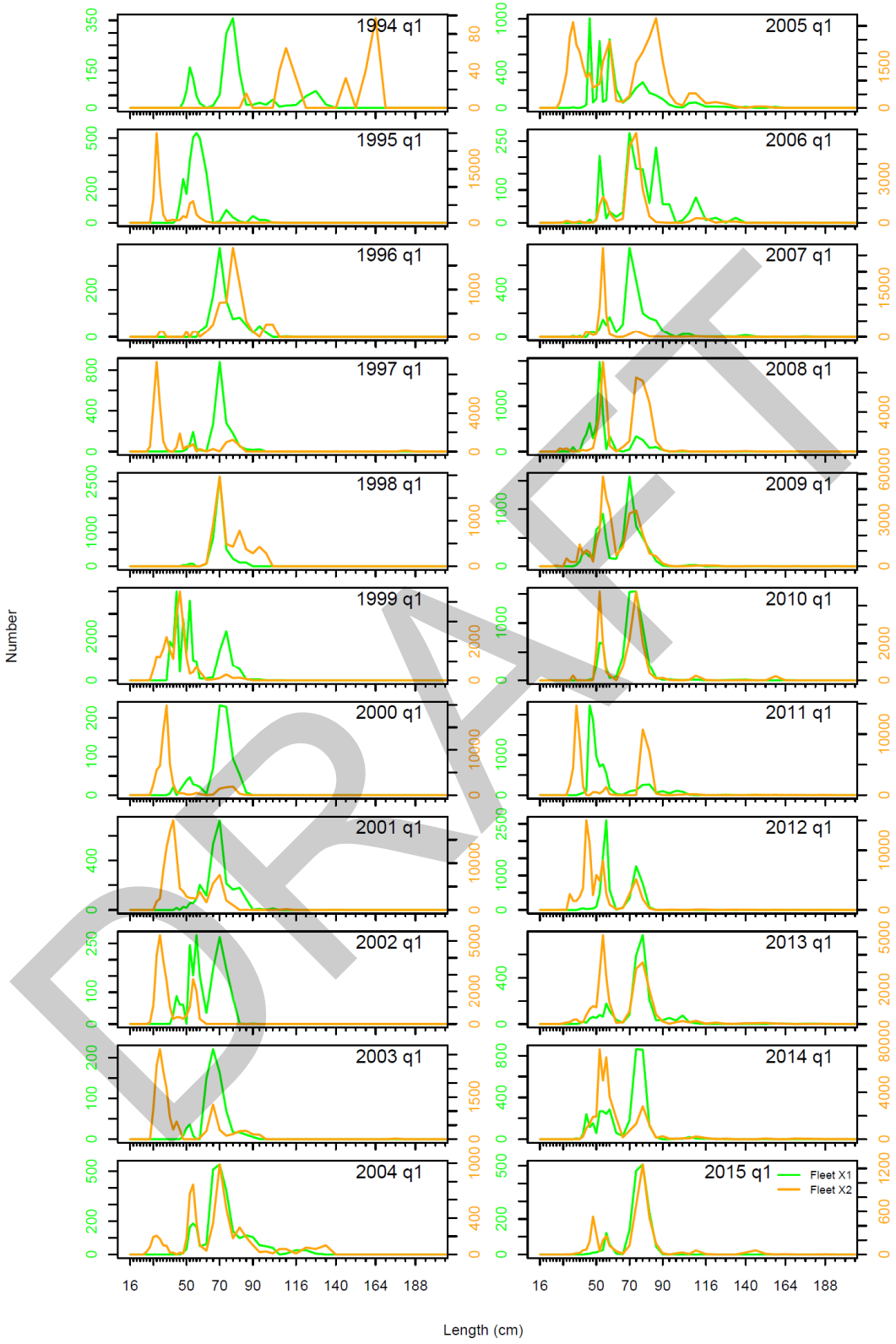


Fig. 8a Estimated length frequency of PBF caught by set-net in quarter 1 (Jan-Mar). The data of area 1, 2 and 3-5 are aggregated as fleet X1 and X2, respectively. All yearly data are aggregated.

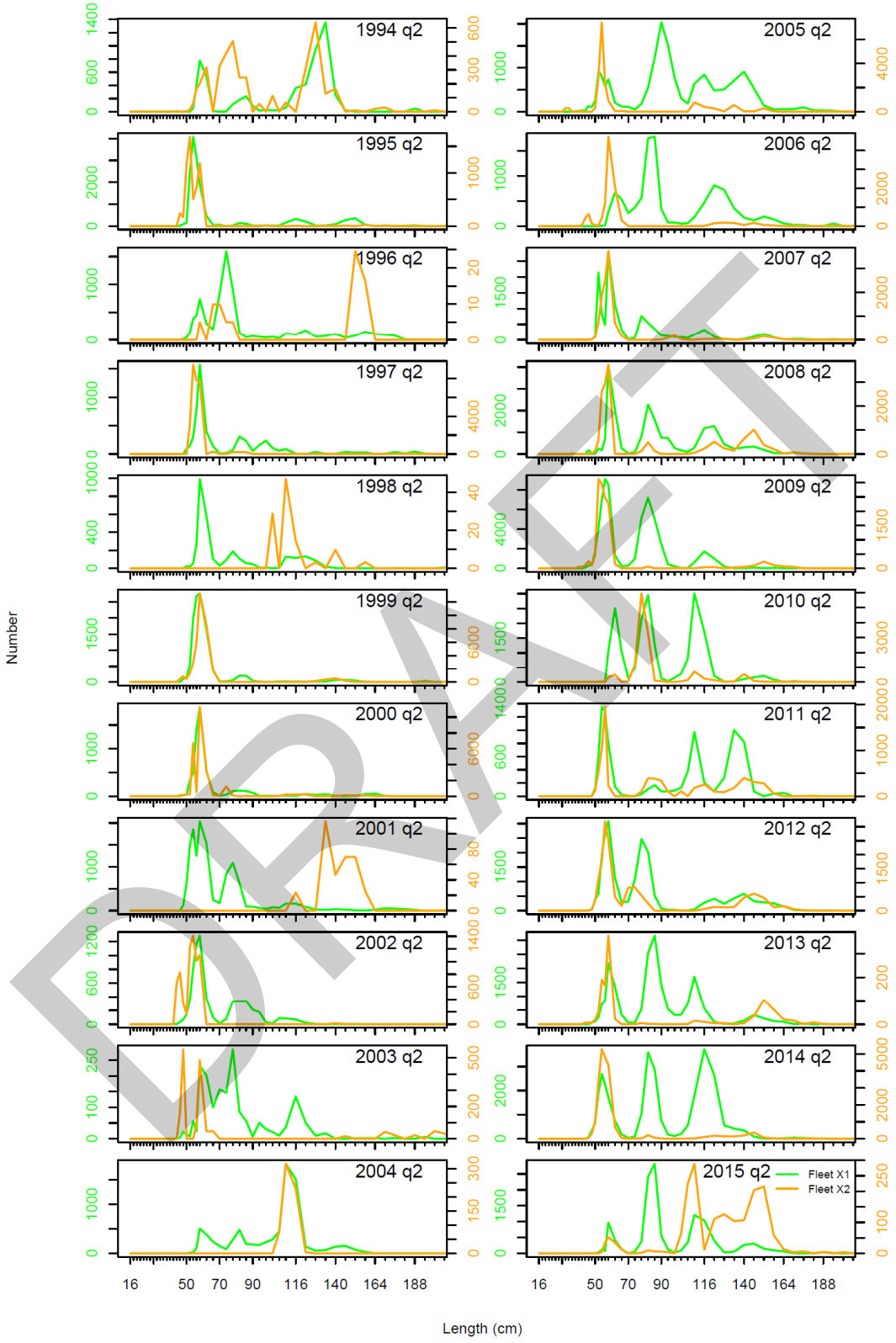


Fig. 8b Estimated length frequency of PBF caught by set-net in quarter 2 (Apr-Jun). The data of area 1, 2 and 3-5 are aggregated as fleet X1 and X2, respectively. All yearly data are aggregated.

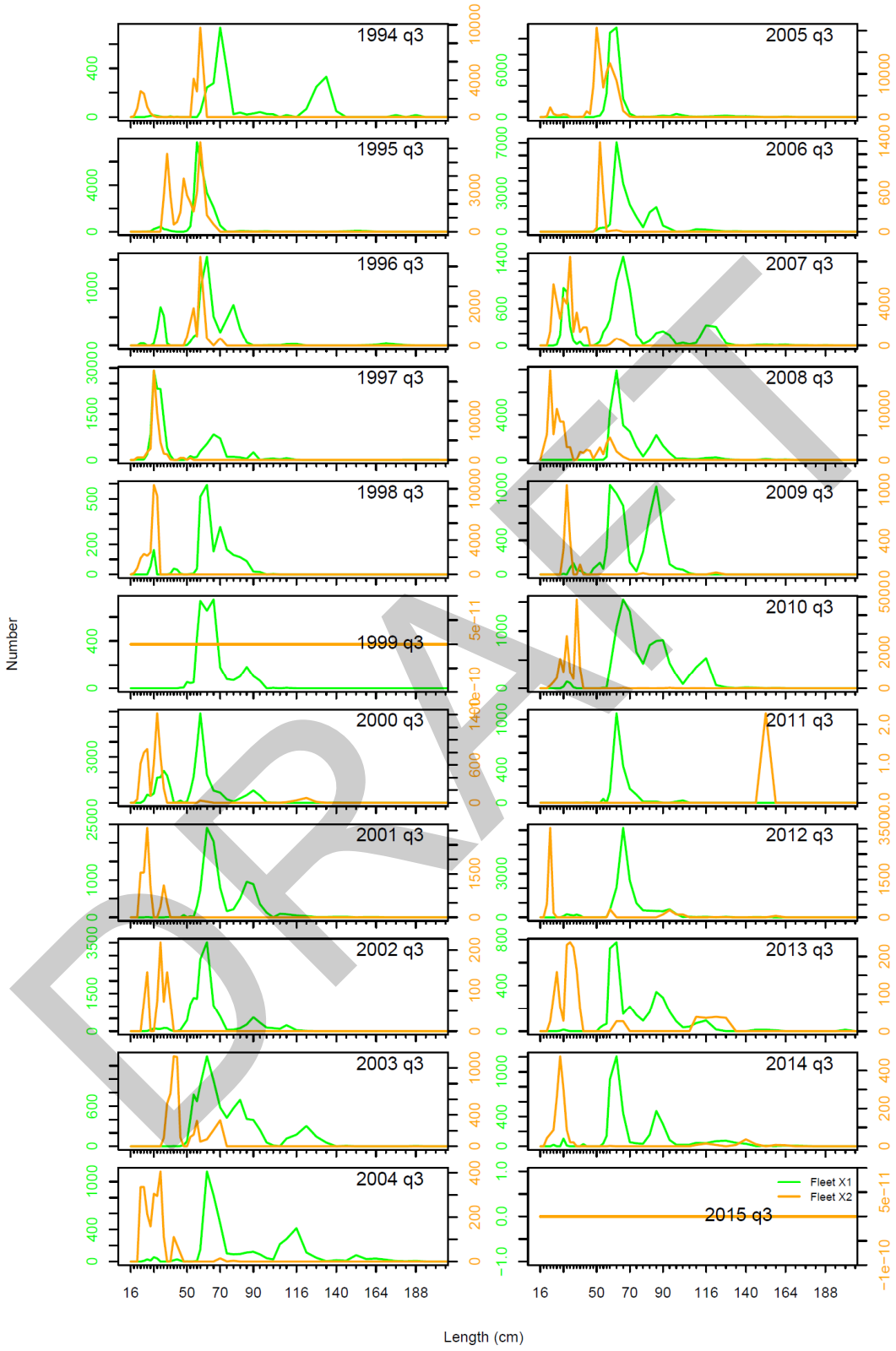


Fig. 8c Estimated length frequency of PBF caught by set-net in quarter 3 (Jul-Sep). The data of area 1, 2 and 3-5 are aggregated as fleet X1 and X2, respectively. All yearly data are aggregated.

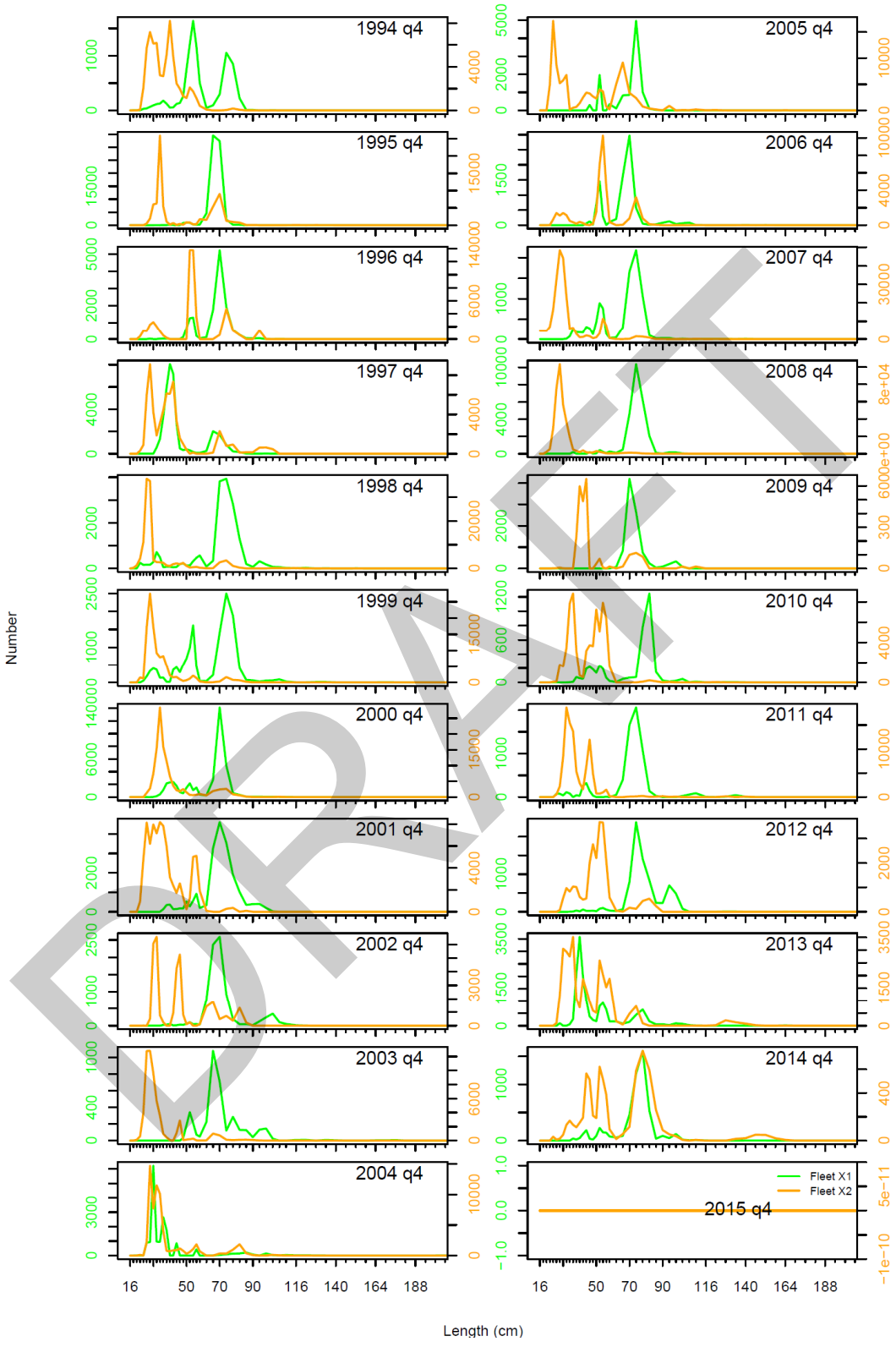


Fig. 8d Estimated length frequency of PBF caught by set-net in quarter 4 (Oct-Dec). The data of area 1, 2 and 3-5 are aggregated as fleet X1 and X2, respectively. All yearly data are aggregated.