Estimation of catch at size of Pacific bluefin tuna, *Thunnus orientalis*, caught by Japanese tuna purse seine operated in Pacific ocean.[1]

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1. Introduction

Japanese purse seine fishery catching adult Pacific Bluefin tuna (PBF) *Thunnus orientalis* is classified into the Tuna Purse Seine fleet (Fleet 3) in the Stock Synthesis III model (ISC/10-1/PBFWG/09). This fishery operates in the North Pacific Ocean and the Sea of Japan (ISC/07/PBF-1/01). Main landing ports are shown in Fig.1. In the North Pacific Ocean, tuna purse seine fisheries occasionally target adult PBF during June to August. In the Sea of Japan, tuna purse seine fishery specific for PBF started in the early 1980s and matured PBF are mainly landed between July and August (ISC/06/PBF-WG/09). In last ISC meeting, it was suggested that the Fleet3 be separated into the Pacific and the Japan Sea fisheries (ISC/11-1/PBFWG/09). Following this suggestion, length distributions and catch effort collected in Sakai-minato port facing the Sea of Japan was reported at the last ISC meeting (ISC/11-1/PBFWG/04, ISC/12-1/PBFWG/07 and ISC/12-1/PBFWG/09). However, length measurement data collected from the Pacific Ocean side were not analyzed in detail.

Therefore, this document summarized currently available length data collected from tuna purse seine fishery operated in the Pacific Ocean, and discussed estimated catch at size.

2. Material and Method

2.1 Fork Length frequency data（ISC/07/PBF-1/8）

Until 1993 length measurements or body weight data of the Pacific Bluefin tuna purse seine were assembled in the database of NRIFSF. This database was started from 1952 onward and the data summarized by month. Most of the measurements were reported in weight in 1kg intervals. Before 1986 they were taken from the sales slips of the fish at Tsukiji market to where the fish were sent from

north eastern part of Japan (Honma and Suzuki 1978). Sampling at landing ports started only in 1986. The main sampling port on the Pacific Ocean side has been Shiogama. Therefore, to create the length compositions for the periods before 1994, the weight records of individual fish were converted to lengths with length-weight relationship by month, which was estimated by Takeuchi (ISC/07/PBF-1/08).

From 1992, length measurements have been made at several landing ports on the Pacific side, from the tuna purse seine catches through the Research program on Japanese Bluefin tuna (RJB). . In RJB database, landed PBF were categorized into large size PBF "*maguro*" and small size PBF "*meji*". These two categories correspond to the processing status of fish, i.e., gilled and gutted for "*maguro*" and round fish for "*meji*".

In the last stock assessment, input data of length distribution of Fleet3 were used for the period since 1974 because of the lack of size data less than 100cm before 1974. In this document, data analysis was conducted by calendar year.

2.2 Catch data（ISC/07/PBF-1/10 and ISC/11-1/PBFWG/09）

Quarterly catch of PBF by Tuna Purse Seine fleet around Japan were estimated based on the Japanese national statistics, logbook data submitted by fishers, monthly landing records by markets and monthly catch data collected by the Research program on Japanese Bluefin tuna (RJB).

"Japanese national statistics" is a database composed of the annual catch in weight by fishery and species of fish caught since 1952. Logbook data recorded set-by-set operational data since 1968 and amount of PBF catch was reported since 1971. In logbook information, the PBF catches were recorded by two categories;

catch of the fish smaller than 10kg and fish weighing more than 10kg.

The RJB data are summarized based on length measurements by samplers and associated weight from the sales slips since 1992. The main landing ports on the Pacific Ocean side have been Shiogama and Ishinomaki according to RJB database (Fig. 2). The former has been the main landing port of "*maguro*", and the latter has been that of "*meji*".

Since dates of the catch of PBF by purse seiners and date of the size measurement at the landing port may have some time lags, the monthly sums of the weight of measured PBF may exceed amount of catch reported in the logbook.

In this document length distributions were analyzed by the category of the PBF less than 10 kg and over 10 kg until 1993 and by the categories of "*maguro*" and "*meji*" landed in Shiogama and Ishinomaki since 1994. Catch in number of fish was estimated from catch in weight, using mean weight calculated based on weight data for each quarter and size category of fish. When size information was not available in some quarter, the average weight of that year throughout all the quarters was applied, and for the year when size measurements were not carried out both in neither 2nd nor 3rd qt, the average weight of quarterly measurement data was applied.

2.3 Data analysis

Tables 1 and 2 show for quarterly periods, catch, sum of weight of sampled fish and ratio of sum of number of fish measured to the total catch in number by each category and by each database. In this document the PBF caught in the 1st qt is combined into that of the 2nd qt, and likewise that of the 4th qt to the 3rd qt, because the samplings in the 1st and 4th quarters are very minor. Besides,

the fishing in the 1st qt actually occurs in March and is justified to be added to the following quarter, and the same is true since the fishing in the 4th qt occurs only in October.

The size frequencies obtained either through length sampling or conversions from weight data for individual fish are raised by the corresponding catch in number of fish per year/quarter and size category stratum. However, as many year-quarter strata, or the smaller fish (*i.e.* in category of less than 10kg) are missing size data, data substitutions are required where length data are missing for the fish of less than 10kg or "*meji*" (i.e. 1978-2nd qt, 1979-3rd qt, 1980, 1984, 1993-2nd qt, 1995-3rd qt, 1999-3rd qt, 2000, 2001-3rd qt, 2002-3rd qt, 2004-3rd qt, 2005-3rd qt, 2007, 2009-2rd qt, 2010). In order to explore appropriate procedures of data substitution, length data were analyzed regarding temporal changes in the length distributions within each category. In this document effects of year and quarter were considered in the relation with the length data. The relationship by category and period was analyzed by GLM of statistical data analysis software R (R Development Core Team 2011), and the model used in the analysis is as follows:

$$\text{Length} = \text{year} + \text{quarter} \qquad (1)$$

The level to substitute was chosen from results of GLM described. More details can be found in Oshima *et al.* (ISC/12-1/PBFWG/02).

Result and Discussion

Even after 1973, coverage rate of weight data for the category of less than 10kg was quite lower than that of weight data for category of more than 10kg. Sum of number of fish measured to catch in number in the category of less than 10kg was low until

1993. Length measurement less than 10kg was not carried out in many cases even after 1994 (Table 1 and 2). Length distributions are variable, significantly between years (Table 3). As the result of GLM analysis, when length distribution was not available in some quarter, the combined length distribution of that year throughout the quarters was applied, and for the year when size measurements were not carried out both in neither 2nd nor 3rd qt, the combined length distribution of quarterly measurement data was applied.

Observed and weighted length distributions of more than 10kg and "*maguro*" PBF by year were shown in Fig. 3. Except 2005, weighted length distributions were similar in the tendencies to the length distributions used in SS3 model of the last stock assessment.

Observed and weighted length distributions of less than 10kg and "*meji*" PBF by year were shown in Fig. 4. Weighted length distributions were different from the observed length distributions considerably for the period until 2010. Especially, the length distribution in 1997, 1999, 2002 and 2005 differed greatly.

In this document, catch at size was estimated by simpler method. It seems that it is desirable to use this result although there is limited number of size data for the small PBF. The causes for significant differences between actual and weighted length distributions were discussed in ISC/07/PBF-1/8, with the conclusion that it was a result of quality of data in each period and each category. Therefore one of the alternative options may be to exclude data of the small PBF categorized into "*meji*" after 1993 from size data of Fleet 3. The other alternative may be a use of "super year" i.e. the size distributions combined for all years or "super season" i.e. combine all the size data combined through seasons but year specific.

Number of record of set collected by logbook was

summarized in Table 4. Most of single operation (more than 90% of operations (hauls)) caught only fish of one of the two categories, larger or smaller than 10kg. This can be interpreted that, according to the fact that a purse seine haul consists of a single school which is not likely to be mixture of fish larger and smaller than 10kg.

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Table 1. Summary of size data base and logbook collected by TPS fiseries before 1994.

Calendar year	qt	Amount of catch(ton)		Weight measurement				mean weight(ton)		Estimated Number		coverage rate %(number)	
		≥10kg	<10kg	≥10kg Sum of weight	≥10kg Freq	<10kg Sum of weight	<10kg Freq	≥10kg	<10kg	≥10kg	<10kg	≥10kg	<10kg
1975	2	944.8	2469.8	1490.8	51034	0.1	18	0.03	0.01	32343	350057	157.8	0.01
1976		1042.7	79.4	220.7	1984	0.7	700	0.11	0.00	9373	79975	21.2	0.83
1977		2281.8	1780.9	1071.6	30556	5.8	775	0.04	0.01	65063	236700	47.0	0.33
1978		9393.3	950.1	2740.0	44795	▤	▤	0.06	0.01	153569	142445	29.2	0.00
1979		10887.8	257.0	4760.0	54582	0.0	1	0.09	0.01	124847	42835	43.7	0.00
1980		5896.8	270.8	2085.3	19194	▤	▤	0.11	0.01	54276	40602	35.4	0.80
1981		5573.6	970.4	3102.3	69245	7.8	979	0.04	0.01	119942	122017	57.7	0.19
1982		3475.4	1935.0	3092.7	51852	3.7	426	0.06	0.01	58269	223995	89.0	2.50
1983		6323.6	5627.2	4615.5	118627	140.8	19151	0.04	0.01	162530	765300	73.0	▤
1984		417.1	2031.1	288.3	6499	0.0	1	0.04	0.01	9402	304516	69.1	0.00
1985		956.3	1940.7	1070.4	36623	0.9	109	0.03	0.01	32722	277243	111.9	0.02
1986		1637.1	4703.0	826.6	27476	328.4	40080	0.03	0.01	54414	542458	50.5	8.93
1987		1195.2	3678.4	1098.1	53107	20.4	3090	0.02	0.01	57803	448945	91.9	4.17
1988		537.7	489.7	685.0	24775	7.5	1201	0.03	0.01	19449	74186	127.4	0.64
1989		958.2	1175.6	332.8	13213	2.1	333	0.03	0.01	38041	187180	34.7	1.53
1990		221.7	138.3	72.4	2259	4.0	795	0.03	0.01	6922	21814	32.6	2.17
1991		462.3	183.2	193.6	3999	2.1	333	0.05	0.01	9552	36645	41.9	4.41
1992		827.7	849.3	710.3	27730	37.5	5816	0.03	0.01	32298	131858	85.8	▤
1993		717.6	525.6	120.3	1913			0.06	0.01	11415	78800	16.8	
1974	3	3100.3	590.1	1260.7	15762	21.7	3925	0.08	0.01	38760	106563	40.7	3.68
1975		461.3	615.5	742.5	25168	2.7	338	0.03	0.01	15637	77142	160.9	0.44
1976		371.0	655.4	686.6	18069	0.1	6	0.04	0.01	9764	77111	185.1	0.01
1977		443.9	603.3	969.8	26968	0.8	767	0.04	0.00	12344	597844	218.5	0.13
1978		78.2		1843.8	19351			0.10	0.01	821		2357.8	
1979		1491.6	1244.7	2369.0	51339	60.6	10080	0.05	0.01	32326	179053	158.8	0.02
1980		1100.2	4059.2	746.0	22557	101.2	13935	0.03	0.01	33267	583941	67.8	10.02
1981		5083.6	12697.1	7039.7	279943	1.8	247	0.03	0.01	202156	1702597	138.5	5.16
1982		7562.4	4646.6	5191.6	133730	5.7	695	0.04	0.01	194799	562215	68.7	0.01
1983		1685.7	576.6	1688.8	20482	2.7	376	0.08	0.01	20444	78866	100.2	0.12
1984		437.9	745.8	1068.4	15807			0.07	0.01	6479	107288	244.0	0.48
1985		236.1	653.3	142.1	4554	0.1	13	0.03	0.01	7569	81663	60.2	0.02
1986		467.7	604.7	496.6	18781	60.6	10080	0.03	0.01	17687	100594	106.2	10.02
1987		1589.0	1961.4	1350.9	55578	101.2	13935	0.02	0.01	65371	270075	85.0	5.16
1988		1285.6	724.6	994.2	29334	0.1	7	0.03	0.01	37950	80511	77.3	0.01
1989		2141.8	1481.0	477.2	15386	11.7	1395	0.03	0.01	69062	176520	22.3	0.79
1990		976.3	1498.0	444.1	15541	12.7	2088	0.03	0.01	34163	245527	45.5	0.85
1991		1971.4	1494.4	531.1	22084	13.2	2440	0.02	0.01	81969	276328	26.9	0.88
1992		1299.2	883.3	1039.1	27395	61.9	8742	0.04	0.01	34247	124797	80.0	7.00
1993		3666.4	164.3	285.3	4453	1.3	204	0.06	0.01	57230	25817	7.8	0.79

☐ ;it is shown that there is no data.

▤ ;it is shown that it is the period which needs substitution .

Table 2. Summary of RJB size data collected by TPS fiseries after 1993.

year	qt	Amount of catch(ton)		Weight mesurement				length measurement		mean weight(ton)		Estimated Number		coverage rate %(number)	
				maguro		meji		Freq							
		maguro	meji	Sum of weight	Freq	Sum of weight	Freq	maguro	meji	maguro	meji	maguro	meji	maguro	meji
1994	2	2038.8		89.3	900			900		0.10	0.02	20544		4.4	
1995	2	1436.6	0.5	77.4	769	0.2	3	769	3	0.10	0.07	14278	6	5.4	50.0
1996	2	2244.1	397.3	133.3	1435		112	1435	112	0.09	0.02	24153	16282	5.9	0.7
1997	2	319.2	873.9	8.8	75		21	75	21	0.12	0.02	2711	35812	2.8	0.1
1998	2	0.1								0.08	0.02	1			
1999	2	4042.4	753.7	52.8	1296		22	1296	22	0.04	0.02	99181	30885	1.3	0.1
2000	2	3251.5	308.5	91.1	1689			1689		0.05	0.02	60262	12643	2.8	
2001	2	741.1		12.7	138			138		0.09	0.02	8027		1.7	
2002	2	517.8	45.4	62.3	540	0.1	26	540	26	0.12	0.00	4487	9797	12.0	0.3
2003	2	145.8		27.9	297			297		0.09	0.02	1552		19.1	
2004	2	550.0	98.1	50.7	703			729		0.07	0.00	7628	4021	9.6	0.0
2005	2	157.4	133.8	8.1	145	1.8	403	145	403	0.06	0.01	2821	30390	5.1	1.3
2006	2	32.7	777.3	7.4	130	4.6	329	130	329	0.06	0.01	571	56203	22.8	0.6
2007	2	143.0	79.8	13.2	169			169		0.08	0.02	1836	3271	9.2	
2008	2										0.02				
2009	2	0.1	3.9							0.09	0.02	1	158		
2010	2	25.0	1.6	1.3	48			48		0.03	0.02	892	64	5.4	
1994	3	4166.2	122.0	205.1	2444	1.6	126	2449	126	0.08	0.01	49638	9750	4.9	1.3
1995	3	2520.8	3.8	204.3	1923			1923		0.11	0.02	23732	245	8.1	
1996	3	2084.8	190.6	70.9	989	0.8	101	989	101	0.07	0.01	29063	25389	3.4	0.4
1997	3	2049.4	1643.4	110.7	1633	6.8	336	1633	336	0.07	0.02	30226	81496	5.4	0.4
1998	3	1398.6	571.4	86.2	1169	2.0	155	1169	155	0.07	0.02	18975	29910	6.2	0.5
1999	3	4681.2	399.4	165.5	2462			2462		0.07	0.02	69657	26022	3.5	
2000	3	3371.0	592.6	152.9	2531			2531		0.06	0.02	55814	38610	4.5	
2001	3	1554.1	563.0	34.0	489			489		0.07	0.02	22368	36681	2.2	
2002	3	2639.7	149.0	120.5	1589	2.2	124	1589	124	0.08	0.02	34797	9708	4.6	
2003	3	73.9	220.7	10.1	141			141		0.07	0.02	1031	12654	13.7	
2004	3	2105.5	37.9	130.5	1124			1124		0.12	0.02	18141	2473	6.2	
2005	3	112.0	52.4	37.9	222			222		0.17	0.02	657	3411	33.8	
2006	3	171.9	450.9	23.0	211		31	211	31	0.11	0.02	1580	29381	13.4	
2007	3	283.9	2.9	56.6	406			406		0.14	0.02	2037	192	19.9	
2008	3														
2009	3	716.4	56.5	124.3	628			628		0.20	0.02	3619	3678	17.4	
2010	3														

☐ ;it is shown that there is no data.

▥ ;it is shown that it is the period which needs substitution .

Table 3-1. Statistical results of GLM analysis before 1994.

less than 10kg	Df	Deviance	AIC
		4237074	406537
-as.factor(qt)	1	4404023	408732
-as.factor(year)	25	6244607	428540

Table 3-2. Statistical results of GLM analysis after 1993.

"*meji*"	Df	Deviance	AIC
		99769	12301
-as.factor(qt)	1	107950	12440
-as.factor(year)	9	422464	14866

Table 4. Number of record caught bluefin tuna by logbook.

year	qt	>=10kg only	<10kg only	both	Total	year	qt	>=10kg only	<10kg only	both	Total
1974	3	40	15		55	1992	2	42	76	14	132
	4	7			7		3	103	59	24	186
1975	2	37	181	5	223	1993	2	15	5	2	22
	3	39	46	3	88		3	65	9	7	81
	4	1			1	1994	2	79	4	2	85
1976	2	22	12		34		3	137	15	5	157
	3	25	35		60		4		1		1
1977	2	69	76	2	147	1995	2	82	2	1	85
	3	11	18	1	30		3	127		1	128
1978	1	2	1		3		4		1		1
	2	165	39		204	1996	2	112	32	6	150
	3	2			2		3	52	11	5	68
1979	1	1			1	1997	2	12	22	1	35
	2	249	13		262		3	54	37	31	122
	3	61	67	4	132	1998	2	1	3	1	5
1980	2	105	19		124		3	25	19	8	52
	3	59	96	17	172	1999	2	47	17	22	86
1981	2	114	64	5	183		3	90	13	15	118
	3	91	301	37	429	2000	2	63	15	12	90
1982	2	108	81	6	195		3	104	19	24	147
	3	158	123	15	296	2001	2	32	1	1	34
	4	1			1		3	17	15	2	34
1983	2	138	242	51	431	2002	2	14	5		19
	3	60	37	3	100		3	68	2	5	75
1984	2	17	120	11	148		4	1			1
	3	33	65	4	102	2003	2	4			4
1985	2	43	123	9	175		3	3			3
	3	18	64	5	87		4	1	3	1	5
1986	2	85	283	45	413	2004	2	17	4	3	24
	3	92	46	6	144		3	67	1		68
1987	2	31	173	34	238	2005	2	14	13	3	30
	3	16	42	6	64		3	7	3		10
	4	4	8	2	14	2006	2	8	13	11	32
1988	2	31	43	16	90		3	5	5	2	12
	3	31	38	11	80	2007	2	71	3		74
1989	2	39	117	24	180		3	19	1		20
	3	77	86	8	171	2008	2		1		1
1990	2	31	46	11	88	2009	2	1	1		2
	3	43	92	17	152		3	44	1		45
1991	2	22	16	7	45	2010	2	2	1		3
	3	56	111	32	199		3		1		1
						Total		3839 (49.1%)	3373 (43.1%)	606 (7.8%)	7818

Fig. 1. Map showing landing port of the PBF by Japanese tuna purse seine fishery.
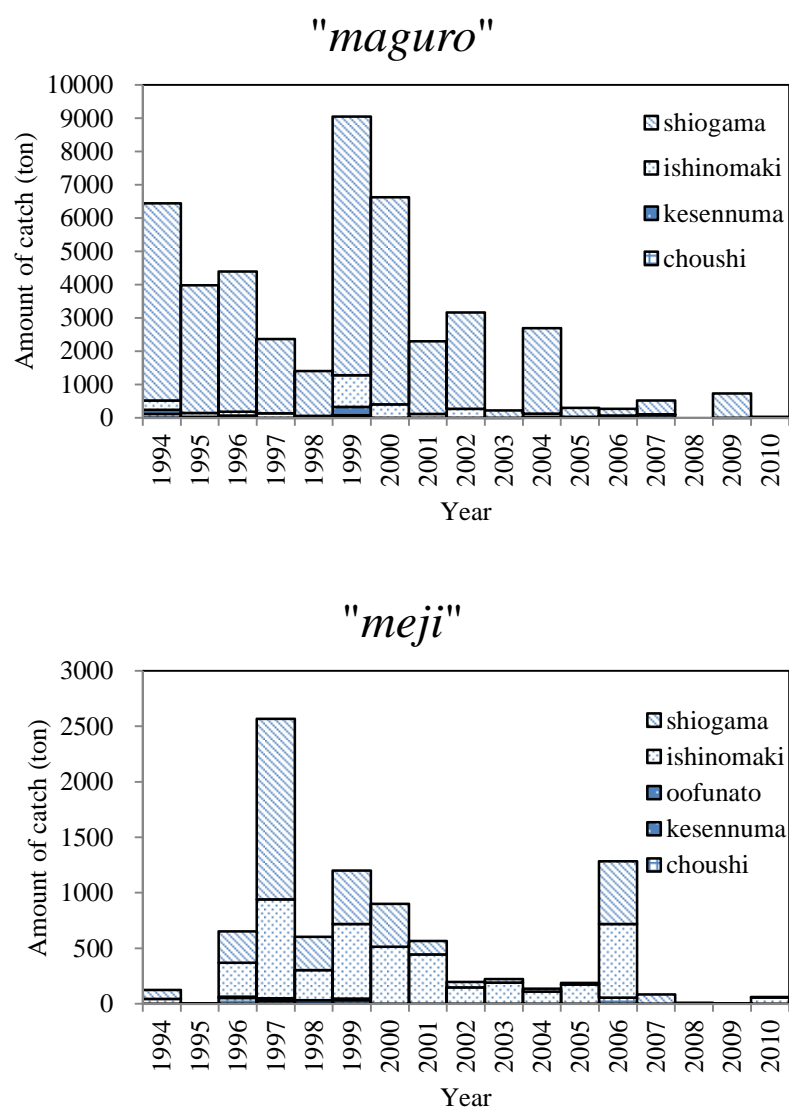
"*maguro*"

"*meji*"

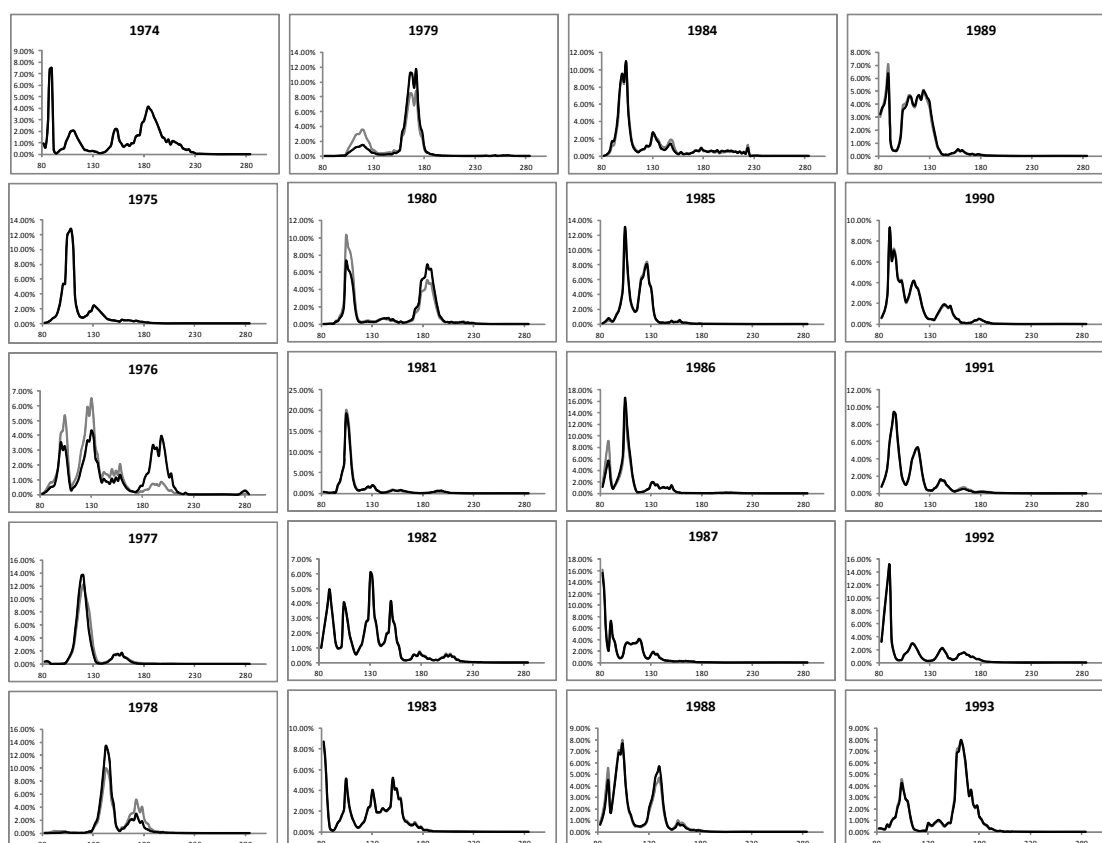Fig. 2. Annual catch in weight of the PBF caught by TPS by landing port from RJB database.

Fig. 3. Observed (gray) and weighted (black) length distributions of large size PBF caught by tuna purse seine.
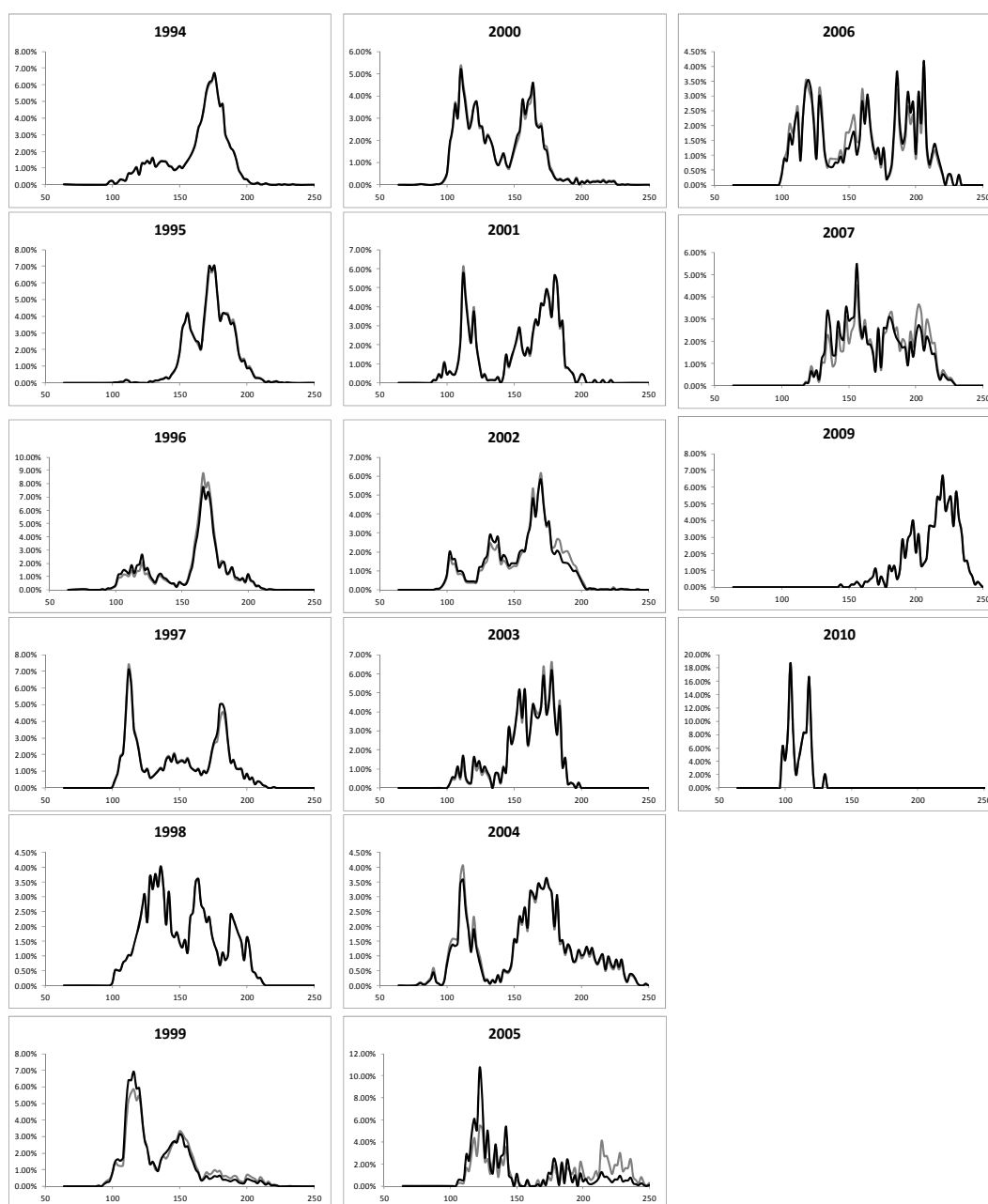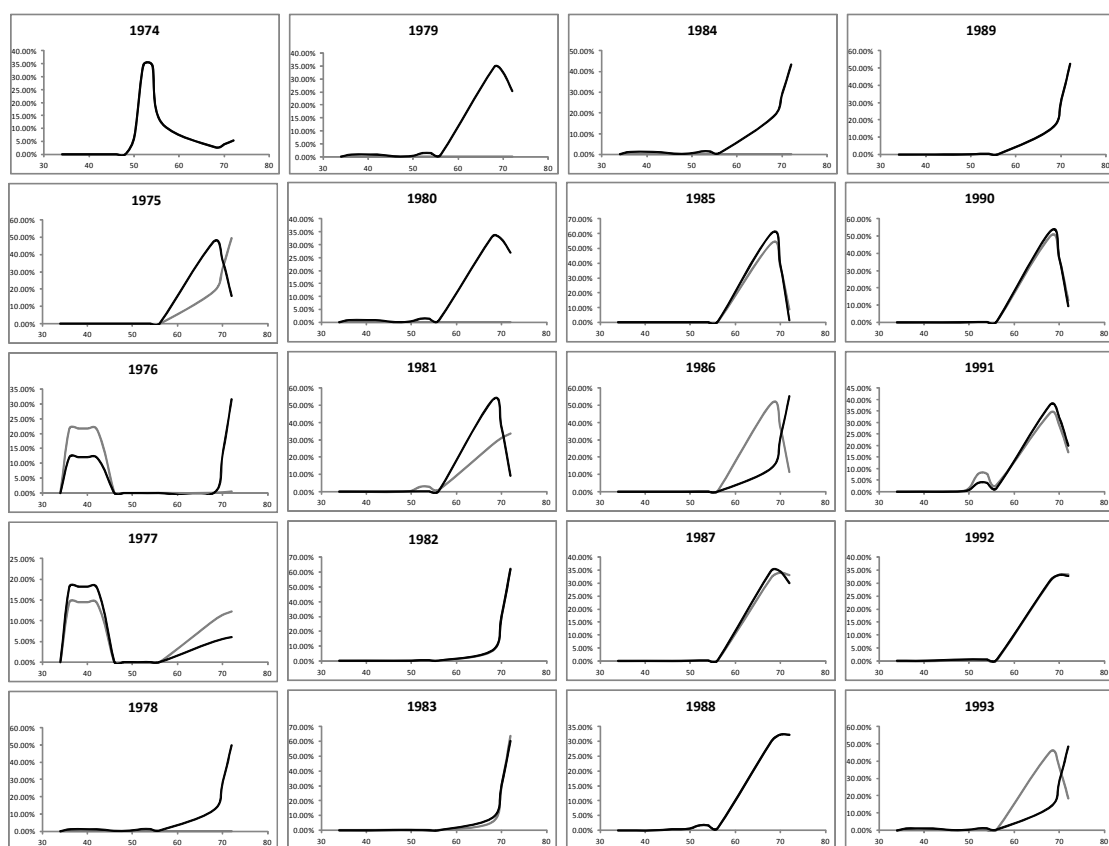
Fig. 3. Continued.

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Fig. 4. Observed (gray) and weighted (black) length distributions of small size PBF caught by tuna purse seine.
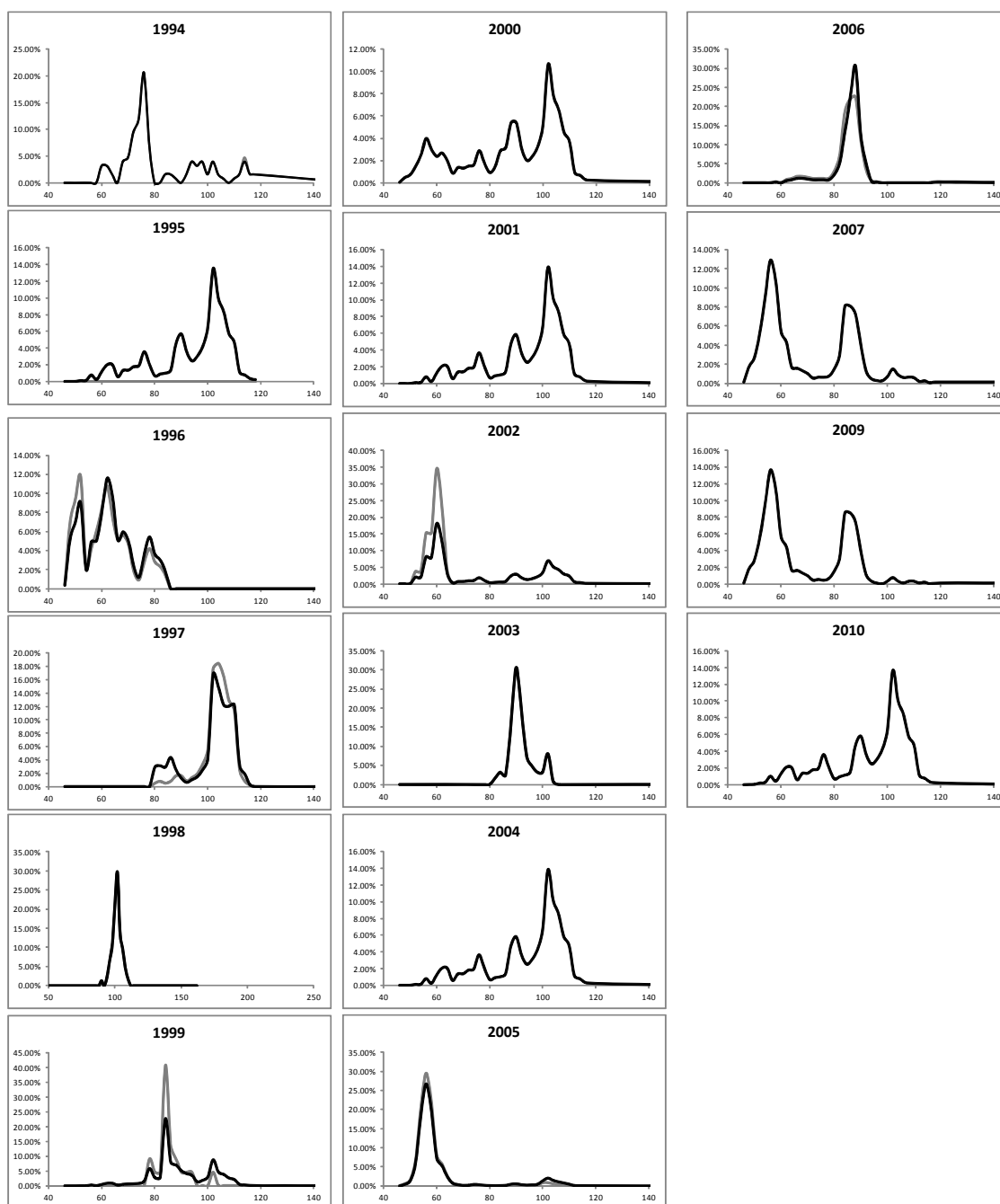
Fig. 4. Continued.