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Update and re-examination of the estimation of catch at size of Pacific Bluefin tuna *Thunnus orientalis* caught by Japanese set-net fishery

Mikihiko Kai and Yukio Takeuchi

National Research Institute of Far Seas Fisheries, Fisheries Research Agency
5-7-1 Orido, Shimizu, Shizuoka 424-8633, Japan

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Summary

This paper provides update of the catch at size of Pacific Bluefin tuna caught by Japanese set-net fishery for stock assessment. The estimation method of catch at size was re-examined to improve the accuracy of the estimation through reducing the sampling bias. The catch at size is calculated based on size sampling and three types of catch data for the years 1994 - June 2011. Newly added two data sources had increased in the geographical coverage of the catch. The data used in the analysis are stratified according to the results of generalized linear model (GLM) into prefecture, year, month, and brand name in principle. For the stratum without size sampling data, pooled data were used as substitutes. The order of the factor for pooling is determined from GLM. The length compositions of samples are raised by the estimated catch in number by stratum and combined altogether to make the catch at size by year and quarter. In order to judge the reliability of the estimation of the catch at size, two indices: Index I (Proportion of number of fish sampled to roughly estimated catch in number) and Index II (Proportion of catch requiring substitution against the total catch in number) are defined. The reliability of the estimation method is also discussed using sensitivity analysis. The estimated catch at size had two modes and both of them had been found at smaller size. This result may suggest that Japanese set-net fishery mainly catches relatively small sized fish between 20 and 90 cm and size sampling data by year and quarter have a large sampling bias. In addition, the estimated catch at size by year and area was substantially different between "West area" faced to Sea of Japan and any other areas. Moreover, it was concerned about the uncertainty of the estimation due to the substitutions irrespective of low Index I and high Index II for certain year-quarter strata. In conclusions, we propose to: (1) remove the unreliable estimated catch at size for certain year-quarter strata based on the Index I (e.g. less than 3%) and Index II (e.g. more than 50%), if set-net fishery is treated as single fleet in Stock synthesis (SS) model as ever :(2) separate the set-net fishery into two fleets (i.e. catch at size in quarter 3 and 4 in "West area", and any other quarters and areas) for the SS model as an alternative fleet definition of Japanese set-net fishery.

1. Introduction

Stock assessment of Pacific Bluefin tuna (PBF) *Thunnus orientalis* have been conducted using length based integrated model stock synthesis 3 (SS3) in recent years (Anonymous, 2008). The accuracy of the estimation largely depends on the quality of input data, especially for size data. The size sampling of Japanese set-net fishery at some local markets is insufficient and most of the collected data associate with sampling biases. It is because of the shortage in researchers, physical distance to the sampling ports, insufficient motivations for the measurement and uncooperative nature of the fishers (Ichinokawa and Takeuchi, 2008). Weighting the size data from the sampling by corresponding catches is one of the good ways to reduce the effect of the sampling bias.

Kai (2011) estimated catch at size using PBF catch and size sampling data from Japanese set-net fishery for the years 1994-2009. The data used in the analysis were stratified into four main fishing areas, four size groups, months, and years. The estimated catch at size was quite different from that used in the previous stock assessment. In particular, the estimated proportions of small sized fish increased substantially. ISC PBF Working Group Workshop held in January 2011 noted that the new procedures adopted may have resulted in improved catch-at-size data for stock assessment but the new procedure were relatively complicated and the uncertainties were poorly understood. Therefore, it was recommended that more work be put into understanding and determining the uncertainties in the catch at size derived by this method.

This working paper provides the update and re-examination of the estimation of catch at size using catch and size sampling data of PBF caught by Japanese set-net fishery for the years 1994 - June 2011. The data are stratified by prefectures, brand name (size category for auction), months, and years in principle. This spatio-temporal stratification is different from that adopted by either Ichinokawa (2008) or Kai (2011) who estimated the catch at size by prefectures and quarters or by four main fishing areas and months, respectively. Furthermore, the geographical coverage of catch was expected to increase by using catch data from "SD report" (the Annual Report of Catch Statistics on Fishery and Aquaculture published by the Statistics Department, Ministry of Agriculture, Forestry and Fisheries, the government of Japan) or "JFA data" (monthly catch data by landing ports, derived from the Survey on Catch of Bluefin Tuna in Japan's Coastal Areas implemented by Japan Fishery Agency, Ministry of Agriculture, Forestry and Fisheries, the government of Japan). However, in the previous analysis, only catch data from "RJB data" (catch data obtained from collection of auction records at the unloading sites) were used. Different strata and three types of data sources are used in this study in order to improve accuracy of estimation of the catch at size. The reliability of estimation methods is discussed through examination of uncertainties in the estimation of catch at size.

2. Materials and Methods

2.1 Data sources

We used three different types of data sources (**Table 1**). "RJB data" has more detailed information on catch compared with other two data sources as well as containing size data from port sampling. However, since it is intended to sample from "major fishing ports for PBF", it has less coverage of catch than other data sources (**Fig.1**). On the other hand, the information on catch of "SD report" does not have some details such as month, quarter, and brand name, while it is supposed to give national total catch. Hence, "RJB data" are mainly used for the analysis in this study and the catch of "SD report" is used to raise the length/weight compositions because the coverage of catch is much better than “RJB data”. The “JFA data” are also considered to give national total catch. For 2010 and 2011, “JFA data” are used to raise the length/weight compositions to “true” catch in number instead of catch of “SD report” because “SD report” has a 2 year lag after the data are collected.

2.1.1 Details of three types of data sources

“**RJB data**”

The survey program 'The Research of Japanese Bluefin tuna (**RJB**)' has been conducted by National Research Institute of Far Seas Fisheries (NRIFSF) by funding from the Japanese government since 1992 to accomplish collection of information on PBF landings by coastal and offshore fisheries. This source of data provides catch (Sales slips) and size sampling data collected at Japanese local fishing ports since the year 1992 and those data until June 2011 are used in this analysis. But the data in 1992 and 1993 are not used in this study because of low data coverage in the initial of the project. Catch and size sampling data include information on species, year, month, day, fishing gear, fishing area, landed port, brand name, product status (e.g. round or gilled and gutted). As the conversion factor of gilled and gutted weight to round weight: 1.15 was applied, which is almost identical to the case of Atlantic Bluefin tuna.

“**SD report**”

The Annual Report of Catch Statistics on Fishery and Aquaculture published by the Statistics Department, Ministry of Agriculture, Forestry and Fisheries, the government of Japan (SD report, formerly referred to as “SID report”). The latest SD report available is for 2009. In the latest SD report, all PBF were categorized into “Bluefin tuna” regardless of fish size, whereas small PBF had been sorted into “Other tunas” in the SD report published for 2007 or earlier years. The data include information on species, year, fishing gear, and landing ports. The data in 2005 is not available for some prefectures but there is information on the annual national total catch which is larger than combined total of available prefectural catches. Hence, prefectural catch in 2004 from the same prefecture are substituted for the missing prefectural catches in 2005 and the national total catch from “SD report” was allocated among all prefectures proportionally to the prefectural catches (including substituted data). The data in 2006 have information on only national total catch, so that the national total catch is allocated to each prefecture using the proportion of catches by prefecture in 2007. Prefectural data for the year 2007-2009 have some discrepancies between reported national total catch and the aggregated annual total of available prefectural catches. The discrepancies were caused as annual national total catch contains catches by three types of set-nets: (large-scale, small-scale, and salmon set-nets) but prefectural catches only include catch by large-scale set-net. Hence, the excess amount of annual national total catch is allocated to each prefecture under the assumptions that the proportions of annual prefectural catch by small-scale and salmon set-nets are the same as that by large scale set-net.

"**JFA data**"

Monthly catch data by landing ports, derived from the Survey on Catch of Bluefin Tuna in Japan's Coastal Areas implemented by Japan Fishery Agency, Ministry of Agriculture, Forestry and Fisheries, the government of Japan. The survey had been launched since April 2008. The catch data consisting of weight for the period April 2008 - June 2011 have information on year, month, fishing gear, landed port, and brand name (since 2010).

2.1.2 Size sampling data of "RJB"

The size sampling data contains fork length (FL) by 1 cm intervals (truncating to cm) and/or body weight (BW) of either 1kg (truncating to kg) or 0.1kg precision (truncating to 0.1kg). The data consists of length, and/or weight for each fish. The fish with only weight is converted to length by the equation of weight-length (W-L) relationships (Kai, 2007). **Table 2** shows number of sized fish by prefecture (**Fig.2**). Most of the measurements in "Hokkaido" and Aomori" are of weight alone, while the number of weight alone data in the remaining prefectures are lower than that of length alone data. Hence, the catch at size in "Hokkaido" and "Aomori" are estimated based on the body weight rather than converting weight to length. Total number of fish sampled by prefectures has tendency to be relatively large corresponding to the annual average catch (**Table 2**).

2.1.3 Catch data of "RJB"

The catch data mainly consists of catch in weight and sometimes record both in weight and number of fish and it is possible to calculate mean body weight of fish when the weight and number are available. **Table 2** shows summary of catch data. The proportions of catch with records of both weight and number to total catch (%) are extremely high for "Hokkaido", "Aomori", "Yamagata", "Nigata", "Totori", "Yamaguchi", "Ehime", "Kochi", "Miyazaki", and "Okinawa". The use of catch in number for raising size data is expected to produce smaller errors than using catch in weight. The relative annual catch ("RJB data"/"SD report" for years 1994-2009 and "RJB data"/"JFA data" for years 2010-2011) by prefectures shows that the catch in main set-net fishery prefectures such as "Aomori", "Iwate", "Miyagi", "Kanagawa", "Nigata", "Toyama", "Ishikawa" is relatively high rate of coverage through the years (**Fig.3**).

2.2 Data analysis

The main purpose of the data analysis in this study is to adjust the sampling bias for the estimation of the catch at size through raising the length compositions of sampled fish, proportionally to the estimated total catch at each stratum. To accomplish this objective, the key points are the magnitude of the spatio-temporal coverage of catch and size sampling data and determination of the appropriate stratum. Hence, two types of data sources are used to satisfy the high coverage of catch (“SD report” for the year 1994-2009 and “JFA data” for the year 2010-2011) in addition to the RJB data which has more detailed information.

2.2.1 Stratification of the data

Catch at size by year and quarter is the least stratification required for the SS model. However, the mean lengths of fish are distinct between months and areas (Kai 2011). “SD report” provides catch only broken down by prefecture and year. The brand name (size category for auction) is very useful information indicating rough size ranges of fish caught by Japanese set-net fishery. Hence, these factors (year, quarter, month, area, prefecture, and brand name) are considered in this study as the factors for stratifications. However, some strata may lack size sampling data. In order to implement the substitution easily in case of no size sampling data, brand name may be used for approximating size categories. We define three size groups (“S" < 50cm ≤ "M" < 100cm ≤ "L") based on the mean length of each brand name categories (**Appendix tables**). We also define four separate areas “North area”, “East area”, ”West area”, and “South area” (**Fig.2**) based on the main fishing areas of PBF caught by Japanese set-net fishery (Kai 2011).

2.2.2 Determination of appropriate stratum by prefecture

The appropriate stratum for size sampling data by prefecture is determined using generalized linear model (GLM) (McCullagh and Nelder, 1989). Generally, GLM is a flexible generalization of ordinary linear regressions and has a common algorithm for the estimation of parameters by maximum likelihood. Therefore, GLM allows us to examine the effects of the variables on the variation of the mean length/weight within strata (or among stratums) through comparison of the goodness of fit. We used the following four combinations of explanatory variables with three types of error distribution: (a) Normal distribution, (b) Lognormal distribution, and (c) Gamma distribution (link = log) for each model.

Model 1: Mean length/weight = Intercept + Year + Month + Brand name
Model 2: Mean length/weight = Intercept + Year + Month + Size group
Model 3: Mean length/weight = Intercept + Year + Quarter + Brand name
Model 4: Mean length/weight = Intercept + Year + Quarter + Size group

GLM is carried out using R software (version 2.13) in conjunction with the MASS package. In order to choose the appropriate model and error distribution, the model selection is conducted based on the Akaike’s information criterions (AIC) (Akaike, 1973) because it is a measure of the relative goodness of a statistical model.

2.2.3 Determination of appropriate data pooling

If size sampling data is unavailable in a stratum, substitution of the size data is necessary. Hence, the data is pooled from the least influential factor or a combination of the factors on the variation for the mean weight/length of size sampling data. We determine them from GLM using following models based on the selected model above.

Model 5: Mean length/weight = Intercept + variable1 + variable2 +variable3
Model 6: Mean length/weight = Intercept + variable1 + variable2
Model 7: Mean length/weight = Intercept + variable1 + variable3
Model 8: Mean length/weight = Intercept + variable2 + variable3
Model 9: Mean length/weight = Intercept + variable1
Model 10: Mean length/weight = Intercept + variable2
Model 11: Mean length/weight = Intercept + variable3

The model selection is conducted based on the AIC, as well. We define that a small value of AIC indicates the factor or a combinations of factors more important.

2.2.4 Two Indices for judging of reliability

Since it is difficult to judge the reliability of estimation of catch at size, we define two indices based on the size sampling data and proportion of substitution:

(1) Index I (Coverage rate)

Proportion of number of fish sampled to roughly estimated catch in number of SD report,

(2) Index II (Substitution rate)

Proportion of catch requiring substitution against the total catch in number of SD report

Most of the Index I in prefectures are lower than 10% except for “Aomori”, “Miyagi”, “Yamagata”, ”Nigata”, and “Totori” (**Table 3**). The Index II in some prefectures are more than 50% (**Table 3**). In order to reduce the effect of the high proportion of substitutions on the estimated catch at size, size sampling data of “Ibaragi”, “Chiba”, ”Ishikawa”, “Shizuoka”, “Wakayama”, “Totori”, “Shimane”, “Ehime”, “Kochi”, “Miyazaki”, and “Kagoshima” where the Index II is more than 50% are stratified and substituted by the “area” rather than “prefecture” (i.e. the catches were matched to size data pooled not by prefecture but by area).

2.2.5 Sensitivity analysis

In the previous section, the cut-off line of 50 % is used as a maximum Index II. However, since the

50% is decided arbitrarily the effect of the cut-off value on the estimated catch at size is examined using sensitivity analysis. We considered three scenarios for the cut-off values of Index II as shown in **Table 4** and compared the estimated catch at size by year and quarter.

2.3 Procedure of estimation of catch at size by year and quarter

A schematic procedure for the estimation of catch at size by year and quarter is shown in **Fig.4**.

1) Create weight/length compositions in number of fish, using "RJB" size sampling data by year, month (or quarter), brand name (or size group), and prefecture (or area). Hereafter, the notation of parentheses will not be repeated.
2) If there is a stratum without weight/length information, pooled size composition by stratum is applied.
3) The order of the factors to pool the weight/length composition is determined from the result of GLM described above.
4) Calculate the weight/length compositions (in relative value, i.e. %).
5) Estimate the "RJB data" catch in number by prefecture using following equations;

$$N_{y,m,b}^{\mathrm{RJB}} = N_{y,m,b}^{\mathrm{RJB}} \qquad \text{for stratum having catch in number}$$
$$\widehat{N}_{y,m,b}^{\mathrm{RJB}} = \frac{C_{y,m,b}^{\mathrm{RJB}}}{\Sigma_{\mathrm{i}}(w_{i,y,m,b} \times r_{i,y,m,b}^{\mathrm{RJB}})} \qquad \text{for stratum having catch in weight but in number} \quad (1)$$

where N is the "RJB data" catch in number, $\widehat{N}$ is the estimated catch in number, C is the "RJB data" catch in weight, w is the body weight corresponding to the fork length, r is relative values of weight/length compositions, i is bin class, y is year, m is month, and b is brand name, respectively.
6) Calculate the catch at size by stratum through weighting size compositions r by the catch in number (combined N and $\widehat{N}$) as follows;

$$f_{i,y,m,b}^{\mathrm{RJB}} = r_{i,y,m,b}^{\mathrm{RJB}} \times \left(N_{y,m,b}^{\mathrm{RJB}} + \widehat{N}_{y,m,b}^{\mathrm{RJB}}\right) \qquad (2)$$

where f is the catch at size.
7) Combine all the catch at size by brand name together because "SD report" has no information on brand name and make the catch at size by year and month.
8) For years 1994-2009, if the annual "SD report" catch is larger than annual "RJB data" catch, calculate the ratio of catch for "SD report" and "RJB data". Under the assumptions that the proportions of "SD report" catch by month for a year is same as that of the "RJB" catch by month for a year, estimate the total "SD report" catch in number using following equations;

$$N_{y,m}^{\text{SD report}} = R_{y}^{\text{SD report/RJB}} \times N_{y,m}^{\text{RJB}} \qquad \text{for } R_{y}^{\text{SD report/RJB}} > 1$$
$$N_{y,m}^{\text{SD report}} = N_{y,m}^{\text{RJB}} \qquad \text{for } R_{y}^{\text{SD report/RJB}} \leq 1 \qquad (3)$$

where R is the ratio of catch for “JFA data” and “RJB data”.

10) For years 2010-2011, if the “JFA data” catch by year and month is larger than “RJB” catch by year and month, calculate the ratio of catch for “JFA data” and “RJB”. And estimate the total “JFA data” catch in number using following equations;

$$N_{y,m}^{\text{JFA}} = R_{y,m}^{\text{JFA/RJB}} \times N_{y,m}^{\text{RJB}} \qquad \text{for } R_{y,m}^{\text{JFA/RJB}} > 1$$
$$N_{y,m}^{\text{JFA}} = N_{y,m}^{\text{RJB}} \qquad \text{for } R_{y,m}^{\text{JFA/RJB}} \leq 1 \qquad (4)$$

11) Estimate the catch at size for years 1994-2011 and month through multiplying N and $f^{\text{RJB}}/\sum f^{\text{RJB}}$ together as follows;

$$f_{i,y,m} = N_{y,m} \times \frac{f_{i,y,m}^{RJB}}{\sum_i f_{i,y,m}^{RJB}} \qquad (5)$$

12) For the “Hokkaido” and “Aomori”, convert the total raised weight compositions into length composition using weight-length relationship of set-net data obtained from all areas in Japan because the weight and length data of “Hokkaido” and “Aomori” are lacking in some bins between 20cm and 150cm (**Fig 5**).

13) Combine all the catch at size of all prefectures together and make the catch at size by year and quarter.

3. Results

3.1 Determination of appropriate stratum by prefecture

Model 1 with lognormal error distribution was selected by AIC for all the prefectural data. The catch and size sampling data by prefecture are stratified by the year, month, and brand name in principle. However, a combination of the stratification by year, month, size group and area is also used for the prefectural data which either has no size sampling data or high proportion of catch data requiring substitution (i.e. High value of Index II). Determined spatial stratum by prefecture is shown in **Table 5.**

3.2 Determination of appropriate data pooling for substitution

The order of the least influential factor or a combination of the factors on the mean weight/length of size sampling data is determined by the AIC and shown in **Table 6**. Hence, the data is pooled, in order (from the small to large) of numbers in the **Table 6**.

3.3 Estimated catch at size by year and quarter and comparison with size sampling data

Length compositions of samples and estimated catch at size by year and quarter were compared in **Fig.6**. Some of the shapes of estimated catch at size were clearly different from those of total of size sampling data. Obvious modes were appeared in the range less than 50cm for some estimated catch at size, while such modes were not apparent with size data of sampling.

3.4 Combined estimated catch at size altogether and comparison with size data

The estimated catch at size was compared with that size composition of sampled fish (**Fig. 7**). The length range of the majority of fish for real sampled size data was 50-130 cm while that for catch at size was 20-100 cm. A bimodal pattern clearly appeared in the estimated catch at size as well as an obvious mode was appeared in the range less than 50cm.

3.5 Sensitivity analysis

We compared the three estimated catch at size by year and quarter (**Fig. 8**, **Table 4**) by changing cut-off value of index II for definitions of spatial stratification. The results showed that the most of the shapes of estimated catch at size were quite similar among three scenarios (**Fig. 8**).

4. Discussion

4.1 Examination of uncertainties in the estimation of catch at size

In the estimation of the catch at size, it is difficult to judge which method is the best but it is possible to discuss the appropriateness of the methods. The results of the sensitivity analysis for the stratification (**Fig.8**) indicated that the differences of the stratification in each prefecture (i.e. prefecture with brand name or area with size group) did not influence on the estimated catch at size by year and quarter. These results suggest that the effect of the uncertainties in the use of the prefecture with brand name instead of area with size group as factors of stratification on the estimation of catch at size is small, if the cut-off value of Index II is reasonable (i.e. not extremely high or low). However, extremely high (low) cut-off value of Index II may make the size data of most of the prefectures stratify into year, month, brand name (size group), and prefecture (area). The high (low) value is not appropriate due to high substitution rate (unsuitable stratification which is different from the result of GLM) resulting in the low reliability of the estimation. Consequently, Base-case is more appropriate because the cut-off value of Index II is reasonable and the estimated catch at size are based on the main prefectures of set-net fishery, where both catches and size of sampling are large. However, we consider that it is not appropriate to use the estimated catch at size in some strata (e.g. Q1 in 1996, 1998, 2009 Q4 in 2004) which have low index I (less than 3%) and high Index II (over 50%) (**Table 7**).

4.2 Need for separation of the set-net fishery by area and quarter?

The estimated catch at size by area and quarter were shown in **Fig.9**. The length range of the fish mainly caught is substantially different between “West-area” and any other areas. A clear mode was appeared in the range less than 50cm for quarters 3 and 4 in the “West-area”. “West-area” facing to the Sea of Japan has the largest catch from summer to winter (**Table 8**). On the other hand, remaining areas and quarter showed clear modes in the range more than 50 cm. These results indicate that the length range of a fish caught by Japanese set-net fishery is obviously different by area and quarter. The set-net is passive gear and the total number of set nets does not frequently change due to the high cost of renewal and replacement fee. Hence, the estimated catch at size by area and quarter may be affected neither by change of fishing effort or by change of targeting by size but by the differences of availability of fish by size in different areas and quarters. The locations of set-net fishing are widely spread along the Japanese coastal area and young PBF is known to do seasonal migration (Itoh et al. 2003). Hence, it is reasonable to think that the size of fish caught to the set-net fishery is variable by area and quarter of catches. Additionally, selectivity of fleet in the integrated model (SS) represents combination of availability of fish by size/age and gear selectivity. Therefore, we propose to separate the set-net fishery into two fleets (i.e. catch at size in quarter 3 and 4 in “West area”, and any other quarters and areas) for the SS model as an alternative fleet definition of Japanese set-net fishery.

4.3 Sampling bias

Comparison between length compositions of sampled fish and estimated catch at size by year and quarter in each area are shown in **Fig.10**. Clear mode appeared in the range less than 50cm for catch at size as well as length compositions of sampled in “West area” and “South area” especially for quarter 3 and 4. But the clear mode was appeared only catch at size if all the areas are combined (**Fig.6**). These conflicting results are caused by the low proportion of size sampling data in “West area” and “South area” (**Table 8**). In reality, the large number of small sized fish less than 50cm is expected in the catches in these areas, but with large fluctuations, because recruitment occurs in these areas from autumn to winter. Hence, it is also reasonable that the availability of fish to the set-net fishery in these areas is variable among years and quarters. These results may suggest that size sampling data by year and quarter had a large sampling bias. However, this high variability in catches of small sized fish suggests that it is possible to reduce the sampling bias through adopting a proper estimation method such as applied in this study. Consequently, it was cleared that the sampling bias of set-net fishery is mainly caused by the disproportional sampling in stratum. Also, the result of the estimated bimodal catch at size in **Fig. 7** clearly shows that at least two different cohorts possibly of age-0 and age-1 fish are included in the catch of Japanese set-net fishery. This shift of the major component of age-classes from ages 1-3 in the previous stock assessment of PBF to ages 0-1 in this study will make the shape of the selectivity change into double normal with wider range or shift to smaller size in the stock synthesis (SS) model.

4.4 The reliability of the estimation method

The review in this study on the estimation methods for catch at size suggests the new method is more accurate than the previous study in 2011. The advantages are (1) Increase of the coverage of catch due to the use of "SD report", (2) Utilization of finer levels of stratifications (e.g. brand name and prefecture), (3) Statistical approach for not only stratification but also data pooling for substitution. However, we still concern about the uncertainty of the estimation due to the substitutions irrespective of low Index I and high Index II especially for the estimation in "West area" and "South area" (Table.8). Consequently, we propose to remove the unreliable estimated catch at size for certain year-quarter strata based on the Index I (e.g. less than 3%) and Index II (more than 50%), if set-net fishery is treated as single fleet in SS model as ever.

5. Conclusions

We propose to: (1) remove the unreliable estimated catch at size for certain year-quarter strata based on the Index I (e.g. less than 3%) and Index II (more than 50%), if set-net fishery is treated as single fleet in SS model as ever :(2) separate the set-net fishery into two fleets (i.e. catch at size in quarter 3 and 4 in "West area", and any other quarters and areas) for the SS model as an alternative fleet definition of Japanese set-net fishery.

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Table 1. Information of three data sources on PBF catch.

Data source	Information of data sources on catch					
	Period	Month	Quarter	Prefecture	Brand name	Proportion of mean catch (%) to that of SD report
RJB data	1994－JUN2011	Yes	Yes	Yes	Yes	56
JFA data	APR2008－JUN2011	Yes	Yes	Yes	No[1]	91
SD report	1952－2009	No	No	Yes[2]	No	100

1. After 2010 some data in local market have the information of brand name
2. No prefectural data in 2006 and lacking in some prefectural data in 2005

Table 2. Summary of size sampling and catch data of PBF by prefecture.

Prefecture	Size sampling data				Catch data				
	RJB data (1994-2011)							SD report (1994-2009)	JFA data (2008-2010)
	Number of length alone	Number of weight alone	Number of both length and weight	Total number	Annual average catch (ton)	Catch in number	Proportion of catch in weight which has catch in number (%)	Annual average catch (ton)	
Hokkaido	96	9,585	1,051	10,732	30.8	94979	100.0	155.3	59.0
Aomori	0	131,057	624	131,681	157.3	216423	99.1	173.1	359.0
Iwate	4,722	0	18,004	22,726	141.3	75743	29.7	179.5	174.7
Miyagi	17,195	0	11,436	28,631	88.6		0.0	79.3	138.5
Akita	0	0	0	0	0.0		-	8.9	3.9
Yamagata	134	0	50	184	0.0	461	100.0	0.3	0.6
Fukushima	0	0	0	0	0.0		0.0	1.4	0.0
Ibaragi	13	0	0	13	5.4		0.0	2.5	0.1
Chiba	6	0	0	6	0.0		-	20.7	17.1
Tokyo	0	0	0	0	0.0		-	0.5	0.5
Kanagawa	764	1	488	1,253	14.6	147	0.4	14.3	16.8
Nigata	0	10,495	17,719	28,214	144.9	250946	96.0	139.5	239.1
Toyama	19,744	9	2,764	22,517	144.0	34044	4.3	126.9	147.2
Ishikawa	631	7	200	838	13.5		0.0	148.4	97.3
Fukui	0	0	0	0	0.0		-	50.3	34.2
Shizuoka	0	0	4	4	6.9		0.0	17.2	12.5
Mie	1,956	0	219	2,175	7.6	607	8.2	24.3	11.9
Kyoto	0	0	0	0	0.0		-	42.8	15.3
Hyogo	0	0	0	0	0.0		-	3.0	0.5
Wakayama	307	99	79	485	3.0	12	1.5	13.1	10.7
Totori	0	13	11	24	0.0	27	100.0	0.0	257.2
Shimane	12	43	0	55	19.5	50027	63.8	39.9	53.4
Yamaguchi	428	0	2,122	2,550	6.7	26306	88.6	16.7	26.2
Tokushima	0	0	0	0	0.0		-	0.6	0.7
Ehime	1	0	205	206	0.6	5751	99.7	0.0	0.2
Kochi	0	0	47	47	5.1	28558	100.0	37.7	7.6
Fukuoka	0	0	0	0	0.0		-	0.1	0.0
Saga	0	0	0	0	0.0		-	0.3	0.1
Nagasaki	0	0	0	0	1.2		0.0	58.0	60.6
kumamoto	0	0	0	0	0.0		-	0.1	0.5
Oita	0	0	0	0	0.0		-	1.4	0.2
Miyazaki	0	0	4	4	0.4	1288	90.6	1.6	0.1
Kagoshima	1	58	160	219	2.3	564	6.8	11.6	18.3
Okinawa	0	0	0	0	0.9	164	94.0	0.4	0.0

Table 3. Proportion of number of fish sampled (Index I) and catch data requiring substitution (Index II) by prefecture.

Prefecture and area	(1) Number of fish sampled	(2) Catch in number requiring substitution	(2) Roughly estimated catch in number	Index I: proportion (%) of number of fish sampled (1)/(3)	Index II :proportion (%) of catch requiring substitution (2)/(3)	Prefecture where Index II is less than 50%
Hokkaido	10,636	61,158	338,628	3.1	18.1	○
Aomori	131,681	42,721	272,862	48.3	15.7	○
Iwate	22,726	164,752	531,382	4.3	31	○
Miyagi	28,631	10,507	181,297	15.8	5.8	○
Yamagata	184	67	586	31.4	11.4	○
Ibaragi	13	33,091	33,091	0	100	
Kanagawa	1,253	65,440	89,150	1.4	73.4	
Nigata	28,214	40,601	289,214	9.8	14	○
Toyama	22,517	152,796	1,217,953	1.8	12.5	○
Ishikawa	838	717,929	729,300	0.1	98.4	
Shizuoka	4	82,698	82,698	0	100	
Mie	2,175	50,674	101,661	2.1	49.8	○
Wakayama	485	13,749	20,886	2.3	65.8	
Totori	24	14	27	88.9	51.9	
Shimane	55	138,187	153,865	0	89.8	
Yamaguchi	2,550	4,750	74,952	3.4	6.3	○
Ehime	206	4,255	5,631	3.7	75.6	
Kochi	47	135,929	179,514	0	75.7	
Miyazaki	4	6,135	6,136	0.1	100	
Kagoshima	219	24,930	28,047	0.8	88.9	
North area	142317	103879	611490	23.3	17	
East area	51370	208350	745770	6.9	27.9	
West area	54382	1054344	2465897	2.2	42.8	
South area	4393	383810	513723	0.9	74.7	

Table 4. Three scenarios of sensitivity analysis.

Scenario	Cut-off value of Index II (%)	Number of selected prefectures where the spatial stratum is prefecture
Base-case	50%	9
Case1	25%	7
Case2	75%	12

Table 5. Determined spatial stratum by prefecture. If Index II is less or more than 50 %, prefecture or area is selected, respectively. "No choice" means no size sampling data.

Prefecture	RJB size sampling data	Determined spatial stratum	Prefecture	RJB size sampling data	Determined spatial stratum
Hokkaido	○	Prefecture	Kyoto	-	No choice
Aomori	○	Prefecture	Hyogo	-	No choice
Iwate	○	Prefecture	Wakayama	○	Area
Miyagi	○	Prefecture	Totori	○	Area
Akita	-	No choice	Shimane	○	Area
Yamagata	○	Prefecture	Yamaguchi	○	Prefecture
Fukushima	-	No choice	Tokushima	-	No choice
Ibaragi	○	Area	Ehime	○	Area
Chiba	○	Area	Kochi	○	Area
Tokyo	-	No choice	Fukuoka	-	No choice
Kanagawa	○	Area	Saga	-	No choice
Nigata	○	Prefecture	Nagasaki	-	No choice
Toyama	○	Prefecture	kumamoto	-	No choice
Ishikawa	○	Area	Oita	-	No choice
Fukui	-	No choice	Miyazaki	○	Area
Shizuoka	○	Area	Kagoshima	○	Area
Mie	○	Prefecture	Okinawa	-	No choice

Table 6. Selected models and order of the factor or a combination of the factors to pool the size sampling data. The data is pooled, in order from the small to large of numbers. Y, M, B, and S indicate year, month, brand name, and size group, respectively.

Prefecture or Area	Selected model	Order of the factor or the combinations of factors to pool the size sampling data						
		Y, M, B (S)	Y, M	M, B (S)	Y, B (S)	Y	M	B (S)
Hokkaido	Mean weight = Year+Month+Brand name	7	3	5	6	2	1	4
Aomori	−	7	3	5	6	2	1	4
Iwate	Mean length = Year+Month+Brand name	7	3	5	6	2	1	4
Miyagi	−	7	3	5	6	2	1	4
Yamagata	−	7	6	5	3	2	4	1
Kanagawa	−	7	6	5	4	2	3	1
Nigata	−	7	3	6	5	1	2	4
Toyama	−	7	5	6	3	1	4	2
Ishikawa	−	7	3	6	5	1	2	4
Mie	−	7	4	5	6	1	2	3
Wakayama	−	7	3	5	6	2	1	4
Totori	−	7	5	3	6	2	1	4
Yamaguchi	−	7	3	5	6	2	1	4
Kagoshima	−	7	3	6	5	1	2	4
Shimane	−	7	6	5	3	2	4	1
Ehime	−	6	7	5	3	4	2	1
North area	Mean weight = Year+Month+Size class	7	3	5	6	2	1	4
East area	Mean length = Year+Month+Size class	7	3	5	6	2	1	4
West area	−	7	3	5	6	2	1	4
South area	−	7	3	5	6	2	1	4

Table 7. Proportion of number of fish sampled (Index I) and catch data requiring substitution (Index II) for year-quarter stratum.

Year	Quarter	(1) Number of fish sampled	(2) Catch in number requiring substitution	(2) Roughly estimated catch in number	Index I: proportion (%) of number of fish sampled (1)/(3)	Index II :proportion (%) of catch requiring substitution (2)/(3)
1994	Q1	441	1922	3579	12.3	53.7
1994	Q2	1408	2259	9393	15	24
1994	Q3	703	7440	18778	3.7	39.6
1994	Q4	3282	52607	105943	3.1	49.7
1995	Q1	900	26042	30993	2.9	84
1995	Q2	3297	7412	25260	13.1	29.3
1995	Q3	2915	32282	99454	2.9	32.5
1995	Q4	20106	46829	183405	11	25.5
1996	Q1	353	10982	12995	2.7	84.5
1996	Q2	2060	11710	19861	10.4	59
1996	Q3	2722	26639	40562	6.7	65.7
1996	Q4	4461	74402	114280	3.9	65.1
1997	Q1	795	10779	74272	1.1	14.5
1997	Q2	1241	18902	24854	5	76.1
1997	Q3	1719	31907	75858	2.3	42.1
1997	Q4	1938	54861	120710	1.6	45.4
1998	Q1	464	12365	18939	2.4	65.3
1998	Q2	2012	5293	10237	19.7	51.7
1998	Q3	1434	20405	31627	4.5	64.5
1998	Q4	3220	32332	90587	3.6	35.7
1999	Q1	990	10548	46394	2.1	22.7
1999	Q2	6022	18317	36523	16.5	50.2
1999	Q3	1349	24701	29290	4.6	84.3
1999	Q4	3533	51830	153268	2.3	33.8
2000	Q1	1207	12322	82042	1.5	15
2000	Q2	1707	9071	23943	7.1	37.9
2000	Q3	5023	50343	88711	5.7	56.7
2000	Q4	6814	96120	225806	3	42.6
2001	Q1	558	24434	132095	0.4	18.5
2001	Q2	5251	12957	32335	16.2	40.1
2001	Q3	4784	28757	54981	8.7	52.3
2001	Q4	4396	28107	140283	3.1	20
2002	Q1	401	18103	54376	0.7	33.3
2002	Q2	1986	7826	14764	13.5	53
2002	Q3	5211	30386	85562	6.1	35.5
2002	Q4	4688	63066	125146	3.7	50.4
2003	Q1	477	5278	18383	2.6	28.7
2003	Q2	2305	3001	7737	29.8	38.8
2003	Q3	10660	12133	38242	27.9	31.7
2003	Q4	1605	17975	73282	2.2	24.5
2004	Q1	957	8635	16780	5.7	51.5
2004	Q2	3109	6150	12906	24.1	47.7
2004	Q3	3689	15114	25238	14.6	59.9
2004	Q4	2171	45758	90335	2.4	50.7
2005	Q1	2310	39856	70443	3.3	56.6
2005	Q2	7213	28273	50724	14.2	55.7
2005	Q3	9764	52881	112735	8.7	46.9
2005	Q4	3570	28843	152592	2.3	18.9
2006	Q1	1520	26453	41582	3.7	63.6
2006	Q2	4112	7065	18176	22.6	38.9
2006	Q3	10962	9601	39329	27.9	24.4
2006	Q4	3246	26137	69092	4.7	37.8
2007	Q1	1204	16654	53016	2.3	31.4
2007	Q2	5699	12414	32823	17.4	37.8
2007	Q3	8742	18621	47924	18.2	38.9
2007	Q4	2341	45477	142155	1.6	32
2008	Q1	1409	27914	41852	3.4	66.7
2008	Q2	9135	19650	59286	15.4	33.1
2008	Q3	17521	12787	79151	22.1	16.2
2008	Q4	3178	30155	105912	3	28.5
2009	Q1	1311	46859	60573	2.2	77.4
2009	Q2	6487	50479	136798	4.7	36.9
2009	Q3	3976	15788	41251	9.6	38.3
2009	Q4	2239	4589	28316	7.9	16.2
2010	Q1	1513	16684	24730	6.1	67.5
2010	Q2	4415	13939	34493	12.8	40.4
2010	Q3	1225	10251	27556	4.4	37.2
2010	Q4	1983	18360	35409	5.6	51.9
2011	Q1	1187	68899	81802	1.5	84.2
2011	Q2	1836	13452	29151	6.3	46.1

Table 8. Proportion of number of fish sampled (Index I) and catch data requiring substitution (Index II) for year-quarter stratum in each area.

Year	Quarter	North area					East area				
		(1) Number of fish sampled	(2) Catch in number requiring substitution	(2) Roughly estimated catch in number	Index I: proportion (%) of number of fish sampled (1)/(3)	Index II :proportion (%) of catch requiring substitution (2)/(3)	(1) Number of fish sampled	(2) Catch in number requiring substitution	(2) Roughly estimated catch in number	Index I: proportion (%) of number of fish sampled (1)/(3)	Index II :proportion (%) of catch requiring substitution (2)/(3)
1994	Q1	210	0	78	269	0	0	267	267	0	100
1994	Q2	398	290	539	74	54	562	26	2788	20	1
1994	Q3	167	1976	2043	8	97	314	749	2547	12	29
1994	Q4	996	319	31486	3	1	419	35112	40297	1	87
1995	Q1	15	0	17	88	0	19	17	1244	2	1
1995	Q2	909	391	1902	48	21	1638	85	11194	15	1
1995	Q3	1335	16609	37275	4	45	1384	108	26503	5	0
1995	Q4	15833	6249	27812	57	23	1487	87	79709	2	0
1996	Q1	0	0	0	NA	NA	0	322	322	0	100
1996	Q2	442	399	946	47	42	1470	37	6183	24	1
1996	Q3	1685	10722	13545	12	79	942	70	6699	14	1
1996	Q4	2575	8213	12300	21	67	686	339	9604	7	4
1997	Q1	0	0	0	NA	NA	0	707	707	0	100
1997	Q2	176	20	251	70	8	637	384	3244	20	12
1997	Q3	602	1000	1832	33	55	790	8743	15779	5	55
1997	Q4	558	260	6081	9	4	731	20991	54268	1	39
1998	Q1	18	0	22	82	0	0	1080	1080	0	100
1998	Q2	991	47	1758	56	3	923	295	2822	33	10
1998	Q3	850	1597	2658	32	60	371	214	3300	11	6
1998	Q4	745	5646	6549	11	86	863	179	6665	13	3
1999	Q1	45	0	60	75	0	0	328	328	0	100
1999	Q2	4761	0	6444	74	0	811	1015	6282	13	16
1999	Q3	749	43	1216	62	4	568	368	3667	15	10
1999	Q4	1028	561	2459	42	23	786	14617	23501	3	62
2000	Q1	6	0	7	86	0	0	85	85	0	100
2000	Q2	529	0	651	81	0	692	164	4722	15	3
2000	Q3	2513	8	12746	20	0	2351	27486	46087	5	60
2000	Q4	3039	6707	15999	19	42	2323	17256	45998	5	38
2001	Q1	42	0	65	65	0	0	653	653	0	100
2001	Q2	4206	0	8451	50	0	762	2973	9151	8	32
2001	Q3	4072	0	22069	19	0	639	13204	16371	4	81
2001	Q4	2345	0	22966	10	0	956	1786	15220	6	12
2002	Q1	14	0	4	350	0	0	164	164	0	100
2002	Q2	1026	2	488	210	0	642	1377	4814	13	29
2002	Q3	2773	34	42562	7	0	2408	4336	16575	15	26
2002	Q4	3347	2	38272	9	0	1039	4113	9822	11	42
2003	Q1	1	0	1	100	0	0	65	65	0	100
2003	Q2	1944	0	2482	78	0	223	438	1701	13	26
2003	Q3	8694	0	21109	41	0	1859	5744	9529	20	60
2003	Q4	265	3	7622	4	0	312	2577	2965	11	87
2004	Q1	90	0	109	83	0	0	447	447	0	100
2004	Q2	1421	0	1725	82	0	1221	3690	5447	22	68
2004	Q3	2751	61	4255	65	1	775	3141	5809	13	54
2004	Q4	818	0	4526	18	0	315	3104	3419	9	91
2005	Q1	512	0	770	67	0	0	907	907	0	100
2005	Q2	4421	0	6848	65	0	856	1897	7520	11	25
2005	Q3	7236	0	12339	59	0	1501	7968	26685	6	30
2005	Q4	2513	0	10902	23	0	80	1473	7081	1	21
2006	Q1	100	0	229	44	0	0	902	902	0	100
2006	Q2	1901	0	4268	45	0	1040	6	3379	31	0
2006	Q3	8712	0	23520	37	0	1956	5801	11447	17	51
2006	Q4	1653	0	5365	31	0	619	5634	8135	8	69
2007	Q1	433	0	526	82	0	0	1968	1968	0	100
2007	Q2	3704	0	7550	49	0	953	24	6042	16	0
2007	Q3	7359	5131	25747	29	20	934	414	8144	11	5
2007	Q4	42	61	5262	1	1	805	310	6083	13	5
2008	Q1	68	0	80	85	0	0	519	519	0	100
2008	Q2	5109	0	13588	38	0	1538	4	11776	13	0
2008	Q3	13670	84	23165	59	0	1877	37	21898	9	0
2008	Q4	845	2341	8813	10	27	1467	90	30088	5	0
2009	Q1	1	11	106	1	10	26	277	821	3	34
2009	Q2	3924	13169	32988	12	40	2091	28	46168	5	0
2009	Q3	3212	2723	20486	16	13	733	38	7161	10	1
2009	Q4	1420	658	13826	10	5	708	219	9927	7	2
2010	Q1	0	123	123	0	100	8	42	301	3	14
2010	Q2	93	7657	10041	1	76	1033	47	10034	10	0
2010	Q3	146	1846	5073	3	36	888	98	7896	11	1
2010	Q4	17	494	876	2	56	321	561	2465	13	23
2011	Q1	0	113	113	0	100	18	5	241	7	2
2011	Q2	242	8309	15504	2	54	0	138	138	0	100

Table 8. continued.

Year	Quarter	West area					South area				
		(1) Number of fish sampled	(2) Catch in number requiring substitution	(2) Roughly estimated catch in number	Index I: proportion (%) of number of fish sampled (1)/(3)	Index II :proportion (%) of catch requiring substitution (2)/(3)	(1) Number of fish sampled	(2) Catch in number requiring substitution	(2) Roughly estimated catch in number	Index I: proportion (%) of number of fish sampled (1)/(3)	Index II :proportion (%) of catch requiring substitution (2)/(3)
1994	Q1	211	602	2049	10	29	20	1053	1185	2	89
1994	Q2	442	1331	5417	8	25	6	612	649	1	94
1994	Q3	217	2182	11649	2	19	5	2533	2539	0	100
1994	Q4	1858	8694	25455	7	34	9	8482	8705	0	97
1995	Q1	837	24999	28368	3	88	29	1026	1364	2	75
1995	Q2	675	4073	8534	8	48	75	2863	3630	2	79
1995	Q3	173	4322	24330	1	18	23	11243	11346	0	99
1995	Q4	2763	36300	71491	4	51	23	4193	4393	1	95
1996	Q1	349	5701	7325	5	78	4	4959	5348	0	93
1996	Q2	143	7134	8570	2	83	5	4140	4162	0	99
1996	Q3	84	6265	10729	1	58	11	9582	9589	0	100
1996	Q4	1194	50084	76248	2	66	6	15766	16128	0	98
1997	Q1	779	4411	67660	1	7	16	5661	5905	0	96
1997	Q2	279	7318	8933	3	82	149	11180	12426	1	90
1997	Q3	87	17952	53247	0	34	240	4212	5000	5	84
1997	Q4	595	25007	51568	1	48	54	8603	8793	1	98
1998	Q1	446	9827	16379	3	60	0	1458	1458	0	100
1998	Q2	90	3192	3849	2	83	8	1759	1808	0	97
1998	Q3	150	7101	13636	1	52	63	11493	12033	1	96
1998	Q4	1568	20080	70631	2	28	44	6427	6742	1	95
1999	Q1	945	8362	44148	2	19	0	1858	1858	0	100
1999	Q2	368	16747	22515	2	74	82	555	1282	6	43
1999	Q3	32	22330	22447	0	99	0	1960	1960	0	100
1999	Q4	1667	34203	123696	1	28	52	2449	3612	1	68
2000	Q1	1193	9150	78863	2	12	8	3087	3087	0	100
2000	Q2	427	6203	15458	3	40	59	2704	3112	2	87
2000	Q3	147	8803	15087	1	58	12	14046	14791	0	95
2000	Q4	1424	67370	157386	1	43	28	4787	6423	0	75
2001	Q1	513	22492	130057	0	17	3	1289	1320	0	98
2001	Q2	276	7603	12202	2	62	7	2381	2531	0	94
2001	Q3	39	6097	6586	1	93	34	9456	9955	0	95
2001	Q4	997	23429	96507	1	24	98	2892	5590	2	52
2002	Q1	387	5274	41543	1	13	0	12665	12665	0	100
2002	Q2	286	3037	5661	5	54	32	3410	3801	1	90
2002	Q3	18	18867	18894	0	100	12	7149	7531	0	95
2002	Q4	302	47374	65475	0	72	0	11577	11577	0	100
2003	Q1	476	3360	16464	3	20	0	1853	1853	0	100
2003	Q2	113	303	806	14	38	25	2260	2748	1	82
2003	Q3	37	248	834	4	30	70	6141	6770	1	91
2003	Q4	1007	11652	56729	2	21	21	3743	5966	0	63
2004	Q1	825	3807	9725	8	39	42	4381	6499	1	67
2004	Q2	464	933	4207	11	22	3	1527	1527	0	100
2004	Q3	102	7718	8687	1	89	61	4194	6487	1	65
2004	Q4	965	41184	79157	1	52	73	1470	3233	2	45
2005	Q1	1787	32743	62304	3	53	11	6206	6462	0	96
2005	Q2	1903	9066	13732	14	66	33	17310	22624	0	77
2005	Q3	137	28695	29604	0	97	890	16218	44107	2	37
2005	Q4	633	16930	76315	1	22	344	10440	58294	1	18
2006	Q1	1414	22502	37396	4	60	6	3049	3055	0	100
2006	Q2	943	3224	6085	15	53	228	3835	4444	5	86
2006	Q3	245	512	828	30	62	49	3288	3534	1	93
2006	Q4	950	14285	49165	2	29	24	6218	6427	0	97
2007	Q1	718	11258	44934	2	25	53	3428	5588	1	61
2007	Q2	976	9282	15220	6	61	66	3108	4011	2	77
2007	Q3	55	328	839	7	39	394	12748	13194	3	97
2007	Q4	1465	40308	125209	1	32	29	4798	5601	1	86
2008	Q1	1283	20599	33622	4	61	58	6796	7631	1	89
2008	Q2	2466	10749	24436	10	44	22	8897	9486	0	94
2008	Q3	1905	3474	21279	9	16	69	9192	12809	1	72
2008	Q4	690	19234	56738	1	34	176	8490	10273	2	83
2009	Q1	1229	36273	47395	3	77	55	10298	12251	0	84
2009	Q2	458	34545	54843	1	63	14	2737	2799	1	98
2009	Q3	9	10828	11158	0	97	22	2199	2446	1	90
2009	Q4	81	844	1000	8	84	30	2868	3563	1	80
2010	Q1	1466	12045	19706	7	61	39	4474	4600	1	97
2010	Q2	3265	5615	13759	24	41	24	620	659	4	94
2010	Q3	35	2160	3486	1	62	156	6147	11101	1	55
2010	Q4	1609	14896	25989	6	57	36	2409	6079	1	40
2011	Q1	1149	67009	79416	1	84	20	1772	2032	1	87
2011	Q2	1561	3819	12237	13	31	33	1186	1272	3	93

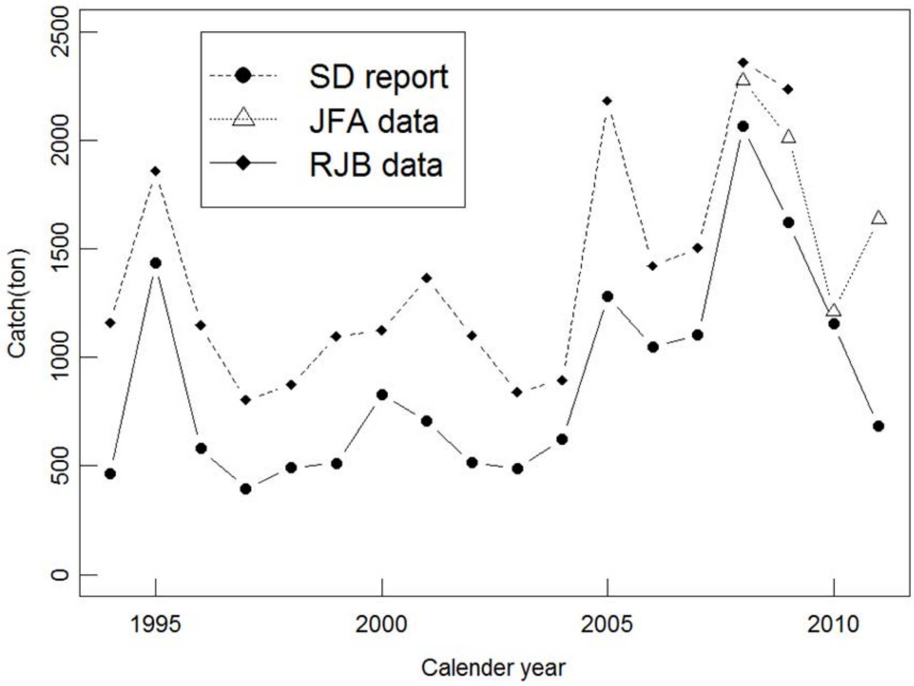

Figure 1. Comparisons of annual catch (tons) of PBF caught by Japanese set-net fishery for years 1994-JUN 2011 among three data sources: “SD report”, “JFA data”, and “RJB data”.

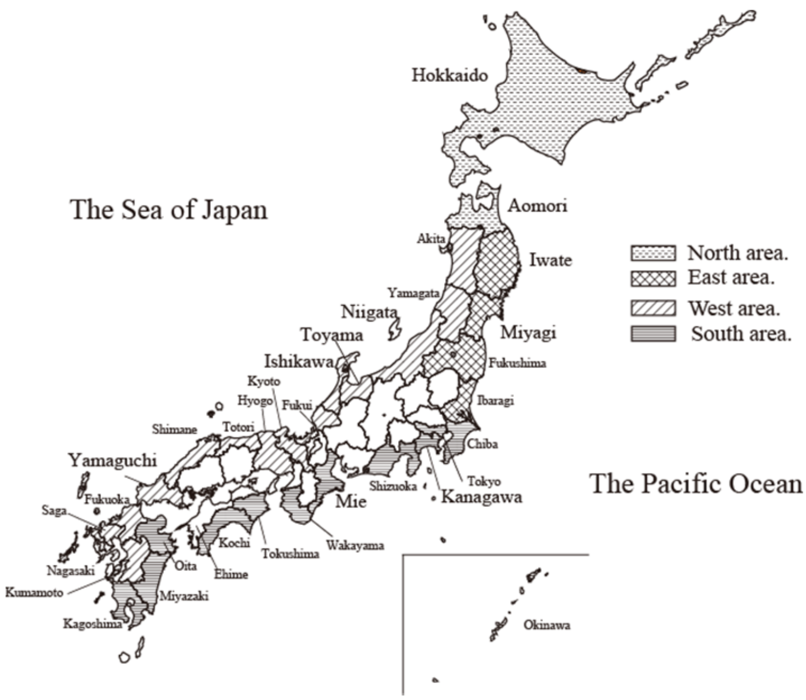

Figure 2. Map of prefectures and four separate areas for stratification.

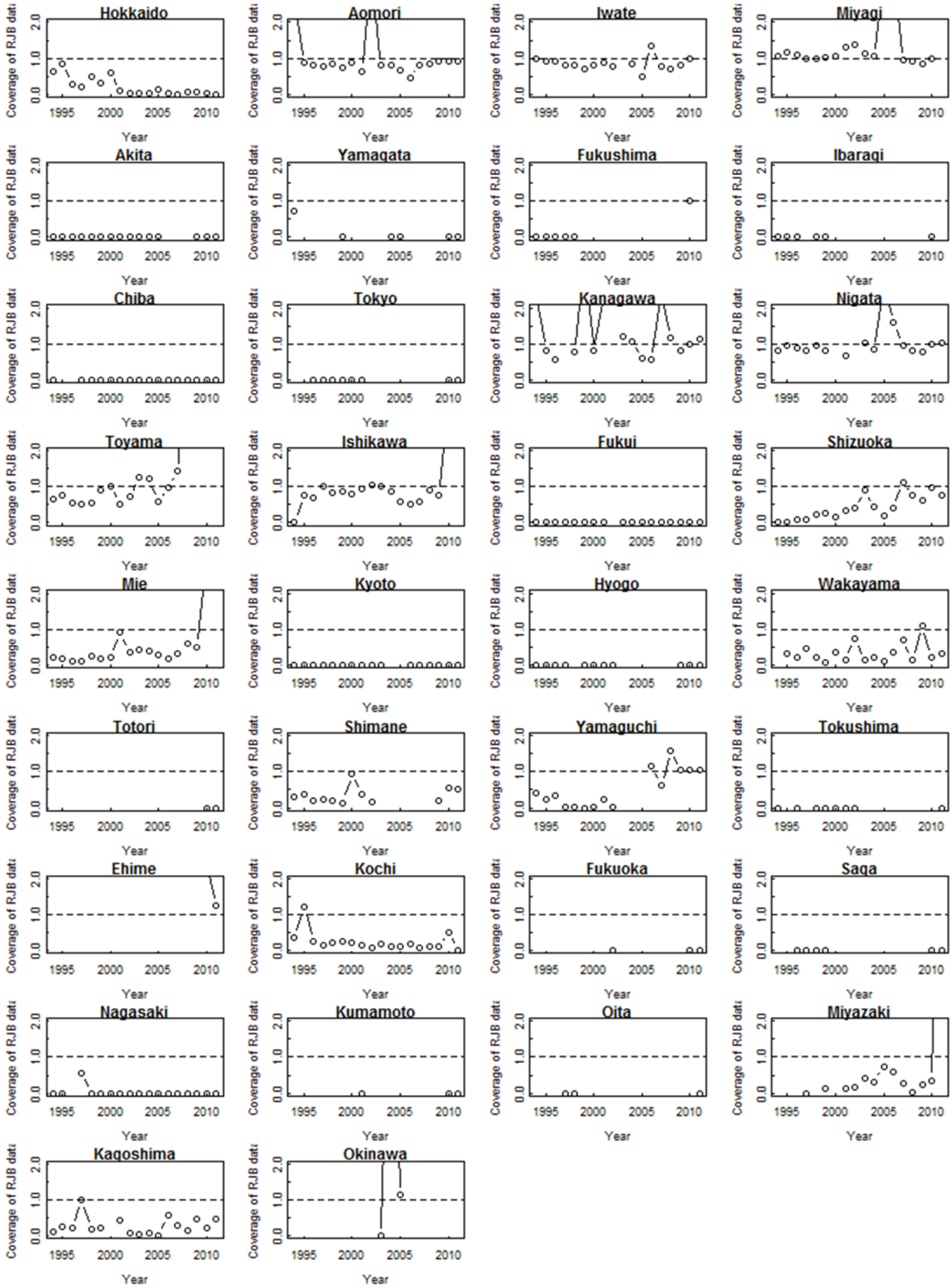

Figure 3. Ratio of RJB annual catch by prefecture ("RJB data"/"SD report" for years 1994-2009 and "RJB data"/"JFA data" for years 2010-2011).

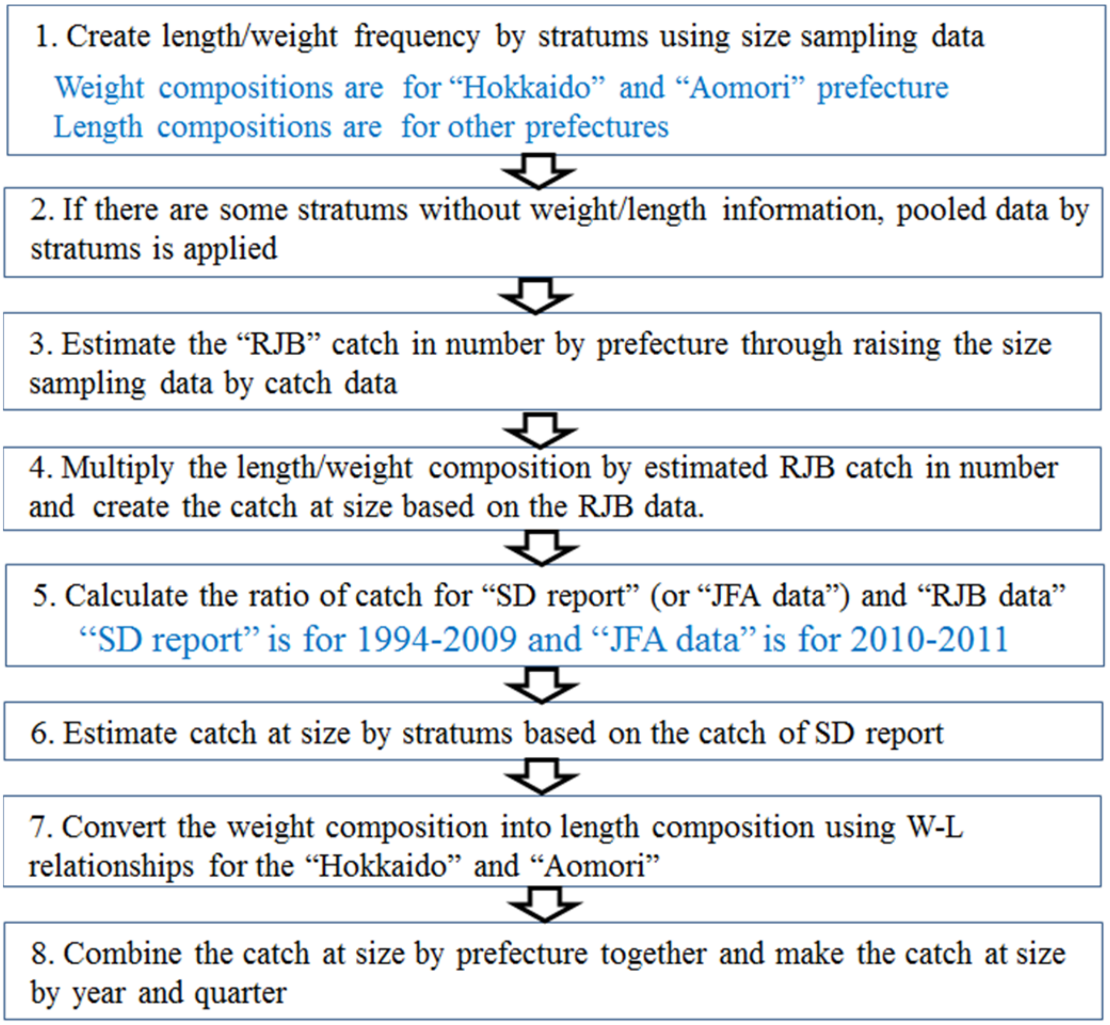

Figure 4. Procedures for the estimation of catch at size.

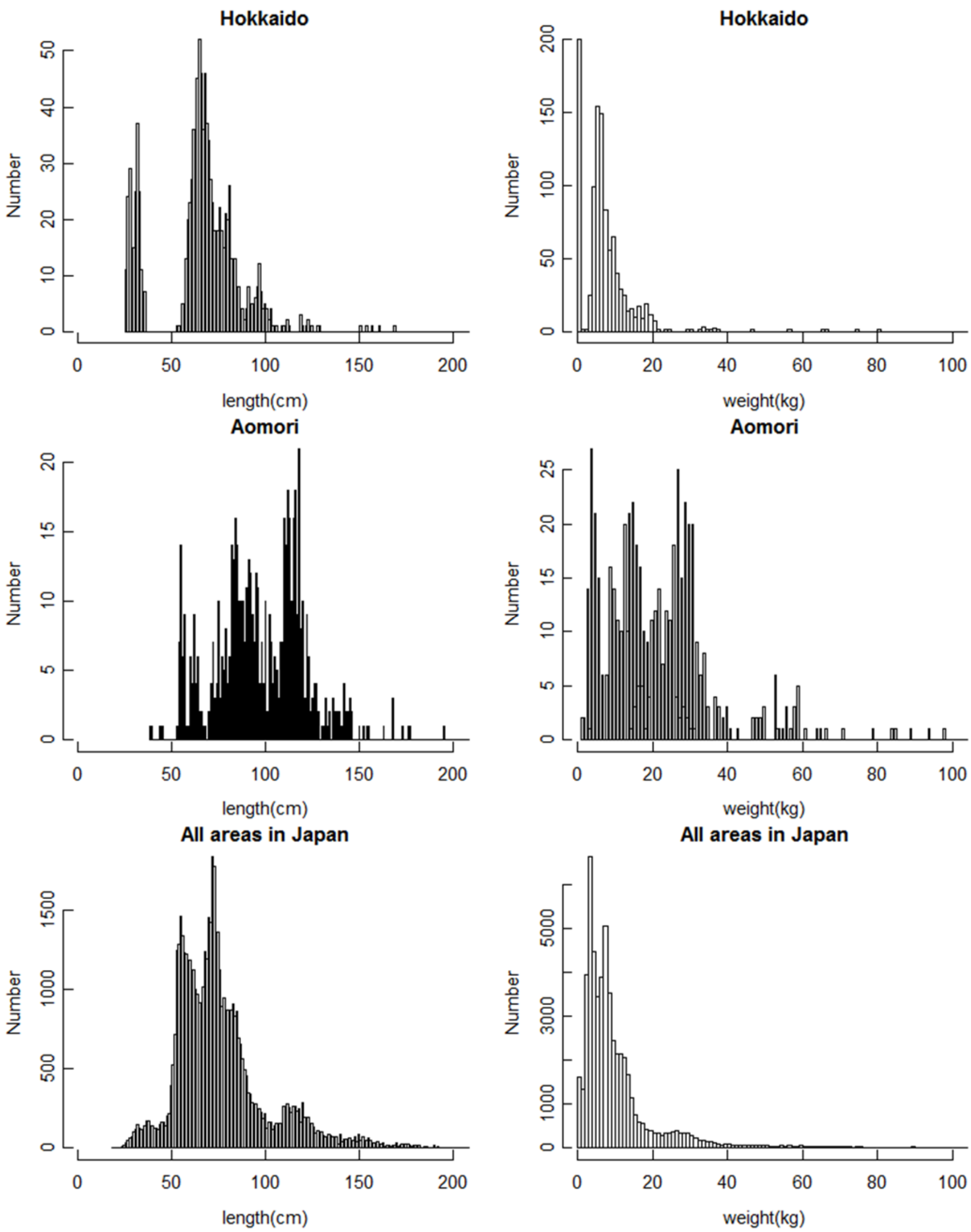

Figure 5. Length and weight compositions of size sampling data having both weight and length data for single fish in “Hokkaido”, “Aomori”, and “All areas in Japan”.

Figure 6. Length compositions of samples (solid black line) and estimated catch at size (dotted red line) of PBF caught by Japanese set-net fishery by year and quarter. Size_N and EST_N indicate that the numbers of size sampling data and estimated number.

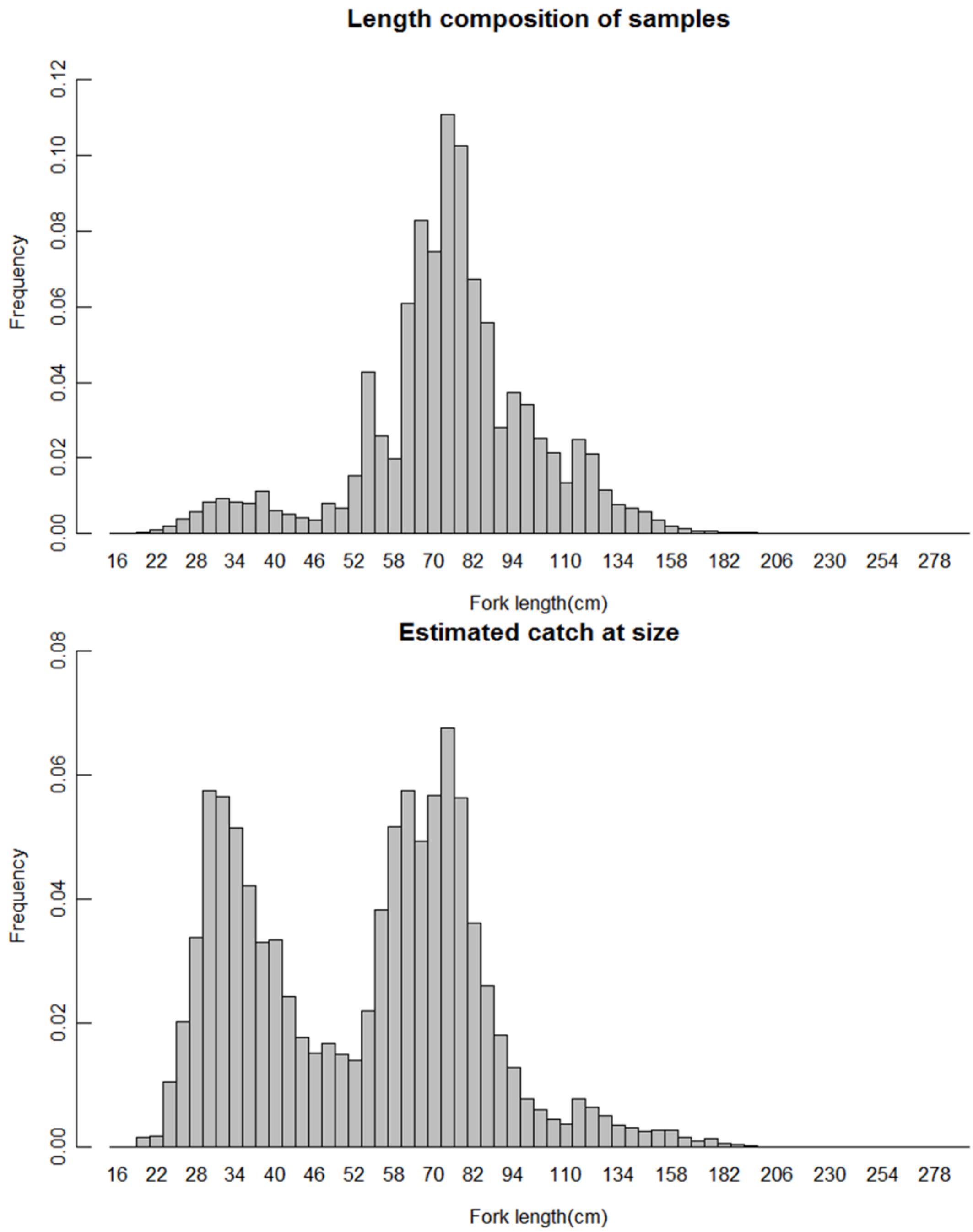

Figure 7. Length compositions of samples (Upper panel) and estimated catch at size (Lower panel) for all combined.

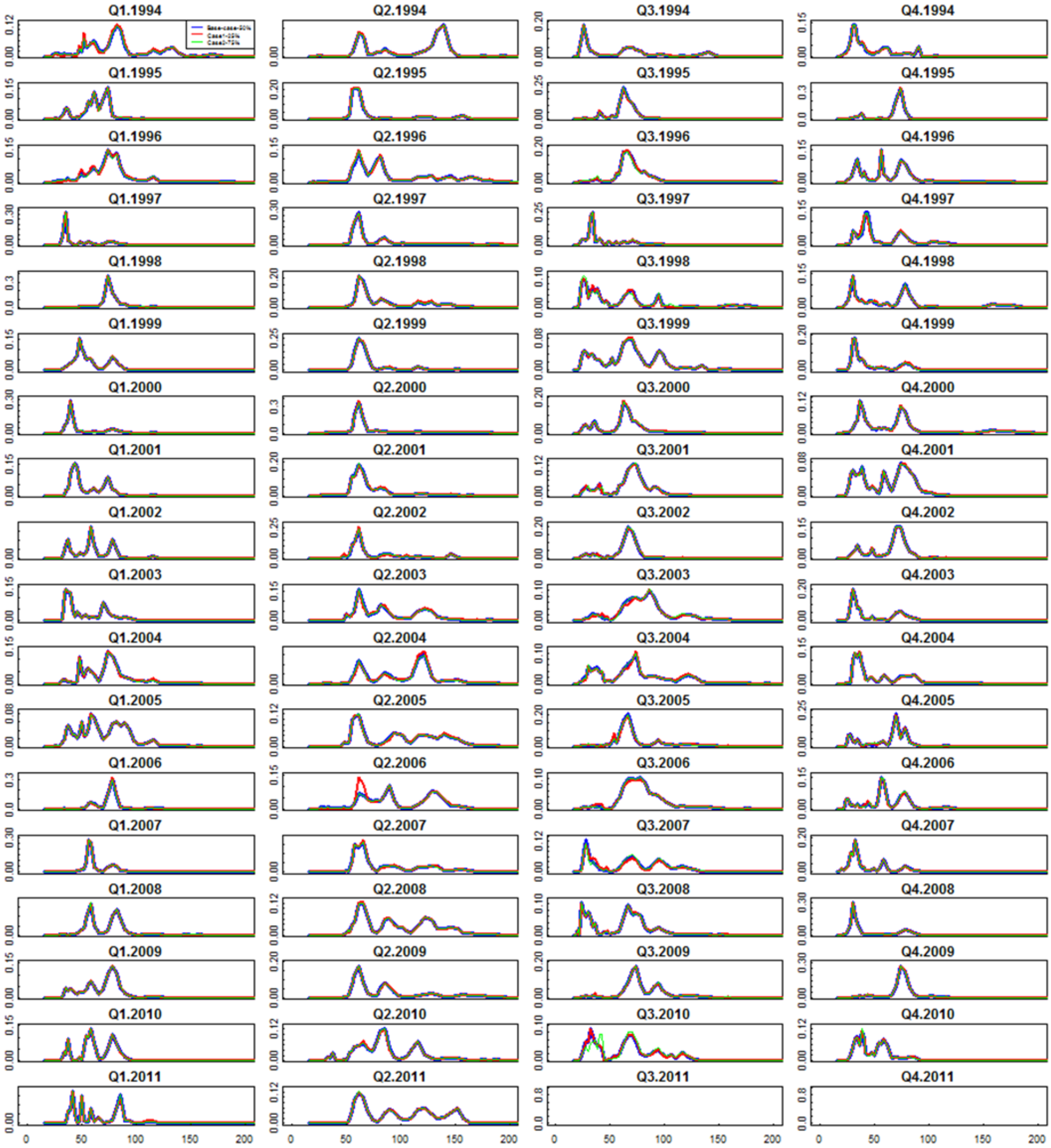

Figure 8. Comparison of estimated catch at size (cm) among three scenarios. Base-case (Index II is less than 50%, blue line), case1 (Index II is less than 25%, red line), and case2 (Index II is less than 75%, green line).

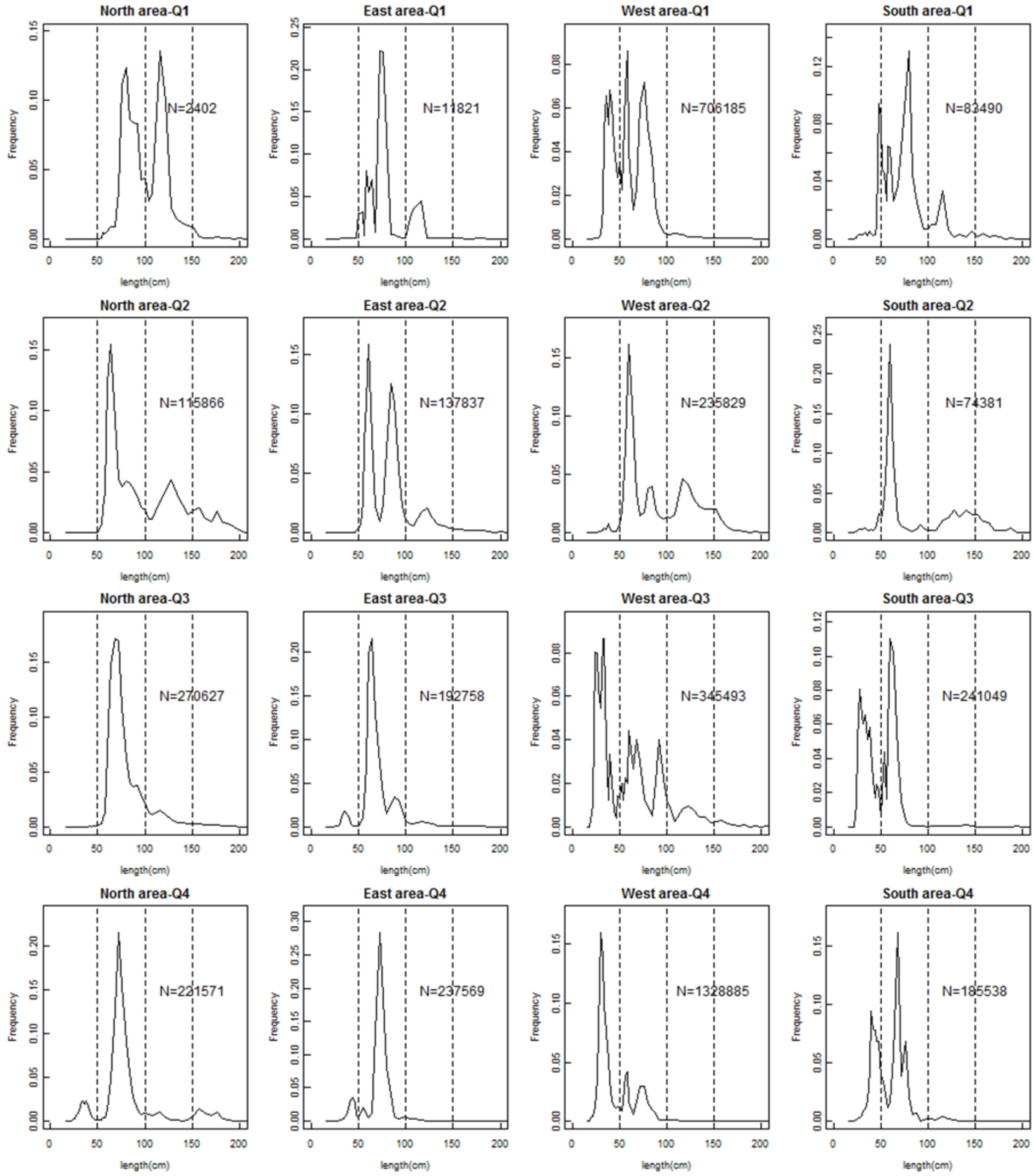

Figure 9. Estimated catch at size (cm) by area and quarter.

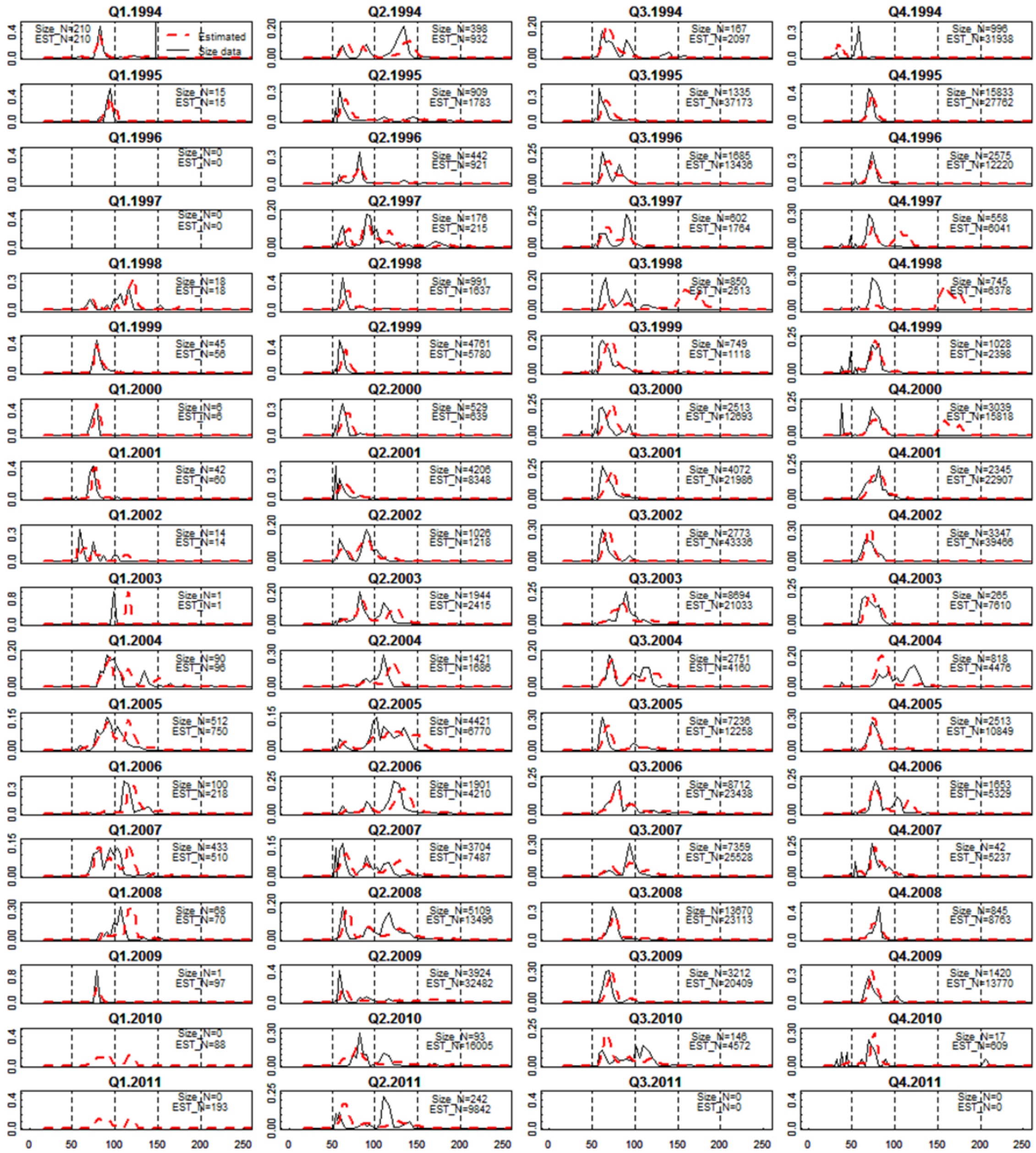

Figure 10-a. Length composition of sample (solid black line) and estimated catch at size (dotted red line) of PBF caught by Japanese set-net fishery by year and quarter in **North area**. Size_N and EST_N indicate that the numbers of size sampling data and estimated number.

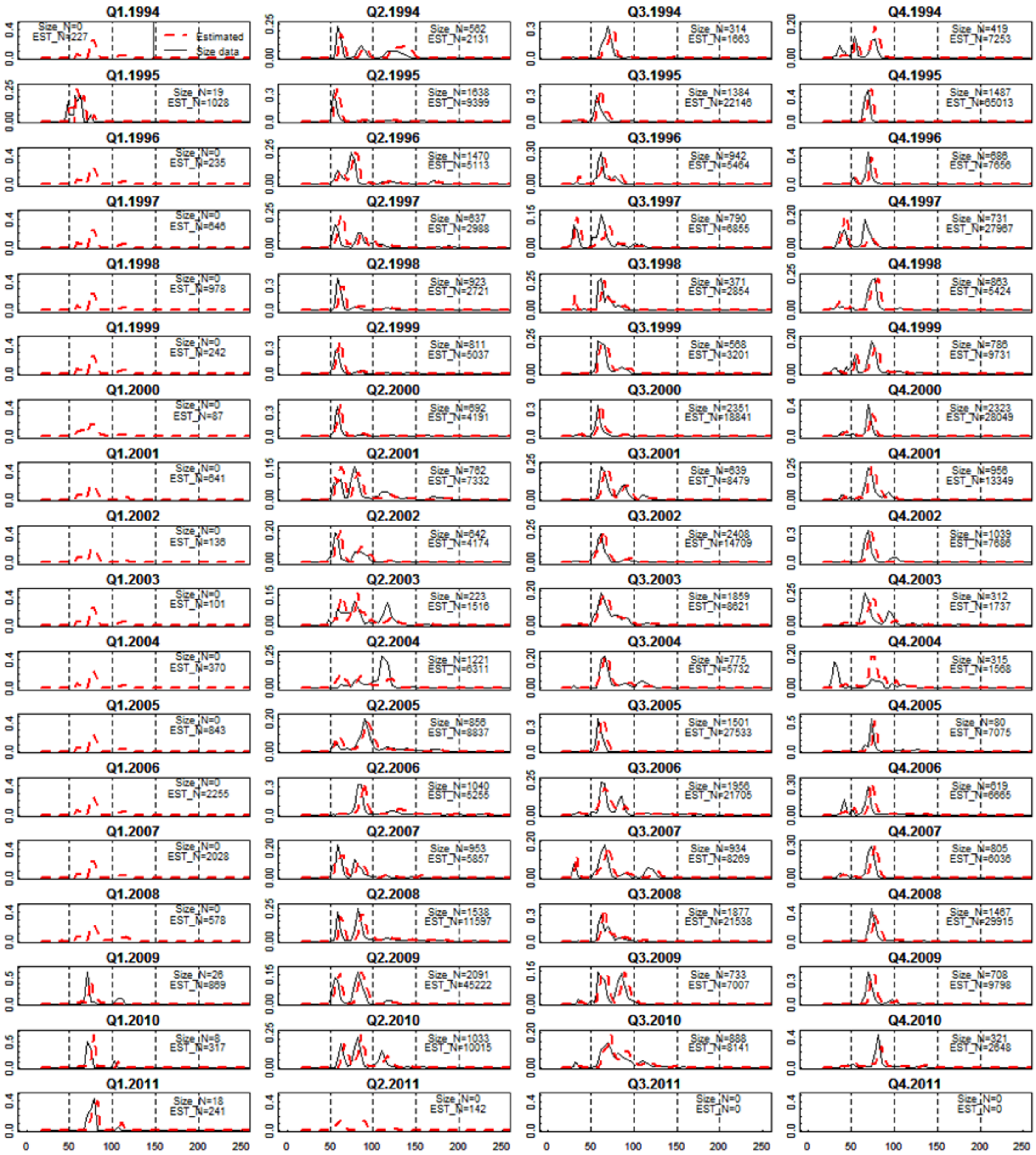

Figure 10-b. Length composition of sample (solid black line) and estimated catch at size (dotted red line) of PBF caught by Japanese set-net fishery by year and quarter in **East area**. Size_N and EST_N indicate that the numbers of size sampling data and estimated number.

Figure 10-c. Length composition of sample (solid black line) and estimated catch at size (dotted red line) of PBF caught by Japanese set-net fishery by year and quarter in **West area**. Size_N and EST_N indicate that the numbers of size sampling data and estimated number.

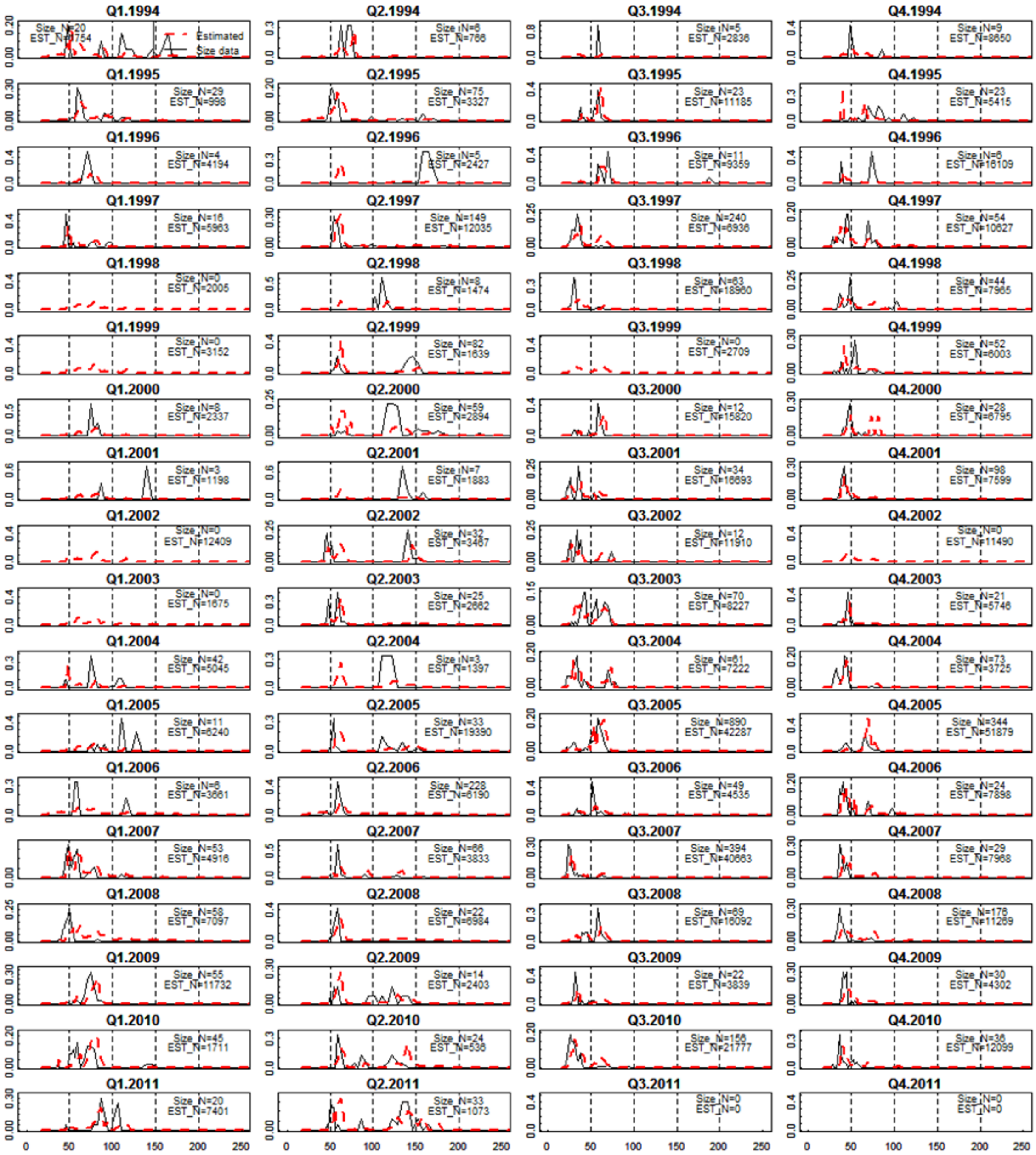

Figure 10-d. Length composition of sample (solid black line) and estimated catch at size (dotted red line) of PBF caught by Japanese set-net fishery by year and quarter in **South area**. Size_N and EST_N indicate that the numbers of size sampling data and estimated number.

Appendix tables

Table A1. Information of size sampling and catch data by brand name in “Hokkaido”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾒｼﾞ	7,273.0	72.9	7.3	297.7	48,304.0	6.2	M	
ﾏｸﾞﾛ	2,969.0	80.3	11.0	124.3	7,113.0	17.5	M	
幼魚	216.0	30.4	0.5	11.5	19,450.0	0.6	S	
ﾒｼﾞﾏｸﾞﾛ	174.0	75.4	7.8	72.9	9,635.0	7.6	M	
ﾒｼﾞ小	52.0	54.5	3.5	37.5	6,241.0	6.0	M	
No name	39.0	89.1	13.9	NA	NA	NA	M	L
ﾏｸﾞﾛ大	5.0	88.8	14.0	3.2	135.0	23.6	M	L
ｷｽﾞ	3.0	72.2	6.7	NA	NA	NA	M	
ﾖｺﾜ	1.0	32.0	1.1	NA	NA	NA	S	
小ﾒｼﾞ	NA	NA	NA	0.0	1.0	1.1	S	
小鮪	NA	NA	NA	3.5	4,079.0	0.9	S	
大ﾏｸﾞﾛ	NA	NA	NA	3.8	21.0	183.2	L	

Table A2. Information of size sampling and catch data by brand name in “Aomori”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾒｼﾞ	92,819.0	74.9	8.0	1,047.4	135,915.0	7.5	M	
ﾏｸﾞﾛ	13,565.0	115.0	33.6	1,091.1	30,929.0	35.2	L	
ﾒｼﾞﾏｸﾞﾛ	12,930.0	84.4	11.1	143.9	12,906.0	11.2	M	
めじまぐろ	4,619.0	76.8	9.0	41.8	4,619.0	9.1	M	
ｸﾛﾏｸﾞﾛ	2,576.0	121.0	35.0	94.7	2,566.0	36.9	L	
まぐろ	2,068.0	119.6	36.4	86.6	2,069.0	41.8	L	
丸	1,458.0	93.6	15.2	50.9	3,079.0	16.5	M	
丸ﾏｸﾞﾛ	383.0	107.9	22.4	8.6	383.0	22.3	L	
ｺﾞﾝﾀ	347.0	94.0	15.6	9.1	658.0	13.8	M	
ﾒｼﾞ鮪	145.0	86.0	13.3	3.7	192.0	11.8	M	
ﾊﾗﾄﾘ	136.0	118.4	33.4	NA	NA	NA	L	
大ﾒｼﾞ	127.0	94.6	15.1	213.8	14,335.0	14.9	M	
ﾒｼﾞ大	116.0	72.8	6.9	1.0	145.0	6.8	M	
ﾊﾗﾄﾘﾏｸﾞﾛ	79.0	119.8	33.3	NA	NA	NA	L	
ﾏｸﾞﾛ小	64.0	96.0	17.3	2.9	188.0	15.4	M	
ﾒｼﾞ小	62.0	60.9	4.0	0.8	229.0	3.5	M	
10.0	29.0	83.6	10.3	NA	NA	NA	M	
9.0	21.0	80.2	9.1	NA	NA	NA	M	
6.0	16.0	70.3	6.1	NA	NA	NA	M	
小ﾏｸﾞﾛ	16.0	99.8	20.0	0.4	16.0	22.6	M	
鮪	16.0	118.0	35.8	0.6	16.0	36.6	L	
小ﾒｼﾞ	15.0	35.2	0.7	0.0	21.0	0.8	S	
5.0	11.0	68.5	5.6	NA	NA	NA	M	
メジ鮪	10.0	78.3	9.7	0.1	10.0	9.7	M	
8.0	9.0	78.2	8.4	NA	NA	NA	M	
7.0	8.0	74.9	7.4	NA	NA	NA	M	
11.0	6.0	86.0	11.2	NA	NA	NA	M	
別口ﾒｼﾞ	6.0	78.3	8.8	NA	NA	NA	M	
本ﾏｸﾞﾛ	5.0	109.1	31.6	0.2	5.0	36.3	L	
19.0	3.0	103.2	19.5	NA	NA	NA	L	
ｷｽﾞﾒｼﾞ	3.0	69.5	6.0	NA	NA	NA	M	
No name	2.0	90.3	18.0	NA	NA	NA	M	
12.0	2.0	88.6	12.3	NA	NA	NA	M	
20.0	2.0	106.3	21.4	NA	NA	NA	L	
２入れ	2.0	102.2	19.0	NA	NA	NA	L	
特大	2.0	119.2	30.9	0.1	2.0	31.0	L	
16.0	1.0	96.6	16.0	NA	NA	NA	M	
18.0	1.0	101.6	18.6	NA	NA	NA	L	
3.0	1.0	57.5	3.3	NA	NA	NA	M	
ﾏｸﾞﾛ大	NA	NA	NA	1.0	23.0	43.0	L	
メジ	NA	NA	NA	33.5	8,117.0	4.1	M	
小	NA	NA	NA	0.0	0.0	NA	NA	M

Table A3. Information of size sampling and catch data by brand name in “Iwate”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾒｼﾞ	14,402.0	66.7	6.4	1,280.5	50.0	15.0	M	
ﾒｼﾞﾏｸﾞﾛ	6,823.0	71.9	8.5	641.7	70,624.0	8.3	M	
ﾏｸﾞﾛ	946.0	125.8	38.0	215.3	0.0	NA	L	
ｸﾛﾏｸﾞﾛ	542.0	120.1	31.9	277.7	4,334.0	37.8	L	
ｺﾒｼﾞ	13.0	29.5	0.5	54.3	16.0	10.1	S	
ﾋﾟﾝﾒｼﾞ	NA	NA	NA	60.4	332.0	11.4	M	
ﾎﾝﾏｸﾞﾛ	NA	NA	NA	7.5	0.0	NA	NA	L
ﾒｼ	NA	NA	NA	0.4	19.0	19.6	L	
メジ	NA	NA	NA	0.2	20.0	10.2	M	
ﾒｼﾞ抜き	NA	NA	NA	3.0	90.0	20.5	L	
小ﾒｼﾞ	NA	NA	NA	1.7	258.0	6.8	M	

Table A4. Information of size sampling and catch data by brand name in “Miyagi”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾒｼﾞ	24,677.0	66.5	6.3	1,181.7	0.0	NA	M	
ﾏｸﾞﾛ	1,990.0	124.2	35.4	294.4	0.0	NA	L	
めじ	1,182.0	59.0	5.3	50.1	0.0	NA	M	
No-name	712.0	56.5	5.0	NA	NA	NA	M	
まぐろ	70.0	123.4	34.6	69.6	0.0	NA	L	

Table A5. Information of size sampling and catch data by brand name in “Yamagata”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾒｼﾞ	180.0	36.2	1.1	0.7	458.0	1.4	S	
ﾋﾗｶﾞﾂ	4.0	37.3	1.0	NA	NA	NA	S	
ﾏｸﾞﾛ	NA	NA	NA	0.1	3.0	43.7	L	

Table A6. Information of size sampling and catch data by brand name in “Nigata”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾀﾞｲﾒｼﾞ	9,993.0	80.1	10.8	635.3	61,359.0	10.2	M	
ﾏｸﾞﾛ	6,849.0	122.5	38.6	1,433.5	30,799.0	45.9	L	
ｼｮｳﾒｼﾞ	6,274.0	53.4	3.0	262.7	119,390.0	2.2	M	
ﾁｭｳﾒｼﾞ	5,098.0	63.9	5.3	204.4	39,312.0	5.2	M	
No-name	NA	NA	NA	70.5	86.0	4.0	M	
ﾒｼﾞ	NA	NA	NA	2.2	0.0	NA	NA	M

Table A7. Information of size sampling and catch data by brand name in “Toyama”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾒｼﾞ	18,581.0	50.8	3.3	1,953.2	32,007.0	0.3	M	
ｼﾋﾞｺ	2,855.0	36.8	1.1	NA	NA	NA	S	
ﾏｸﾞﾛ	910.0	133.6	45.1	112.0	2,008.0	50.6	L	
ﾒｼﾞｼﾋﾞｺ	78.0	49.6	2.8	525.9	29.0	9.2	S	
中ﾒｼﾞ	48.0	56.4	3.1	NA	NA	NA	M	
ｼﾋﾞ	31.0	30.8	0.5	NA	NA	NA	S	
大ﾒｼﾞ	14.0	97.8	16.1	NA	NA	NA	M	

Table A8. Information of size sampling and catch data by brand name in “Mie”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾖｺﾜ	1,931.0	48.1	2.5	74.6	194.0	3.9	S	
ﾖｺﾜ仔	134.0	26.1	0.3	NA	NA	NA	S	
ﾏｸﾞﾛ	63.0	120.4	35.6	7.9	88.0	28.0	L	
ｸﾛﾏｸﾞﾛ	24.0	117.6	29.6	30.6	225.0	32.6	L	
小ﾏｸﾞﾛ	23.0	77.1	8.4	NA	NA	NA	M	
ｸﾛﾏｸﾞﾛ小	NA	NA	NA	0.2	0.0	NA	NA	M
ﾏｸﾞﾛ小	NA	NA	NA	0.7	9.0	12.1	M	
ﾖｺﾜｷｽﾞ	NA	NA	NA	0.0	0.0	NA	NA	M
ﾖｺﾜ極小	NA	NA	NA	10.8	71.0	6.4	M	
ﾖｺﾜ小	NA	NA	NA	2.3	19.0	1.3	S	
ﾖｺﾜ大	NA	NA	NA	5.0	0.0	NA	NA	M
ﾖｺﾜ中	NA	NA	NA	3.0	0.0	NA	NA	M
ﾖｺﾜ特小	NA	NA	NA	1.0	0.0	NA	NA	M
ﾖｺﾜ特大	NA	NA	NA	0.5	1.0	8.0	M	M

Table A9. Information of size sampling and catch data by brand name in “Yamaguchi”.

Brand	Number of size data	Mean length of size data	Mean weight of size data	Catch in weight(ton)	Catch in number	Mean weight of catch(kg)	Size class	Size class2
ﾖｺﾜ	1,168.0	54.3	3.4	55.0	21,806.0	2.3	M	
ﾋｯｻｹﾞ	1,128.0	79.4	10.3	50.8	4,098.0	10.0	M	
ﾏｸﾞﾛ	254.0	124.3	37.0	14.0	402.0	34.7	L	