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AN EXPLORATION INTO JAPANESE SIZE DATA OF TROPICAL TUNA SPECIES BECAUSE OF A PROMINENT SIZE-FREQUENCY RESIDUAL PATTERN IN THE STOCK ASSESSMENT MODEL

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CONTENTS

ABSTRACT

Recent stock assessments of bigeye tuna (*Thunnus obesus*) in the eastern Pacific Ocean (EPO) have shown a prominent residual pattern in size frequency for the Japanese longline fishery. The pattern consists of positive residuals (observations larger than model predictions) for medium-size fish (around 75-125 cm) in the late 1980s, shifting to larger fish (around 125-175 cm) after 1990. The prominent residual pattern was partially improved, but not eliminated, by implementing new spatial definitions for the longline fishery, based on uniformity in historical trends of catch per unit of effort (CPUE) and size data, and time-varying selectivity for the longline fisheries. As the size data of the longline fishery in these stock assessments were Japanese, the Japanese longline fishery seems to have suddenly begun catching larger fish after 1990. Therefore, collaborative work between IATTC and Japan was carried out to address the problem. In preliminary investigations, similar differences in size composition were also detected for yellowfin tuna (*Thunnus albacares*). Three hypotheses to explain this size-composition shift are developed: 1) change in Japanese longline fishing strategies, such as selection of fishing ground and/or fishing season between the two periods (pre- and post-1990), 2) development of new fishing gear that affected the sizes of tuna caught around 1990, and 3) change in the size data collecting and reporting system around 1990. Regarding the first hypothesis, the number of hooks of the Japanese longline fishery in the EPO had reached its highest historical level in 1991, after which it decreased, with

some fluctuations, and the effort of the fishery became more concentrated in specific areas. However, the shift of the size composition occurred in all areas for both species (bigeye and yellowfin), thus the change in the spatial distribution of effort is not considered to have caused the shift. The difference in the seasonality of the effort between the two periods (pre- and post-1990) was less than 1%, which indicates that the fishing schedule by quarter had not changed around 1990. Regarding the second hypothesis, mainlines made of nylon began to be deployed around 1990 by smaller Japanese longline vessels operating in the vicinity of Japan, and their use spread rapidly throughout this fishery. However, the new gear was unlikely to be popular with the larger longline vessels in the EPO around 1990, according to interviews with fishermen and given that logbook data show that the proportion of longline sets using nylon mainlines was only about 50% in 1994. In addition, there was no strong evidence that the material of the main line affects the fish size composition. Regarding the third hypothesis, there were two items to be investigated, the vessel type (commercial vessel and training vessel) and the unit of fish size (weight or length). Although the average size of fish caught by the commercial vessels was larger than those of the training vessels in many cases, the ratio of sample size by vessel type was similar between the two periods (prior- and post 1990). Therefore, the difference in fish size by vessel type did not directly affect the size compostion shift in 1990. However, it is important to update the Japanese longline size data with the information about the vessel type for modeling the fishery's selectivity, since there are clear differences in size compostion between the vessel types. As for the other component of the third hypothesis, until 2010 the raw weight data were converted to length before being submitted to the IATTC by the Japanese National Research Institute of Far Seas Fisheries (NRIFSF). The average fish lengths converted from the weight group were smaller than those of the length group in many cases, which indicated that the weight-length conversion caused an underestimation of fish size. The number of length measurements increased after 1990 for both species, and exceeded, or was equal to, the number of weight measurements in 1991, and since then the length measurements has predominated. However, the changes of the average weight for both species did not present a clear shift in 1990. This indicates that the shift in size composition in 1990 for both species is unlikely to represent a real change in fish size. The combined effects of the change in the data-collecting system and the underestimation of fish size from the weight-length conversion probably lead to an artificial shift in the size composition. It is important to update Japanese size data with the information about the unit of measurement. The informative size data is useful for investigating the previously-developed stock assessment models with two time blocks, new fishery definitions, and selectivity.

1. INTRODUCTION

Recent stock assessments of bigeye tuna in the eastern Pacific Ocean have shown a prominent residual pattern in the size frequencies of the longline fishery. The pattern consists of positive residuals (observations larger than model predictions) for medium-size fish (around 75-125 cm) around the late 1980s shifting to larger fish (around 125-175 cm) after 1990. As the size data of the longline fishery in these stock assessments was Japanese, the Japanese longline fishery seems to have suddenly begun to catch larger fish after 1990.

The prominent residual pattern was partially improved, but not eliminated, by implementing new spatial definitions for the longline fishery, based on uniformity in historical trends of CPUE and size data (Lennert-Cody 2010, 2013), and time-varying selectivity, assuming that the changes in fishing operations resulted in changes in the catchability/selectivity of the longline fisheries (Aires-da-Silva *et al*. 2010). These size-composition data are very influential on parameter estimates and any resulting management advice, and for this reason the size data of these fisheries was downweighted in the recent stock assessment (Anonymous, (IATTC), 2015). This downweighting approach is appropriate if the size data do not contain reliable information about the abundance of the species; however, it is also possible that they contain good information about stock assessment parameters, but the model is misspecified. A clear explanation of the shift in size composition would improve the modelling. Aires-da-Silva *et al*. (2010) hypothesized that the shift resulted from a change in operational practices in this fishery around 1990, and investigated the historical changes in the number of hooks between floats (NHBF), which is often considered as a proxy for target species, and the vessels' fishing strategies could be reflected by the NHBF. An increase in NHBF was observed around 1989-1990, but it was not abrupt. Thus, the change in fishing operations detected through NHBF is not considered the reason for the shift in size composition in 1990.

Since the size data submitted by Japan to the IATTC does not have detailed information about the data collecting and reporting system and method of data collection, collaborative work between the IATTC and Japan is needed to address the problem (Okamoto 2014, Anonymous 2015). In a preliminary investigation, similar differences in size composition were also detected for yellowfin (Figure 1).

The aim of this study is to reveal the reason for the strong shift in 1990 in the size composition data of the Japanese longline fishery for bigeye and yellowfin tunas in the EPO. Three hypotheses to explain the size composition shift are developed: 1) change in Japanese longline fishing strategies, such as selection of fishing ground and/or fishing season between the two periods (pre- and post 1990), 2) development of new fishing gear that affected the sizes of tuna caught around 1990, and 3) change in the size data collecting and reporting system around 1990. In addition, a comparison between the IATTC and NRIFSF size databases was conducted. The results of the comparison are summarized in Appendix A.

2. METHODS

The NRIFSF size database (NRIFS-DB) is continuously updated. The data, including all data updated in the last several years, are submitted once a year to IATTC. However, the repeated data updates and submissions might cause an unintended discrepancy between the two databases, and if the discrepancy existed around 1990, it might be a reason for the shift in size composition in 1990.

In order to investigate the three hypotheses mentioned above, the NRIFSF catch-and-effort and size databases were used. The catch-and-effort database stores fishing location, number of hooks, and catch in both numbers and in weight, by species, in each set, with information about the material of the fishing gear, NHBF, and vessel type (commercial or training), based on mandatory reports from Japanese vessels. The size database, based on similar reports, stores fishing location, species, size, unit of fish size (weight (kg) and length (cm)), and vessel type (commercial or training).

3. RESULTS AND DISCUSSION

The length frequencies of bigeye and yellowfin, by area, and the two periods (1975-1989 and 1990-2013) indicated by the size data used in the last stock assessments (Figure 1) (Aires-da-Silva e*t al*. 2015, Minte-Vera *et al*. 2015), show that, for all areas and both species, there was a greater proportion of larger fish in the later period than in the earlier period. The area definitions coincided with those of the last stock assessments in 2015.

HYPOTHESIS 1: Change in Japanese longline fishing strategies such as selection of fishing grounds and/or fishing season between the two periods (pre- and post-1990)

The number of Japanese longline hooks deployed in the EPO reached its highest historical level in 1991, since when it decreased, with some fluctuations, and fell to 26% of its highest value in 2013 (Figure 2). During this decreasing phase, changing the fishing strategy of selecting for the fishing ground spatially and temporally could affect the shift in size composition. The proportion of number of hooks by quarter, area, and period (pre- and post-1990) indicated that, for bigeye, the ratio increased by 6% in the southern hemisphere (LL S) in the later period (Table 1); for yellowfin, the proportion in that area (LL S) reached over 90% for both periods, and there was no large difference between the two periods. Although the fishing effort focused on the specific area (LL S for bigeye) in the later period, the shift in size composition occurred in all areas (Figure 1) for both species. Thus, the change in spatial distribution of effort is not considered responsible for the size shift. The difference in seasonal proportion of effort between the two periods was less than 1%, which indicates that the fishing schedule by quarter did not change around 1990 (Table 1).

HYPOTHESIS 2: Development of new fishing gear around 1990 that affected the size of tuna caught

Longlines main line made of nylon were first deployed around 1990 by smaller Japanese longline vessels operating in the vicinity of Japan, and rapidly spread throughout this fishery. If this newly-developed gear was in widespread use in the EPO around 1990, and also caught larger fish, , the change of fishing gear may be the reason for the shift of size composition in 1990.

Between 1953 and 2010, researchers from local government fishery institutions, NRIFSF and a predecessor of NRIFSF nterviewed fishing masters at several ports including Yaidu, one of the principal landing ports for tuna by Japanese longline vessels. The interviews collected information about fishing grounds, fish size, fishing gear, etc., and the results were summarized monthly and reported in an organ of the Japanese fisherman's organization. After 1982, the summary reports were published by NRIFSF every six months until 2010. The report for July-December 1989 (Anonymous (NRIFSF) 1989) described that mainlines made of nylon had been introduced in commercial fishing operations near Japan (east of 140°E) instead of the traditional *kuronawa* main line, made of cotton thread, and produced CPUEs two and four times higher for bigeye and albacore, respectively, compared to the traditional main line.

The next volume of the report (January-July 1990) included a short summary entitled "Comparison of CPUE between nylon and traditional longline gear". It stated that the new nylon gear had been deployed since 1989 by the smaller longline vessels, for both branch lines and mainline. In 1990 it spread rapidly, to 90% of smaller vessels and some medium-sized vessels. The report also described higher CPUEs of bigeye and albacore than those of the traditional gear. Unfortunately, the report did not directly mention the situation of the new gear in the EPO, but certain descriptions suggest that it was not very popular with the larger vessels in 1990. At that time the Japanese longline vessels in the EPO were almost all larger vessels (Uosaki and Bayliff 1999).

Because the material of the main line was added to the mandatory logbook in 1994, subsequent historical changes in the application of the nylon gear can be traced (Figure 3). The proportion of number of hooks by mainline material (nylon and traditional) showed that in the EPO in 1994 the proportion of nylon gear was around 50%, and increased gradually to around 90% in 2007. Thus the new gear was apparently not popular for larger longline vessels in the EPO in 1990.

Comparisons of the median size of fish caught by commercial vessels,by year, during 1994-1998 did not reveal clear differences in the annual length frequencies by main line material (Figures 4.1, 4.2). Thus, the main line material did not much affect the size of fish caught.

HYPOTHESIS 3: Change in the size data collecting and reporting system around 1990

There were two components to be investigated, the vessel type (commercial or training) and the unit of fish size (weight or length). Until 2010, the raw weight data were converted to lengths before being submitted to the IATTC by NRIFSF, using the method described in Appendix B. The vessel type (commercial or training) was not specified in the size data submitted. We investigated whether changing the size data collecting and reporting system regarding these two components around 1990 affected the shift in size composition.

3.1. Commercial vs. training vessels

The NRIFSF database contains size data for yellowfin from commercial vessels since 1951 and from training vessels since 1965, and for bigeye since 1965 for both vessel types. The proportion of samples from commercial vessels to total number of samples for bigeye and yellowfin during 1965-2013 was 72% and 76%, respectively (Figures 5.1 and 5.2). From 1975 to 1981 the proportion of commercial vessels decreased rapidly to about 20% or less for both species. In the northern area (LL N), the size data for both species from training vessels comprised between 50 and 100% of the data in the late 1980s, while in other areas almost all size data had been reported by commercial vessels since the early 1980s. Generally, the size data from commercial vessels dominated, but there were large annual fluctuations and area-specific features in the proportions for both species. In addition, further explanation for the size data for yellowfin before 1964 is not provided in this paper because the details about the origin of the data are not available (Table A.1).

A comparison of length frequencies of bigeye by vessel type during 1975-2013 showed a lower proportion of 80-100 cm fish, and a higher proportion of fish over 140 cm, for the commercial vessels (Figure 5.3), and yellowfin from commercial vessels showed higher proportions of fish over 120 cm compared to those from training vessels. In addition, for these comparisons, the weight data are converted to lengths. The length frequencies of both species broken down by period (pre- and post-1990), vessel type (commercial or training), and area, suggested that the differences between vessel types were clear for both periods and both species (Figure 5.4a, b), except for bigeye in area LL I during the earlier period (1975-1989).

Since the proportions of samples by vessel type were similar around 1990 (Figure 5.5), the difference in size composition by vessel type did not directly affect the shift in the size composition in 1990. The seasonal pattern of effort differed between the two periods of the training vessel data (Table 1). The proportions of effort by area and quarter were similar to those of commercial vessels in the earlier period (1975-1989), but in the later period (1990-2014), effort was concentrated in the LL N area for both species. The commercial and the training vessels used different fishing strategies after 1990. Thus, it is important to update the size data for the Japanese longline fishery with the information about vessel type for modeling the fishery's selectivity, since there are clear differences in size compostion between the vessel types after 1975.

In addition, from 1965 to 1989 the size data from the commercial vessels is almost entirely (>95%) weight for both species, while it is almost entirely (>99.9%) length for training vessels. In order to have enough samples for the comparisons by vessel type and year (Figures 5-3, 5-4a, b), the weight data were converted into length. This could cause bias, as noted below, in the comparison by vessel type. If the bias exists, the length frequencies converted from weight of the commercial vessels will be underestimated, thus the actual discrepancy between the vessel types will be much larger than those presented in this section.

3.2. Unit of fish size (weight vs. length)

Comparisons of length frequencies by unit of measurement (weight (kg) and length (cm)) from 1975 to 2013 indicated that, for both species, the measured lengths were greater than the lengths derived from converting weight data (Figure 6.1). The differences between measured length and converted length were found in many cases when the size data were broken down into area and period for both species (Figure 6.2a, b). Using only the weight data from commercial vessels, the average body weight of fish by area did not show any considerable change around 1990 (Figure 6.3a, b).

In response to a resolution by the Commission for the Conservation of Southern Bluefin Tuna (CCSBT), since 1988 Japanese longline vessels that catch southern bluefin tunaare required to measure the fish.

This also affected Japanese longline vessels that caught tropical tuna species. The proportion of length data increased after 1990 for both species, equalled that of the weight data in 1991, and since then has dominated (Figure 5.5).

The evidence we present indicates that the shift in size composition in 1990 for both species is unlikely to be due to a real change in the size of fish caught. The combined effects of a change in the data collecting system and the underestimation of fish size from the weight-length conversion probably leads to an artificial shift in size composition. It is important to update Japanese size data with the information about the unit of measurement. The informative size data should be used to improve the previously-developed stock assessment models.

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REFERENCES

Alexandre Aires-da-Silva, Mark N. Maunder and Cleridy E. Lennert-Cody. 2010. An investigation of the longline fishery length frequency residual pattern in the stock assessment of bigeye tuna in the eastern Pacific Ocean. BET-01-05 (DRAFT). External review of IATTC bigeye tuna assessment, La Jolla, California, USA, 3-7 May 2010. 32 pp.

Alexandre Aires-da-Silva and Mark N. Maunder. 2015. Status of bigeye tuna in the eastern Pacific Ocean in 2014 and outlook for the future. SAC-06-05. Inter-American Trop. Tuna Comm., La Jolla, California, USA, 11-15 May 2015. 11 pp.

Anonymous (IATTC). 2015. Meeting report Scientific Advisory Committee Sixth meeting. Inter-American Trop. Tuna Comm., La Jolla, California, USA, 11-15 May 2015. 52 pp.

Anonymous (NRIFSF). 1989. Every half year report for operation status of Japanese longline vessel based on commercial vessel loading at Yaizu fishing port (July to December in 1989). Volume 13: 60 pp.

Anonymous (NRIFSF). 1990. Every half year report for operation status of Japanese longline vessel based on commercial vessel loading at Yaizu fishing port (January to June in 1990). Volume 14: 62 pp.

Carolina V. Minte-Vera, Alexandre Aires-da-Silva and Mark N. Maunder. 2015. Status of yellowfin tuna in the eastern Pacific Ocean in 2014 and outlook for the future. SAC-06-06. Inter-American Trop. Tuna Comm., La Jolla, California, USA, 11-15 May 2015. 11 pp.

Lennert-Cody, C.E., Minami, M., Tomlinson, P.K., Maunder, M.N., 2010. Exploratory analysis of spatial–temporal patterns in length-frequency data: an example of distributional regression trees. Fish. Res. 102, 323–326.

Lennert-Cody, C. E., Maunder, M. N., Aires-da-Silva, A., & Minami, M. 2013. Defining population spatial units: Simultaneous analysis of frequency distributions and time series. Fish. Res. 139, 85-92.

Hiroaki, Okamoto. 2014. Overview of size data for bigeye tuna caught by Japanese longline fishery in the Pacific Ocean. SAC-05-INF-D. Inter-American Trop. Tuna Comm., La Jolla, California, USA, 12-16 May 2014. 13 pp.

Koji, Uosaki, and W. H. Bayliff. 1999. A review of the Japanese longline fishery for tunas and billfishes in the eastern Pacific Ocean, 1988-1992. Inter-Amer. Trop. Tuna Comm., Bull., 21 (6): 273-488.

TABLE 1. Proportion of length-composition measurements, by area and quarter, for commercial vessels in two periods (1975-1999 and 2000-2013), and the differences in proportions between bigeye and yellowfin. The area definitions for the two species coincide with those of the stock assessments in the eastern Pacific Ocean in 2015.

Period	Area	Commercial					Training				
		Quarter				Total	Quarter				Total
		1	2	3	4		1	2	3	4	
BIGEYE											
1	LL N	0.04	0.01	0.01	0.04	0.10	0.04	0.03	0.03	0.07	0.17
	LL C	0.03	0.10	0.08	0.03	0.23	0.01	0.05	0.03	0.06	0.14
	LL S	0.16	0.07	0.08	0.16	0.47	0.06	0.15	0.11	0.24	0.55
	LL I	0.02	0.05	0.10	0.03	0.19	0.01	0.01	0.06	0.06	0.14
	Total	0.25	0.23	0.26	0.26		0.12	0.23	0.23	0.42	
2	LL N	0.03	0.00	0.01	0.05	0.09	0.01	0.01	0.02	0.39	0.44
	LL C	0.04	0.08	0.05	0.02	0.19	0.03	0.01	0.01	0.02	0.07
	LL S	0.18	0.09	0.09	0.18	0.54	0.06	0.06	0.06	0.17	0.35
	LL I	0.01	0.04	0.10	0.02	0.18	0.01	0.02	0.09	0.02	0.14
	Total	0.26	0.22	0.26	0.27		0.11	0.11	0.18	0.60	
Difference	LL N	-0.01	-0.01	0.00	0.01	-0.01	-0.03	-0.01	0.00	0.32	0.27
	LL C	0.01	-0.02	-0.03	-0.01	-0.04	0.03	-0.04	-0.02	-0.04	-0.07
	LL S	0.02	0.01	0.02	0.02	0.06	0.00	-0.08	-0.05	-0.07	-0.20
	LL I	-0.01	0.00	0.00	0.00	-0.01	0.00	0.01	0.02	-0.03	0.00
	Total	0.01	-0.01	-0.01	0.01		0.00	-0.12	-0.05	0.18	
YELLOWFIN											
1	LL N	0.04	0.01	0.01	0.04	0.10	0.04	0.01	0.02	0.07	0.14
	LL S	0.21	0.22	0.25	0.22	0.90	0.07	0.23	0.20	0.35	0.86
	Total	0.25	0.23	0.26	0.26		0.12	0.23	0.23	0.42	
2	LL N	0.03	0.00	0.01	0.05	0.09	0.01	0.01	0.02	0.39	0.43
	LL S	0.23	0.21	0.25	0.22	0.91	0.10	0.11	0.15	0.20	0.57
	Total	0.26	0.22	0.26	0.27		0.11	0.11	0.18	0.60	
Difference	LL N	-0.01	-0.01	0.00	0.01	-0.01	-0.03	0.00	0.00	0.32	0.29
	LL S	0.02	-0.01	-0.01	0.00	0.01	0.03	-0.12	-0.05	-0.15	-0.29
	Total	0.01	-0.01	-0.01	0.01		0.00	-0.12	-0.05	0.18	

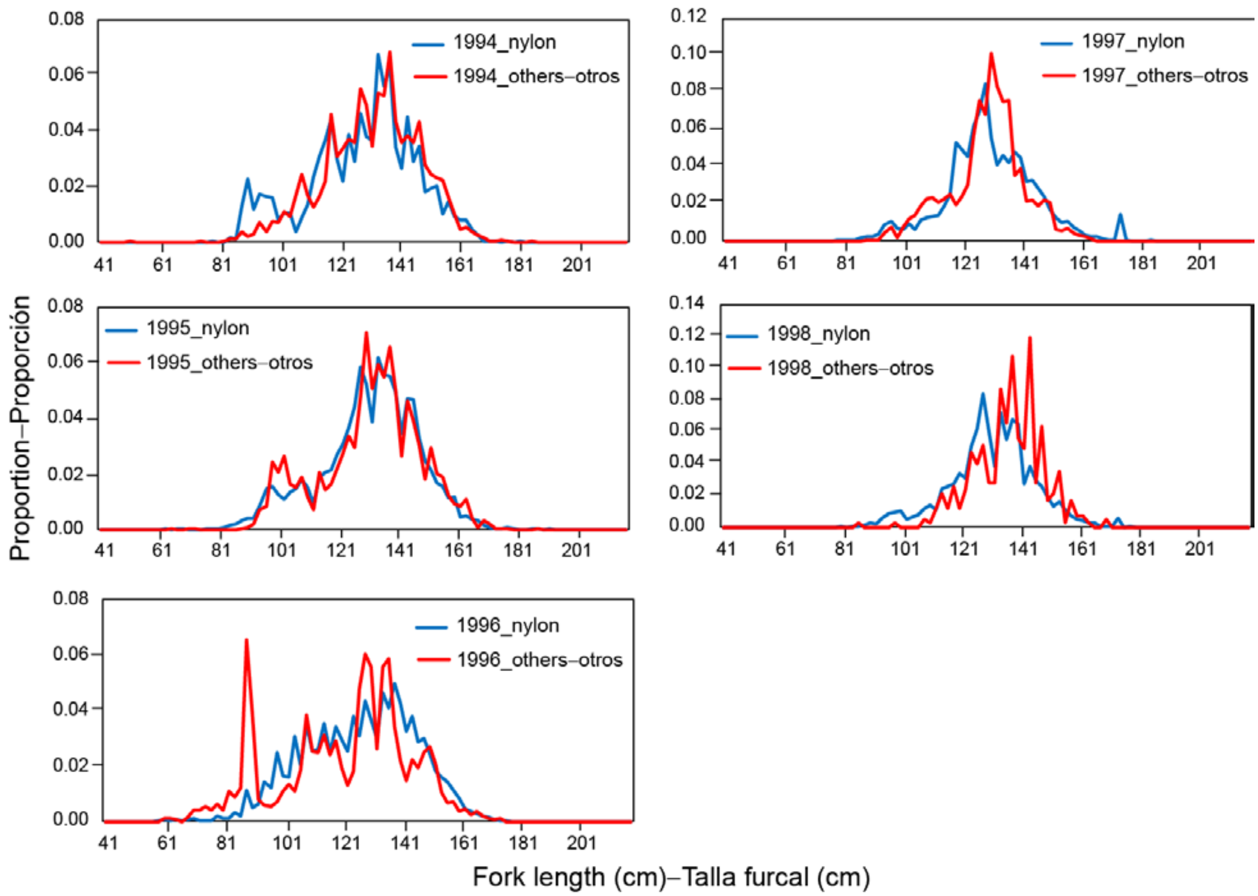

FIGURE 1. Length frequencies of bigeye (upper four panels) and yellowfin (lower two panels) caught in the Japanese longline fishery during two periods (1975-1989 (blue line); 1990-2013 (red line)) in the eastern Pacific Ocean. by area. The area definitions and fishery numbers coincide with those of the stock assessments in 2015.

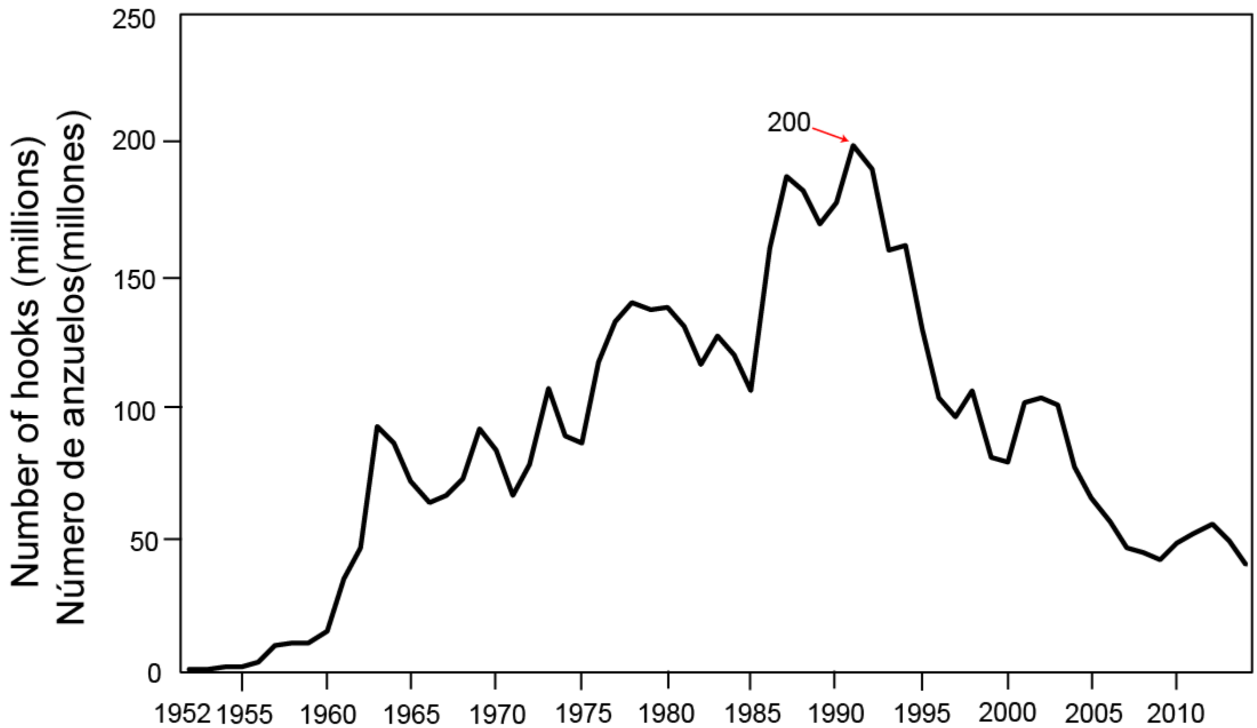

FIGURE 2. Historical changes in number of hooks in the Japanese longline fishery in the eastern Pacific Ocean, 1952-2014. The historical highest number of hooks recorded was 200 million in 1991.

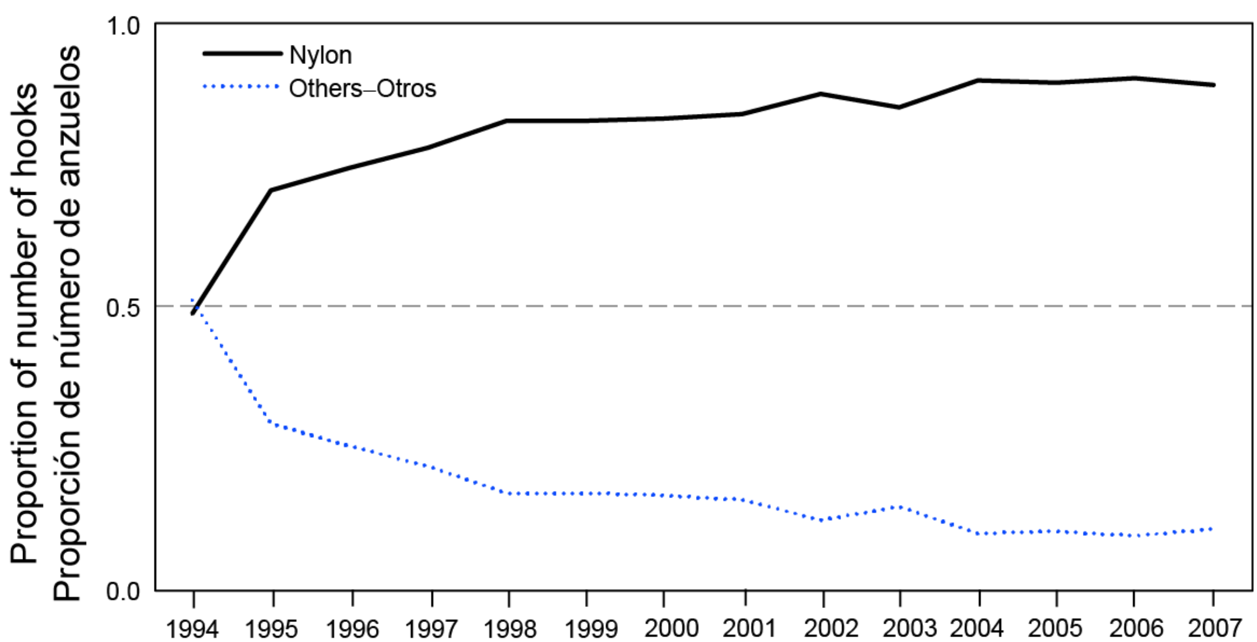

FIGURE 3. Proportion of hooks by main line material, 1994-2007.

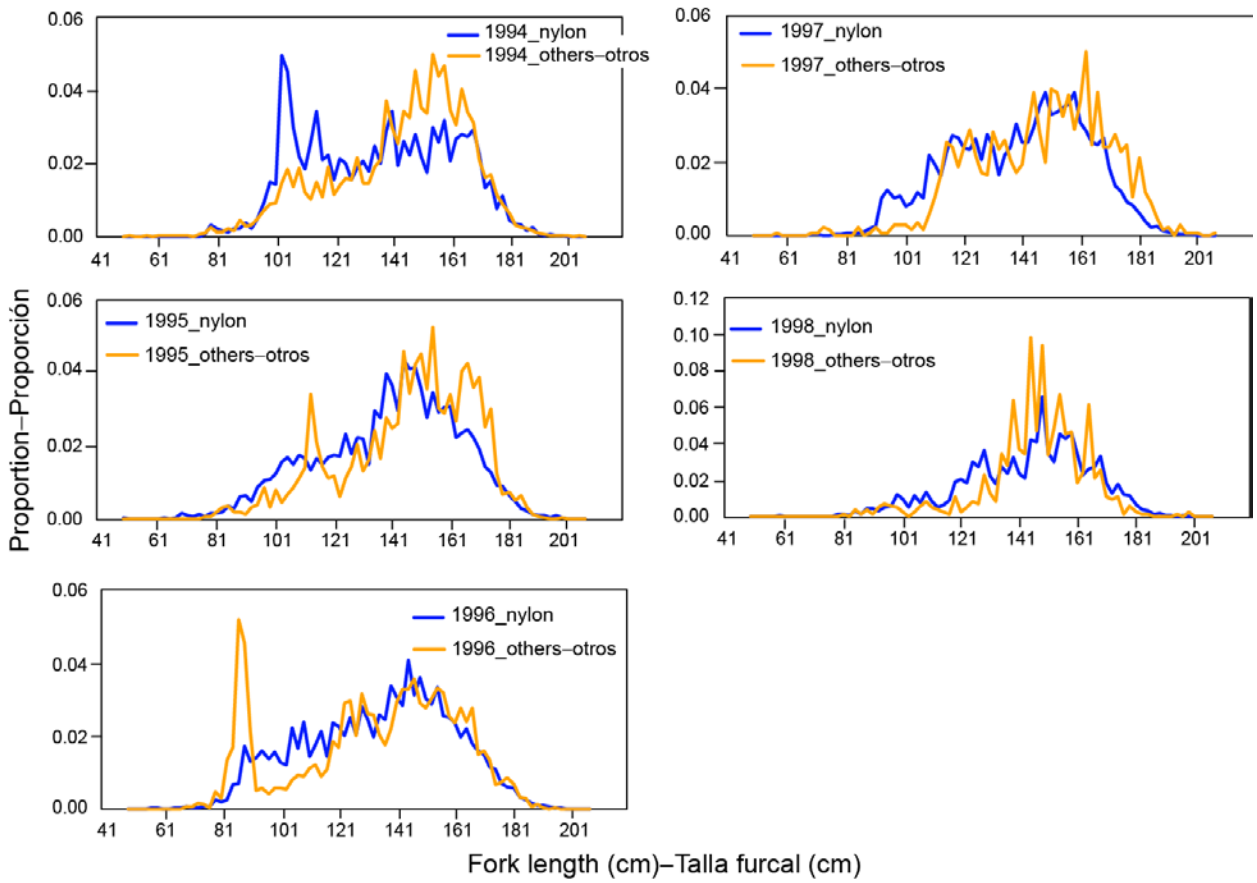

FIGURE 4.1. Length frequencies of bigeye caught by Japanese commercial vessels, by year and material of main line (blue; nylon, orange; others (including traditional *kuronawa*)), 1994-1998. Excludes length data converted from weight.

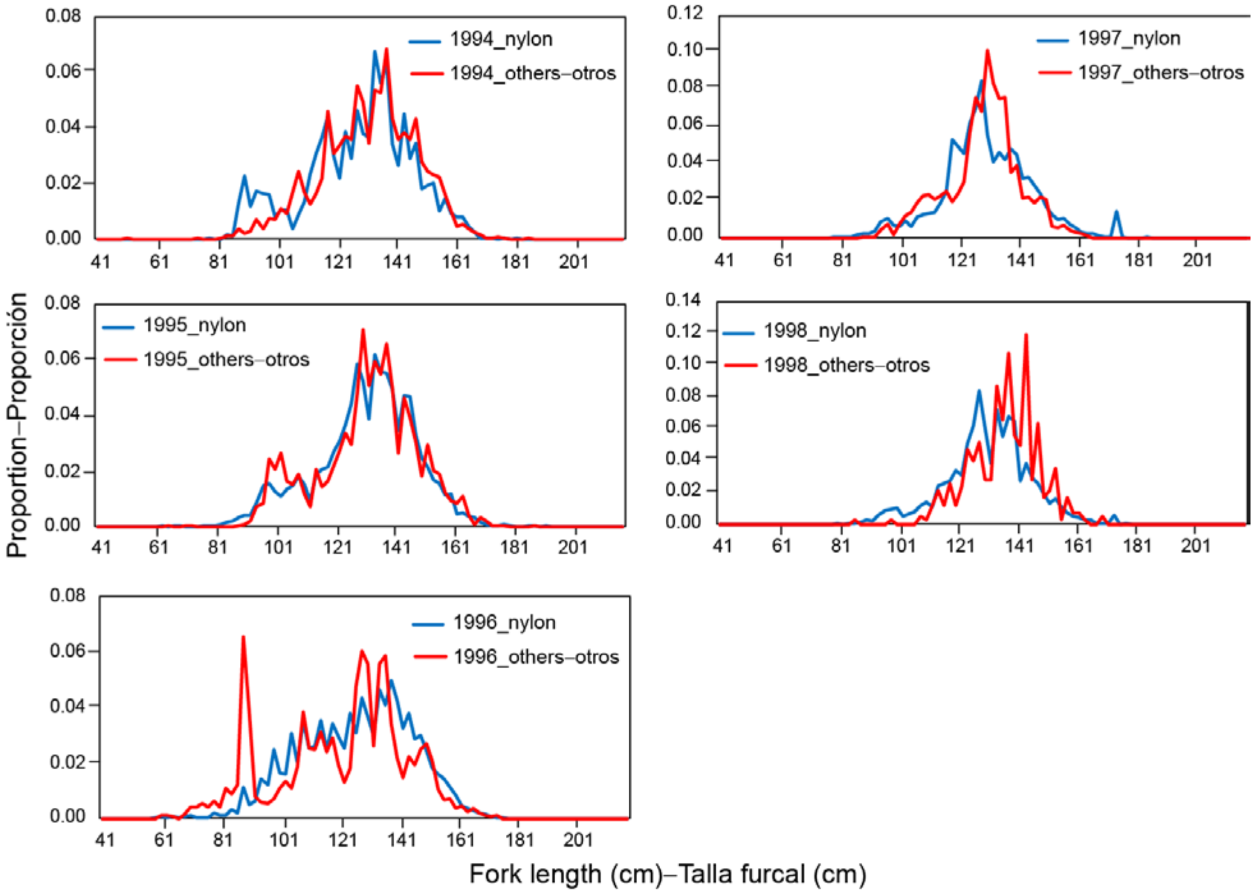

FIGURE 4.2. Length frequencies of yellowfin caught by Japanese commercial vessels, by year and material of main line (blue; nylon, red; others (including traditional *kuronawa*)), 1994-1998. Excludes length data converted from weight.

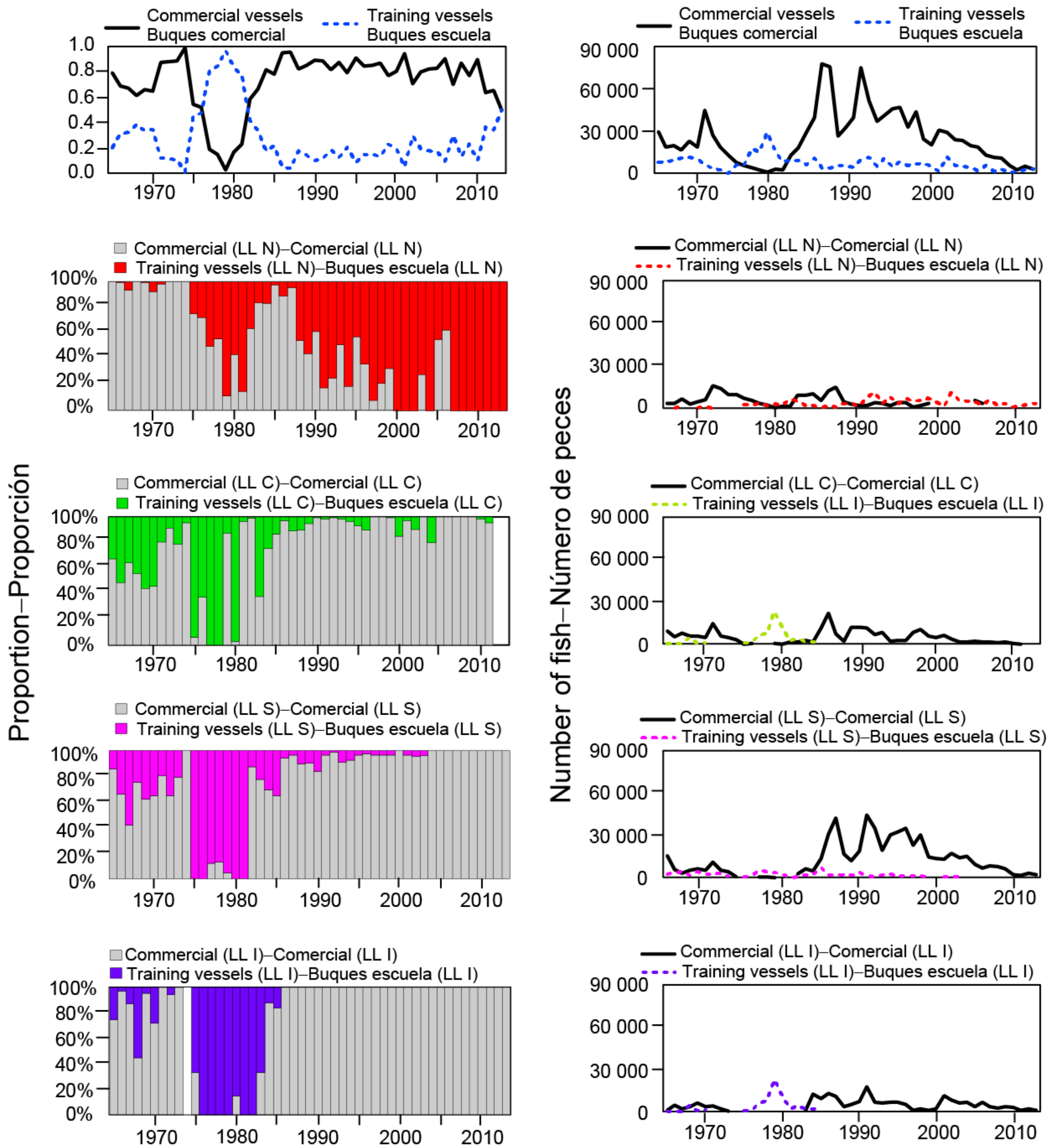

FIGURE 5.1. Bigeye proportion (left panels) and number of fish (right panels) of size data of Japanese longline vessels in the eastern Pacific Ocean, by vessel type (commercial and training) and area. Area aggregated proportion and number of fish are also presented in the top panels. The area definitions coincide with those of the stock assessments in 2015.

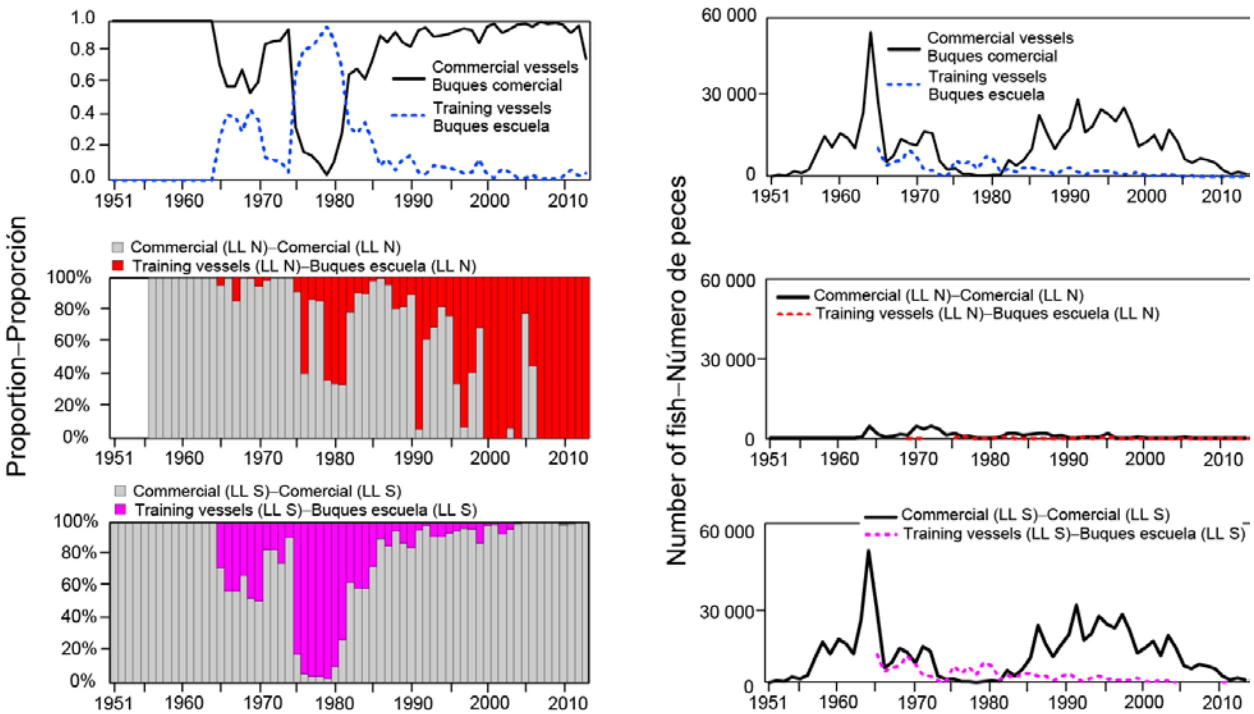

FIGURE 5.2. Yellowfin proportion (left panels) and number of fish (right panels) of size data of Japanese longline vessels in the eastern Pacific Ocean by vessel type (commercial and training) and area. Area aggregated proportion and number of fish are also presented in the top panels. The area definitions coincide with those of the stock assessments in 2015.

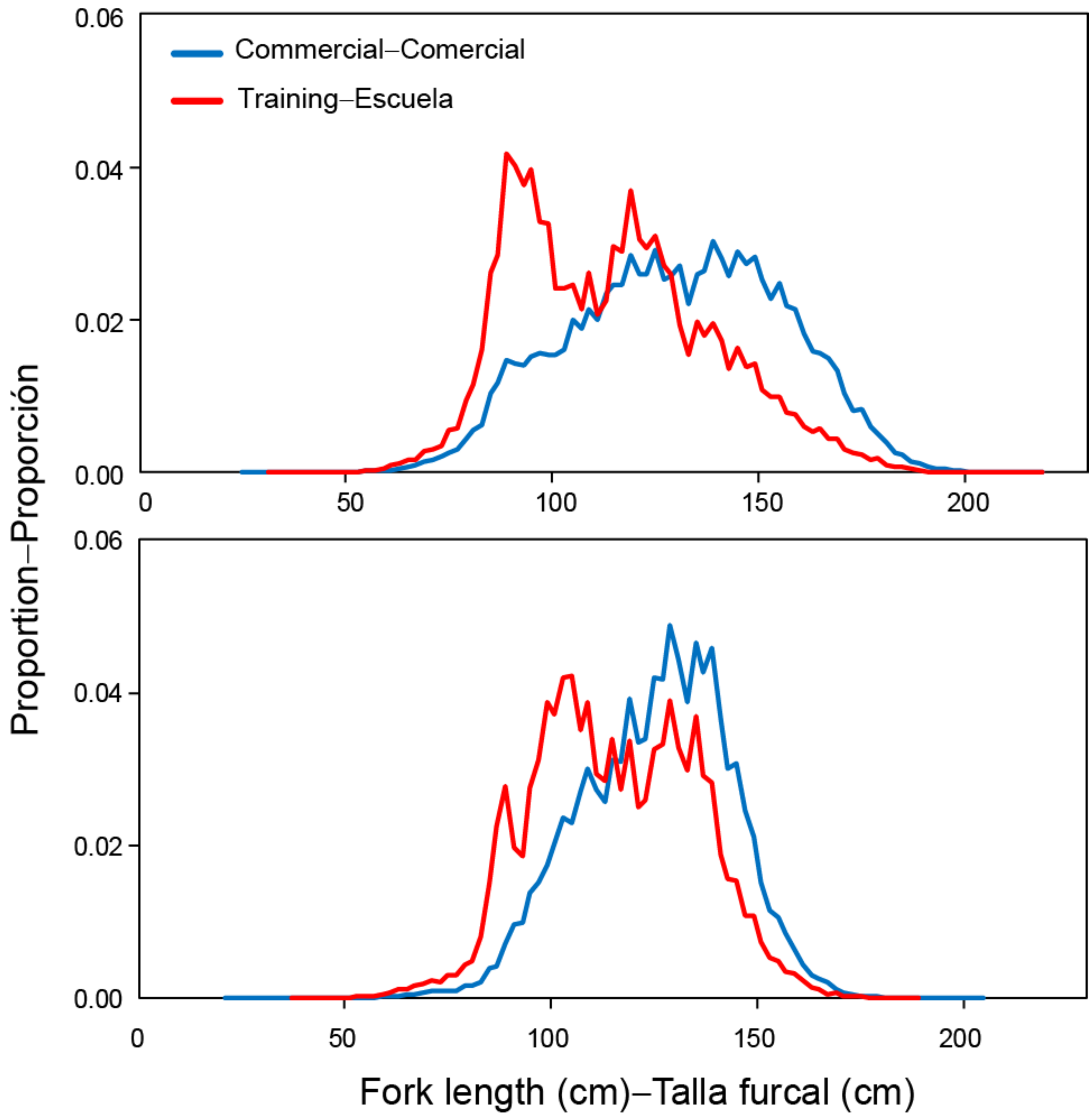

FIGURE 5.3. Comparison of length-frequencies of bigeye (top panel) and yellowfin (bottom panel) caught in the eastern Pacific Ocean of Japanese longline between commercial vessels (blue line) and training vessels (red line)catches in the eastern Pacific Ocean, 1975-2013. For the comparison the weight data is converted into length using same compiling method for size data submission to IATTC from NRIFSF before 2010.

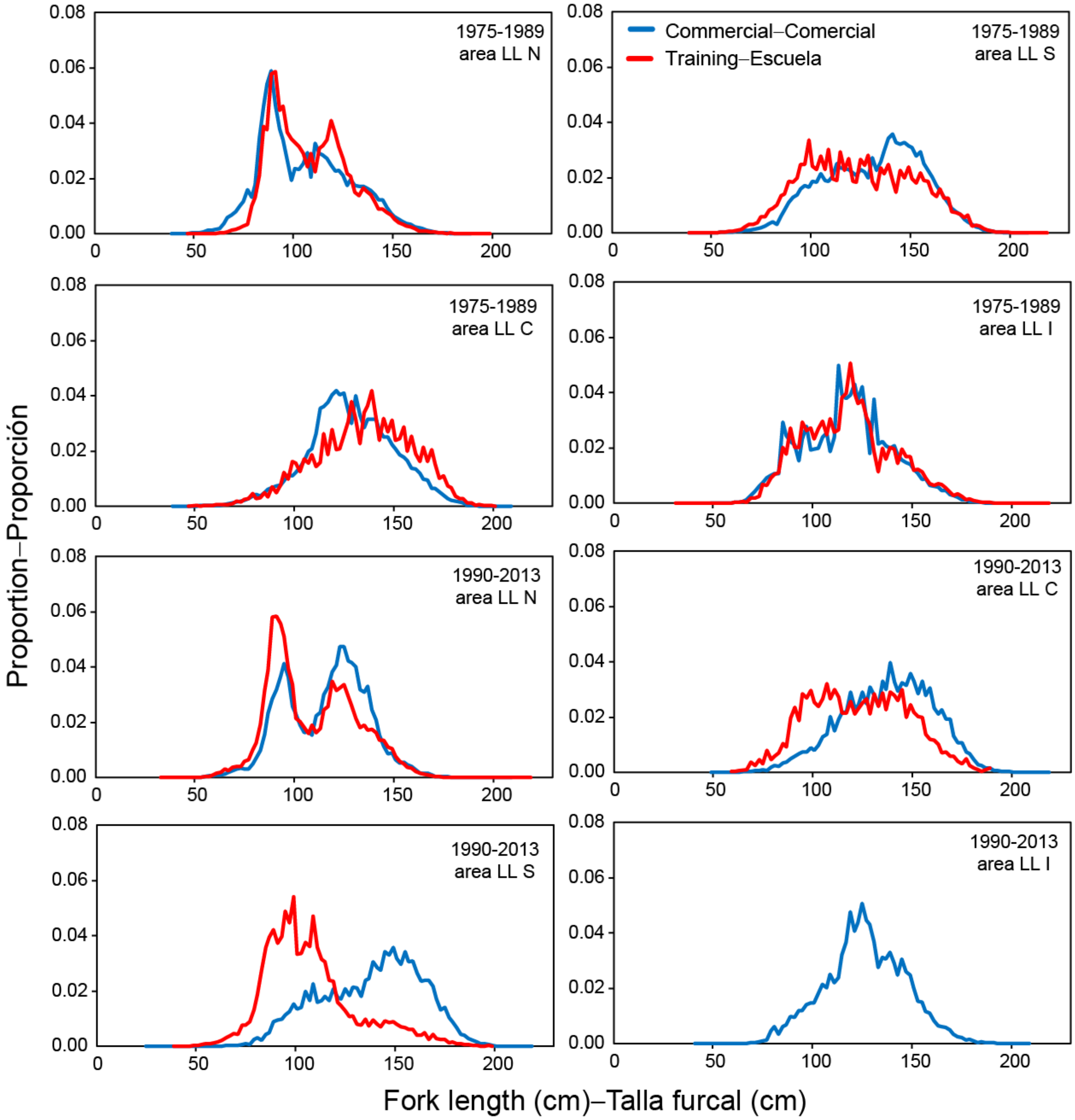

FIGURE 5.4a. Comparison between commercial vessels (blue line) and training vessels (red line) of length frequency of bigeye, by area and period (pre- and post-1990), in the eastern Pacific Ocean. The area definition coincides with those of the stock assessments in 2015. For the comparison the weight data is converted into length using same compiling method for size data submission to IATTC from NRIFSF before 2010.

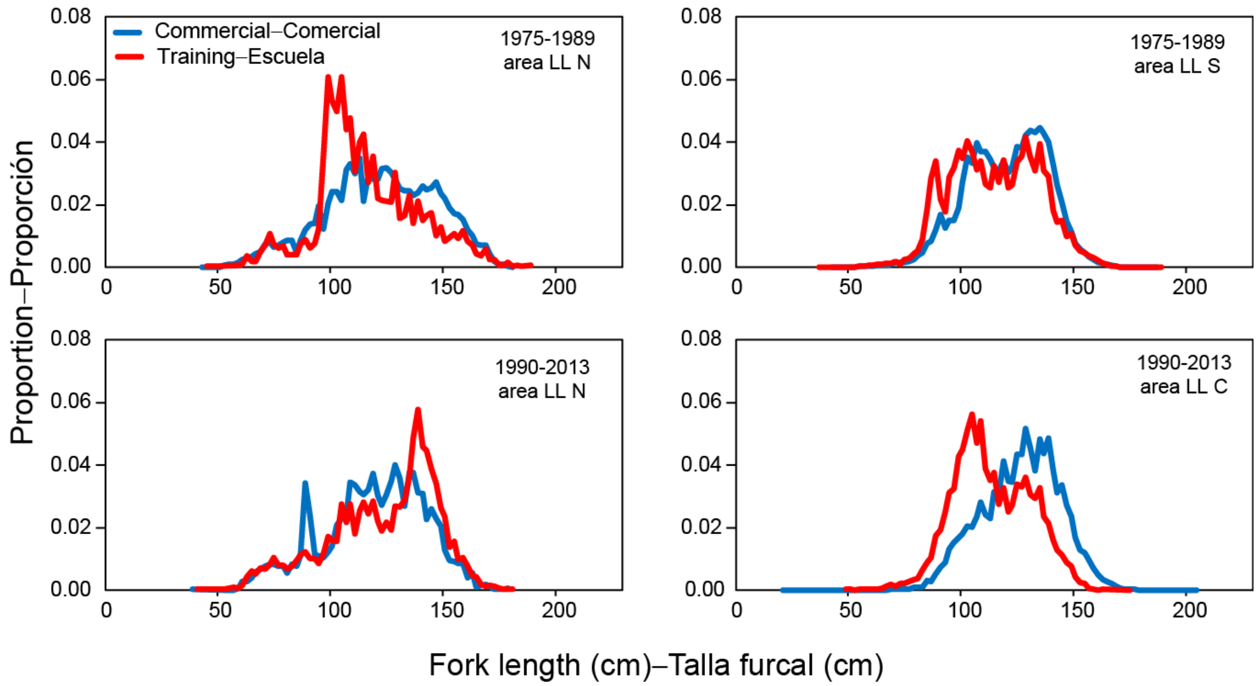

FIGURE 5.4b. Comparison between commercial vessels (blue line) and training vessels (red line) of length frequency of yellowfin, by area and period (pre- and post-1990), in the eastern Pacific Ocean. The area definition coincides with those of the stock assessments in 2015. For the comparison the weight data is converted into length using same compiling method for size data submission to IATTC from NRIFSF before 2010.

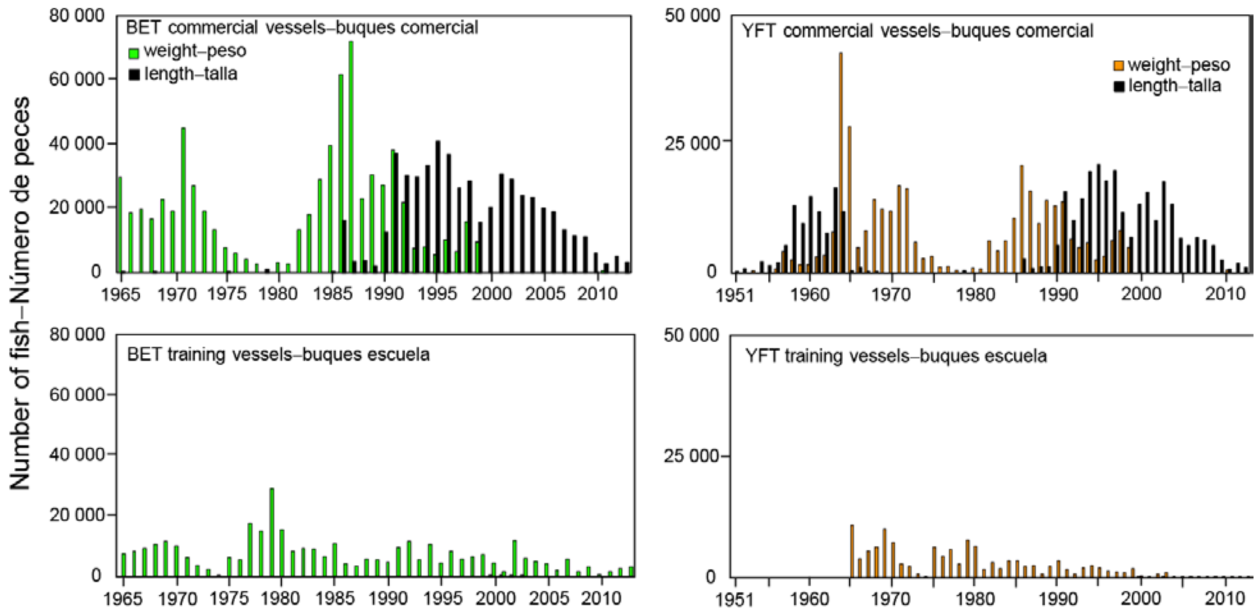

FIGURE 5.5. Number of Japanese longline size data for bigeye (left panels) and yellowfin (right panels) in the eastern Pacific Ocean, by vessel type (commercial or training) and unit of fish size (weight (kg) and length (cm), 1965-2013.

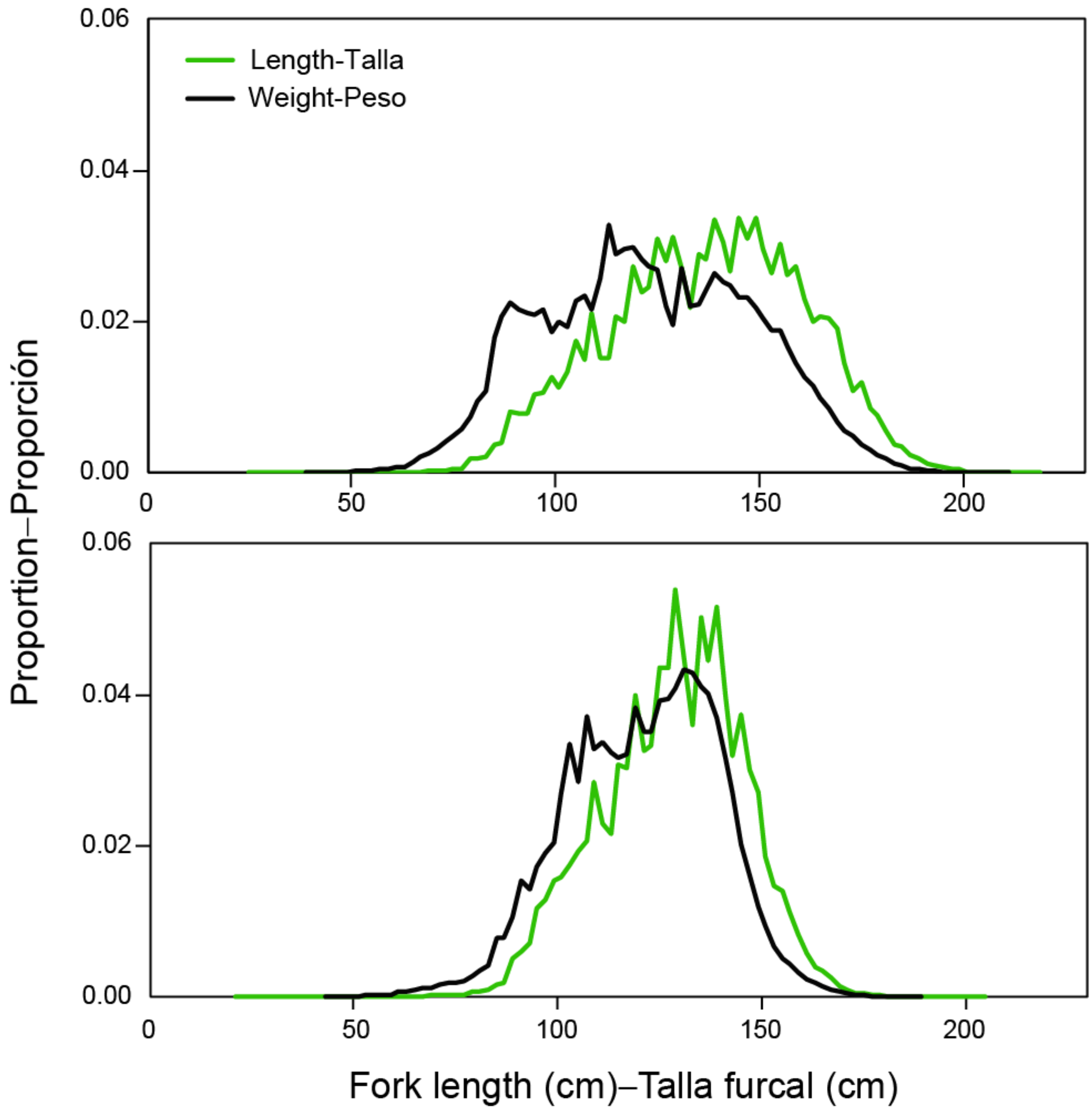

FIGURE 6.1. Comparison between length data (green line) and length data converted from weight data (black) for length-frequency of bigeye (top panel) and yellowfin (bottom panel) in the eastern Pacific Ocean, 1975-2013.

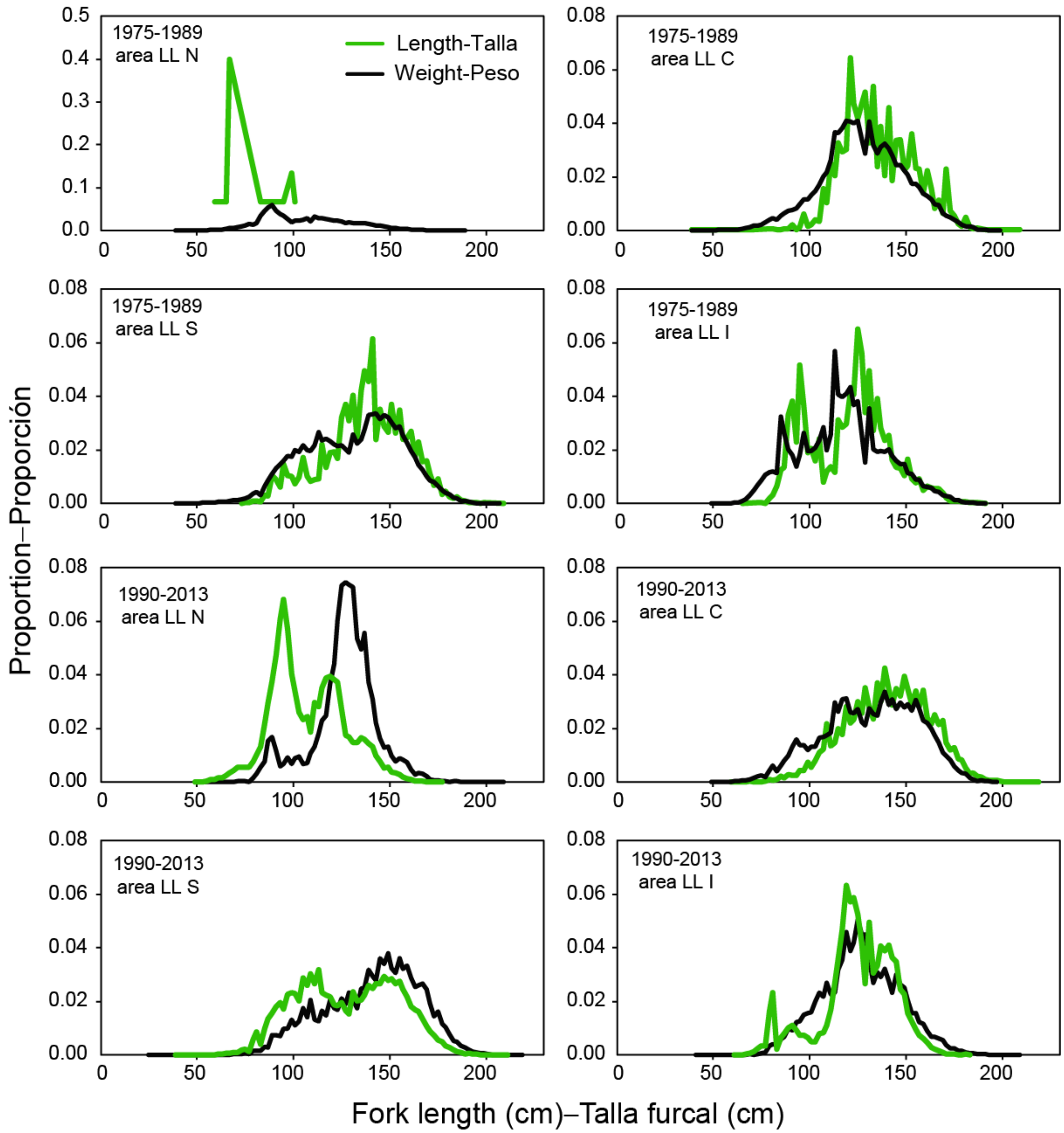

FIGURE 6.2a. Comparison of length frequencies of bigeye based on length data (green line) and length data converted from weight data (black line), from commercial vessels only, by area and period (pre- and post-1990), in the eastern Pacific Ocean.

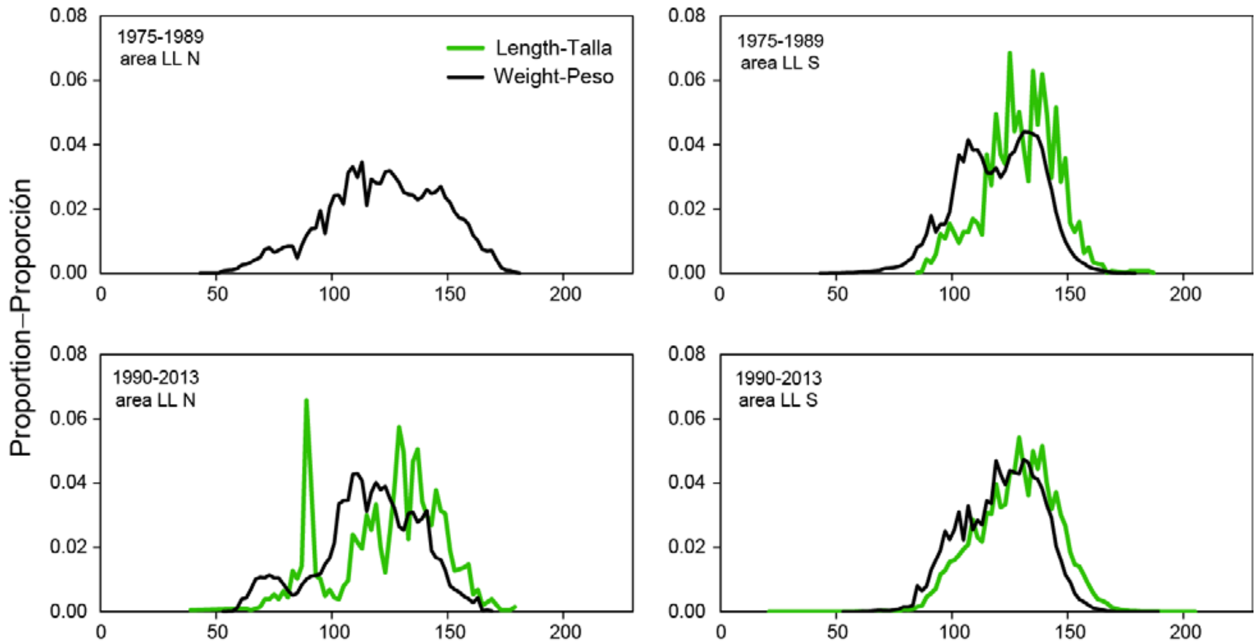

FIGURE 6.2b. Comparison of length frequencies of yellowfin based on length data (green line) and length data converted from weight data (black line), from commercial vessels only, by area and period (pre- and post-1990), in the eastern Pacific Ocean.

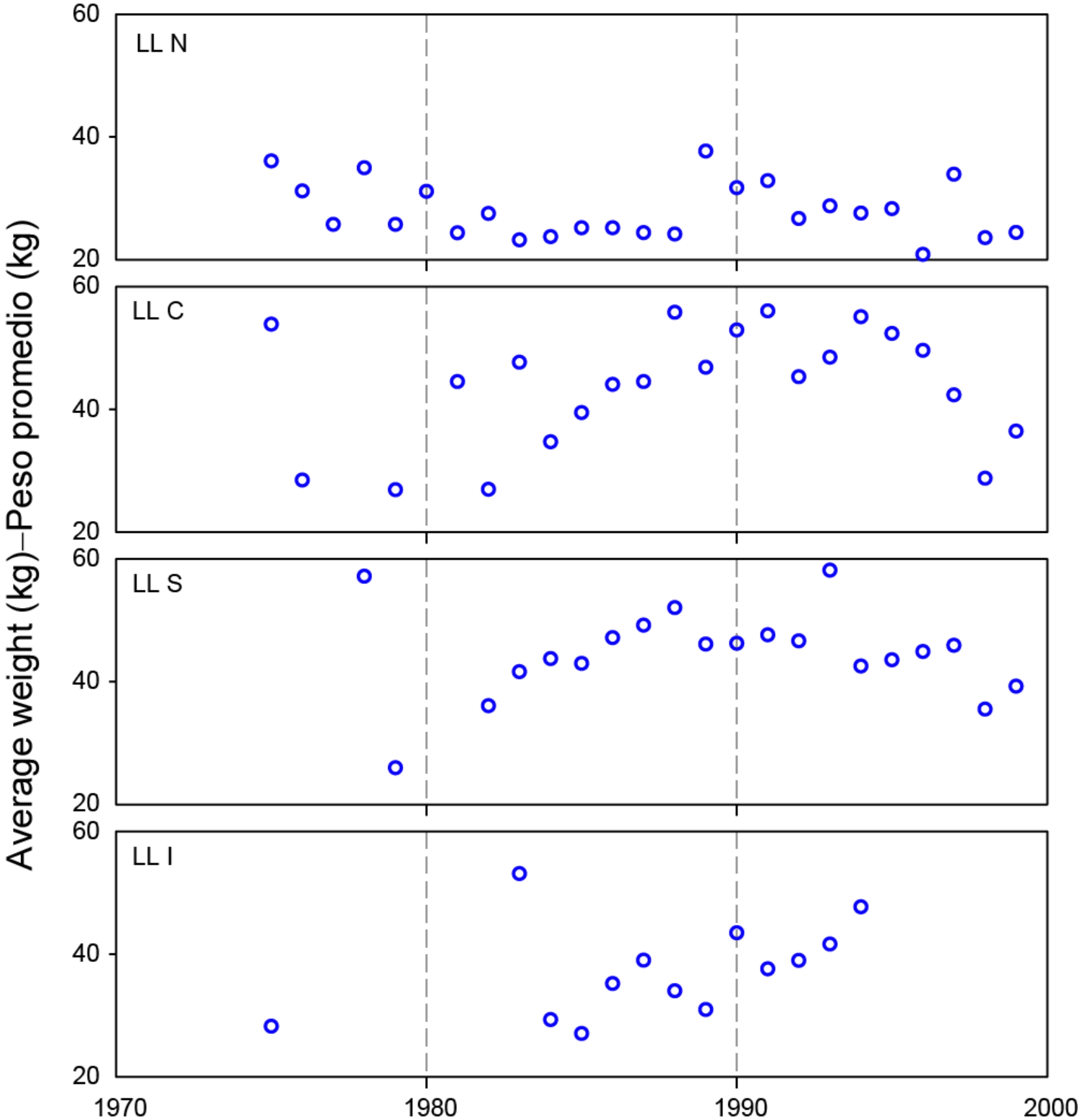

FIGURE 6.3a. Inter-annual changes in average weight (kg) of bigeye, by area, based on weight data from commercial vessel only, in the eastern Pacific Ocean. The areas correspond to those defined in the 2015 stock assessment (1: LL-N, 2: LL-C, 3; LL-S, 4; LL-I).

FIGURE 6.3b. Inter-annual changes in average weight (kg) of yellowfin, by area, based on weight data from commercial vesselonly, in the eastern Pacific Ocean. The areas correspond to those defined in the 2015 stock assessment (1: LL-N, 2: LL-S, 3; size data for 15°N Level).

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APPENDIX A

COMPARISON BETWEEN JAPANESE SIZE DATA IN IATTC AND NRIFSF DATABASES

Japanese longline size data for bigeye and yellowfin for the area east of 180°W was submitted to IATTC with a spatial resolution 10° of latitude by 20° of longitude (10° x 20°) from 1965 to 2001, and with a 5° by 10° resolution after 2002. Size data with the finer spatial resolution (5° by 10°) was submitted before 2001 only for the area between 140 and 160°W, in order to establish consistency with the western border (150°W) of the IATTC Convention area.Before 2010, the size data in weight were converted into lengths before being submitted. After 2011 the weight based data have not been converted to lengths, but instead submitted with information on the measuring unit (weight or length). In addition, a comparison between databases was conducted, using size data in the IATTC database as of November 2015 and in the NRIFSF database as of August 2015.

All the size data for Japanese longline vessels in the IATTC database were length-based after 1965. The number of size data for bigeye and yellowfin in both databases was almost the same from 1965 to 1998 (Table A.1, Figure A.1). However, the number of size data in some strata (year and 10° x 20°) from 1985 to 1989 showed slight discrepancies for the two species. The discrepancy could result from an allocation error in year; *i.e.,* the size data for 1989 in the NRIFSF database were allocated to 1988 in the IATTC database (Table A.2).

From 1999 to 2010 there are large discrepancies in the number of size data for both species. In some strata (year and 10° by 20°), the number of size data in the IATTC database is larger than in the NRIFSF-DB. When the spatial resolution of the size data was changed from 10° x 20° to 5° x 10° in 2002, the methodology for compiling the size data at NRIFSF was also changed. A lack of size data for the area west of 150°W for certain years was observed, which is one of the reasons for the large discrepancy; however, this was not necessarily applicable for the the whole period (1999-2010). Around 2002, when the submitted spatial resolution changed, there may have been some trial and error in the method of compiling size data, which led to the lack of size data. In 2011 the computer program for compiling the data was changed again, and at that time the discrepancy in the number of size measurements between the two databases was very small. The slight discrepancies for both species after 2011 mainly resulted from the exclusion of the weight-based size data from the IATTC database.

TABLE A.1. Comparison between IATTC and NRIFSF data bases of the number of Japanese longline size data for bigeye and yellowfin. The total number of size data by year for IATTC is the number of spatial resolution with 10° of latitude by 20° of longitude (10 by 20) before 2001 and after that it is the number of spatial resolution with 5 by 10. The annual total number for NRIFSF is the sum of all spatial resolutions. Although the values of IATTC-DB show only in integer values, in some case the number of size data are registered with decimal points.

bigeye	IATTC (Total)	NRIFSF (Total)	IATTC (5 by 10)	IATTC (10 by 20)	NRIFSF (1 by 1, 5 by 5 and 5 by 10)	NRIFSF (10 by 20)
1950						
1951						
1952						
1953						
1954						
1955						
1956						
1957						
1958						
1959						
1960						
1961						
1962						
1963						
1964						
1965	74,596	74,600	14,655	74,596	52,789	21,811
1966	51,382	51,385	11,125	51,382	38,971	12,414
1967	52,150	52,153	8,612	52,150	40,028	12,125
1968	42,175	42,176	8,641	42,175	34,513	7,663
1969	54,791	54,800	18,431	54,791	43,232	11,568
1970	57,813	57,819	15,969	57,813	44,420	13,399
1971	97,861	97,873	23,163	97,861	60,365	37,508
1972	82,388	82,398	9,085	82,388	50,562	31,836
1973	57,069	57,075	7,255	57,069	36,205	20,870
1974	43,560	43,561	3,827	43,560	27,940	15,621
1975	39,792	39,793	1,857	39,792	26,381	13,412
1976	48,552	48,552	9,110	48,552	40,645	7,907
1977	65,260	65,264	15,308	65,260	53,982	11,282
1978	52,447	52,448	6,229	52,447	47,362	5,086
1979	56,559	56,559	2,781	56,559	52,698	3,861
1980	45,733	45,736	3,937	45,733	41,589	4,147
1981	39,284	39,285	2,000	39,284	37,090	2,195
1982	70,151	70,154	4,194	70,151	50,305	19,849
1983	83,378	83,382	8,147	83,378	64,112	19,270
1984	90,653	90,656	11,625	90,653	69,802	20,854
1985	106,375	103,623	15,408	106,375	86,149	17,474
1986	119,187	121,968	12,204	119,187	105,949	16,019
1987	140,244	139,503	16,448	140,244	128,282	11,221
1988	81,333	81,864	18,108	81,333	77,067	4,797
1989	76,326	76,573	17,209	76,326	75,599	974
1990	77,595	77,600	12,654	77,595	77,218	382
1991	111,261	111,279	14,449	111,261	111,279	
1992	97,198	97,203	20,059	97,198	97,203	
1993	76,940	76,942	19,635	76,940	76,942	
1994	83,859	83,864	18,550	83,859	83,864	
1995	82,028	82,040	15,935	82,028	82,040	
1996	93,017	93,021	29,850	93,017	93,021	
1997	86,283	86,312	25,256	86,283	86,312	
1998	99,087	99,093	35,722	99,087	99,093	
1999	66,482	66,488	26,029	66,482	66,488	
2000	30,570	59,080	6,418	30,570	59,080	
2001	63,401	63,402	13,146	63,401	63,402	
2002	60,234	72,659	60,234		72,659	
2003	38,111	53,411	38,111		53,408	3
2004	47,925	66,992	47,925		66,881	111
2005	49,112	45,243	49,112		45,243	
2006	30,374	42,369	30,374		42,361	8
2007	36,131	36,832	36,131		36,792	40
2008	29,446	29,277	29,446		29,277	
2009	26,762	26,846	26,762		26,762	84
2010	19,979	20,170	19,979		19,979	191
2011	15,681	15,991	15,681		15,991	
2012	18,751	18,733	18,751		18,733	
2013	14,042	14,042	14,042		14,042	

TABLE A.1. (continued; yellowfin)

yelloefin	IATTC (Total)	NRIFSF (Total)	IATTC (5 by 10)	IATTC (10 by 20)	NRIFSF (1 by 1, 5 by 5 and 5 by 10)	NRIFSF (10 by 20)
1950	0		0	0	190	0
1951	0		0	0	1,989	0
1952	0		0	0	6,525	0
1953	0		0	0	4,870	0
1954	0		0	0	5,582	0
1955	0		0	0	22,069	0
1956	0		0	0	10,319	0
1957	0		0	0	23,489	0
1958	0		0	0	41,066	0
1959	0		0	0	45,980	0
1960	0		0	0	38,981	0
1961	0		0	0	56,601	0
1962	0		0	0	35,859	0
1963	0		0	0	60,393	0
1964	0		0	0	94,577	0
1965	80,657	80,656	21,433	80,657	56,421	24,235
1966	34,569	34,569	6,758	34,569	30,130	4,439
1967	35,278	35,266	6,909	35,278	29,191	6,075
1968	41,029	41,029	9,008	41,029	33,994	7,035
1969	45,087	45,086	19,026	45,087	38,423	6,663
1970	68,298	68,296	20,684	68,298	58,799	9,497
1971	63,321	63,321	15,484	63,321	48,442	14,879
1972	74,921	74,921	11,744	74,921	54,865	20,056
1973	30,124	30,124	2,644	30,124	23,146	6,978
1974	20,290	20,290	1,225	20,290	14,976	5,314
1975	21,784	21,784	845	21,784	16,069	5,715
1976	35,000	35,000	6,546	35,000	31,477	3,523
1977	36,582	36,582	5,882	36,582	32,575	4,007
1978	31,361	31,361	4,511	31,361	28,785	2,576
1979	34,446	34,446	3,503	34,446	31,321	3,125
1980	26,698	26,698	2,751	26,698	23,784	2,914
1981	16,098	16,098	448	16,098	15,425	673
1982	41,282	41,282	2,031	41,282	30,757	10,525
1983	39,650	39,650	2,527	39,650	32,858	6,792
1984	44,057	44,057	3,667	44,057	36,826	7,231
1985	37,734	37,181	4,473	37,734	28,931	8,250
1986	50,406	50,689	7,123	50,406	42,783	7,906
1987	49,344	49,405	9,040	49,344	45,530	3,875
1988	44,005	44,070	5,636	44,005	42,167	1,903
1989	33,861	34,004	5,400	33,861	33,456	548
1990	36,031	36,031	5,766	36,031	35,939	92
1991	45,585	45,584	3,524	45,585	45,584	0
1992	26,207	26,207	3,442	26,207	26,207	0
1993	36,289	36,289	7,209	36,289	36,289	0
1994	32,188	32,188	1,172	32,188	32,188	0
1995	37,177	37,180	4,808	37,177	37,180	0
1996	31,875	31,875	5,171	31,875	31,875	0
1997	35,918	36,014	6,567	35,918	36,014	0
1998	27,971	27,971	4,865	27,971	27,971	0
1999	16,850	16,850	2,863	16,850	16,850	0
2000	16,452	19,125	1,516	16,452	19,125	0
2001	19,161	19,161	1,719	19,161	19,161	0
2002	12,941	14,157	12,941	0	14,157	0
2003	21,272	24,218	21,272	0	24,217	1
2004	16,111	15,569	16,111	0	15,557	12
2005	11,389	10,213	11,389	0	10,213	0
2006	5,546	9,093	5,546	0	9,093	0
2007	8,247	8,394	8,247	0	8,394	0
2008	10,495	10,349	10,495	0	10,349	0
2009	6,212	6,218	6,212	0	6,212	6
2010	3,559	3,585	3,559	0	3,559	26
2011	2,303	2,699	2,303	0	2,699	0
2012	4,012	4,013	4,012	0	4,013	0
2013	2,584	2,585	2,584	0	2,585	0

TABLE A.2. Bigeye: difference between IATTC and NRIFSF databases of annual number of size data by latitude and longitude with the spatial resolution 10° of latitude by 20° of longitude (10 by 20), 1985-1989. The value is the number of size data in NRIFSF minus those of IATTC. Cells with rectangle and shading presented similar number in subsequent years.

1985	180-160W	160-140W	140-120W	120-100W	100-80W	80-60W
40-30N	0	0	0	0	0	0
30-20N	0	0	0	0	0	0
20-10N	0	0	6	1	0	0
10-0N	0	0	-1,023	0	0	0
10-0S	2	1	3	0	1	0
20-10S	0	0	0	0	0	0
20-30S	-242	0	-562	0	0	0
30-40S	0	-932	0	0	0	0

1986	180-160W	160-140W	140-120W	120-100W	100-80W	80-60W
40-30N	0	0	0	0	0	0
30-20N	0	0	0	0	0	0
20-10N	0	0	2	4	0	0
10-0N	0	0	1,041	1	0	0
10-0S	0	3	3	0	2	0
20-10S	2	0	0	0	0	0
20-30S	242	0	562	0	0	0
30-40S	0	932	0	0	0	0

1987	180-160W	160-140W	140-120W	120-100W	100-80W	80-60W
40-30N	0	0	0	0	0	0
30-20N	0	0	0	0	0	0
20-10N	0	0	8	14	0	0
10-0N	0	0	-118	-436	0	0
10-0S	0	0	0	0	0	0
20-10S	-194	0	0	0	0	0
20-30S	0	0	0	0	0	0
30-40S	0	0	0	0	0	0

1988	180-160W	160-140W	140-120W	120-100W	100-80W	80-60W
40-30N	0	0	0	0	0	0
30-20N	0	0	0	0	0	0
20-10N	0	0	2	0	1	0
10-0N	0	1	126	444	0	0
10-0S	0	1	0	0	0	0
20-10S	199	1	0	0	0	0
20-30S	0	0	0	0	0	0
30-40S	0	-239	0	0	0	0

1989	180-160W	160-140W	140-120W	120-100W	100-80W	80-60W
40-30N	0	0	0	0	0	0
30-20N	0	0	0	0	0	0
20-10N	0	0	3	1	0	0
10-0N	0	0	4	0	0	0
10-0S	0	2	2	0	0	0
20-10S	0	0	0	0	0	0
20-30S	0	0	0	0	0	0
30-40S	0	239	0	0	0	0

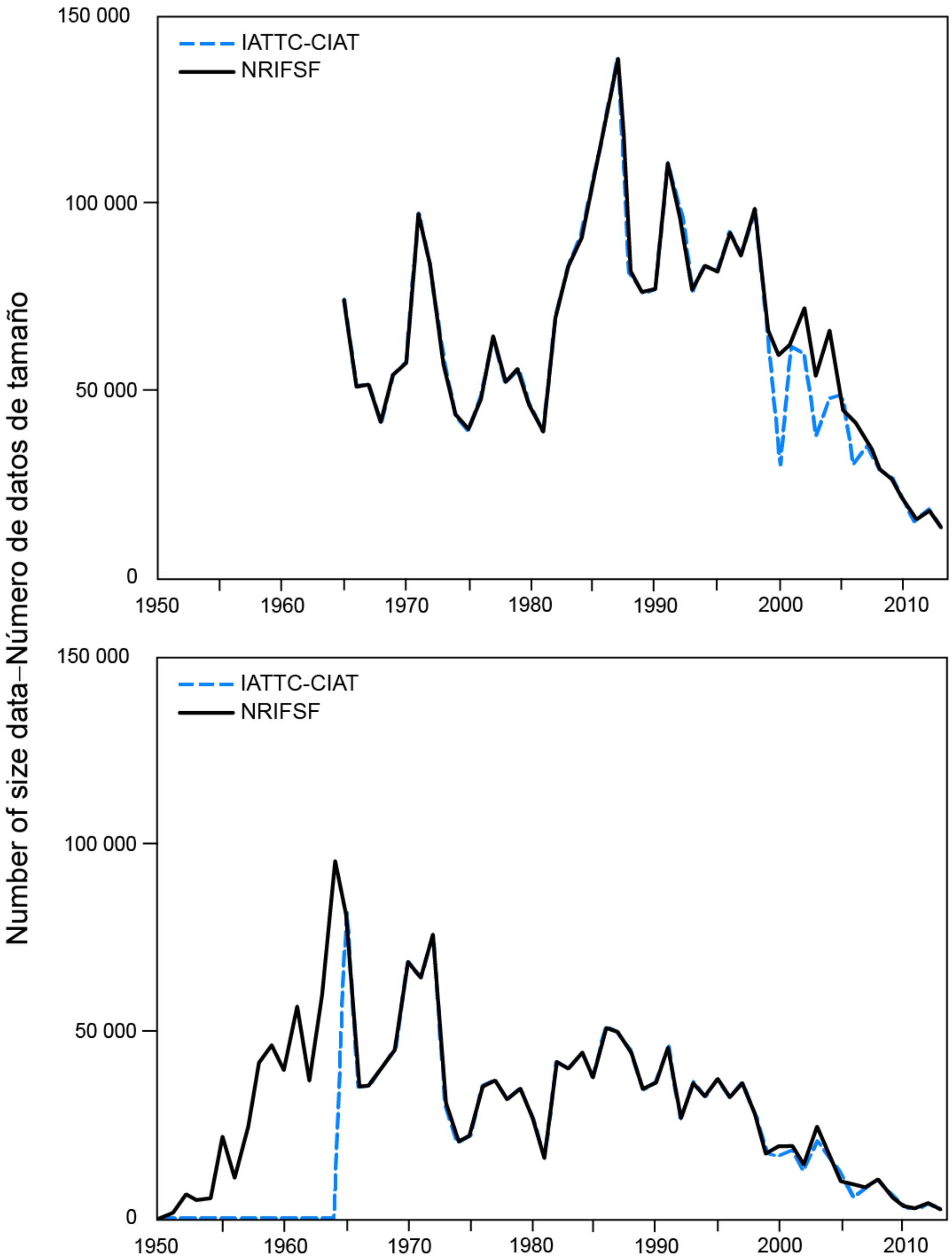

FIGURE A.1, Comparison of the number of Japanese longline size data for bigeye (upper panel) and yellowfin (lower panel) between the IATTC (dashed line) and NRIFSF (solid line) databases.

APPENDIX B

- ✓ The methodology for converting from weight-based data to length data for bigeye and yellowfin tuna caught by Japanese longline fisheries in the eastern Pacific Ocean is presented.
- ✓ A conversion table was prepared that included three columns, 1) weight (kg), 2) length (cm), and 3) proportion (percent). The following table is the example for bigeye caught north of 20°N.
- ✓ There are two types of conversion tables for bigeye, depending on latitude (north and south of 20°N). There is only one conversion table for yellowfin.
- ✓ The published reference for the conversions has not yet been found. Thus, relationship between fork length and gilled-and-gutted weight or round-weight is not certain. In addition, almost all length data in the NRIFSF database of tuna species is fork length, so the length in the conversion matrix is fork length.

TABLE B.1. Example of the conversion table for weight to length for bigeye caught north of 20°N.

If 100 bigeye of 2 kg body weight are caught, the number of fish for each converted length is 18, 20, 22, 24 and 6 for 41 cm, 43 cm, 45 cm, 47 cm and 49 cm, respectively.

sp	weight (kg)	length (cm)	proportion (%)
BET	1	39	100
BET	2	39	14
BET	2	41	18
BET	2	43	20
BET	2	45	22
BET	2	47	24
BET	2	49	2
BET	3	49	24
BET	3	51	28
BET	3	53	31
BET	3	55	17
BET	4	55	17
BET	4	57	36
BET	4	59	38
BET	4	61	9
BET	5	61	32
BET	5	63	44
BET	5	65	24
BET	6	65	22
BET	6	67	50
BET	6	69	28
BET	7	69	25
BET	7	71	56
BET	7	73	19