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COMPARISON OF TUNA LENGTH DATA COLLECTED BY OBSERVERS AND FISHERMEN FROM THE KOREAN LONGLINE FLEET

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The staff's work, including the new assessments of tropical tunas, has been severely disrupted and delayed by the coronavirus pandemic, and many documents for the meeting of the SAC are not yet finalized. However, it is important that the members of the SAC and observers be informed as soon as possible of the direction and extent of the work, and of the very substantial progress that has been made, so some of the most essential documents are being published in draft form, and may be modified after discussion at the virtual sessions of the Committee.

SUMMARY

Increases in the average length of the longline catches of bigeye and yellowfin tunas in the eastern Pacific Ocean (EPO) since about 2010, particularly for yellowfin tuna in recent years, and results from a study comparing fishermen and observer length data from longline fleets operating in the Indian Ocean, have prompted an analysis of fishermen and observer size composition data from longline fleets operating in the EPO. As part of this work, length measurements of bigeye and yellowfin tunas for 2004 - 2018 from logbooks of Korean vessels and from at-sea observers of the Korean national observer program were provided for analysis. Measurements made by fishermen were available in all years, but observer measurement data were only available in 2004, 2005, 2007 and 2013 - 2018. Graphical comparisons between the two sources of length data (fishermen, observers) were made for all years for which there were data from both sources. In addition, comparisons of the length data from the two sources for the most recent years were done using generalized additive mixed models to control for factors that are known to affect size composition, such as fishing location and sex. Results indicate that the length composition data provided by fishermen tend to contain proportionally more large fish, compared to the length data provided by observers, even after removing the effects on size composition of other factors. These results suggest that there are differences between size composition data provided by fishermen and those obtained from observers.

BACKGROUND

Increases in the average length of tropical tunas caught by high seas longline fleets has raised concern about the representativeness of length composition data provided by fishermen, as regards the total catch. A comparison of tuna fork length measurements provided by fishermen to length data collected by observers (IOTC 2019) indicates that the average of observer

[1] Postponed until a later date to be determined

measurements is smaller than the average of fishermen measurements in the Indian Ocean high seas longline fisheries of Taiwan and Seychelles. In addition, increases in average fish length have been observed in the eastern Pacific Ocean (EPO) longline catches of bigeye and yellowfin tunas from the Japanese longline fleet since about 2010 (SAC-11-05), particularly for yellowfin tuna in recent years (SAC-11-07), yet the reason for these increases are not known.

The above results have prompted an analysis of tuna length data collected by observers and fishermen aboard high seas longline vessels operating in the EPO. In this document we present a preliminary analysis of observer and fishermen measurements of fork length of bigeye tuna and yellowfin tuna caught by Korean longline vessels.

DATA AND METHODS

Data on individual fork length measurements (in cm) of bigeye tuna and yellowfin tuna were provided by the Korean national observer program (NOP) and by fishermen for 2004 - 2018. Other information provided to help explain variability in fork length measurements included the date and location (1° latitude and longitude) of fishing, species and sex, a vessel identifier and the source of the length measurements (observer, fishermen). A set identifier was not provided in the data, but was constructed from the vessel identifier, and the date and location of fishing, assuming only one set was made by a vessel in a day and 1° area. In some cases, fork length data were available for observers and fishermen from the same vessel, but not in the same set. Typically, fishermen measured a few fish per set, whereas observers measured as many fish as occurred in the first 70% of the haul (Lee et al. 2020, SAC-11 INF-K).

Several different types of data analyses were undertaken. First, a number of exploratory analyses of the data were done, including maps of the locations of the measurement data, histograms of measurements by year, and empirical cumulative distribution functions (ECDFs), all by year and data source, for each of the two species. Because several studies of variability in the size composition of bigeye and yellowfin tuna catches have found spatial effects to be important (e.g., Lennert-Cody et al. 2013), for those years with the best spatial coverage, comparison of the fork length measurements between observers and fishermen were more formally analyzed using generalized additive mixed-effect models (GAMMs).

The GAMM analysis was a two-step process. First, a GAMM with the following form was fitted to the fork length data from fishermen, by year and species, using the *gam* function of the *mgcv* package (Wood 2006) in R (R Core Team 2018):

fl ~ te(latitude, longitude, k=4) + month + sex + s(vessel, bs=”re”) + error

where “fl” refers to the fork length of an individual fish, “te” refers to a bivariate tensor product smoother, which allows for different smoothing parameters for latitude and longitude, and k is the basis dimension, fixed at a low number to reduce the wiggliness of the spatial surface. Month and sex were factors, and “s” refers to a smooth term for the vessel effect with a random effects basis (bs=“re”). Because the spatial coverage of the observer data, as well as the number of length measurements, were more limited, as compared to the fishermen measurement data, the above model was fitted to only the measurement data from fishermen. The model was fitted separately to the data for the whole EPO from 2015, 2017 and 2018 for bigeye, and 2017 and 2018 for yellowfin.

In the second step, to compare length measurements by source (observer, fishermen), the GAMM fitted to the length data from fishermen was used to predict the lengths of fish measured by observers, and the difference between actual observer measurements and predicted measurements was evaluated. Predictions were only done for those vessels for which there were both observer and fishermen data. The length data of a few vessels were only from observers and were not used in this analysis. Length residuals (observer actual - predicted from fishermen GAMM) were summarized by vessel, using box-and-whisker plots. If observers and fishermen measured in the same way and measured the same component of the catch, we would expect these residuals to be close to zero, assuming the GAMM adequately removes effects of other factors on fork length.

The form of the GAMM above was selected based on exploratory analyses. Initially models were fitted that include data from both sources, and included a "set" effect (as a random effect). However, these models did not converge, seemingly because estimation of a set effect was problematic, given the other covariates in the model. In addition, initially separate spatial surfaces were fitted to the data by source, but sparsity of the observer data in space and time made fitting such models problematic, especially when "month" was included in the model. Models were also fitted with the data source as a fixed effect only, and while this fixed effect was significant (p-value < 0.05), it was decided that fitting only to the data from fishermen and then predicting fork length for the data from observers was a better approach.

To further evaluate the difference between observer and fishermen fork length measurements, a simulation was conducted. The simulation had the following steps: 1) for those vessels represented in the data by measurements made by observers and by fishermen, the data source of the measurements was permuted, keeping the relationship between length and the other covariates unchanged; 2) the GAMM was refit to the "fishermen" data, including those fishermen data of vessels without observer measurements; 3) the fork lengths of the "observer" data were predicted; and 4) the mean residual was computed. This process was repeated 999 times, and the results summarized with histograms of the simulated mean residual values and their relation to the actual mean residual value.

RESULTS

Fishermen length measurements were available in every year, however, observer length measurements were only available in years 2004, 2005, 2007 and 2013 - 2018 (Figures 1 – 3). For the observer measurement data, the largest sample sizes, and the best spatial coverage of the EPO, occurred in 2016 - 2018. However, there were few measurements by fishermen in 2016. For both tuna species, the annual histograms of fork length by source (observers, fishermen) (Figures 2 – 3) and the ECDFs (Figures 4 – 5) suggest that the observer measurement data contain a larger proportion of small fish, compared to the fishermen measurement data.

The GAMM results and the simulation results (Figures 6 – 9) also indicate that, even after accounting for the effects of covariates such as fishing location, month and sex, the observer measurement data contain a larger proportion of small fish. Simple model diagnostic plots are shown in Figures 6 - 7 for 2017; the patterns in the diagnostic plots for other years were generally similar and are not shown. In all five comparisons, the mean of all of the residuals was negative, and there was a tendency for the residuals of many vessels to be skewed towards negative values; however, the median residual for some vessels was close to zero or positive (Figure 8).

An example of the simulation results is shown in Figure 9 for 2017. This figure shows the distribution of the 999 mean residuals obtained from analysis of the 999 simulated data sets, by species, and indicates that the actual mean residual is more negative that all 999 simulated mean residuals; similar results were obtained for the simulations that used data from other years and are not shown.

DISCUSSION AND CONCLUSION

Because the length data from observers and fishermen come from different sets, a more in-depth comparison would include an analysis of the gear characteristics of the different sets to evaluate the possibility of gear effects as an explanation for the differences in size composition. This was not possible in this preliminary analysis but could be undertaken in the future.

There are several possible explanations for the differences in observer and fishermen length measurements. The differences in the length measurements by source may arise because of differences in the way in which the measurement data were collected. This could be investigated by conducting a study whereby fishermen and observers measure exactly the same fish and their measurements compared. The differences might arise because fishermen may non-randomly select fish to be measured from the same catch as is measured by the observers. This might be investigated by conducting interviews with fishermen. Finally, differences could arise because observers and fishermen measure different components of the catch; observers measure all fish in approximately the first 70% of the haul, but fishermen may only measure fish from the retained catch. Discarding does occur but the discard rate is estimated to be low (Lee et al. 2020). These hypotheses for the cause of the difference in measurement data are not mutually exclusive.

The conclusion from this analysis of length composition data collected by fishermen and observers aboard Korean longline vessels is that there are size composition differences between the two sources, with the measurements made by observers including a higher proportion of small fish. This finding is consistent with the results of Lee et al. (2020).

FUTURE RESEARCH

The potential influence of the difference in length data by source on the stock assessments will be evaluated for both yellowfin and bigeye tuna in the future.

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FIGURE 1. Map of locations at which fork length data were available (yellowfin and bigeye, combined), by year and source (NOP (blue diamonds): observers from the national observer program; LB (red x's): fishermen, recorded in logbooks).

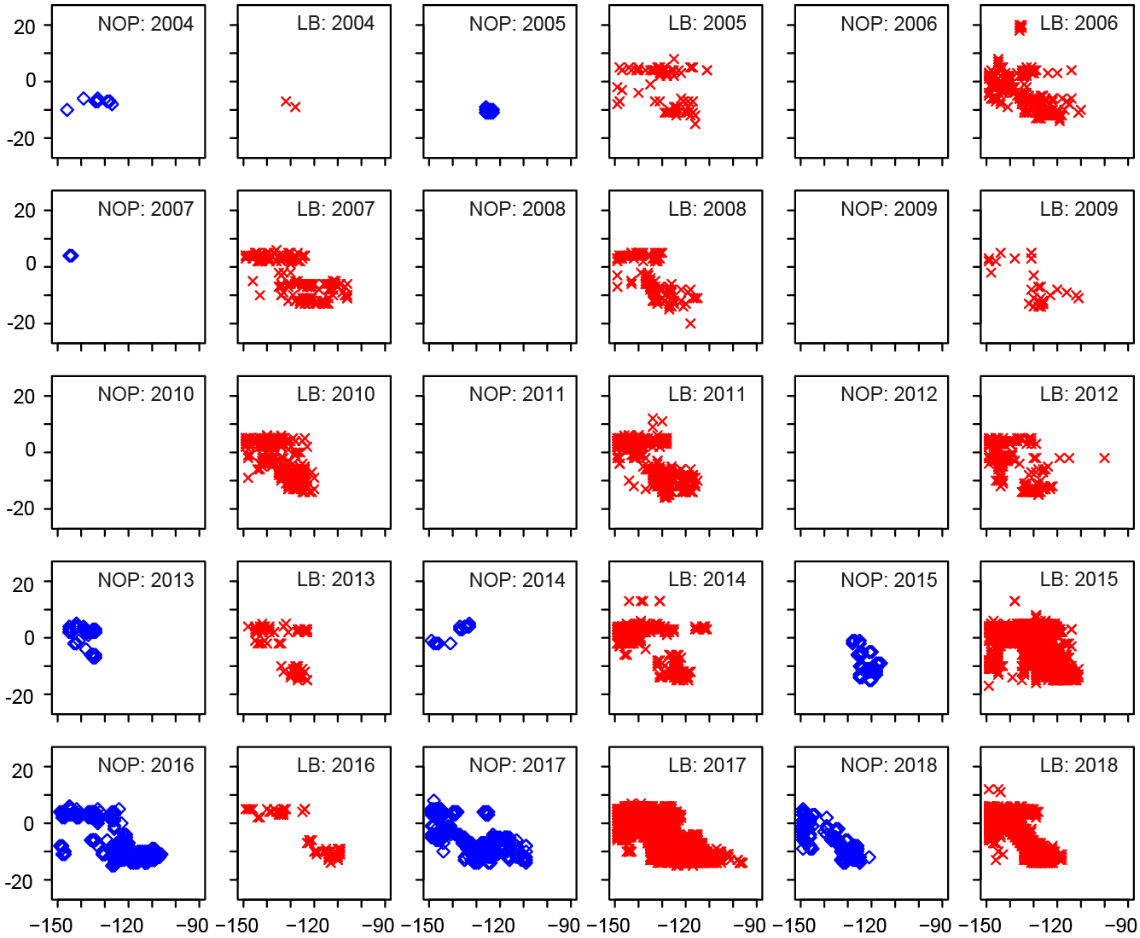

FIGURE 2. Frequency distributions of yellowfin tuna fork length (FL) (proportion of fish in 5 cm intervals), by year and data source (NOP: observers; LB: fishermen) for those years that had measurements from both sources (see Figure 1).

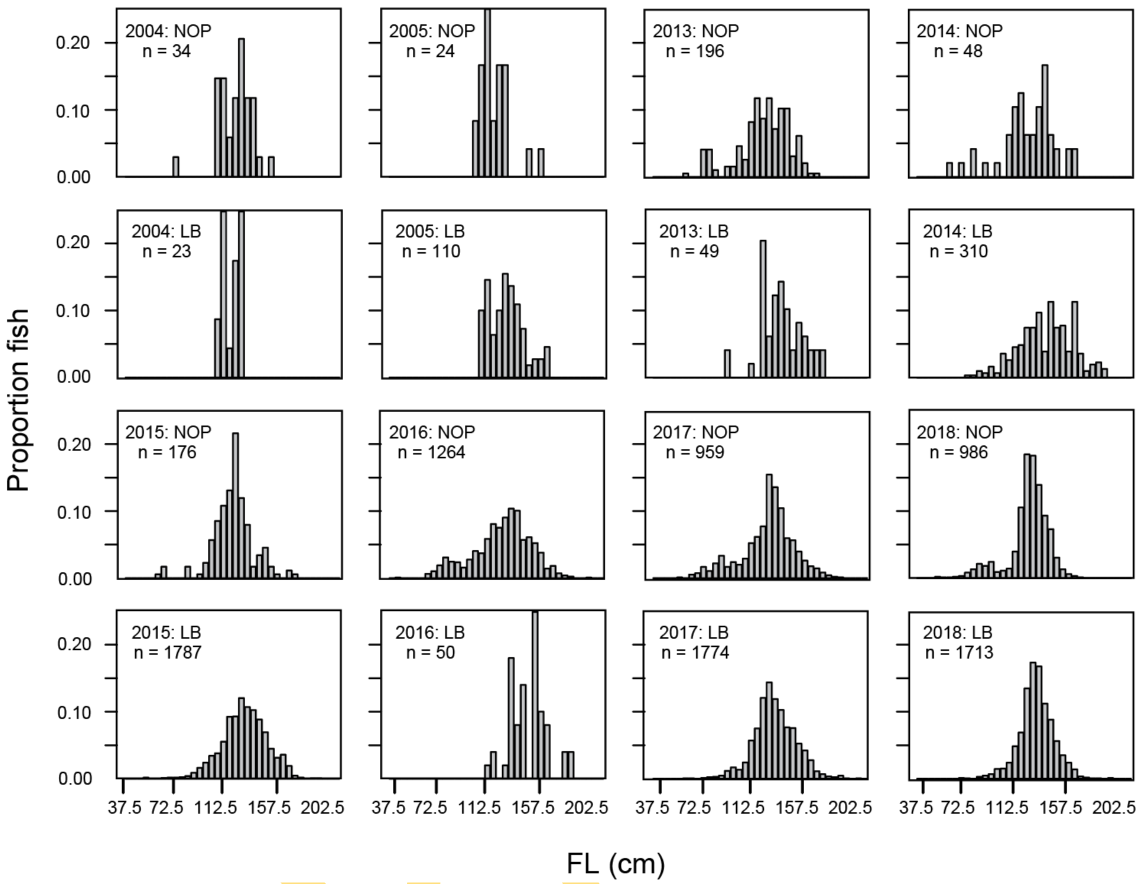

FIGURE 3. Frequency distributions for bigeye tuna fork length (FL) (proportion of fish in 5 cm intervals), by year and data source (NOP: observers; LB: fishermen), for those years that had measurements from both sources (see Figure 1).

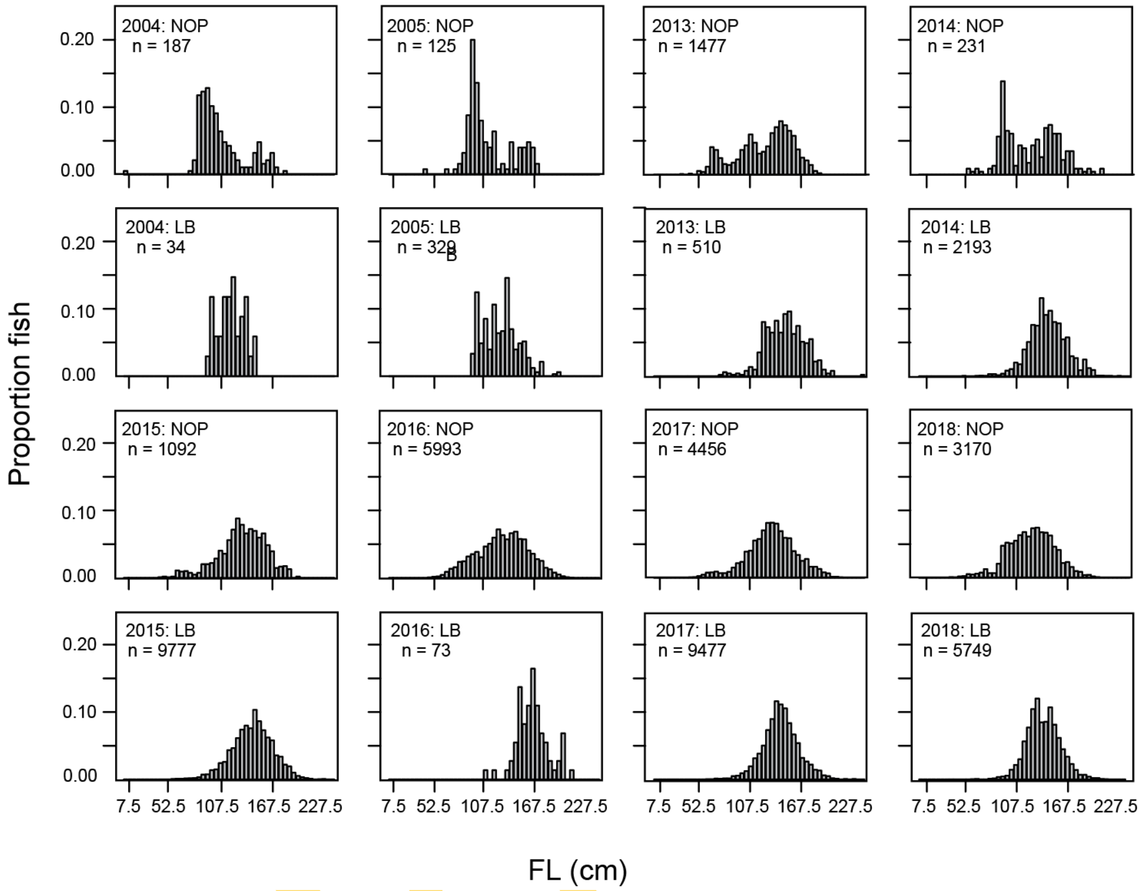

FIGURE 4. Empirical cumulative distribution functions for yellowfin tuna fork length (FL), by year and data source (NOP: observers; LB: fishermen) for those years that had measurements from both sources (see Figure 1).

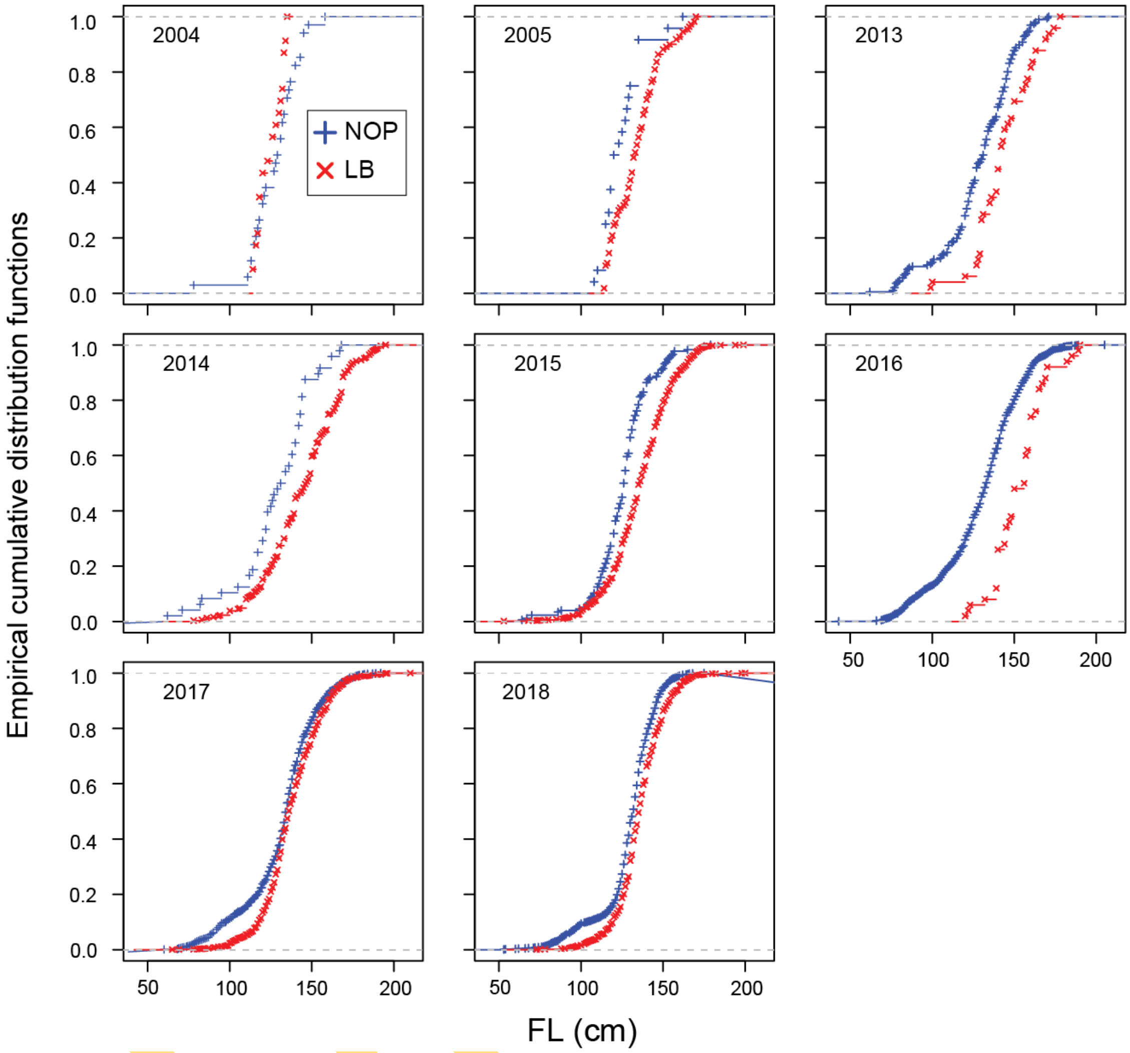

FIGURE 5. Empirical cumulative distribution functions for bigeye tuna fork length (FL), by year and data source (NOP: observers; LB: fishermen) for those years that had measurements from both sources (see Figure 1).

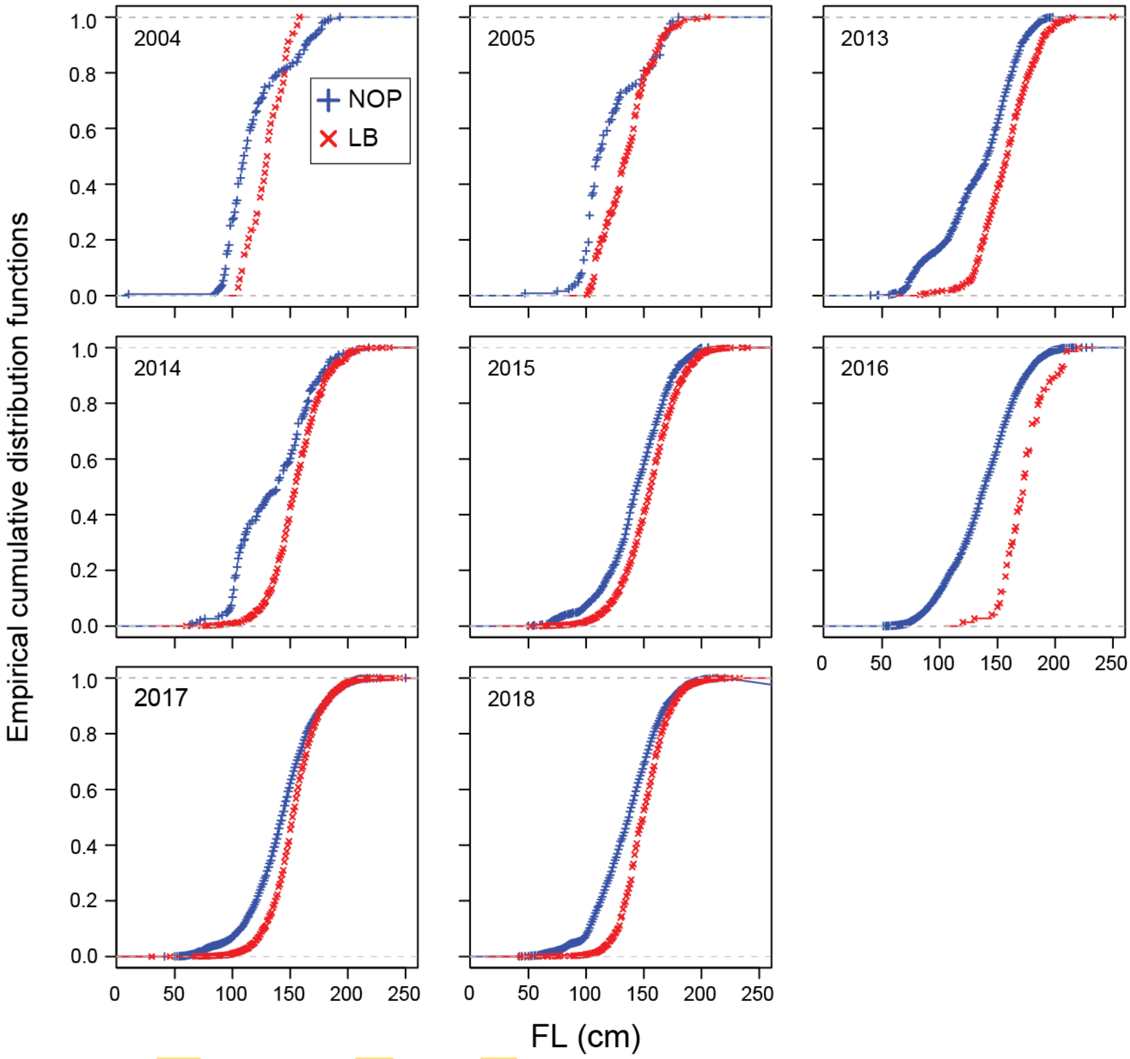

FIGURE 6. Diagnostic plots provided by the mgcv function gam.check for the 2017 GAMM for bigeye tuna fork length.

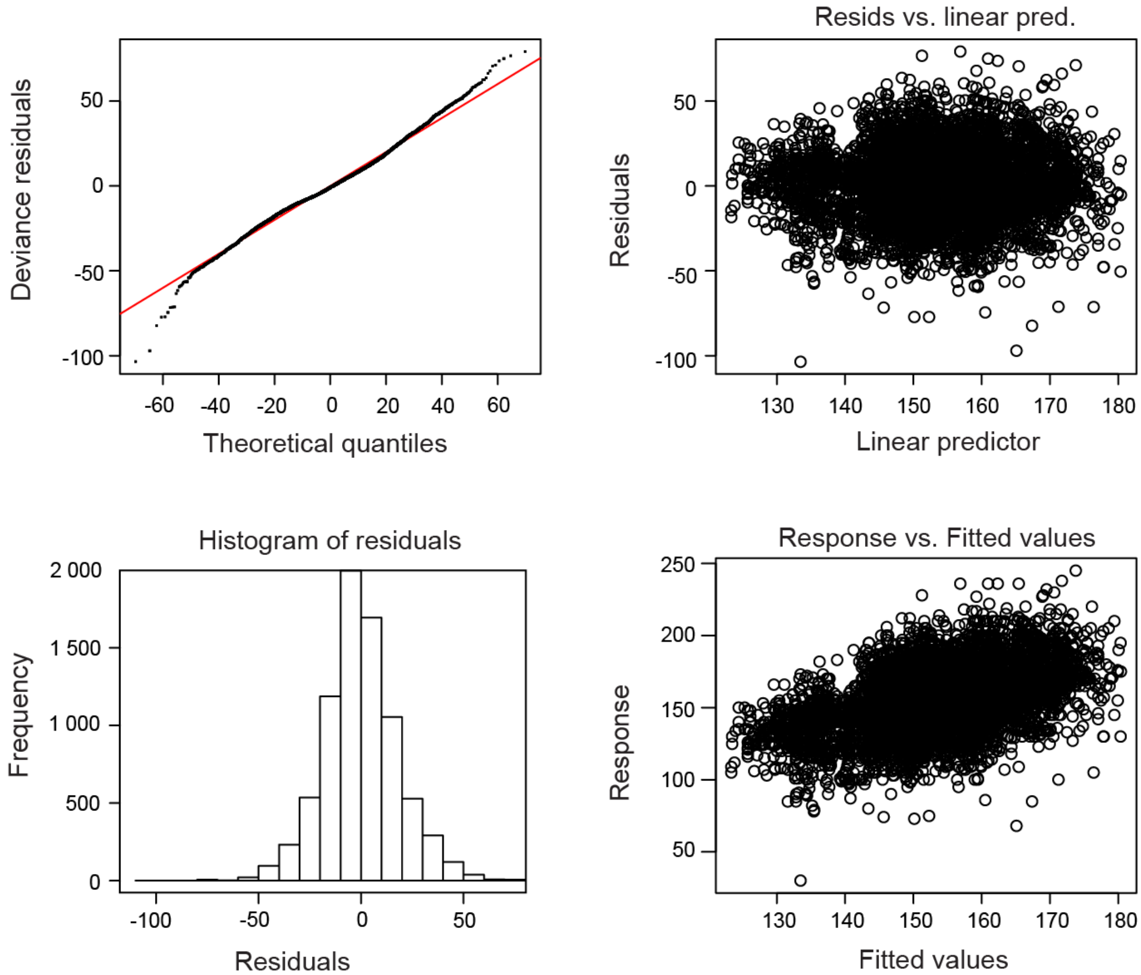

FIGURE 7. Diagnostics plots provided by the mgcv function gam.check for the 2017 GAMM for yellowfin tuna fork length.

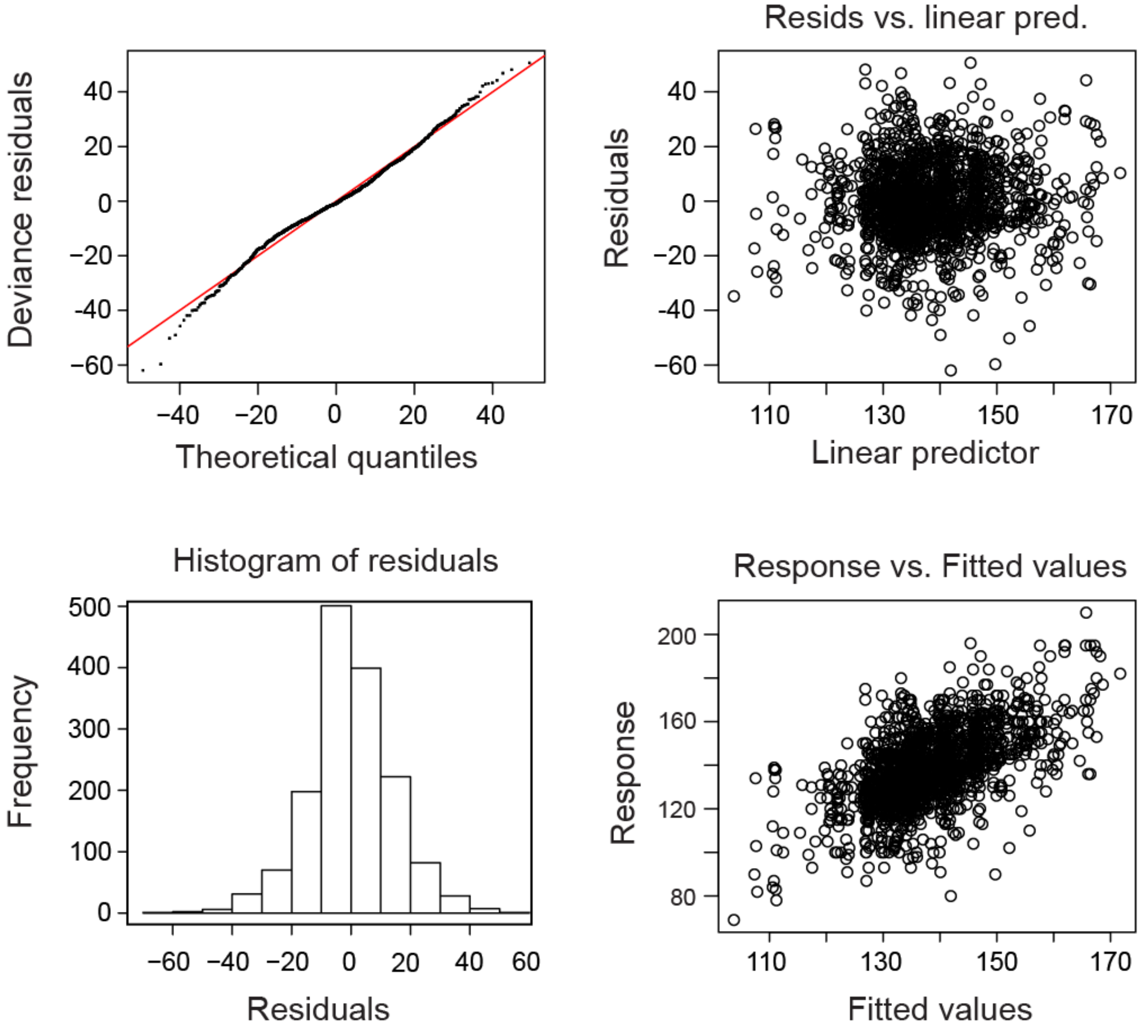

FIGURE 8. Box-and-whisker plots of fork length residuals (cm), by vessel, for those vessels for which fork length data were available for both sources (observers, fishermen), for bigeye tuna (BET; left panels) and yellowfin tuna (YFT; right panels), for years with the largest sample sizes for both sources (see Figures 2 - 3 for the number of measurements per source by year for each species). Blue dashed lines show the mean of the residuals (across vessels) for the year and species. Red dashed lines indicated a residual value of zero.

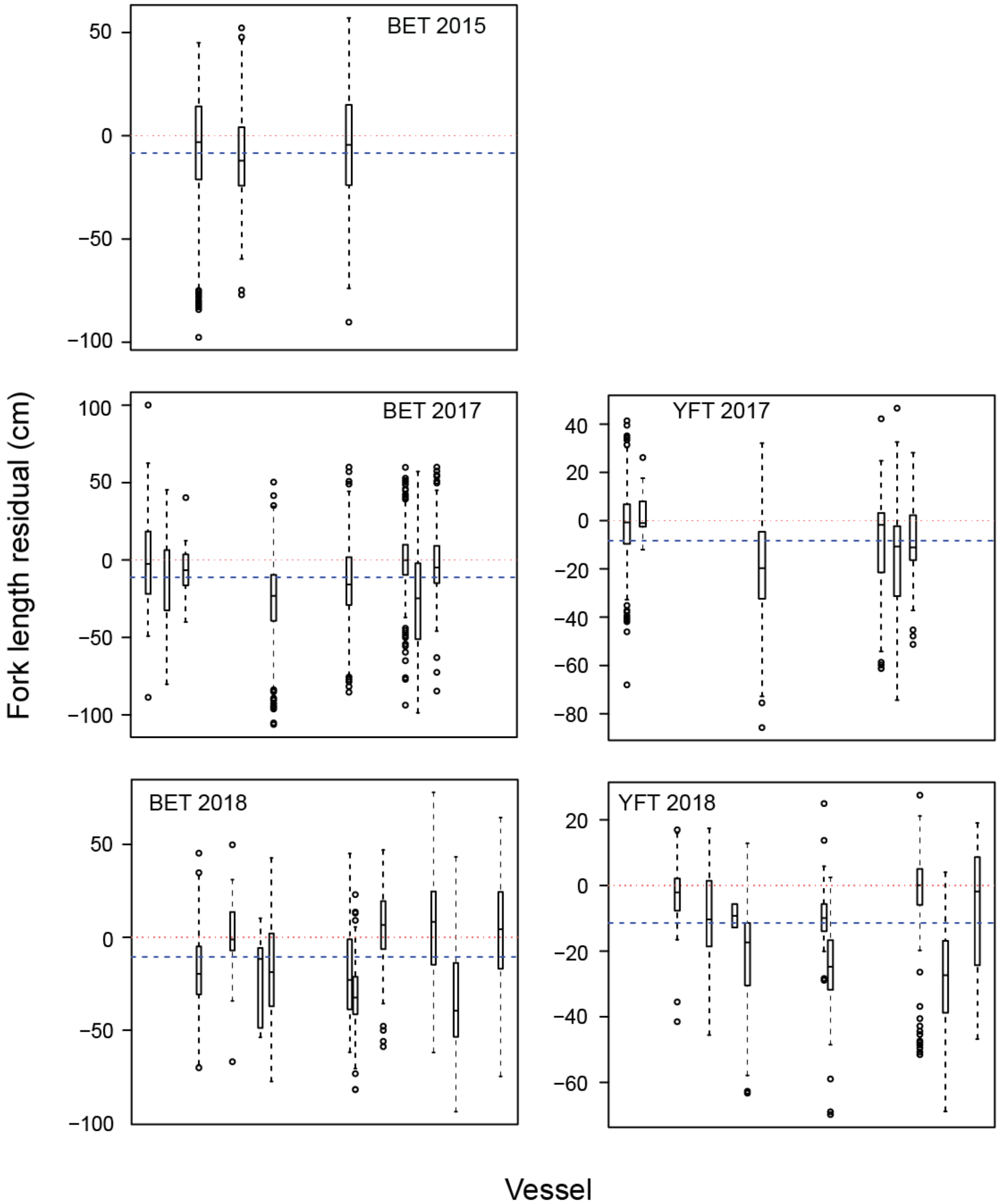

FIGURE 9. Frequency distributions of the 999 mean residuals from analysis of the 999 simulated data sets for 2017, bigeye tuna (BET; top panel) and yellowfin tuna (YFT; bottom panel). Red dashed lines show the value of the actual mean residuals for each species. For each species, the value that corresponds to the red dashed line is outside the range of values that corresponds to the frequency distribution of mean residuals obtained from the simulation.