Size composition for blue marlin *Makaira nigricans* in the Hawaii-based pelagic longline fishery, 1994-2014

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Abstract

This working paper presents size composition data for blue marlin *Makaira nigricans* in the Hawaii-based pelagic longline fishery in 1994–2014 using data from the Pacific Islands Regional Observer Program (PIROP) and in support of the stock assessment update for blue marlin by the ISC Billfish Working Group (BILLWG). Blue marlin eye to fork lengths (EFL; in cm) by region, quarter, and fishery sector are summarized. The shallow-set sector of the fishery occurred more northerly and caught larger blue marlin (mean of 176.9 cm) than the deep-set sector (mean of 165.3 cm), yet the Hawaii-based longline fishery is treated as one fleet in the stock assessment. Mean sizes by year show an increasing trend of blue marlin length since 2000, with a peak in 2013 of 180.9 cm across both sectors. Length frequencies were similar across quarters, although lengths in quarter 1 had a smaller range since 2007 and were not as numerous as in other quarters. Size frequency distributions used for the update assessment were similar to those used for the benchmark assessment using data from 1994-2011.

Introduction

A stock assessment update for striped marlin *Kajikia audax* was recently completed (ISC 2015) under the auspices of the ISC Billfish Working Group (BILLWG). Blue marlin *Makaira nigricans* is the next species scheduled for a BILLWG stock assessment, which will update the previous benchmark assessment (ISC 2013). The results presented herein are intended as input for the stock assessment update.

This working paper (WP) presents compilations of size composition data in 1994-2014 for blue marlin in the Hawaii-based pelagic longline fishery. The presentation of data in this WP follows the presentation of data used for the previous stock assessment (Walsh et al. 2013) for 1995-2011, but in addition to the recent updated years (2012-2014) also includes 1994, which was used in the previous stock assessment. In light of recommendations from the BILLWG

during the past assessment cycle, comparisons of current size composition data with size composition data used in the previous benchmark are provided so as to better understand potential differences in model results. Along with this WP, companion WPs on catch (Chang et al. 2016), and CPUE standardizations (Carvalho et al. 2016) will provide the BILLWG a comprehensive understanding of the updated data from the Hawaii-based longline fishery on blue marlin.

Methods

Data used for this WP were collected by fishery observers of the Pacific Islands Regional Observer Program (PRIOP). Blue marlin size data (eye to fork length in cm; EFL) were compiled from PRIOP measurements in 1994-2014. A total of 9457 records were available.

Two sectors operate within the Hawaii-based longline fishery; a deep-set sector that targets bigeye-tuna and a shallow-set sector that targets swordfish. The PRIOP database includes target species for each record of blue marlin, and although bigeye tuna and swordfish were the majority, other species were also stated as the target. Each sector is defined in regulation based on the number of hooks per float (HKPFL), with the shallow-set sector defined as HKPFL<15, and the deep-set sector defined as HKPFL>=15. Hooks per float was used to distinguish among sectors for this WP.

The spatial location of measurements was reported in the PRIOP database, and each was separated into one of eight regions. Regions were defined as Region 1 = 0–10°N, east of 160°W; Region 2 = 0–10°N, west of 160°W; Region 3 = 10–20°N, east of 160°W; Region 4 = 10–20°N, west of 160°W; Region 5 = 20–30°N, east of 160°W; Region 6 = 20–30°N, west of 160°W; Region 7 = above 30°N, east of 160°W; and Region 8 = above 30°N, west of 160°W. Regional definitions were inclusive of northern and eastern boundaries. The calendar quarter (quarter 1 = January – March, quarter 2 = April – June; quarter 3 = July – September; quarter 4 = October – December) was also reported. We present tabulations of the number of records and mean EFL by region and quarter for each sector, the mean EFL by year as well as the size frequency distributions across years for both sectors combined and for each sector separately, and bubble plots of length to graphically show the size frequency distributions across years by quarter. Eight measurements did not have an associated longitude value, so only 9449 records were used for tabulations of numbers and mean EFLs by region and quarter. Other analyses were not reliant on spatial location and so included all 9457 records.

The benchmark stock assessment used 5 cm length bins from 80-320 cm (left inclusive) for estimating size compositions for the Hawaii-based longline fishery. Six measurements were <80 cm so were assigned to the 80 cm length bin as would be automatically done in the stock assessment model (Methot 2013), and one measurement (350 cm) extended beyond the range of previous measurements, so was included in the 320 cm length bin. The observed size composition from the data in this WP was compared to the observed size composition by season for the benchmark assessment. Given that the same database was used, size compositions in 1994-2011 for the two assessments were expected to be identical.

The graphical output in this WP was produced using the R package **knitr** (Xie 2013) using

the markdown syntax. **knitr** calls the application **Pandoc** (MacFarlane 2014) to write the WP in the PDF format.

Results

Length measurements were summarized by fishery sector for each region and calendar quarter they occurred (Table 1 and 2). The two sectors differed in expanse; there were no records in Regions 1 and 2 for the shallow set sector and few records in Regions 7 and 8 for both sectors. The sectors also differed in sample size, with fewer measurements in the shallow-set sector. Besides these differences, blue marlin in the shallow-set sector were larger than in the deep-set sector, blue marlin in Regions 5 and 7 were larger than in other regions on average, and blue marlin were typically larger in quarters 2 and 3.

The temporal pattern of mean length by fishery sector was similar to that from the benchmark assessment and continues the generally increasing trend of blue marlin average length (Figure 1). Lengths were recorded in the shallow set sector of the fishery in 2002-2003 despite that sector being closed because sets were targeting bigeye tuna and the distinction between sectors based on HKPFL was not yet established (R. Ito, Personal Communication). For the updated years (2012-2014), mean overall length in the fishery declined slightly from 173.3 cm in 2011 to 172.5 cm in 2012, increased to an all-time high of 180.9 in 2013, and then declined in 2014 to 174.1 cm. A similar pattern was observed in the shallow-set sector only, but the change in lengths for each of the updated years was larger, and length increased in 2014 from 2013. Sample sizes were comparable during 2010-2014 in the shallow-set sector so differences in lengths between years were not due to differences in sample size.

Length frequency means and distributions for this update assessment were also similar to frequencies from the benchmark assessment. When averaged across 1994-2014, the mean EFL was 176.9 cm for the shallow-set sector and 165.3 cm for the deep-set sector (Figure 2). Mean EFL across both sectors was 167.1 cm (Figure 3).

Size frequency distributions were similar over time for all quarters (Figure 4). Only a few differences across years and quarters were present. More lengths were measured in the early- to mid-2000s than in other years, and fewer measurements were made in quarter 1 than in other quarters. The range of lengths since 2007 was smaller in quarter 1 than in other quarters, possibly as a consequence of smaller sample size. Lastly, quarters 1 and 4 had a greater number of smaller fish than did other quarters, particularly between 2000 and 2006, yet the lack of smaller (<130 cm) fish after 2006 did not cause the increasing size trend observed in Figure 1.

There were very slight differences in the sample size, mean, and CV of length measurements between the update and benchmark assessment data in common years (1994-2011) (Appendix A). The largest difference in sample size (8 fewer records in the update) occurred in 2004. The largest difference in mean occurred in 2006, quarter 4: 157.17 cm in the update and 158.19 cm in the benchmark. Some quarters (2006, quarters 1 and 2) had the same sample size, but different mean and CV.

Discussion

The data presented in this WP showed similar trends to length data used for the benchmark assessment, with only small differences. We believe the data in this WP represents the best available information on blue marlin length from the Hawaii-based longline fishery, and recommend the data be used for the update assessment.

Table 1: Summary of blue marlin *Makaira nigricans* eye-fork length (EFL) measurements from the Hawaii-based longline fishery taken by PIROP observers in 1994-2014 for the deep-set fishery sector. Results are presented as the mean length (cm), standard deviation, and sample size (N) sorted by regions, and calendar quarters. See text for fishing region, quarter, and fishery sector definitions. Results are based on the 9450 of 9457 records that had location information.

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Region 1	177.8 ± 38.4 (17)	167.9 ± 36.6 (16)	168.7 ± 26.4 (30)	160.2 ± 17.7 (40)
Region 2	158.2 ± 25.1 (137)	172.5 ± 28.3 (119)	161.3 ± 21.8 (276)	159.0 ± 17.9 (143)
Region 3	156.4 ± 30.0 (211)	165.3 ± 21.9 (334)	168.4 ± 21.8 (333)	159.8 ± 32 (237)
Region 4	160.0 ± 22.7 (675)	164.5 ± 18.9 (1854)	166.5 ± 21.6 (653)	158.4 ± 25.3 (629)
Region 5	156.9 ± 37.1 (83)	190.3 ± 36.6 (115)	185.1 ± 39.5 (417)	168.0 ± 42.1 (528)
Region 6	155.5 ± 30.0 (150)	175.4 ± 27.1 (272)	177.2 ± 36.0 (117)	156.8 ± 32.8 (481)
Region 7	NA	290.5 ± 33.9 (2)	195.9 ± 38.8 (67)	161.0 (1)
Region 8	NA	195.5 ± 12.7 (6)	175.9 ± 38.9 (39)	144.7 ± 28.7 (22)

Table 2: Summary of blue marlin *Makaira nigricans* eye-fork length (EFL) measurements from the Hawaii-based longline fishery taken by PIROP observers in 1994-2014 for the shallow-set fishery sector. Results are presented as the mean length (cm), standard deviation, and sample size (N) sorted by regions, and calendar quarters. See text for fishing region, quarter, and fishery sector definitions. Results are based on the 9450 of 9457 records that had location information.

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Region 1	NA	NA	NA	NA
Region 2	NA	NA	NA	NA
Region 3	175.0 ± 12.2 (6)	183.6 ± 21.6 (23)	172.0 ± 19.8 (176)	173.4 ± 28.8 (9)
Region 4	NA	166.6 ± 21.5 (8)	167.2 ± 23.3 (134)	166.4 ± 18.7 (40)
Region 5	168 ± 27.2 (11)	188.4 ± 28.8 (149)	179.6 ± 25.5 (60)	169.7 ± 36.5 (91)
Region 6	181.0 ± 26.1 (10)	179.8 ± 28.1 (503)	175.1 ± 23.3 (111)	193.5 ± 25.0 (13)
Region 7	166.8 ± 17.5 (22)	226.5 ± 84.1 (2)	169.7 ± 59.9 (3)	168.2 ± 10.5 (16)
Region 8	168.5 ± 19.4 (11)	174.4 ± 17 (7)	180.7 ± 49.5 (36)	200.2 ± 27.9 (4)

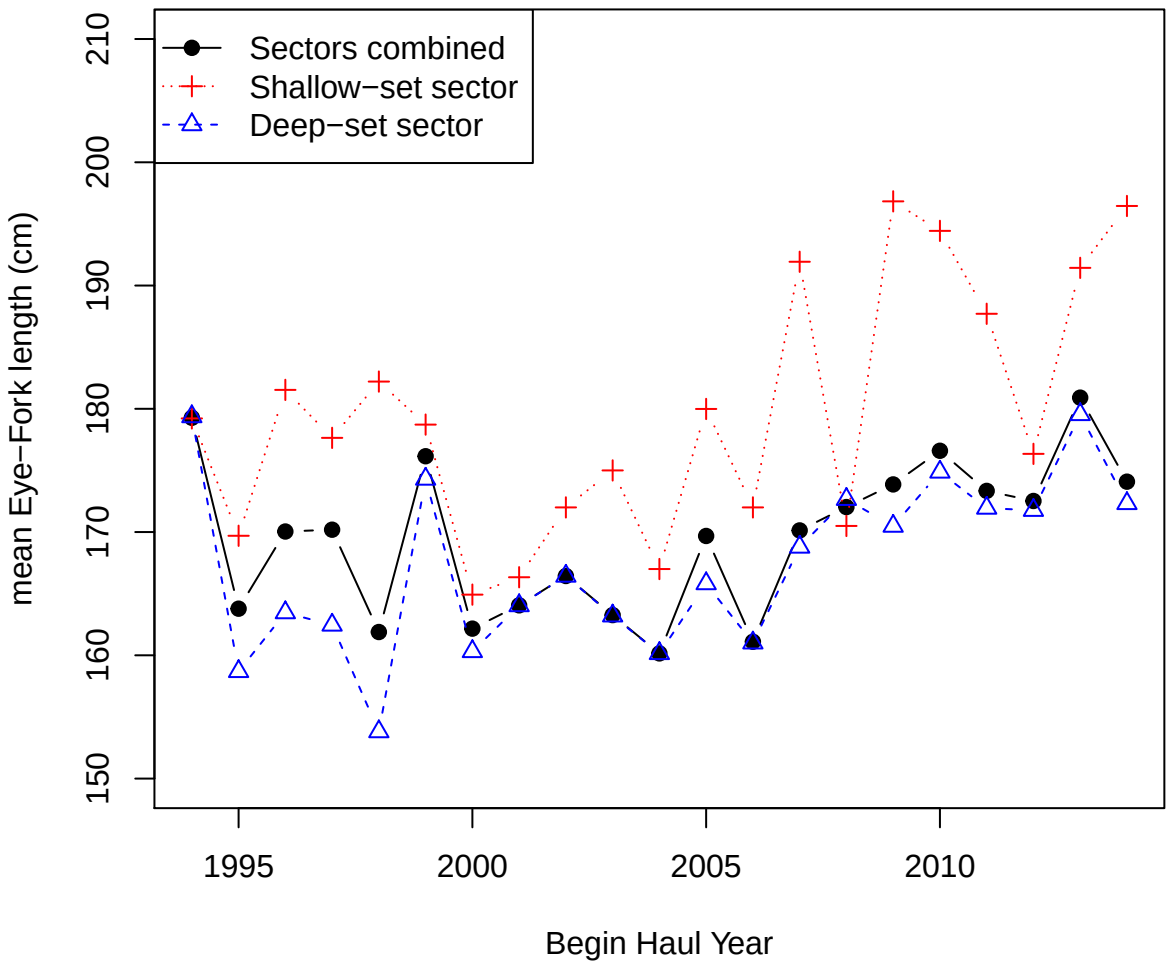
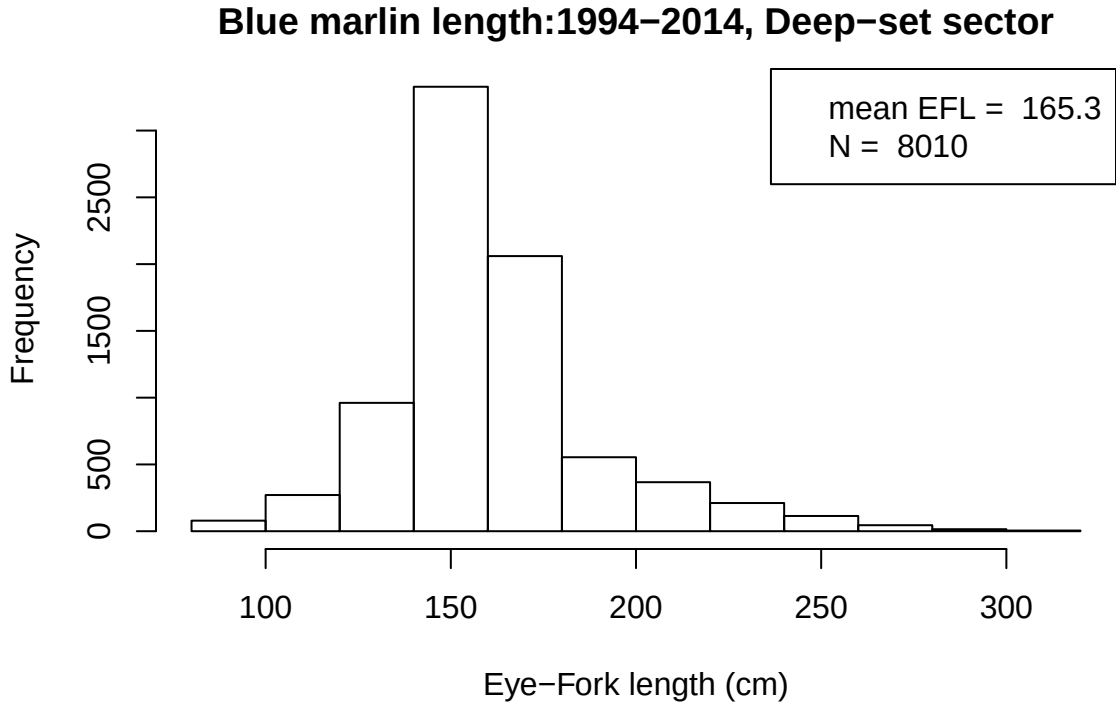


Figure 1: Annual mean blue marlin *Makaira nigricans* eye-fork lengths from 1994-2014 for the deep-set and shallow-set sector of the Hawaii-based longline fishery pooled and individually. See text for fishery sector definitions.



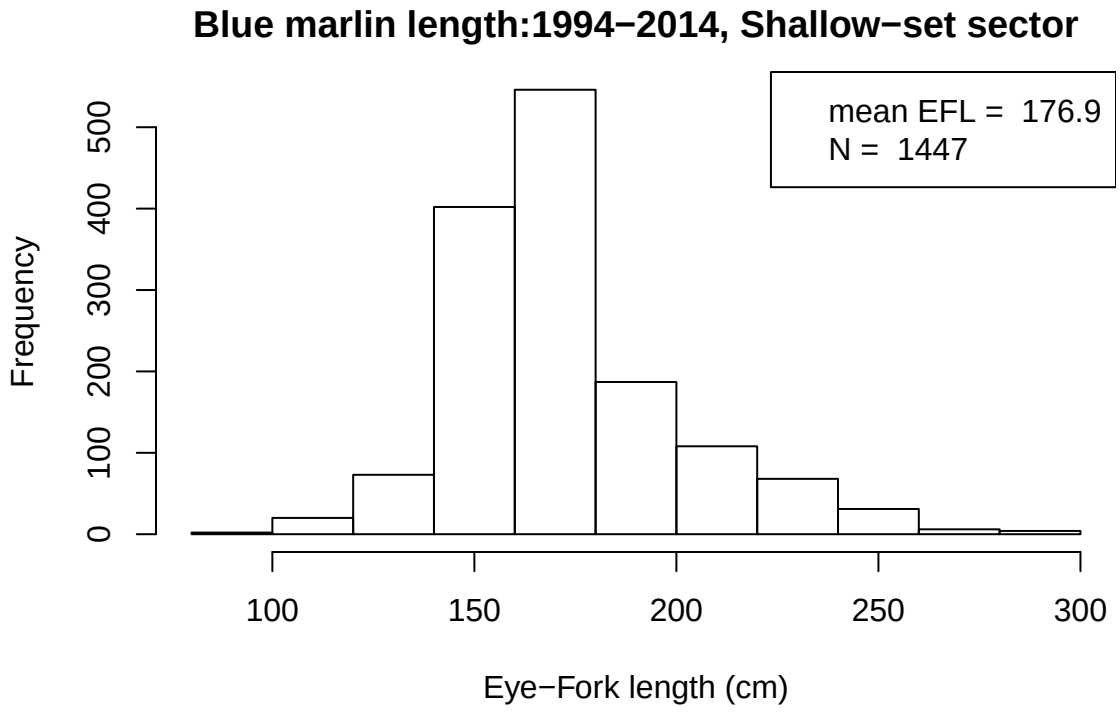


Figure 2: Length frequency distributions of blue marlin *Makaira nigricans* eye-fork lengths measured by fishery observers in 1994-2014 for the deep-set and shallow-set sector of the Hawaii-based longline fishery. See text for fishery sector definitions.

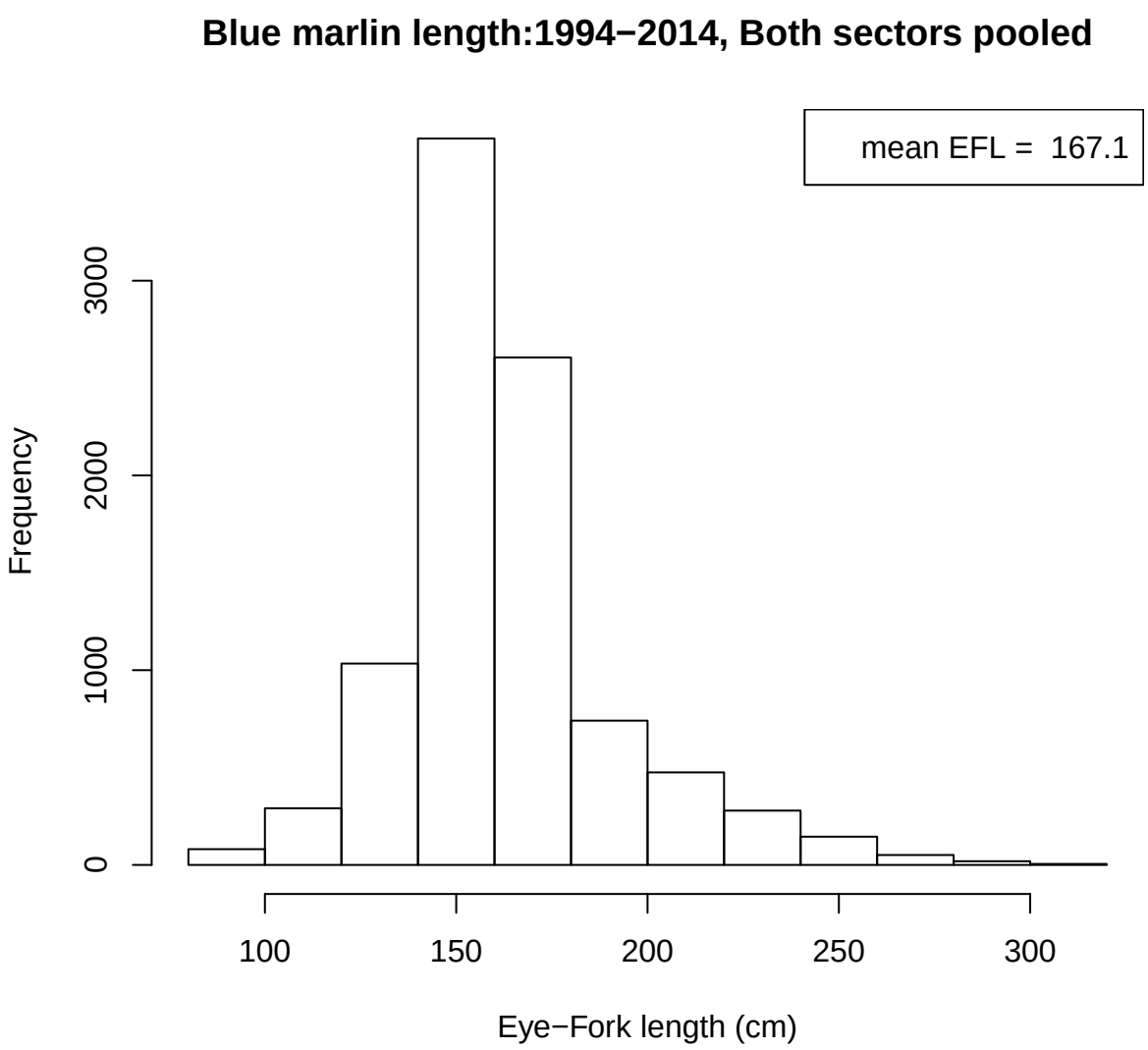


Figure 3: Length frequency distribution of blue marlin *Makaira nigricans* eye-fork lengths measured by fishery observers in 1994-2014 pooled across both sectors of the Hawaii-based longline fishery.

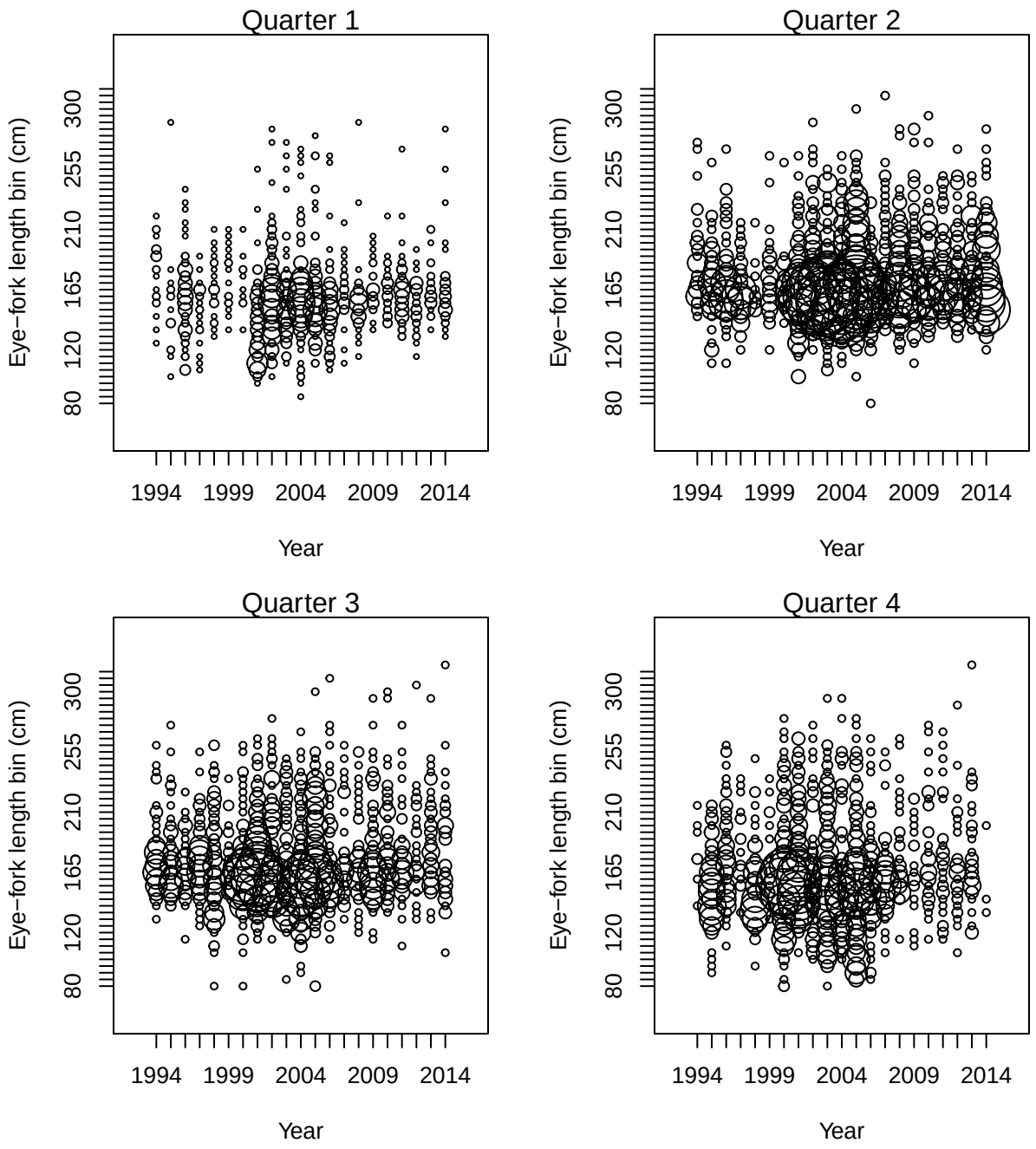


Figure 4: Length frequency plots of measurements of blue marlin *Makaira nigricans* by PRIOP observers of the Hawaii-based longline fishery in 1994-2014 for each calendar quarter. The size of the bubbles is proportional to the number of records in each bin-year combination and is comparable across plots.

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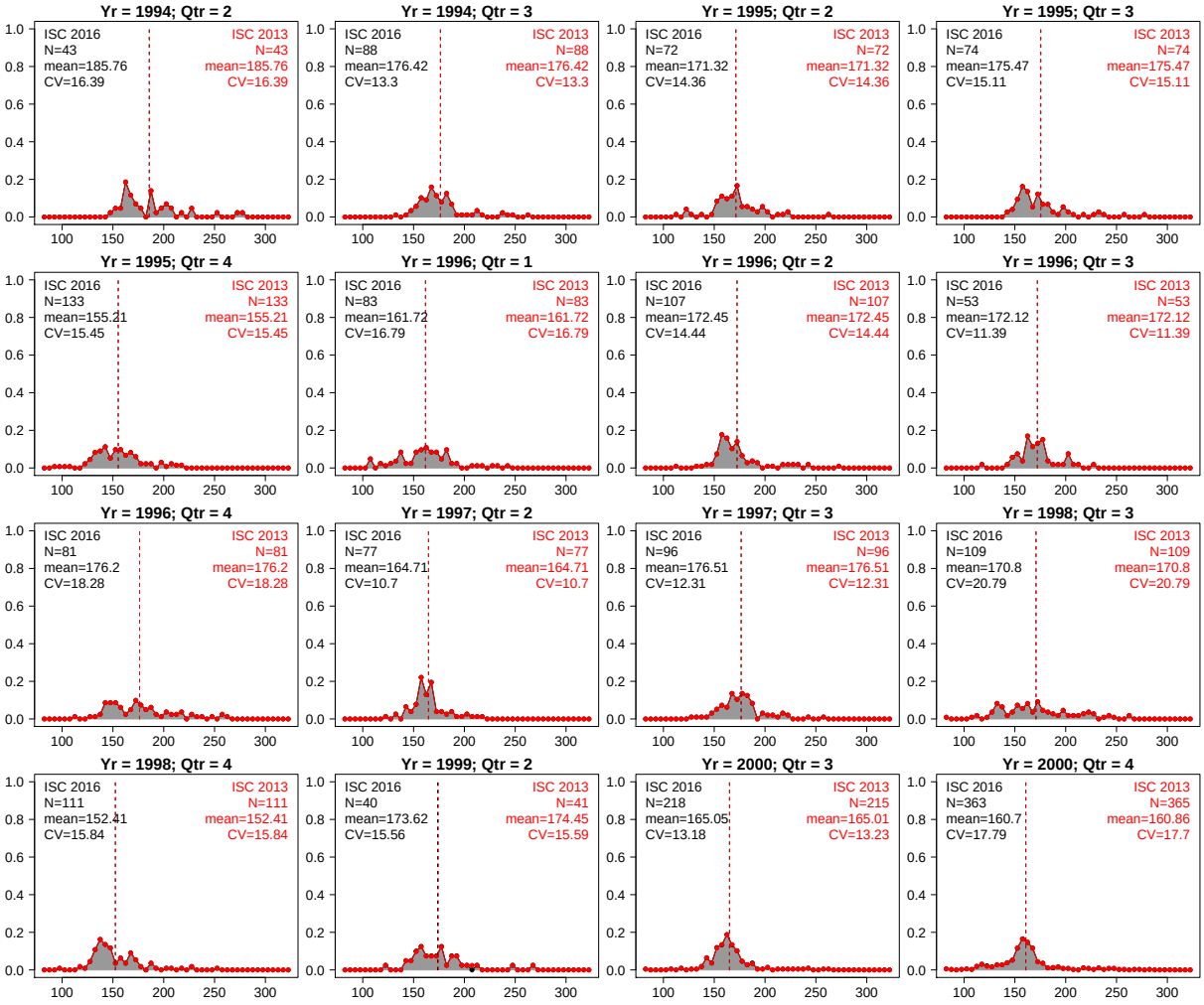
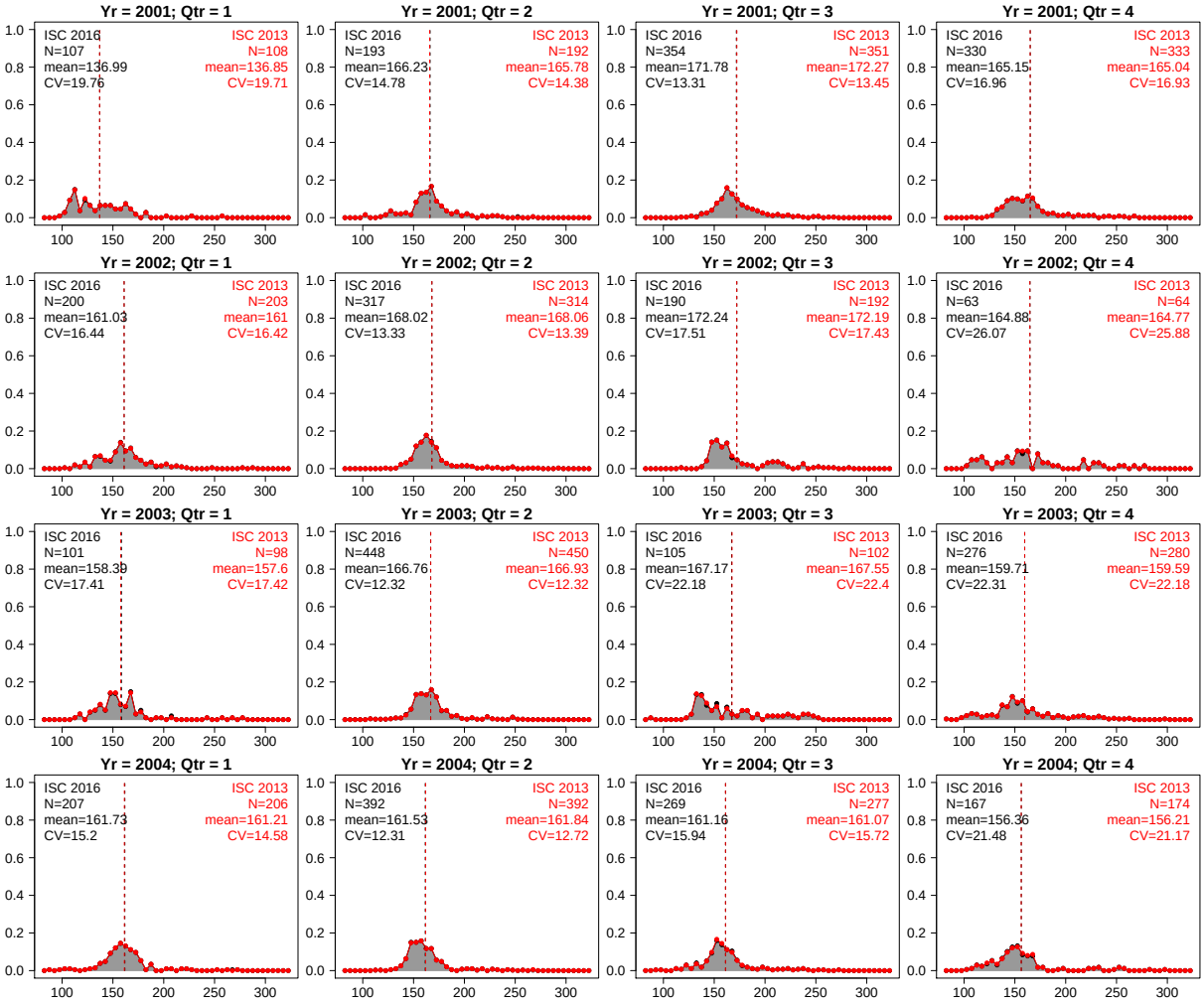
Appendix A

Figure A1: The proportion of blue marlin *Makaira nigricans* caught in the Hawaii-based longline fishery by year and quarter within 5-cm eye-fork length (EFL) bins. Years shown are strictly those that overlap between the benchmark (red) and update (black) assessments. For each year-quarter combination, sample size (N), mean length, and the coefficient of variation (CV) are presented. The y-axis is the proportion. The x-axis is the EFL length bins (cm). See text for definition of quarters.

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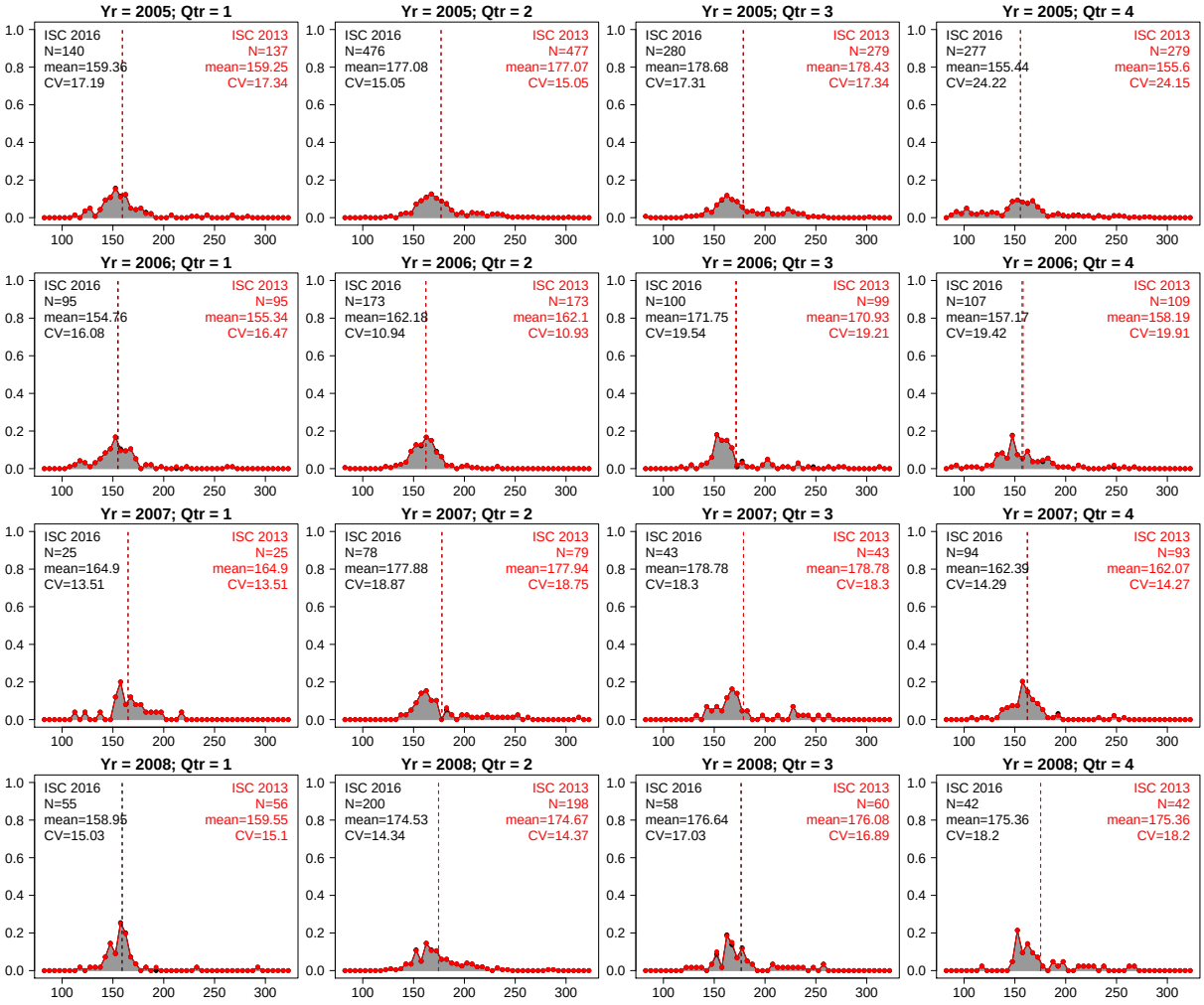
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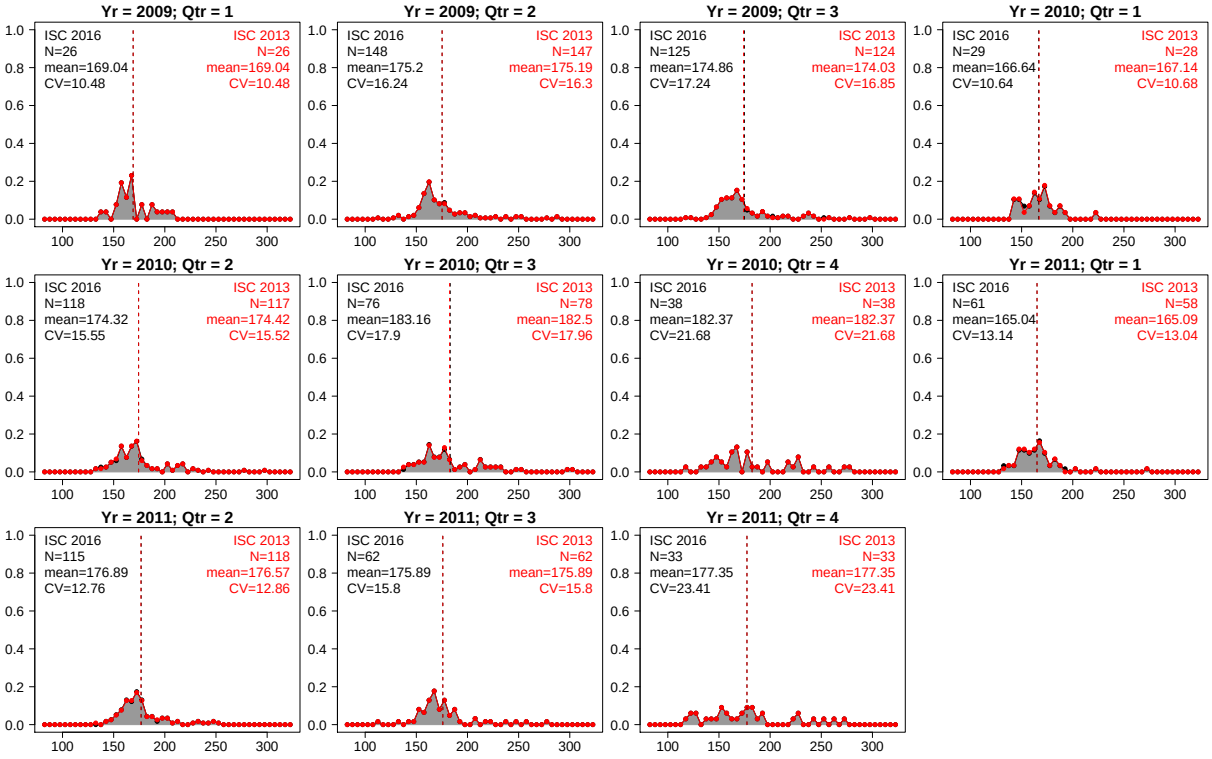
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