INTER-AMERICAN TROPICAL TUNA COMMISSION

2nd REVIEW OF THE STOCK ASSESSMENT OF BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN

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SUMMARY OF PURSE-SEINE DATA AVAILABLE FOR BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN

CONTENTS

The information provided below has been taken from a number of IATTC documents (see the reference list). Because the catch of bigeye tuna by baitboats is very small in comparison to the catches of purse-seine vessels (and longline vessels), this document focuses on a description of data available for the purse-seine fleet.

1. DATA SOURCES

Data for bigeye tuna are obtained from various sources, including vessel logbooks, observer records, unloading records provided by canners and other processors, and the port-sampling program.

1.1. Canner and processor data

Total landings by species for each vessel trip are obtained from canners and processors. These data are not always received immediately after the conclusion of a fishing trip, and in some instances may not be received at all.

1.2. Vessel logbooks

Specially prepared logbooks with spaces for the information of interest to the fishermen and to the IATTC staff are distributed to the fishermen. These logbooks remain on the vessels; at the end of each trip abstracts of the pertinent information are made for retention and analysis by the staff. The information of prime interest to the staff is, for each day, the location of the vessel, whether it was fishing, the times of initiation and completion of each set and the types of sets by the purse seiners, and the catches of each species. Usable logbook data are obtained for about 80 to 90 percent of the total catch. The data for the years prior to the initiation of the IATTC's logbook system in the early 1950s were obtained from logbooks for previous years kept by the fishermen and made available to the staff.

1.3. Observer data

Observers of the IATTC and national observer programs have been placed aboard the international fleet of Class-6 (≥ 364 t) tuna purse-seiners since 1979 for the purpose of gathering data on marine mammal bycatch. These observers have also gathered data on target catch and discards, which, since 1993, have been recorded by weight category: ≤ 2.5 kg, 2.5-15 kg, and > 15 kg. In addition, Daily Activity Records kept by observers provide detailed information on the positions of the vessels and times spent searching and setting. The sampling coverage of the Class-6 international fleet has increased from less than 30 percent prior to 1986 to at or nearly 100 percent since 1992 (Joseph 1994). The data collected by observers are edited by field office staff members, as well as by computer programs, and then archived in computer data bases. Prior to 1979, observer data were only collected for the United States fleet by the U.S. National Marine Fisheries Service.

Until very recently observers were placed on small purse-seine vessels (IATTC Classes 1-5; < 364 t) only under certain limited circumstances (Román *et al*. 2017). In recent years, the number of small-vessel trips that carried an observer has increased (in 2016 the coverage was roughly 12% of trips), However, no formal sampling protocol for the EPO small-vessel fleet exists, and the increase in overall sampling coverage is the result of specific fleet segments carrying observers on a large fraction of their trips.

1.4. Port-sampling data

The port-sampling data are collected following a stratified two-stage sampling protocol (Tomlinson, 2002; Suter, 2010). Vessel wells are the primary sampling unit within a stratum, with unequal numbers of wells sampled per stratum. Fish within a well are the secondary sampling unit. Sampling at both stages is largely opportunistic with the exception that wells are sampled only if all the catch within the well came from the same stratum (strata defined below). Analysis of data from recent years has shown that this restriction can result in a predominance of large-catch sets that are sampled (Lennert-Cody and Tomlinson 2010). More than one well may be sampled per vessel if the catch of other wells comes from different strata. However, typically only one or two wells per trip are sampled. About 50%-60% of trips of large purse-seine vessels and 10-20% of trips of small purse-seine vessels have typically been sampled by the port-sampling program per year, leading to a total of over 800 wells sampled in most years (IATTC 2010a; Vogel, 2014). However, the sampling coverage in terms of percentage of the catch is considerably lower. Sampling strata are defined by the fish-carrying capacity of the vessel (< 364t and ≥ 364t), the date and area of fishing (12 months and 13 areas; Figure 1) and the type of purse-seine set (sets on dolphin-associated tunas; sets on floating-object-associated tunas; sets on unassociated schools of tunas). The sampling areas were optimized for yellowfin prior to the development of the fishery on fish-aggregating devices (FADs), and have remained the same. Since 2000, the 5° area, in addition to the sampling area, was recorded for almost all samples (Lennert-Cody *et al*. 2012). Prior to 2000, the 5° area has been recovered for many samples.

Prior to 2000, the port-sampling program focused on collection of length composition data. The length-composition sampling of bigeye started in 1975. For a well of a trip that met the sampling criteria (i.e., all catch in the well from the same month, area and set type), ideally 50 fish of each species in the catch were measured.

Beginning in 2000, the port-sampling protocol was revised to include sampling for species composition, as well as for length composition. Details of the sampling instructions given to port samplers since 2000 can be found in the Appendix of Suter (2010). Sampling is done in "blocks" so as to extend the sampling over the unloading as much as logistically practical (Wild 1994). The number of blocks depends on the number of species that are anticipated to be in the catch for the particular well to be sampled, as indicated from observer or logbook data for the vessel trip. For each block, the sampler counts, independently from measuring, a number of fish of each species, where the number counted ranges from 50 fish (one species in the catch) to up to 200 fish, depending on the set type and number of species expected. Additionally, the sampler removes 25 fish of each species and measures the fork length to the nearest millimeter. Blocks of counts and measurements are repeated, depending on the set type and number of species believed to be in the well. Ideally, once sampling is finished, a total of 100 or more fish will have been counted for species composition and 50 fish of each species will have been measured.

For both the pre-2000 and recent time periods, in some ports, the catch may have been sorted by species and size category as the fish are unloaded, prior to their being accessible to port samplers. Because of the location of ports where this practice is common, this practice primarily affects yellowfin tuna and skipjack tunas. During these "sorted" unloadings, measurements and possibly counts are done, depending on how the catch is sorted (by species, by size category, or by species and size category).

1.5. At-sea weekly reports

IATTC Resolution C-03-04 requires that all purse-seine vessels that carry observers provide at-sea weekly reports on the date, set type, catch of bigeye (and skipjack and yellowfin), and the 5˚x 5˚ grid location for each set. These weekly reports are made by the observers to the IATTC staff. These at-sea reports have been collected since 2001.

2. CATCH

Catch is estimated for each sampling stratum separately. Catches for coarser strata are estimated as the sum of the results for all of the appropriate strata together (e.g., for spatial stratum groupings see Figure 2).

Prior to 2000, estimates of the EPO total bigeye catch by purse-seine vessels are based principally on data from unloadings. If unloading information is unavailable, the observer records or vessel logbooks are used (in that order). Because the recording of species composition has been shown to be inaccurate, the total catch of bigeye is adjusted based on average ratios by species computed from the 2000-2004 estimates. This has tended to increase the estimated catches of bigeye and decrease those of yellowfin and/or skipjack. Because the unloadings data do not contain information on location or date (other than year) of fishing, the estimated EPO catch of bigeye is prorated to sampling areas, months, set types and vessel size categories based on estimates of the proportion of species catch in each stratum obtained from logbook and observer data.

Beginning in 2000, the port-sampling data were used to determine the species composition of the catch. The total catch of all three tropical tuna species combined, by stratum, is obtained by prorating the combined EPO three-species catch from unloadings and observer and logbook data to strata, using the logbook and observer data information on fishing locations, dates, set types and vessel size categories. The species composition from the port-sampling data is then used to estimate the catch of bigeye per stratum, based on the species composition and size of the catch in sampled wells. This is done by raising the sample data for each well to the total well catch, and then raising the estimated well catches to the stratum total. The reported total catch in weight of all three species in a well and the reported catch in weight of all three species in a stratum are assumed to be correct.

The estimate of total bigeye catch in a well is complicated because the total catch in a well is recorded in weight, but the species composition sampling is in numbers of fish and the average weight differs among species. For unloadings that were not first sorted by species and size, the counts of fish by species in the well are used to estimate the proportional species composition in a well with respect to number of fish. This is then adjusted by the average weight of fish in a well from the length-frequency sampling to get the proportional species composition in a well with respect to weight of fish. The proportional species composition in a well with respect to weight of fish is then used to convert the reported total well weight to total well weight by species. The length-weight relationships used to convert individual lengths to weights are shown in Table 1. For samples obtained from unloadings that were first sorted by species and size, the well-level catch totals by species are estimated as the sum of the weight of each of the sorts (the percentage of the total well weight that corresponds to each sort, is assumed known).

The total catch of a species in a stratum is based on raising the well-level estimates of species catch. First, the proportional species composition, by weight, in a stratum is estimated by summing the estimated total catch over all sampled wells for each species separately and dividing by total catch of all three species in weight of all sampled wells. The reported total strata catch in weight is then multiplied by the strata proportional species composition by weight to get the total catch by species for the stratum.

Expressed in terms of equations, from Tomlinson (2002, 2004), for a given stratum, the estimate of the total catch in weight of species *i* (assuming the sampled unloadings were not species and/or size sorted) is given by:

$$\widehat{W_i} = W\left(\frac{\sum_j^q W_j\left(\frac{\left(\frac{w_{ij}}{m_{ij}}\right)\left(\frac{n_{ij}}{n_{.j}}\right)}{\sum_i^s\left(\frac{w_{ij}}{m_{ij}}\right)\left(\frac{n_{ij}}{n_{.j}}\right)}\right)}{\sum_j^q W_j}\right)$$

where W is the total weight of fish of all three species landed in the stratum (assumed known), W_j is the total weight of fish of all three species in the j^{th} well (assumed known), w_{ij} and m_{ij} are the weight and number of fish of species *i* measured from well *j*, respectively, n_{ij} and n_j are the number of fish of species *i* recorded in the count from well *j* and the number of fish counted from well *j*, respectively, *q* is the number of wells sampled and *s* is the number of species.

Because logistical constraints prohibit sampling of catch of some vessels, and therefore of some strata, there are strata with catch but for which there are no port-sampling data. In such cases, data from other strata (i.e., other areas and/or gears and/or months) are used to represent the strata without samples. On average, annually for 2000-2010, approximately 20% of the total landed catch was associated with sampling strata for which there were no port-sampling data (Lennert-Cody *et al*. 2011).

2.1. Use in the assessment

To conduct the stock assessment of bigeye tuna, the spatial stratification of the purse-seine fisheries (Figure 2) is based on the port-sampling strata, and the estimated species catch is summed over the appropriate port-sampling strata and months to get the quarterly estimated catch by fishery.

3. DISCARDS

Data for fish discarded at sea (in three weight categories) by large purse-seine vessels have been collected by observers since 1993. The observers estimate the total weight of fish caught and weight of discards by species and size groups. The size groups are: small fish (<2.5 kg), medium fish (2.5-15.0 kg), and large fish (>15 kg). These data are used to determine discard rates to estimate total discards based on the purse-seine landings by fishery.

For the purposes of stock assessment, it is assumed that bigeye tuna is discarded from the catches made by purse-seine vessels for one of two reasons: inefficiencies in the fishing process (*e.g.* when the catch from a set exceeds the remaining storage capacity of the fishing vessel) or because the fishermen sort the catch to select fish that are larger than a certain size. In either case, the amount of discarded bigeye is estimated with information collected by IATTC or national-program observers, applying methods described by Maunder and Watters (2003). Regardless of why bigeye is discarded, it is assumed that all discarded fish die.

It is assumed that fish in the small category are generally discarded because they are too small to sell and have been sorted by size for discarding. However, some small fish are also discarded for the same reasons (inefficiencies in the fishing process) that medium and large fish are discarded. Therefore, a base discard rate is determined from the medium and large categories, and this is subtracted from the discard rate of small bigeye to determine the discard rate of small fish due to size sorting.

The complicated description of Maunder and Watters (2003) can be simplified to the following equations. The total catch related to the selectivity corresponding to the landings is (*i.e.* landings plus discards due to inefficiencies)

$$C_B = landings \times (1 + \lambda_B)$$

$$\lambda_B = \frac{D^o_{m\&l}}{C^o_{m\&l} - D^o_{m\&l}}$$

$$D^o_{m\&l} = observed\ discards\ of\ medium\ and\ large\ bigeye$$
$$C^o_{m\&l} = observed\ catch\ of\ medium\ and\ large\ bigeye$$

The total catch related to the selectivity corresponding to the discards sorted by size is

$$D_E = landings \times \lambda_E$$

$$\lambda_E = \frac{D^o_S}{C^o_T - D^o_T} - \lambda_B$$

$$D^o_S = observed\ discards\ of\ small\ bigeye$$
$$C^o_T = observed\ catch\ of\ all\ bigeye$$
$$D^o_T = observed\ discards\ of\ all\ bigeye$$

These calculations are done separately for each stock assessment fishery by quarterly time step.

3.1. Use in the assessment

Estimates of purse-seine discards resulting from inefficiencies in the fishing process are added to the retained catches made by purse-seine vessels because they are assumed to have the same selectivity. Discards that result from the process of sorting the catch are treated as separate fisheries, and the catches taken by these fisheries are assumed to be composed only of fish that are 2-4 quarters old. Estimates of the amounts of fish discarded during sorting are made only for fisheries that take bigeye associated with floating objects because sorting is thought to be infrequent in the other purse-seine fisheries.

No observer data are available to estimate discards by size for surface fisheries that operated prior to 1993, and it is assumed that there were no discards from these fisheries. For surface fisheries that have operated since 1993, there are periods for which observer data are not sufficient to estimate the discards.

For these periods, it is assumed that the discard rate (discards/retained catches) is equal to the discard rate for the same quarter of the previous year or, if not available, the closest year.

It is possible that regulations prohibiting discarding of tuna (2001-2007; IATTC Resolution C-00-08 and subsequent renewals of that resolution) have caused the proportion of discarded fish to decrease.

4. INDICES OF ABUNDANCE

Observer and logbook data on catch and days fished, by location and date, are used to compute indices of relative abundance. The observer data are used, if available; otherwise the logbook data are used.

The catch per unit effort (CPUE) of purse-seine vessels with a fish-carrying capacity greater than 363 t in the purse-seine fisheries was estimated as catch divided by number of days fished. Days fished are assumed to be a better measure of effort than the number of sets because it relates to search time. However, fish-aggregating devices (FADs) are often equipped locator technology, and success is more related to the number of fish under a FAD that is checked than the ability to find FADs. (Since 1996, over 80% of sets on floating objects are estimated to have been sets on FADs; IATTC 2010b, 2018.) Because vessels can make different types of sets (floating-object, which includes FADs; dolphin-associated; free-swimming school) in a trip, the amount of time spent fishing using a particular fishing type is unknown. The number of days fished by set type was estimated from the number of sets, using a multiple regression of total days fished against number of sets by set type (Maunder and Watters, 2001).

$$D_i = \beta_{FO} FO_i + \beta_{UA} UA_i + \beta_{DOL} DOL_i + \varepsilon_i$$

Where D is the days fished, FO is the number of floating object sets, UA is the number of unassociated sets, DOL is the number of dolphin associated sets, the betas are the coefficients of the regression and ε is normally distributed. The regression is calculated separately for each year. The data points in the regression are the sampling area-month strata, and are weighted by the days fished. The number of days fished by set type can then be estimated

$$D_{FO,j} = \beta_{FO} FO_j$$

$$D_{UA,j} = \beta_{UA} UA_j$$

$$D_{DOL,j} = \beta_{DOL} DOL_j$$

where $D_{FO,j}$ is the number of days fished on floating objects in a strata (year, quarter, and fishery) *j*.

The total predicted number of days fished from the regression will differ from the total observed number of days fished for that stratum. Therefore, we rescale the days fished to equal the observed days fished.

The days fished for each fishery by quarter and year is then estimated by summing the data for the appropriate months and market measurement areas. The catch by set type associated with the effort data is also summed by quarter and fishery for each species. The CPUE is estimated by dividing the catch by the number of days fished. The catch data are not corrected by using the species composition sampling.

4.1. Use in the assessment

Not all CPUE data are considered appropriate for use as indices of abundance for use in the assessment. The fisheries excluded were considered inappropriate because the catch rates were extremely low or because they combined gears. In addition, the first two years of the purse-seine floating-object fisheries were excluded because these fisheries were still expanding.

The CPUE from the purse-seine fisheries are considered to provide less reliable indices of abundance due to the targeting of tuna aggregations, compared to indices from the longline fisheries. Therefore, they are not used in the assessment.

5. LENGTH-COMPOSITION

The numbers at length in a stratum for a species are estimated by multiplying the well-level estimates of the proportions at length, combined across all sampled wells, by the estimated total catch, in numbers, for the species in the stratum. Since the total catch for a well and the total catch for a stratum are recorded in weight, the calculations must be converted from weight to numbers, using the average weight of fish in each well. This is done by converting individual length measurements to weight, based on the formulas in Table 1.

Prior to 2000, the estimated number of fish of length *k* for species *i* in the stratum is given by (from Tomlinson *et al*. 1992; assuming samples were not from a species and/or size sorted unloadings):

$$\hat{N}_{ik} = \left(\frac{W_i}{\left(\frac{\sum_{j=1}^{q} W_{ij}}{\sum_{j=1}^{q} \left(\frac{W_{ij}}{\overline{w}_{ij}} \right)} \right)} \right) \left(\frac{\sum_{j=1}^{q} \left(\frac{W_{ij}}{\overline{w}_{ij}} \right) \left(\frac{m_{ijk}}{m_{ij}} \right)}{\sum_{j=1}^{q} \left(\frac{W_{ij}}{\overline{w}_{ij}} \right)} \right)$$

where W_i is the estimated total weight of fish of species *i* landed in the stratum, W_{ij} is the total weight of fish of species *i* in the j[th] well (assumed known), $\overline{w}_{ij} = \frac{w_{ij}}{m_{ij}}$, w_{ij} and m_{ij} are the weight and number of fish of species *i* measured from well *j*, respectively, m_{ijk} is the number of fish in length interval *k* of species *i* measured from well *j*

Beginning in 2000, the estimate number of fish of species *i* in the stratum of length *k* is given by (from Tomlinson 2002, 2004; assuming samples were not from a species and/or size sorted unloadings):

$$\hat{N}_{ik} = W \left(\frac{\sum_{j}^{q} W_j \left(\frac{1}{\sum_{i}^{s} \left(\frac{w_{ij}}{m_{ij}} \right) \left(\frac{n_{ij}}{n_{.j}} \right)} \right) \left(\frac{n_{ij}}{n_{.j}} \frac{m_{ijk}}{m_{ij}} \right)}{\sum_{j}^{q} W_j} \right)$$

where W is the total weight of fish of all species landed in the stratum (assumed known), W_j is the total weight of fish of all species in the j[th] well (assumed known), w_{ij} and m_{ij} are the weight and number of fish of species *i* measured from well *j*, respectively, m_{ijk} is the number of fish in length interval *k* of species *i* measured from well *j*, n_{ij} and n_j are the number of fish of species *i* recorded in the count from well *j* and the number of fish counted from well *j*, respectively, *q* is the number of wells sampled and *s* is the number of species.

For samples obtained from unloadings that were first sorted by species and size, the number of fish of each species in each of the sorted groups is estimated by computing the average weight from lengths converted to weight, and dividing that into the group's total weight. The estimates of catch at length (in numbers) are then the product of the estimate total number of the species in the group and the proportion of the species' length sample for the group that was of length *k*.

5.1. Use in the assessment

The stratum-level estimates of length composition are aggregated by area into the fisheries defined for the assessment and aggregated over months into quarters. Estimates are only computed for stock assessment fisheries for which all strata had port-sampling data. The fishery-level estimates of size composition are converted from numbers at length to proportion at length using a weighted sum of the stratum level proportions at length, with weights equal to the number of wells sampled per stratum. The sample size used in the stock assessment is the number of wells sampled multiplied by 0.05.

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TABLE 1. Lengths L_{ijk} are converted to weights w_{ijk} using coefficients *a* and *b* that depend on the species (for conversion from length in mm to weight in kg); average weight (kg) of measured fish of species *i* in well *j*: $\bar{w}_{ij} = \frac{1}{m_{ij}} \sum_h a\, L_{ijk}{}^b$.

Species	a	b
YFT	1.77E-08	3.02
SKJ	2.55E-09	3.336
BET	4.59E-08	2.90182

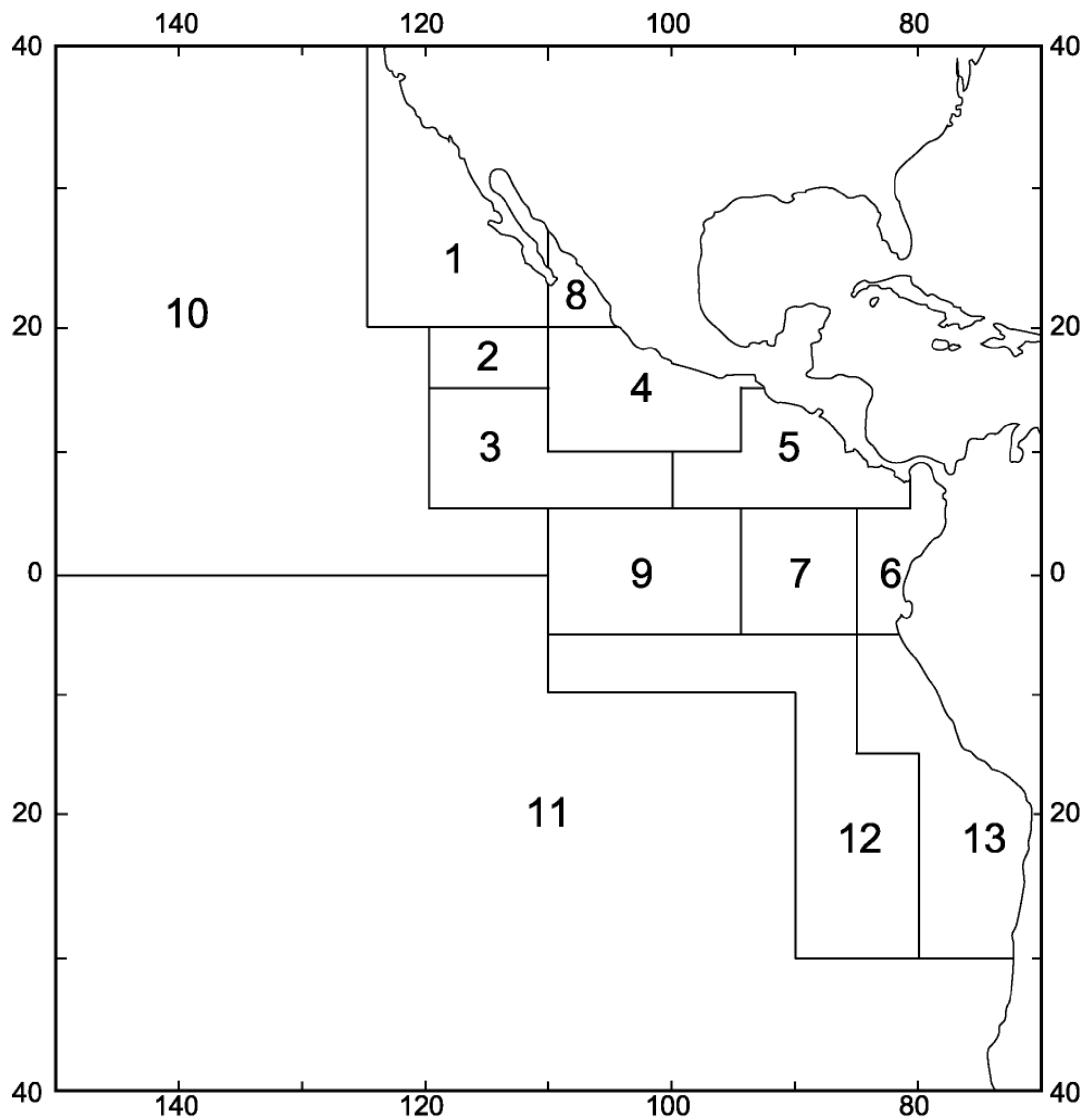

FIGURE 1. The 13 surface fishery port-sampling areas in the EPO.

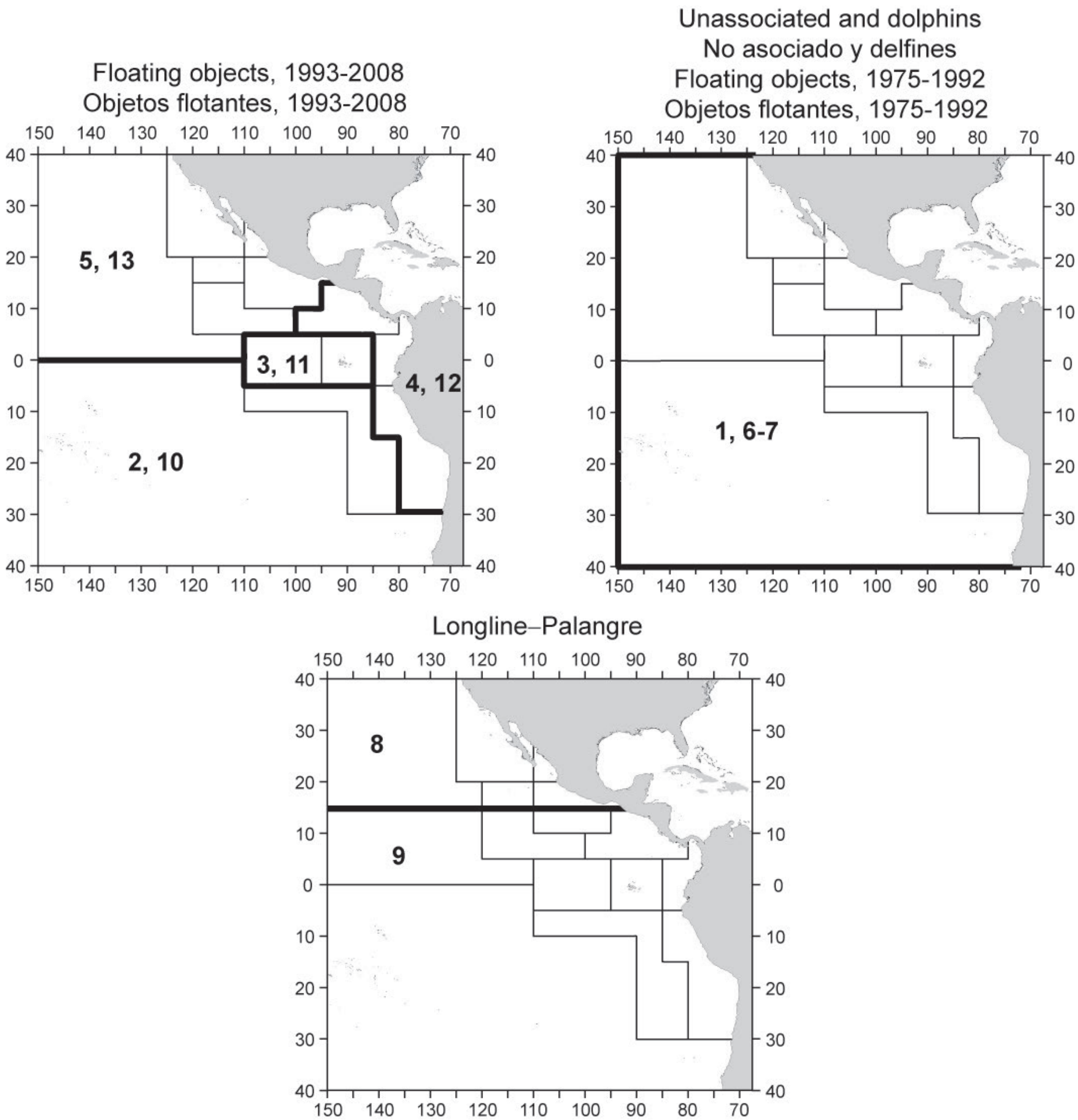

FIGURE 2. Spatial extent of the fisheries defined for the stock assessment of bigeye tuna in the EPO. The thin lines indicate the boundaries of 13 length-frequency sampling areas (Figure 1), the bold lines the boundaries of each fishery defined for the stock assessment, and the bold numbers the fisheries to which the latter boundaries apply.