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INTER-AMERICAN TROPICAL TUNA COMMISSION

EXTERNAL REVIEW OF IATTC BIGEYE TUNA ASSESSMENT

La Jolla, California (USA)
3-7 May 2010

DOCUMENT BET-01-07 (DRAFT)

SUMMARY OF DATA AVAILABLE FOR BIGEYE TUNA IN THE EASTERN PACIFIC OCEAN AND ITS USE IN STOCK ASSESSMENT

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CONTENTS

The information provided below has been taken from a number of IATTC documents (see the reference list).

1. DATA SOURCES

Data for bigeye tuna are derived from various sources, including vessel logbooks, observer records, unloading records provided by canners and other processors, export and import records, reports from governments and other entities, estimates derived from the species and size composition port sampling program, and individual research projects (e.g. age-growth studies, tagging studies).

1.1. Canner and processor data

Total landings by species for each surface fishery trip are obtained from canners and processors.

1.2. Vessel logbooks

Data on the catches and fishing effort by surface gear are obtained from logbook records. 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 records

Observers of the IATTC and national observer programs have been placed aboard the international fleet of Class-6 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. In addition, on a few occasions observers have sampled trips on Class-5 vessels. 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.

1.4. Port sampling

The port sampling data are based on a stratified two-stage sampling design (Tomlinson, 2002; Suter, 2008). Within a purse-seine set type and vessel size class, sampling strata are defined by date and area of fishing (13 areas and 12 months). Although generally opportunistic, sampling at both stages is assumed to approximate simple random sampling. Vessel wells are the primary sampling unit within a stratum, with unequal numbers of wells sampled per stratum. Fish within a vessel's well are the secondary sampling unit. Wells are sampled only if all the catch within the well came from the same stratum. Details of the sampling instructions given to port samplers can be found in the Appendix of Suter (2008). The sampler counts, independently from measuring, the number of fish of each species in a random sample of several hundred fish. Additionally, the sampler randomly removes a number of fish of each species (ideally 50) and measures the fork length to the nearest millimeter. Depending on the port of unloading, fish may be sorted by size and/or species as they are unloaded. The species sampling started in 2000 and the length-composition sampling of bigeye started in 1975.

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˚x5˚ grid location for each set.

1.6. Monthly longline reports

IATTC Resolution C-06-02 requires that CPCs (Contracting Parties, Cooperating non-Contracting Parties, Entities or Fishing Entities) whose annual longline bigeye catches have exceeded 500 mt provide monthly catch reports.

1.7. Data provided by countries

IATTC Resolution C-03-05 recommends data reporting requirements for the longline fleets. The data to be provided are described in the following table, with Level-3 catch and effort data as a minimum

Category	Level	Resolution	Data
Catch and effort	1	Set-by-set, logbook data with information on gear configuration and target species	Total catch in numbers, and weight if available; fishing effort
	2	1°x1°–month, with information on gear configuration and target species	
	3	5°x5°–month, with information on gear configuration and target species	
Length frequency	1	Set position, start or end of set	Length or weight of individual fish
	2	Grid position, best possible spatial temporal resolution of area of capture	

requirement, and, whenever possible, Levels 2 and 1 catch and effort data and length-frequency data. The data should be provided by species and fishing gear

Catch data not provided in the above format are usually obtained aggregated over a year and are provided by countries, or obtained from official websites or reports. These catch data may include catch from methods other than longline, but excludes purse-seine catch by the observer and logbook programs.

More detailed data are also provided to the IATTC by member contries on an ad hoc basis. Details about the Japanese longline fleet are provided in a series of IATTC bulletins (e.g. Matsumoto and Bayliff 2008).

1.8. Vessel information

The IATTC maintains a Regional Vessel Register of vessels authorized to fish for tunas in the eastern Pacific Ocean (EPO). The register includes the gear, flag, and fish-carrying capacity for most of the vessels that fish with purse-seine or pole-and-line gear for bigeye tuna in the EPO. The Register is incomplete for small vessels. It contains records for most large (overall length >24 m) longline vessels that fish in the EPO and in other areas.

Additional information about vessel characteristics is available from the observer and log book database (*e.g.* trip information about the use of helicopters, size of net, number of speed boats,…)

1.9. Biological and other data

The IATTC collects biological data on bigeye tuna through specific research projects. Information is available on maturity, fecundity, sex ratio, and age and growth. Environmental data are also available from a number of sources.

1.10. Tagging

Since 2000, the IATTC staff has conducted several tagging cruises directed at bigeye tuna in the EPO. Data collected include information for bigeye tuna tagged with either conventional or archival tags, and telemetry data on behavior of bigeye tuna associated with and not associated with floating objects.

2. CATCH

Most of the catches are made by the purse-seine and longline fleets; the pole-and-line fleet and various artisanal and recreational fisheries account for a small percentage of the total catches. Detailed data are available for the purse-seine and pole-and-line fisheries. There are some fleets for which we do not have catch estimates. Of particular concern are the small- and medium-sized longline vessels that operate in the EPO targeting bigeye tuna and other pelagic species. In recent years, the IATTC staff has increased its effort toward compiling data on the catches of tunas, billfishes, and other species caught by other gear types, such as trollers, harpooners, gillnetters, and recreational vessels.

Estimates of the total amount of the catch by purse-seine vessels that is landed are based principally on data from unloadings. Details of the purse-seine catch are based on observer and logbook data. Data on the retained catches of most of the larger longline vessels are obtained from the governments of the nations that fish for tunas in the EPO. Data from smaller longliners, artisanal vessels, and other vessels were gathered either directly from the governments, from logbooks, or from reports published by the governments.

2.1. Surface fisheries

Estimates of the total amount of the catch by purse-seine vessels that is landed are based principally on data from unloadings. If unloading information is unavailable, the observer records or vessel logbooks are used (in that order). The recording of species composition is inaccurate. The unloading data for purse-seine and pole-and-line vessels have been adjusted, based on the species composition estimates for yellowfin, skipjack, and bigeye tunas. The current species composition sampling program began in 2000, so the catch data for 2000 and later years are adjusted, based on estimates obtained for each year. The catch data for the previous years were adjusted by applying the average ratio by species from the 2000-2004 estimates. This has tended to increase the estimated catches of bigeye and decrease those of yellowfin and/or skipjack.

Port sampling is used to determine the species composition and the size composition of the catch. For purposes of port sampling, the EPO surface fishery is divided into 12 calendar months, 13 areas (Figure 1, which were optimized for yellowfin tuna), and the following 7 fishing methods:

1. baitboats (includes also bolicheras and jigboats);
2. small purse seiners (<364 mt of fish-carry capacity) setting on schools associated with floating objects;
3. small purse seiners setting on schools associated only with other fish;
4. small purse seiners setting on schools associated with dolphins;
5. large purse seiners (≥364 mt of fish-carry capacity) setting on schools associated with floating

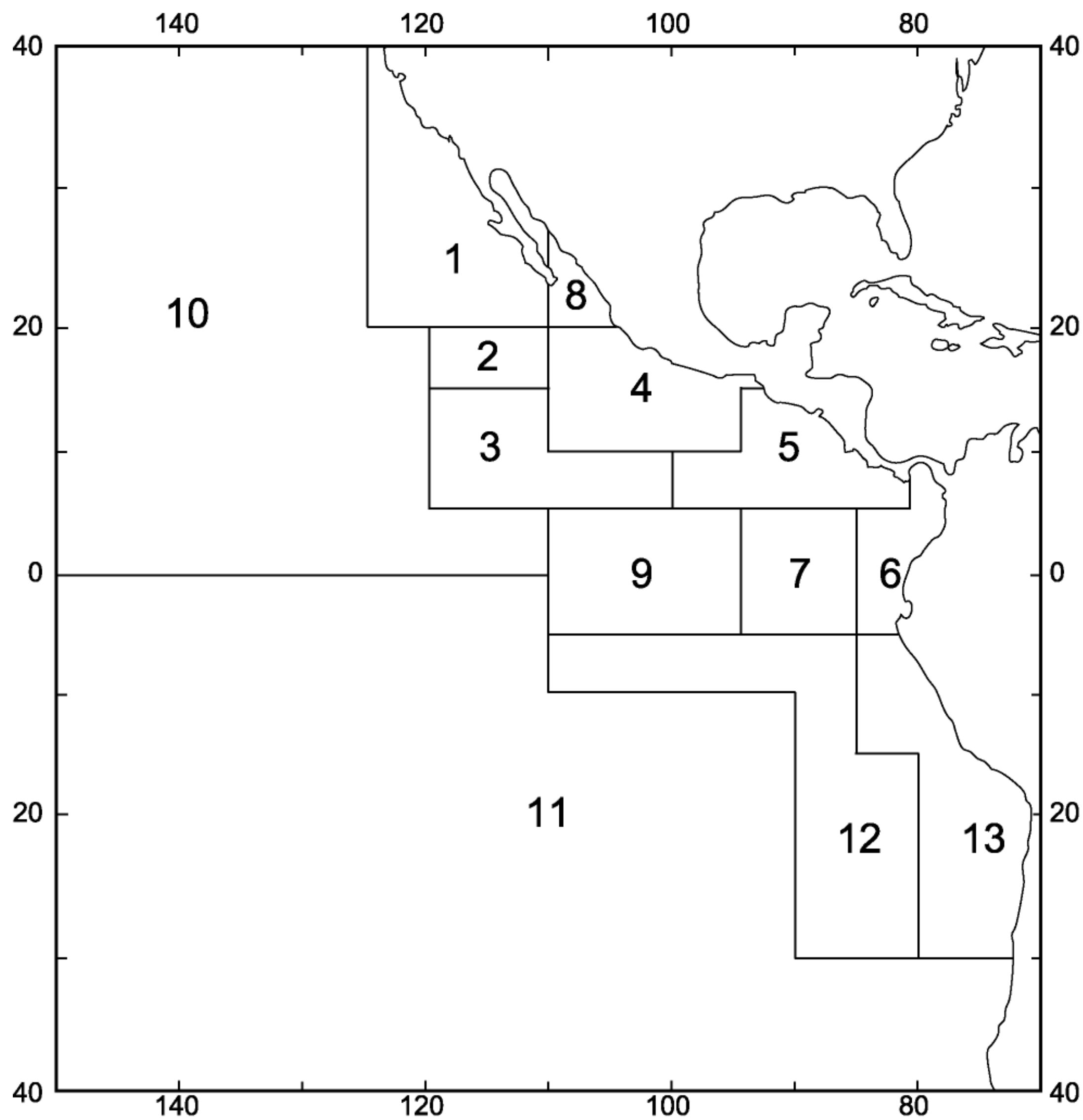

FIGURE 1. The 13 surface fishery port sampling areas in the EPO.

objects;

6. large purse seiners setting on schools associated only with other fish;
7. large purse seiners setting on schools associated with dolphins.

Catch is estimated for each stratum separately. Catches for coarser strata are estimated as the sum of the results for all of the appropriate strata together.

There are three different types of sampling. First, the sampler selects a vessel that is being unloaded and determines from the vessels logbook if any wells being unloaded have fish from only one stratum. Wells containing a mixture of tunas from different strata are not sampled. Second, the sampler counts, independently from measuring, the number of each species in a random sample of several hundred fish. Third, the sampler randomly removes a number of fish of each species (usually 50) and measures and records the lengths of each to the nearest millimeter. Some vessels sort the fish by size and/or species before unloading, making it impossible to obtain either a random species count from the well or a random sample of each species for measuring. For these vessels, the number of fish of each species in each of the sorted groups is estimated by sampling a number of fish for size, computing the average weight, and dividing into the group’s total weight provided by the vessel. There is a problem of strata with catches, but no samples. Data for other areas or gears or months are used to represent the strata without samples.

The species composition from the port sampling is used to estimate the catch of bigeye in a well. Not all wells are sampled, so data for the sampled wells are then used to estimate the bigeye catch for a stratum based on the reported total catch in weight of all species in that stratum. The reported total catch in weight of all species in a well and the reported catch in weight of all species in a stratum are assumed to be correct. The well weight is taken from the observer or logbook data, in that order.

The estimates of bigeye in a well are 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. The species sampling is used to estimate the proportional species composition in a well with respect to number of fish. This is then adjust by the average weight of fish in a well from the length-frequency sampling (the average weight of the species multiplied by the number of that species divided by the average weight of all fish multiplied by the number of all fish) 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 proportional species composition by weight in strata is estimated by summing catch over all sampled wells for each species separately and dividing by total catch 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.

From Tomlinson (2002), for a given stratum, the estimate of the total catch of species i , using data collected with the current port-sampling procedures, is given by:

$$\hat{W}_i = W \left(\frac{\sum_{j=1}^{q} W_j \left(\frac{\left(\frac{w_{ij}}{m_{ij}}\right)\left(\frac{n_{ij}}{n_j}\right)}{\sum_{i=1}^{s} \left(\frac{w_{ij}}{m_{ij}}\right)\left(\frac{n_{ij}}{n_j}\right)} \right)}{\sum_{j=1}^{q} W_j} \right)$$

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, 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 the years for which data for species composition sampling are not available, cannery statistics, observer data, or the vessel's logbook data, in that order, are treated as being correct with respect to species, and a separate estimate is made for each species for each stratum. Average scaling factors for 2000-2008 are calculated by dividing the total catch for all years and quarters for the species composition estimates by the total catch for all years and quarters for the standard estimates and these are applied to the cannery and unloading estimates for 1975-1999. For Fisheries 1, 6, and 7 we used the average over Fisheries 2-5, for Fisheries 2 and 3 we used the average over Fisheries 2 and 3, and for Fisheries 4 and 5 we used the average over Fisheries 4 and 5.

2.2. Longline

The availability of catch data from the longline fisheries varies among the countries. Data on the spatial and temporal distributions of the catches in the EPO by the distant-water longline fleets of China, Chinese Taipei, French Polynesia, Japan, Mexico, the Republic of Korea, and the United States are maintained in databases of the IATTC. The availability of the catch data by 5°x5° is shown in Table 1. Some of the catch is reported in numbers of fish, some in weight, and some in both. Data from other nations are available aggregated by year.

2.3. Use in assessment

To conduct the stock assessment of bigeye tuna, the catch data in the IATTC databases are stratified according to the fishery definitions based on gear, area, and time (quarter) (Figure 2). The spatial stratification of the purse-seine fisheries is based on the port sampling strata, and the catch is simply summed over the appropriate port sampling strata and months to get the quarterly catch by fishery.

The longline fishery is divided into two areas, north and south of 5°N. The spatially detailed catch data are simply summed over the appropriate port sampling strata and months to get the quarterly catch by fishery. Since some of the catch is in numbers and some is in weight; four fisheries are used in the assessment (north and south in numbers and north and south in weight) so that average weight used to convert between numbers and weight is calculated internally in the assessment model.

The detailed longline catch data are missing for some nations. For recent years the monthly reports are used where available. For catch data that is either not spatially or temporally detailed, assumptions need to be made about how to distribute the catch between the two fisheries and among quarters within a year. For data that are available from monthly reports the catch is assigned to the northern and southern fisheries based on the distributions in recent years. For catch data that are aggregated at the annual level, it is split evenly among the quarters and assigned to the southern fishery.

3. DISCARDS

3.1. Purse seine

Data for fish discarded at sea (in three weight categories) by purse-seine vessels with carrying capacities greater than 363 mt 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 scale the total discards based on the total purse-seine landings by fishery.

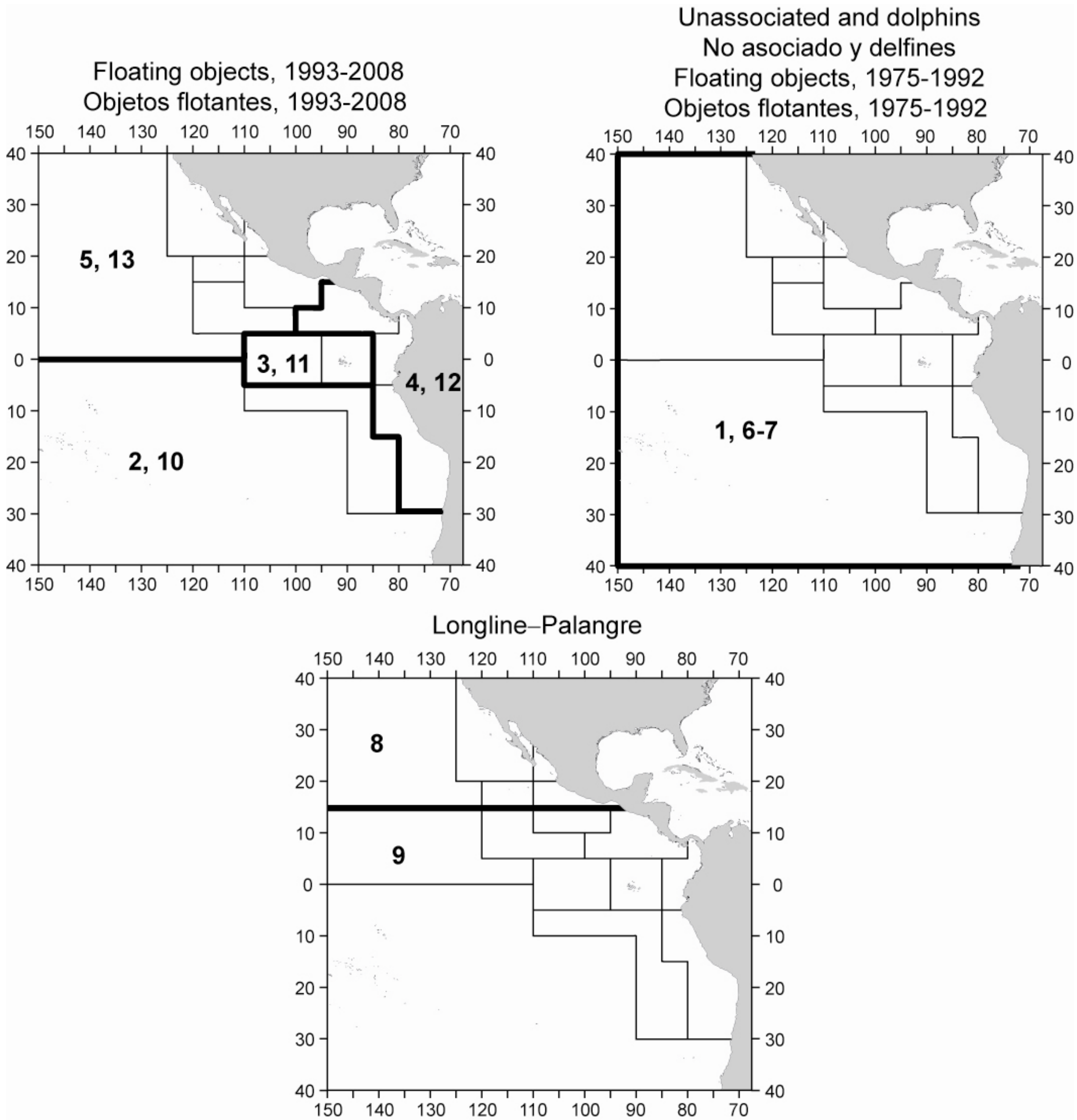

FIGURE 2. Spatial extents of the fisheries defined for the stock assessment of bigeye tuna in the EPO. The thin lines indicate the boundaries of 13 length-frequency sampling areas, the bold lines the boundaries of each fishery defined for the stock assessment, and the bold numbers the fisheries to which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

For the purposes of stock assessment, it is assumed that bigeye tuna are 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 observers, applying methods described by Maunder and Watters (2003). Regardless of why bigeye are 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 fishery by quarterly time step.

3.2. Longline

No information is available on discards from the longline fisheries. It is assumed that bigeye tuna are not discarded from longline fisheries.

3.3. Use in 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

4.1. Purse seine

Data on catch, number of sets by set type, and days fished by location and date are available from the onboard observer and vessel log books. The observer data are used, if available; otherwise the logbook data are used.

Purse-seine catch per unit of effort (CPUE) is calculated as catch divided by the 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, floating objects have locator technology, and success is more related to the number of fish under a fish-aggregating device (FAD) that is checked than the ability to find FADs. Because vessels can make differ types of sets (floating object, 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 is estimated by regressing total days fished versus number of sets for the three set types. The estimated coefficients are the number of days fished corresponding to a single set of each set type. These can then be multiplied by the number of sets by set type to estimate the number of days fished by set type.

The CPUEs of purse-seine vessels with a fish-carrying capacities greater than 363 t in the purse-seine fisheries was estimated as catch divided by number of days fished. 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).

$$D_t = \beta_{FO} FO_t + \beta_{UA} UA_t + \beta_{DOL} DOL_t + \varepsilon_t$$

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.

4.2. Longline CPUE

The longline CPUE data, catch per hook, are standardized, using a delta-lognormal general linear model in which the explanatory variables are latitude, longitude, and hooks per basket. Only Japanese longline data are used in these analyses because the detailed data from the Japanese fleet covers a greater number of years. Hooks per basket information is available only for the Japanese and USA fisheries. The fishing depth of the longline gear has changed over time as the fishery has targeted bigeye tuna. The fishing depth of the gear is related to the number of hooks per basket. The more hooks, the deeper the gear fishes. This change in depth has made bigeye more vulnerable to the longline fishery, and therefore hooks per basket has been used in the general linear model standardization.

4.3. Use in the assessment

Not all CPUE data are considered appropriate for use as indicies 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. The weighting of the CPUE data is determined by estimating an additive constant on the standard deviation of the likelihood for each fishery. The catchability is assumed constant over time.

5. LENGTH-COMPOSITION

5.1. Surface fisheries

Length-frequency samples of bigeye from the catches of purse-seine, pole-and-line, and recreational vessels in the EPO are collected by IATTC personnel at ports of landing in Ecuador, Mexico, Panama, the USA, and Venezuela. The catches of bigeye were first sampled in 1975, and sampling has continued to the present. The fish in a well of a purse-seine or pole-and-line vessel are selected for sampling only if all the fish in the well were caught during the same calendar month, in the same type of set (floating-object, unassociated school, or dolphin), and in the same sampling area (see the section on catch above for more details).

The length-composition data are raised to the well and then strata levels, using the same approach as used for the catch data (described above), except that the data are based on numbers, rather than weight . The species-composition sampling is also used when calculating the length composition. Since the total catch for a well and the total catch for a strata are recorded in weight, the calculations must be converted from weight to numbers, using the average weight of fish in a well.

The length composition sample for a well is raised to the reported catch in the well, based on the species sample and the total number of fish in the well. The total number of fish in the well is calculated from the recorded catch in weight in the well divided by the average weight of tuna (averaged over all three species) in the well. The average weight is calculated from the proportional species-composition sample in numbers multiplied by the average weight by species from the length composition sample.

The numbers at length in a stratum for a species is estimated by multiplying the proportions at length combined across all sampled wells by the numbers for that species. The number for that species is estimated from the total numbers multiplied by the proportion for that species. The total numbers are estimated from the known total catch divided by average weight. The average weight is estimated from the sum of the known weight for all wells sampled divided by the estimated numbers for all wells sampled. The proportion by species is calculated by dividing the sum of a species in all wells sampled by all fish in the wells sampled. The proportion at length is estimated by dividing the sum of a length composition category for a species in all wells sampled by the sum of all fish of that species in the wells sampled. The equations presented in Tomlinson (2002) can be simplified to

$$N_{ik} = W \frac{\sum_j^q W_j \left(\frac{1}{\sum_i^s \frac{w_{ij} n_{ij}}{m_{ij} n_j}} \right) \frac{n_{ij} m_{ijk}}{m_{ij} n_j}}{\sum_j^q W_j}$$

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

5.2. Longline fisheries

Longline length composition data are available only for the Japanese and Chinese Taipei fleets. The Japanese data are available from 1965 and the Chinese Taipei data from 1981. The samples sizes for the

Chinese Taipei fleet are much lower until 2001 (Table 2). The length-frequency data for the Chinese Taipei fleet include more smaller fish than those for the Japanese fleet. There is concern about the representativeness of the length-frequency samples from the Chinese Taipei fleet (Stocker 2005, Anonymous 2006).

The Japanese length-composition data has been provided in two latitude-longitude resolutions 5˚x5˚ and 10˚x20˚ over the years. Only the 5˚x5˚ are used in the assessment.

5.3. Use in assessment

The data are aggregated by area into the fisheries defined for the assessment and aggregated over time into quarters. Only the Japanese data are used for the longline length-composition data. The number of wells is used as the sample size for the surface fisheries in the stock assessment because most of the sampling variation is among wells. The number of bigeye sampled by the longline fleet is so large that the raw sample sizes are too large to use in the stock assessment. The longline sample size is scaled so that the average sample size for the southern longline fishery is the same as the average sample size for the surface fishery that has the greatest average sample size.

6. AGE

Age-at-length data are derived from otolith readings (Schaefer and Fuller 2006). These data consist of age estimates from counts of daily increments on otoliths, and the lengths of 254 fish caught in 2002 by the floating-object fisheries. The age-length data were not collected randomly. They were collected to cover a range of sizes to provide information on mean size at age. It is difficult to accurately age bigeye older than about four years.

6.1. Use in assessment

The data are integrated into a previous assessment to estimate the growth parameters and the variability of length at age. The estimated variability of length at age is used in the current assessment. The data are also integrated into the current assessment as age conditioned on length data.

7. MATURITY/FECUNDITY

The reproductive biology of bigeye tuna was investigated by sampling 1,986 fish caught by purse-seine vessels and 124 fish caught by a longline vessel in the eastern and central Pacific Ocean during February 2000 through March 2003 (Schaefer et al. 2005). Histological evaluations of ovaries from 683 females provided the foundation for the estimates of length-specific reproductive characteristics. The data were used to estimate proportion mature at size, mean relative fecundity, average spawning frequency, and sex ratio at size.

7.1. Use in assessment

The data are used to fix the maturity at age, and fecundity is assumed proportional to weight at age.

The proportion mature at size is also used to develop the sex- and age-specific natural mortality. The Female natural mortality is assumed to increase as individuals mature. The female natural mortality for a particular age is estimated as the average of the natural mortality of mature and immature individuals weighted by the proportion mature.

8. SEX RATIO

Sex-ratio-at length data are available from the purse-seine fishery (N = 1949; Schaefer and Fuller 2006) and the Japanese longline fishery (N = 423656; Naozumi Miyabe pers. com.) fisheries.

8.1. Use in assessment

The sex ratio is used in the estimation of natural mortality. The sex ratio provides information on the difference between male and female natural mortality.

9. TAGGING

The IATTC has collected tagging data for bigeye tuna over the last decade. Both conventional and archival tag data have been collected. However, the tag releases are mostly from the core area of the purse-seine fishery, and movement away from this area has been limited. Recent and future tagging covers a wider spatial range and, as these data become available, they can also be used in the assessments. Length and position at release and at recapture are recorded. Double tagging and tag seeding experiments have also been carried out.

Bigeye tagging experiments took place during 2000 and 2002-2005 with releases between 3N-5S and 95-97W. There were 19,148 plastic dart tags and 323 geolocating archival tags deployed of which about 43%, and 51% have been returned (Schaefer and Fuller, 2009). Bigeye tagging experiments took place during 2008 and 2009 with releases between 8N-2S and 140-155W. There were 8,659 plastic dart tags and 231 geolocating archival tags deployed of which about 12%, and 21% have been returned.

The release locations have been restricted in their distribution.

There are also problems with the credibility of recapture information for the plastic dart tag returns. An analyses of the combined tag seeding data from 2000 and 2002 indicates only about a 68% correct well reporting by finders whom returned tags.

9.1. Use in assessment

The tag data are not currently use in the stock assessments. The growth increment data have been integrated with the age-length data in preliminary analyses of growth, but the estimates have not been used in the assessment. The release and recovery data have been used in preliminary cohort analysis to estimate natural mortality, but the results were too uncertain to provide useful estimates of natural mortality for the assessment. Estimates of natural mortality from tagging data in the western and central Pacific Ocean (Hampton 19xx) are used in estimating the natural mortality rates used in the EPO bigeye assessment.

10. OCEANOGRAPHIC DATA

There is a variety of oceanographic data available that could be used in the bigeye assessment. The IATTC staff is collaborating with Dale Kiefer at the University of Southern California to facilitate the access to environmental data for use in stock assessments.

10.1. Use in assessment

In previous assessments zonal-velocity anomalies (velocity anomalies in the east-west direction) at 240 m depth and the El Niño (southern oscillation) index were used as candidate environmental variables for affecting recruitment. Environmental variables have also been used to model catchability for purse-seine fisheries on floating objects. Environmental data has been used to standardize longline CPUE data using the statistical habitat standardization (statHBS) and neural networks. No environmental variables are used in the current assessment.

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TABLE 1. Data available on a 5x5 degree square resolution. N = catch in numbers, W = catch in weight, E = effort

	CHN			JPN			KOR			MEX			PYF			TWN			USA		
Year	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**
1952				•		•															
1953				•		•															
1954				•		•															
1955				•		•															
1956				•		•															
1957				•		•															
1958				•		•															
1959				•		•															
1960				•		•															
1961				•		•															
1962				•		•															
1963				•		•															
1964				•		•										•	•	•			
1965				•		•										•	•	•			
1966				•		•										•	•	•			
1967				•		•										•	•	•			
1968				•		•										•	•	•			
1969				•		•										•	•	•			
1970				•		•										•	•	•			
1971				•		•										•	•	•			
1972				•		•										•	•	•			
1973				•		•										•	•	•			
1974				•		•										•	•	•			
1975				•		•	•		•							•	•	•			
1976				•		•	•		•							•	•	•			
1977				•		•	•		•							•	•	•			
1978				•		•	•		•							•	•	•			
1979				•		•	•		•							•	•	•			
1980				•		•	•		•							•	•	•			
1981				•		•	•		•							•	•	•			
1982				•		•	•		•							•	•	•			
1983				•		•	•		•							•	•	•			
1984				•		•	•		•							•	•	•			
1985				•		•	•		•	•	•	•				•	•	•			
1986				•		•	•		•	•	•	•				•	•	•			
1987				•		•	•	•	•	•	•	•				•	•	•			
1988				•		•	•	•	•	•	•	•				•	•	•			
1989				•		•	•	•	•							•	•	•			
1990				•		•	•	•	•							•	•	•			
1991				•		•	•	•	•							•	•	•	•		•
1992				•		•	•	•	•				•	•	•	•	•	•	•		•
1993				•		•	•	•	•				•	•	•	•	•	•	•		•
1994				•		•	•	•	•				•	•	•	•	•	•	•		•
1995				•		•	•	•	•				•	•	•	•	•	•	•		•
1996				•		•	•	•	•				•	•	•	•	•	•	•		•
1997				•		•	•	•	•				•	•	•	•	•	•	•		•
1998				•		•	•	•	•				•	•	•	•	•	•	•		•

	CHN			JPN			KOR			MEX			PYF			TWN			USA		
Year	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**	**N**	**W**	**E**
1999				•		•	•	•	•				•	•	•	•	•	•	•		•
2000				•		•	•	•	•				•	•	•	•	•	•	•		•
2001		•	•	•		•	•	•	•				•	•	•	•	•	•	•		•
2002		•	•	•		•	•	•	•				•	•	•	•	•	•	•		•
2003		•	•	•		•		•	•				•	•	•	•	•	•	•		•
2004		•	•	•		•		•	•				•	•	•	•	•	•	•		•
2005		•	•	•		•		•	•				•	•	•	•	•	•	•		•
2006				•		•							•	•	•	•	•	•	•		•
2007		•	•	•		•	•	•	•				•	•	•	•	•	•	•		•
2008	•	•	•													•	•	•			

TABLE 2. Longline length composition sample size

Year	JPN	TWN	Year	JPN	TWN
1965	29679		1987	75041	1461
1966	22702		1988	31295	466
1967	23708		1989	37096	2680
1968	24728		1990	44037	3638
1969	32450		1991	84949	2855
1970	25773		1992	63239	45
1971	30013		1993	42549	127
1972	15642		1994	51893	1366
1973	11959		1995	50574	706
1974	8190		1996	55248	3
1975	7046		1997	38343	
1976	7372		1998	50585	
1977	19655		1999	32083	4
1978	15923		2000	20642	372
1979	29995		2001	32455	22142
1980	17588		2002	46169	64045
1981	9923	5719	2003	29446	142840
1982	14016	1197	2004	31329	135547
1983	21774	420	2005	19392	127309
1984	27101	678	2006	8256	88619
1985	44205	707	2007	11068	67602
1986	71685	414	2008	10019	18099

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