**INTER-AMERICAN TROPICAL TUNA COMMISSION**

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

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# DATA FROM LONGLINE FISHERIES

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## 1. INTRODUCTION

The longline fisheries for bigeye tuna historically had the highest catches until the expansion of the purse-seine fisheries in the mid-nineties. Currently, the indices of abundance used in the stock assessment are derived from standardized catch per unit effort (CPUE) data from the longline fisheries, and provide the stock assessment model of bigeye tuna with the best available information on changes in relative abundance over time (Xu *et al.* 2018). Both the index of abundance and the size composition data used to represent all longline fleets exploiting bigeye tuna in the eastern Pacific Ocean are derived from data submitted by Japan.

In this document we describe the data from longline fisheries that fish for bigeye tuna in the eastern Pacific Ocean as well as the methodology for calculation of the longline catches by stock assessment strata. For a comprehensive metadata description of the longline data held by the IATTC see Griffiths and Duffy (SAC-08-07b).

## 2. CATCHES

### 2.1. Data provided by countries

#### 2.1.1. Annual submission

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, and the Republic of Korea, by the coastal nations fleets such as Mexico and the United States, and other nations are maintained in databases of the IATTC.

IATTC Resolution C-03-05 establish the data reporting requirements for the longline fleets. Level-3 catch and effort data as a minimum requirement (data on the resolution of 5° latitude by 5°of longitude –month, Box 1). Whenever possible, more detailed Levels 2 and 1 catch and effort data and length-frequency data should be submitted. The data should be provided by species and fishing gear, and the deadline for the annual submission is June 30 of every year. 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 countries on an *ad hoc* basis. The availability of the Level-3 catch and effort 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.

**Box 1** –IATTC Resolution C-03-05

IATTC resolution C-03-05 on Data Provision established that "the data be provided, by species and fishing gear, where practical, via vessel logbooks and unloading records, and otherwise in aggregated form as in the following table, with Level 3 catch and effort data as a minimum requirement, and, whenever possible, Levels 2 and 1 catch and effort data and length-frequency data."

| 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 | |

The following exceptions shall apply to the immediate entry into force of this resolution:

a. For vessels of less than 24 meters in length overall, the requirements of this resolution shall not enter into force until 1 January 2007. However, each member shall make its best efforts to provide as much data as possible for these vessels.

b. Catch data from artisanal vessels may be reported as total annual catches, without data on fishing effort.

c. Catch data from recreational fishing vessels may be reported as total annual catches, without data on fishing effort.

Eighteen CPCs[1] have reported at least one year of bigeye annual catch on longline or other non-purse seine gears to the IATTC. Of those, nine had reported level 3 gridded 5°x5°–month data for four years or more (Table 1). When annual data (in weight) and level 3 data are both available, we computed the coverage of the level 3 data by assuming the annual data is the total catch of bigeye tuna for the CPCs in the EPO.

**Japan** reported the Level 3 data exclusively in numbers (Appendix I). The numbers transformed into weight using the average weight reported by Matsumoto and Bayliff (2008) indicate that the coverage of the Level 3 data is most likely 100% (Figure 1).

**Korea**.reported Level 3 data in numbers from 1975 to 1986 (Appendix I). For the other year  when Korea reported level 3 data, both numbers and weight were reported, except for 2003-2005, for which only weight was reported. For most of the series, the Level 3 data has less than full coverage (Figure 1) and needs to be raised.

[1] Members and Cooperating non-Members

**Chinese Taipei** level 3 data reported was in both numbers and weight for the whole period (Appendix I). In several years from the mid 90's to the mid 2000's, the level 3 weight data reported summed, for the EPO on an annual basis was larger than the data used in the FSR (Figure 1).

**United States of America** also reports exclusively numbers (Appendix I). There is no average weight available, the coverage Level 3 data is 100% according to the meta-data information submitted by USA.

**Vanuatu** has reported catches since 2000, but only in 2007 did it start to report level 3 data in both numbers and in weight (Appendix I). Only for 2016 was the data reported only in numbers. Those values were transformed to weight using the average weight for the series. It is likely that the coverage of the level 3 data is 100% (Figure 1).

**Belize** has reported catches since 2001, and for 2009 -2013 reported level 3 data in both numbers and in weight (Table 7). The level 3 data available has less than full coverage (Figure 1).

**China** has reported total annual catches as well as level 3 data since 2001, except for 2006 when no level 3 data was reported. For 2001 to 2005 (and 2007) only weight was reported. Both numbers and weight level 3 data have been reported since 2008 (Appendix I). The level 3 data available has 100% coverage for the whole series, with exception of 2001 (Figure 1). To compute the distribution of catches in space and quarter for 2006, the FSR data will have to be split assuming the same ratio as in previous years.

**French Polynesia** has reported total annual catches as well as level 2 data since 1992. For most of the series, except for recent years (2014-2016), the level 3 data has less than full coverage. A notable year is 1999, when the level 3 weight data was only 5% of the FSR catches. That year's catches were much larger that the preceding and subsequent ones (Appendix I, Table I.8).

**TABLE 1.** Availability in IATTC databases of longline catch data (used for the Fisheries Status Report, Table A-3e) and Level-3 data (aggregated to 5° x 5°area–month resolution) for bigeye, 1975-2016.

| **Flag** | Numbers of years FSR | Catch range FSR (t) Min | Max | Number of years Level-3 data |
|---|---|---|---|---|
| JPN | 42 | 10,427 | 91,981 | 42 |
| KOR | 42 | 606 | 17,883 | 39 |
| TWN | 42 | 77 | 17,253 | 42 |
| USA | 31 | 1 | 3,050 | 25 |
| PYF | 25 | 7 | 3,652 | 25 |
| CRI | 24 | 1 | 28 | * |
| CHL | 18 | 1 | 37 | * |
| ECU | 17 | 5 | 852 | * |
| VUT | 17 | 318 | 3,277 | 10 |
| CHN | 16 | 709 | 10,066 | 15 |
| BLZ | 15 | 0 | 1,987 | 6 |
| PAN | 10 | 6 | 364 | * |
| ESP | 9 | 5 | 196 | * |
| MEX | 6 | 0 | 42 | 4 |
| SLV | 6 | 2 | 11 | * |
| PER | 5 | 1 | 154 | * |
| PRT | 4 | 2 | 8 | * |
| HND | 1 | 9 | 9 | * |

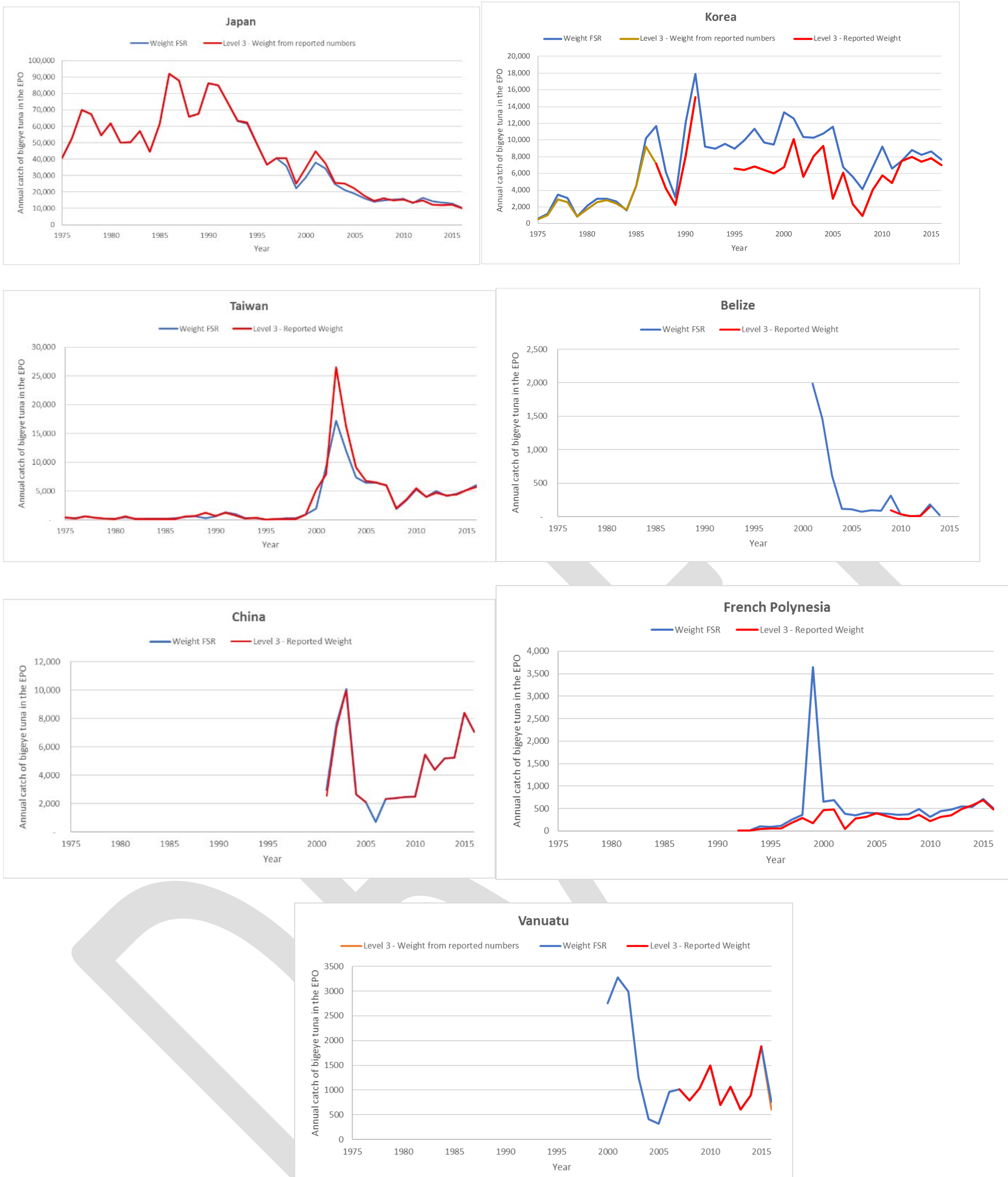


**FIGURE 1.** Coverage of the Level 3 data (5°x 5° area–month), by CPC and year.

### 2.1.2. Monthly reports

CPCs whose annual longline bigeye catches have exceeded 500 t are required to provide monthly catch reports. The current annual limits are established in IATTC Resolution C-17-02:

| Metric tons | 2018-2020 |
|---|---:|
| China | 2,507 |
| Japan | 32,372 |
| Korea | 11,947 |

| | |
|---|---|
| Chinese Taipei | 7,555 |
| United States | 750 |

The resolution also states that the above CPCs may make a single transfer of a portion of its bigeye tuna catch limit each year to any other CPCs in the above list. The CPCs above are likely to report monthly catches. The other CPCs can only fish 500 metric tons or less (their respective catches of bigeye tuna in 2001), and will not provide monthly reports.

### 2.1.3. Estimation of total catches by area

To conduct the current stock assessment of bigeye tuna (Xu *et al.* 2018), the catch data in the IATTC databases are stratified according to fishery definitions based on gear, area, and time (quarter). Some CPCs report catch in numbers and others in weight. For each area two fisheries are defined, one in numbers and one 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 fisheries and among quarters within a year. For data that are available from monthly reports the catch is assigned to the 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 one of the fisheries. This procedure was made manually and several decisions on data substitution had to be made, which resulted in a time-consuming process. For the spatial model in development, the catches also need to be distributed on space and time, with different potential spatial configurations.

An algorithm was developed to compute the catches in a timely and standardized way.

To calculate the longline catches two types of data are used:

a. Total catch from the Task I data by year compiled for the Fisheries Status Report ("FSR" data) in Tb3_AnnualCatchBET_LL&otherGears) plus any monthly report for the current year.
b. Catch in 5°x 5°–month resolution, with information on gear configuration and target species – Level 3 data from Resolution C-03-05 ("gridded" data).

The catches by area are calculated as follows. The algorithm was coded in R (Appendix II) and checked in Excel. The pseudo-code is as follows:

I. If catch numbers are available in the gridded data, we use it and assume 100% coverage.
II. If only weight is available in the gridded data, we:
    a. Default algorithm: compare the total catch in weight on a year from the gridded data to the aggregated FSR data, if it is less, split the FSR by area and quarter using the ratio from the weight in the gridded data set, if it is more, use the gridded weight directly.
    b. Alternative algorithm: for special countries for which there is previous knowledge that the gridded data set has less than 100% coverage (KOR, TWN):
        i. If both numbers and weight are available in the gridded data, compare total weight on a year to the FSR data, if it is less, split the FSR by area and quarter using the ratio from the weight in the gridded data set, if it is more, use the gridded number directly.
        ii. If only weight is available in the gridded data, compare total weight on a year to the FSR data, if it is less, split the FSR by area and quarter using the ratio from the weight in the gridded data set, if it is more, use the gridded weight directly.
III. If there are no weight or numbers in the gridded data for a year, split the FSR using the closest year of gridded data available, prefer the data in weight, if it is not available, use numbers.
IV. If there is only FSR data, and it is a coastal country, allocate the catches to the country's EEZ.
V. If there is only FSR data, and it is not a coastal country, use expert knowledge/best judgement (*e.g*. country reports).

VI. For the current year in the series, if the countries had not yet sent the information, assume the catch is the same as the previous year.

Figures 2 and 3 show the catches computed for the spatial model using the algorithm described above with those catches computed for the SAC9 stock assessment using either all countries with the default algorithm 2a or applying the special algorithm 2b for the countries that underreport the level 3 data. The catches in Figure 2 should be used in the spatial model as the algorithm is applied consistently for all years and corrects for underreporting.

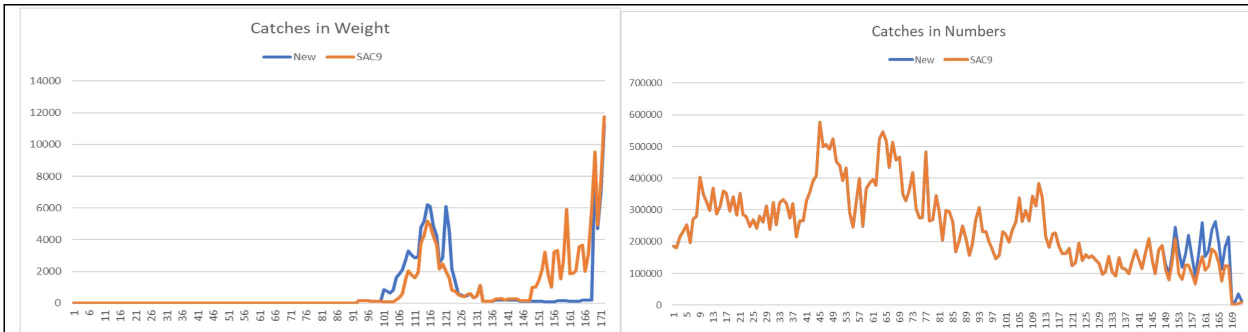


**FIGURE 2.** Catches for all EPO for all countries computed using the default algorithm 2a.

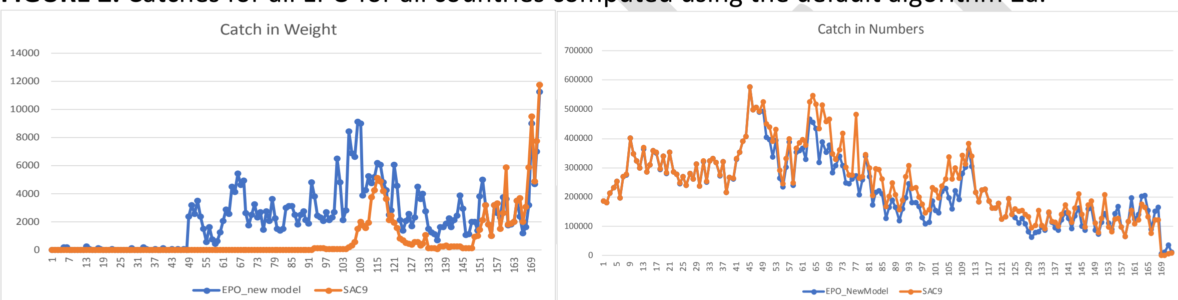


**FIGURE 3.** Catches for all EPO for all countries with special countries using the alternative algorithm 2b (*i.e.* for Korea and Chinese Taipei the annual catch is distributed in space and by quarter using the proportions in weight from the level 3 data in weight) and the rest using the default algorithm.

## 3. DISCARDS

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

## 4. 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 following Hoyle and Maunder (2006, SAR-7-07). 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. When there are more hooks between a float, some of the hooks will fish much deeper than when less hooks between floats are used. However, other factors such as hook line length, currents, and setting speed also impact the fishing depth of the longline. Details about the Japanese longline fleet are provided in a series of IATTC bulletins (*e.g*. Matsumoto and Bayliff 2008). A collaboration between the scientists from CPCs and the staff was recommended to examine potential effects on CPUE of changes in fishing practice, and between scientists from Japan and the staff to analyze operational level catch and effort data (BET-01 Meeting report).

Considerable progress has been made in that regard, culminating in project H.1d, "Improve indices of abundance based on longline CPUE data" of the Strategic Science Plan being partially funded by the IATTC and the four main distant-water fleets granting the staff access to their operational level catch and effort data for research related to the project.

## 5. SIZE-COMPOSITION DATA

Size-composition data are currently available from two longline fleets (Japan and Chinese Taipei). There is uncertainty regarding the quality of the Chinese Taipei data in the Pacific Ocean and in other oceans (*e.g.* Report of the Nineteenth North Pacific Albacore Workshop, Geehan and Hoyle, 2013), and until this is resolved, these data are have not been used to assess the tropical tuna stocks in the EPO. The main source of information for size composition of the longline fleets are the data provided by Japan. It was recommended that a detailed examination of the Japanese length-frequency data was undertaken (BET-01-Meerting report), as an increase in the median length since 1990 was noted and there was no simple explanation at the time why such a change may have occurred. The problem was addressed right after the review by splitting the longline fisheries into "early" and "late" and allowing for different selectivities for the two periods.

In 2016, collaborative investigations of the Japanese length-frequency data were undertaken. The main findings were (Satoh *et al.* 2016 SAC 07-03d):

1. Data from two types of vessels was available, commercial and training vessels. The data from training vessels showed length-frequencies skewed towards smaller sizes than data from the commercial vessels. When data was reported to the IATTC the type of vessel was not mentioned.
2. Data from commercial vessels was measured in weight or in length, with predominance of the data in weight from early 1980s to early 1990s. The data was always submitted in length to the IATTC, the weight data was converted into length by the National Research Institute of Far Seas Fisheries (NRIFSF) of Japan before submission. Whether the original measurement was length or weight was not reported.
3. Data provided in two latitude-longitude resolutions 5˚x5˚ and 10˚x 20˚ over the years.

Satoh *et al.* (2016) also noted that (1) does not seem to be the explanation for the shift in size: "although the average size of fish caught by the commercial vessels was larger than those of the training vessels in many cases, the ratio of sample size by vessel type was similar between the two periods (prior- and post 1990)." The authors also noted that (2) solely does not seem to explain the shift: "The average fish lengths converted from the weight group were smaller than those of the length group in many cases, which indicated that the weight-length conversion caused an underestimation of fish size. The number of length measurements increased after 1990 for both species, and exceeded, or was equal to, the number of weight measurements in 1991, and since then the length measurements have predominated. However, the changes of the average weight for both species did not present a clear shift in 1990. This indicates that the shift in size composition in 1990 for both species is unlikely to represent a real change in fish size." However, as explained below, the conversion factor from processed weight to whole weight (and then to length) is likely the cause of the lower lengths in the early period.

Following this collaborative work, Japan replaced all the data from 1975 on with data in the 5˚x5˚ resolution (Figure 4), with indication on the type of vessels and in the original measurement. The IATTC retained some of the data in the 10˚x 20˚ resolution that was not contained in the new submission. Most of the data in the 10˚x 20˚ resolution was replaced by data in the 5˚x5˚ resolution. Since 2011, Japan has submitted data collected by the on-board observers. For some years data recorded by the fishers and by the observers were both submitted, but since 2015, only observer data has been submitted.

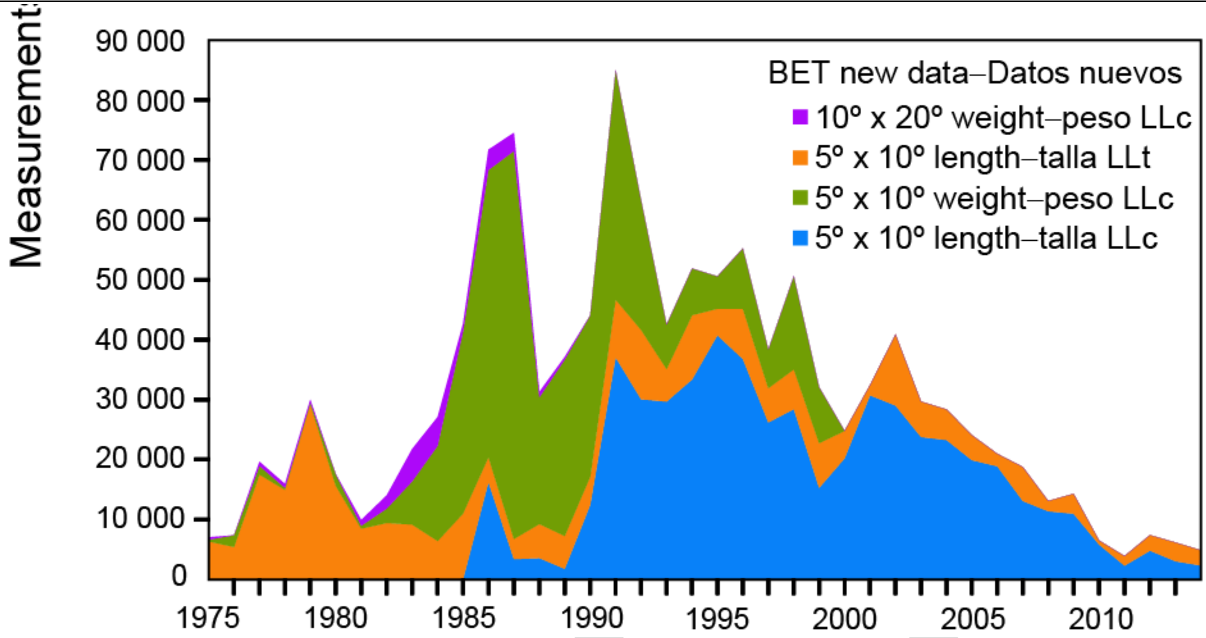


**FIGURE 4.** Number of size measurements of bigeye (BET) from the EPO during the stock assessment period (1975-2014), by type of vessel (LLc: commercial longline vessel; LLt: longline training vessel), spatial resolution (10° x 20° or 5° x 10°), and measurement type (weight: gilled-and-gutted weight; length: fork length) Source: Minte-Vera *et al.* SAC 07-04a.

The effects of the new submission in the stock assessment was investigated (Minte-Vera *et al.* 2016 SAC 07-04a , Minte-Vera *et al.* 2017). The data was entered as the original measurement (length or weight) in the stock assessment, so that any conversion between weight and length was done within the assessment models. The time blocks were removed.

In the SS3 models, a size-transition matrix is produced to compute the expected whole weight from the length-at-age model and the variability of length-at-age and the length-weight relationship. The length-weight relationship used in the stock assessment model for bigeye (Aires-da-Silva and Maunder 2010) is from Nakamura and Uchiyama (1966):

$$w = 3.661 \text{ X } 10^{-5} \, l^{2.90182}$$

The weight data submitted by Japan is gilled and gutted weight (GGw). There are no conversion factors for gilled-and-gutted weight specific to the EPO at this time. The conversion factors developed by Langley *et al.* (2006) for the entire Pacific were used to convert GGw to weight (w) prior to include in the model:

$$\text{Bigeye: } w = 1.3264 * GGw^{0.969}$$

where *w* is whole weight, in kilograms, and *GGw* is the weight of the gilled-and-gutted fish in the ultra-low-temperature (ULT) freezer vessels. Processing the fish prior to ULT freezing included removing the operculum and the tail, which were retained when the fish were merely chilled (Langley *et al.* 2006). The ULT freezer vessels were introduced in the Japanese fleet in 1966, and by 1980 all Japanese distant-water vessels were UTL vessels (Langley *et al.* 2006). About 10% of the data used to derive the conversion factor was from the tropical EPO, the rest comes from the Australian Exclusive Economic Zone

In order to avoid “sawtooth” distributions (large peaks followed by troughs at regular size intervals) in the converted data, caused by applying the conversion to low-resolution data (Langley *et al.* 2006), each 1-kg raw gilled-and-gutted weight class was divided into into 10 equally-spaced intervals. The conversion factor was then applied to each interval, and 10% of the frequency of the original weight class was added to the converted weight class. In SS3 the weight classes had to be adjusted so that each weight class corresponds roughly to each length class.

The converted weight-frequency data was not compatible with the length-frequency data for the same fisheries and was recommended not to be used in a base-case assessment model (Minte-Vera *et al.* 2016). The average weight from the weight-frequency data tends to be lower than expected by the models that also incorporate length-frequency data and assume the same selectivity for both data types, indicating that there may be a bias caused by the conversion factor. Removing the weight data from the analysis eliminated the pattern in residuals of the fit to the length composition data without the need for a time block in selectivity. A conversion factor specific for the EPO should be developed.

Because the training-vessel length-frequency data may not represent the commercial data but may still have information about the dynamics of the population (*e.g*. recruitment), this data was included in the model as coming from a "survey" (in SS3 terminology), that is a fishery for which there are no catches associated but a selectivity may be estimated.

The current base case model (Xu *et al.* 2018) fits to the training vessel length-composition data representing "survey", to the commercial length-composition to represent the commercial fleets and to the weight-frequency data as "surveys" as well.

The inclusion of the revised data somewhat improved the "recruitment shift", described as a prominent pattern in the stock assessment of bigeye tuna in the EPO, but fail to solve it. The recruitment shift was larger when both length and weight data were used than when only length data was used. This may also be an indication of a potential bias in the conversion factors, as described above.

## 6. OTHER DATA

### 6.1. Vessel registry

Resolution C-18-06, which amends and replaces C-14-01 (Regional Vessel Register), established that the CPCs shall notify the Director by 30 June each year of their vessels on the Regional Vessel Register flying their flag that were actively fishing in the IATTC Convention Area for species covered by the Convention from 1 January to 31 December of the previous year.

### 6.2. On-board observers

Resolution C-11-08 requires that at least 5% of the fishing effort (defined as days fishing) by longline vessels over 20 m length overall (LOA) carry a scientific observer, and that each CPC should report annually about the observer program to the IATTC. Only in 2019 are the CPCs starting to report the raw data taken by the observers. The staff prepared guidelines for minimum data requirements (Wiley *et al.* 2017).

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**APPENDIX I.** Comparison of the annual aggregated data of bigeye tuna used in the IATTC Fisheries Status Report (FSR) and the Level 3 data submitted by CPCs (data extraction from 07 July 2018, except for Vanuatu which was updated to the IATTC on 25 September 2018)

**Table I.1 - Belize**

| BLZ | FSR data | Level 3 data (5°x5°–month; Resolution C-03-05) | | | | | Coverage of Level 3 data (weight from 5°x5°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight (t) | Weight from numbers | Weight from 5°x5° | |
| 2001 | 1,987 | * | * | * | * | * | * |
| 2002 | 1,459 | * | * | * | * | * | * |
| 2003 | 604 | * | * | * | * | * | * |
| 2004 | 120 | * | * | * | * | * | * |
| 2005 | 112 | * | * | * | * | * | * |
| 2006 | 75 | * | * | * | * | * | * |
| 2007 | 93 | * | * | * | * | * | * |
| 2008 | 89 | * | * | * | * | * | * |
| 2009 | 315 | 2,046 | 93 | 0.0456 | * | * | 0.30 |
| 2010 | 34 | 648 | 33 | 0.0516 | * | * | 0.98 |
| 2011 | 6 | 272 | 6 | 0.0203 | * | * | 0.99 |
| 2012 | 12 | 175 | 9 | 0.0516 | * | * | 0.74 |
| 2013 | 182 | 3,205 | 148 | 0.0462 | * | * | 0.81 |
| 2014 | 24 | * | * | * | * | * | * |
| 2015 | * | * | * | * | * | * | * |
| 2016 | 0 | - | - | - | - | - | - |

**Table I.2- China**

| CHN | FSR data | Level 3 data (5°x5°–month; Resolution C-03-05) | | | | | Coverage of Level 3 data (weight from 5°x5°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight (t) | Weight from numbers | Weight from 5°x5° | |
| 2001 | 2,939 | * | 2,550 | * | * | * | 0.87 |
| 2002 | 7,614 | * | 7,351 | * | * | * | 0.97 |
| 2003 | 10,066 | * | 9,973 | * | * | * | 0.99 |
| 2004 | 2,645 | * | 2,645 | * | * | * | 1.00 |
| 2005 | 2,104 | * | 2,104 | * | * | * | 1.00 |
| 2006 | 709 | * | * | * | * | * | * |
| 2007 | 2,324 | * | 2,324 | * | * | * | 1.00 |
| 2008 | 2,379 | 57,136 | 2,360 | 0.04131 | * | * | 0.99 |
| 2009 | 2,481 | 58,224 | 2,497 | 0.04289 | * | * | 1.01 |
| 2010 | 2,490 | 54,504 | 2,490 | 0.04569 | * | * | 1.00 |
| 2011 | 5,450 | 127,587 | 5,450 | 0.04272 | * | * | 1.00 |
| 2012 | 4,386 | 99,648 | 4,385 | 0.04401 | * | * | 1.00 |
| 2013 | 5,199 | 128,445 | 5,199 | 0.04048 | * | * | 1.00 |
| 2014 | 5,253 | 130,698 | 5,253 | 0.04019 | * | * | 1.00 |
| 2015 | 8,401 | 220,790 | 8,400 | 0.03804 | * | * | 1.00 |
| 2016 | 7,052 | 189,515 | 7,052 | 0.03721 | * | * | 1.00 |

**Table I.3 - Japan**

| JPN | FSR data | Level 3 data (5°x5°–month; Resolution C-03-05) | | | | | Coverage of Level 3 data (weight from 5°x5°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight[1] (t) | Weight from numbers[2] | Weight from 5°x5° | |
| 1975 | 40,726 | 792,340 | * | 0.0513 | 40,647 | * | 1.00 |
| 1976 | 52,827 | 974,674 | * | 0.0541 | 52,730 | * | 1.00 |
| 1977 | 70,024 | 1,296,738 | * | 0.054 | 70,024 | * | 1.00 |
| 1978 | 67,214 | 1,261,057 | * | 0.0533 | 67,214 | * | 1.00 |
| 1979 | 54,377 | 1,250,050 | * | 0.0435 | 54,377 | * | 1.00 |
| 1980 | 61,951 | 1,122,300 | * | 0.0552 | 61,951 | * | 1.00 |
| 1981 | 49,970 | 981,717 | * | 0.0509 | 49,969 | * | 1.00 |
| 1982 | 50,199 | 1,061,288 | * | 0.0473 | 50,199 | * | 1.00 |
| 1983 | 57,185 | 1,193,849 | * | 0.0479 | 57,185 | * | 1.00 |
| 1984 | 44,587 | 1,027,301 | * | 0.0434 | 44,585 | * | 1.00 |
| 1985 | 61,627 | 1,378,671 | * | 0.0447 | 61,627 | * | 1.00 |
| 1986 | 91,981 | 1,865,733 | * | 0.0493 | 91,981 | * | 1.00 |
| 1987 | 87,913 | 1,619,020 | * | 0.0543 | 87,913 | * | 1.00 |
| 1988 | 66,015 | 1,187,317 | * | 0.0555 | 65,896 | * | 1.00 |
| 1989 | 67,514 | 1,321,219 | * | 0.0511 | 67,514 | * | 1.00 |
| 1990 | 86,148 | 1,604,247 | * | 0.0537 | 86,148 | * | 1.00 |
| 1991 | 85,011 | 1,496,669 | * | 0.0568 | 85,011 | * | 1.00 |
| 1992 | 74,466 | 1,304,131 | * | 0.0571 | 74,466 | * | 1.00 |
| 1993 | 63,190 | 1,062,018 | * | 0.0596 | 63,296 | * | 1.00 |
| 1994 | 61,471 | 1,069,057 | * | 0.0584 | 62,433 | * | 1.02 |
| 1995 | 49,016 | 876,856 | * | 0.056 | 49,104 | * | 1.00 |
| 1996 | 36,685 | 686,986 | * | 0.0534 | 36,685 | * | 1.00 |
| 1997 | 40,571 | 631,947 | * | 0.0642 | 40,571 | * | 1.00 |
| 1998 | 35,752 | 762,470 | * | 0.0531 | 40,487 | * | 1.13 |
| 1999 | 22,224 | 503,942 | * | 0.0498 | 25,096 | * | 1.13 |
| 2000 | 28,746 | 628,987 | * | 0.0548 | 34,468 | * | 1.20 |
| 2001 | 38,048 | 751,799 | * | 0.0594 | 44,657 | * | 1.17 |
| 2002 | 34,193 | 620,768 | * | 0.0604 | 37,494 | * | 1.10 |
| 2003 | 24,888 | 472,716 | * | 0.0541 | 25,574 | * | 1.03 |
| 2004 | 21,236 | 444,333 | * | * | 25,043 | * | 1.18 |
| 2005 | 19,113 | 393,459 | * | * | 22,175 | * | 1.16 |
| 2006 | 16,235 | 313,229 | * | * | 17,654 | * | 1.09 |
| 2007 | 13,977 | 256,548 | * | * | 14,459 | * | 1.03 |
| 2008 | 14,909 | 285,699 | * | * | 16,102 | * | 1.08 |
| 2009 | 15,490 | 261,979 | * | * | 14,765 | * | 0.95 |
| 2010 | 15,847 | 273,340 | * | * | 15,405 | * | 0.97 |
| 2011 | 13,399 | 242,220 | * | * | 13,652 | * | 1.02 |
| 2012 | 16,323 | 262,144 | * | * | 14,774 | * | 0.91 |
| 2013 | 14,258 | 214,743 | * | * | 12,103 | * | 0.85 |
| 2014 | 13,634 | 211,121 | * | * | 11,899 | * | 0.87 |
| 2015 | 13,097 | 216,817 | * | * | 12,220 | * | 0.93 |
| 2016 | 10,427 | 178,996 | * | * | 10,088 | * | 0.97 |

[1] From Matsumoto and Bayliff. 2008. IATTC Bull. 24(1), Table 3, pg. 140.
[2] For 2004 on, the average weight from 1994-2003 was used

**Table I.4 - Korea**

| KOR | FSR data | Level 3 data (5°x5°–month; Resolution C-03-05) | | | | | Coverage of Level 3 data (weight from 5°x5°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight (t) | Weight from numbers | Weight from 5°x5° | |
| 1975 | 606 | 11,796 | * | * | 526 | 526 | 0.87 |
| 1976 | 1,195 | 22,040 | * | * | 982 | 982 | 0.82 |
| 1977 | 3,467 | 64,203 | * | * | 2,861 | 2,861 | 0.83 |
| 1978 | 3,040 | 57,039 | * | * | 2,542 | 2,542 | 0.84 |
| 1979 | 824 | 18,948 | * | * | 844 | 844 | 1.02 |
| 1980 | 2,189 | 39,653 | * | * | 1,767 | 1,767 | 0.81 |
| 1981 | 2,966 | 58,259 | * | * | 2,597 | 2,597 | 0.88 |
| 1982 | 2,969 | 62,767 | * | * | 2,797 | 2,797 | 0.94 |
| 1983 | 2,614 | 54,582 | * | * | 2,433 | 2,433 | 0.93 |
| 1984 | 1,613 | 37,175 | * | * | 1,657 | 1,657 | 1.03 |
| 1985 | 4,510 | 100,895 | * | * | 4,497 | 4,497 | 1.00 |
| 1986 | 10,187 | 206,622 | * | * | 9,209 | 9,209 | 0.90 |
| 1987 | 11,681 | 177,835 | 7,181 | 0.0404 | 7,926 | 7,181 | 0.61 |
| 1988 | 6,151 | 101,643 | 4,218 | 0.0415 | 4,530 | 4,218 | 0.69 |
| 1989 | 3,138 | 54,593 | 2,198 | 0.0403 | 2,433 | 2,198 | 0.70 |
| 1990 | 12,127 | 225,055 | 8,121 | 0.0361 | 10,031 | 8,121 | 0.67 |
| 1991 | 17,883 | 400,646 | 15,089 | 0.0377 | 17,856 | 15,089 | 0.84 |
| 1992 | 9,202 | * | * | * | * | * | * |
| 1993 | 8,924 | * | * | * | * | * | * |
| 1994 | 9,522 | * | * | * | * | * | * |
| 1995 | 8,992 | 212,492 | 6,591 | 0.0310 | 9,471 | 6,591 | 0.73 |
| 1996 | 9,983 | 187,014 | 6,422 | 0.0343 | 8,335 | 6,422 | 0.64 |
| 1997 | 11,376 | 180,693 | 6,795 | 0.0376 | 8,053 | 6,795 | 0.60 |
| 1998 | 9,731 | 187,533 | 6,441 | 0.0343 | 8,358 | 6,441 | 0.66 |
| 1999 | 9,431 | 167,009 | 6,004 | 0.0359 | 7,443 | 6,004 | 0.64 |
| 2000 | 13,280 | 171,241 | 6,756 | 0.0395 | 7,632 | 6,756 | 0.51 |
| 2001 | 12,576 | 241,060 | 10,110 | 0.0419 | 10,744 | 10,110 | 0.80 |
| 2002 | 10,358 | 131,004 | 5,605 | 0.0428 | 5,839 | 5,605 | 0.54 |
| 2003 | 10,272 | * | 8,065 | * | * | 8,065 | 0.79 |
| 2004 | 10,729 | * | 9,264 | * | * | 9,264 | 0.86 |
| 2005 | 11,580 | * | 2,938 | * | * | 2,938 | 0.25 |
| 2006 | 6,732 | 128,182 | 6,109 | 0.0477 | 5,713 | 6,109 | 0.91 |
| 2007 | 5,611 | 43,709 | 2,301 | 0.0526 | 1,948 | 2,301 | 0.41 |
| 2008 | 4,150 | 18,090 | 941 | 0.0520 | 806 | 941 | 0.23 |
| 2009 | 6,758 | 77,488 | 4,032 | 0.0520 | 3,454 | 4,032 | 0.60 |
| 2010 | 9,244 | 114,679 | 5,733 | 0.0500 | 5,111 | 5,733 | 0.62 |
| 2011 | 6,617 | 88,532 | 4,865 | 0.0549 | 3,946 | 4,865 | 0.74 |
| 2012 | 7,450 | 108,752 | 7,449 | 0.0685 | 4,847 | 7,449 | 1.00 |
| 2013 | 8,822 | 160,669 | 8,006 | 0.0498 | 7,161 | 8,006 | 0.91 |
| 2014 | 8,203 | 144,630 | 7,445 | 0.0515 | 6,446 | 7,445 | 0.91 |
| 2015 | 8,635 | 154,933 | 7,836 | 0.0506 | 6,905 | 7,836 | 0.91 |
| 2016 | 7,692 | 149,553 | 6,981 | 0.0467 | 6,665 | 6,981 | 0.91 |

**Table I.5 – Chinese Taipei**

| TWN | FSR data | Level 3 data (5°x5°–month; Resolution C-03-05) | | | | | Coverage of Level 3 data (weight from 5°x5°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight (t) | Weight from numbers | Weight from 5°x5° | |
| 1975 | 401 | 9,114 | 456 | 0.0500 | * | 456 | 1.14 |
| 1976 | 268 | 4,285 | 211 | 0.0492 | * | 211 | 0.79 |
| 1977 | 595 | 11,703 | 596 | 0.0510 | * | 596 | 1.00 |
| 1978 | 405 | 7,938 | 403 | 0.0508 | * | 403 | 1.00 |
| 1979 | 234 | 5,272 | 234 | 0.0443 | * | 234 | 1.00 |
| 1980 | 195 | 2,192 | 108 | 0.0491 | * | 108 | 0.55 |
| 1981 | 480 | 12,621 | 640 | 0.0507 | * | 640 | 1.33 |
| 1982 | 197 | 3,191 | 144 | 0.0451 | * | 144 | 0.73 |
| 1983 | 244 | 2,687 | 163 | 0.0606 | * | 163 | 0.67 |
| 1984 | 194 | 2,500 | 153 | 0.0611 | * | 153 | 0.79 |
| 1985 | 188 | 2,650 | 126 | 0.0475 | * | 126 | 0.67 |
| 1986 | 257 | 2,810 | 146 | 0.0518 | * | 146 | 0.57 |
| 1987 | 526 | 10,531 | 606 | 0.0575 | * | 606 | 1.15 |
| 1988 | 591 | 10,622 | 665 | 0.0626 | * | 665 | 1.13 |
| 1989 | 311 | 23,548 | 1,246 | 0.0529 | * | 1,246 | 4.01 |
| 1990 | 596 | 13,333 | 715 | 0.0536 | * | 715 | 1.20 |
| 1991 | 1,291 | 25,423 | 1,265 | 0.0497 | * | 1,265 | 0.98 |
| 1992 | 1,032 | 15,157 | 727 | 0.0480 | * | 727 | 0.70 |
| 1993 | 297 | 4,595 | 237 | 0.0515 | * | 237 | 0.80 |
| 1994 | 255 | 7,755 | 367 | 0.0473 | * | 367 | 1.44 |
| 1995 | 77 | 1,550 | 67 | 0.0435 | * | 67 | 0.88 |
| 1996 | 95 | 1,948 | 103 | 0.0529 | * | 103 | 1.09 |
| 1997 | 256 | 4,250 | 131 | 0.0308 | * | 131 | 0.51 |
| 1998 | 314 | 5,238 | 149 | 0.0284 | * | 149 | 0.47 |
| 1999 | 890 | 26,607 | 910 | 0.0342 | * | 910 | 1.02 |
| 2000 | 1,916 | 99,794 | 5,194 | 0.0521 | * | 5,194 | 2.71 |
| 2001 | 9,285 | 151,466 | 7,953 | 0.0525 | * | 7,953 | 0.86 |
| 2002 | 17,253 | 621,061 | 26,539 | 0.0427 | * | 26,539 | 1.54 |
| 2003 | 12,016 | 363,163 | 16,263 | 0.0448 | * | 16,263 | 1.35 |
| 2004 | 7,384 | 226,910 | 9,108 | 0.0401 | * | 9,108 | 1.23 |
| 2005 | 6,441 | 170,739 | 6,775 | 0.0397 | * | 6,775 | 1.05 |
| 2006 | 6,412 | 150,176 | 6,497 | 0.0433 | * | 6,497 | 1.01 |
| 2007 | 6,057 | 138,219 | 5,988 | 0.0433 | * | 5,988 | 0.99 |
| 2008 | 1,852 | 42,522 | 1,991 | 0.0468 | * | 1,991 | 1.07 |
| 2009 | 3,396 | 66,812 | 3,493 | 0.0523 | * | 3,493 | 1.03 |
| 2010 | 5,276 | 112,133 | 5,481 | 0.0489 | * | 5,481 | 1.04 |
| 2011 | 3,957 | 84,473 | 3,987 | 0.0472 | * | 3,987 | 1.01 |
| 2012 | 4,999 | 92,789 | 4,710 | 0.0508 | * | 4,710 | 0.94 |
| 2013 | 4,162 | 81,147 | 4,195 | 0.0517 | * | 4,195 | 1.01 |
| 2014 | 4,511 | 86,233 | 4,379 | 0.0508 | * | 4,379 | 0.97 |
| 2015 | 5,181 | 98,097 | 5,157 | 0.0526 | * | 5,157 | 1.00 |
| 2016 | 6,054 | 107,752 | 5,693 | 0.0528 | * | 5,693 | 0.94 |

**Table I.6 – United States of America**

| USA | FSR data | Level 3 data (5°x5°–month; Resolution C-03-05) | | | | | Coverage of Level 3 data (weight from 5°x5°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight (t) | Weight from numbers | Weight from 5°x5° | |
| 1985 | 3 | * | * | * | * | * | * |
| 1986 | 9 | * | * | * | * | * | * |
| 1987 | 7 | * | * | * | * | * | * |
| 1988 | 6 | * | * | * | * | * | * |
| 1989 | * | * | * | * | * | * | * |
| 1990 | 1 | * | * | * | * | * | * |
| 1991 | 12 | 160 | * | * | * | * | * |
| 1992 | 93 | 2,408 | * | * | * | * | * |
| 1993 | 55 | 1,395 | * | * | * | * | * |
| 1994 | 9 | 228 | * | * | * | * | * |
| 1995 | 75 | 3,571 | * | * | * | * | * |
| 1996 | 85 | 1,348 | * | * | * | * | * |
| 1997 | 123 | 1,629 | * | * | * | * | * |
| 1998 | 195 | 2,891 | * | * | * | * | * |
| 1999 | 230 | 4,369 | * | * | * | * | * |
| 2000 | 164 | 1,887 | * | * | * | * | * |
| 2001 | 147 | 3,077 | * | * | * | * | * |
| 2002 | 132 | 3,914 | * | * | * | * | * |
| 2003 | 238 | 4,012 | * | * | * | * | * |
| 2004 | 149 | 4,308 | * | * | * | * | * |
| 2005 | 536 | 11,992 | * | * | * | * | * |
| 2006 | 89 | 1,124 | * | * | * | * | * |
| 2007 | 424 | 9,099 | * | * | * | * | * |
| 2008 | 1,277 | 28,101 | * | * | * | * | * |
| 2009 | 730 | 18,708 | * | * | * | * | * |
| 2010 | 1,356 | 31,970 | * | * | * | * | * |
| 2011 | 1,050 | 25,034 | * | * | * | * | * |
| 2012 | 875 | 20,792 | * | * | * | * | * |
| 2013 | 2,054 | * | * | * | * | * | * |
| 2014 | 2,081 | 54,028 | * | * | * | * | * |
| 2015 | 3,050 | 69,945 | * | * | * | * | * |
| 2016 | 2,088 | 51,240 | * | * | * | * | * |

**Table I.7 – Vanuatu**

| VUT | FSR data | Level 3 data (5°x5°–month; Resolution C-03-05) | | | | | Coverage of Level 3 data (weight from 5°x5°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight (t) | Weight from numbers | Weight from 5°x5° | |
| 2000 | 2,754 | * | * | * | * | * | * |
| 2001 | 3,277 | * | * | * | * | * | * |
| 2002 | 2,995 | * | * | * | * | * | * |
| 2003 | 1,258 | * | * | * | * | * | * |
| 2004 | 407 | * | * | * | * | * | * |
| 2005 | 318 | * | * | * | * | * | * |
| 2006 | 960 | * | * | * | * | * | * |
| 2007 | 1,013 | 28,390 | 1,012 | 0.035633 | * | 1,012 | 1.00 |
| 2008 | 790 | 21,416 | 789 | 0.036857 | * | 789 | 1.00 |
| 2009 | 1,032 | 29,199 | 1,032 | 0.035356 | * | 1,032 | 1.00 |
| 2010 | 1,496 | 38,665 | 1,500 | 0.038785 | * | 1,500 | 1.00 |
| 2011 | 694 | 18,537 | 695 | 0.03748 | * | 695 | 1.00 |
| 2012 | 1,063 | 27,010 | 1,062 | 0.039327 | * | 1,062 | 1.00 |
| 2013 | 604 | 14,045 | 604 | 0.043028 | * | 604 | 1.00 |
| 2014 | 897 | 21,286 | 897 | 0.042161 | * | 897 | 1.00 |
| 2015 | 1,888 | 42,449 | 1,888 | 0.044479 | * | 1,888 | 1.00 |
| 2016 | 762 | 13,565 | * | * | * | * | * |
| 2017 | 757 | * | * | * | * | * | * |

**Table I.8 - French Polynesia**

| PYF | FSR data | Level 2 data (1°x1°–month; Resolution C-03-05) | | | | | Coverage of Level 2 data (weight from 1°x1°/FSR weight) |
|---|---|---|---|---|---|---|---|
| | Weight (t) | Reported numbers | Reported weight (t) | Average weight (t) | Weight from numbers | Weight from 1°x1° | |
| 1992 | 7 | 202 | 7 | 0.036782 | * | 7 | 0.99 |
| 1993 | 7 | 211 | 7 | 0.031659 | * | 7 | 0.99 |
| 1994 | 102 | 1,626 | 47 | 0.029164 | * | 47 | 0.47 |
| 1995 | 97 | 1,976 | 53 | 0.027039 | * | 53 | 0.55 |
| 1996 | 113 | 2,329 | 62 | 0.026466 | * | 62 | 0.55 |
| 1997 | 250 | 6,828 | 183 | 0.026829 | * | 183 | 0.73 |
| 1998 | 359 | 11,653 | 292 | 0.025019 | * | 292 | 0.81 |
| 1999 | 3,652 | 6,965 | 168 | 0.024154 | * | 168 | 0.05 |
| 2000 | 653 | 19,658 | 472 | 0.023997 | * | 472 | 0.72 |
| 2001 | 684 | 16,785 | 479 | 0.028514 | * | 479 | 0.70 |
| 2002 | 388 | 1,650 | 47 | 0.028242 | * | 47 | 0.12 |
| 2003 | 346 | 11,299 | 273 | 0.024192 | * | 273 | 0.79 |
| 2004 | 405 | 14,036 | 312 | 0.022194 | * | 312 | 0.77 |
| 2005 | 398 | 15,412 | 398 | 0.025829 | * | 398 | 1.00 |
| 2006 | 388 | 12,864 | 331 | 0.025755 | * | 331 | 0.85 |
| 2007 | 361 | 10,040 | 263 | 0.026217 | * | 263 | 0.73 |
| 2008 | 367 | 10,509 | 268 | 0.025521 | * | 268 | 0.73 |
| 2009 | 484 | 12,260 | 360 | 0.029369 | * | 360 | 0.74 |
| 2010 | 314 | 8,001 | 226 | 0.028198 | * | 226 | 0.72 |
| 2011 | 445 | 11,951 | 315 | 0.026374 | * | 315 | 0.71 |
| 2012 | 472 | 10,898 | 343 | 0.031515 | * | 343 | 0.73 |
| 2013 | 543 | 13,690 | 493 | 0.036009 | * | 493 | 0.91 |
| 2014 | 541 | 19,419 | 568 | 0.029231 | * | 568 | 1.05 |
| 2015 | 712 | 24,350 | 692 | 0.028402 | * | 692 | 0.97 |
| 2016 | 497 | 16,198 | 477 | 0.029462 | * | 477 | 0.96 |

## APPENDIX II – R code implementing the algorithm to compute the catches from longline fleets by stock assessment area

```
###################################################################################
###### This code processes the raw LL catch data into the format for Stock Assessment
###### Version3: Include coastal countries in the allocation code
###### Version2: Increased flexibility for various species and spatial configuration
###### by specifying the number of areas and years
###### Haikun and Carolina,
###### 10/11/2018
###### The procedure can be found in C:\Users\hkxu\OneDrive - IATTC\IATTC\stock assessment\LL Catch allocation\version2
###################################################################################
# set working directory
Dir <- "C:/Users/hkxu/OneDrive - IATTC/IATTC/stock assessment/Spatial Model/LL Catch/1/"
setwd(Dir)
source("C:/Users/hkxu/OneDrive - IATTC/IATTC/stock assessment/Spatial Model/LL Catch/Area_Code.R")
library("tidyverse")
# load both gridded data and FSR data
Grid_Catch <- read.table(paste0(Dir,"Tb2c_CatchBET&YFT_AreasLL_newAreas.txt"), header = TRUE, sep = ",")
FSR_Catch <- read.table(paste0(Dir,"Tb3_AnnualCatchBET_LL&otherGears.txt"), header = TRUE, sep = ",")
Grid_Catch <- data.frame(Grid_Catch)
FSR_Catch <- data.frame(FSR_Catch)
# make sure area code starts from 1
Grid_Catch$NewAreas <- Areas(Grid_Catch$Lat,Grid_Catch$Lon,1)
data <- data.frame("Lat"=Grid_Catch$Lat,"Lon"=Grid_Catch$Lon,"Areas"=as.factor(Grid_Catch$NewAreas))

wmap <- map_data("world")
ggplot() +
 geom_point(aes(x = Lon,y = Lat,color=Areas), data = data, size=6,shape=15) +
 geom_polygon(data=wmap,aes(long, lat, group = group),fill = "black",colour = "white",alpha = 1,lwd=0.5) +
 coord_quickmap(ylim = c(-40,40),xlim = c(-150,-70)) +
 theme_bw(8)

ggsave(filename = "Areas.png", dpi = 300, width = 5,height = 5)
# specify the countries to be analyzed in the LL catch allocation
Countries <- as.character(unique(Grid_Catch$FlagAbv))
# Countries <- c("KOR")
Special_Countires <- c("KOR","TWN")

n_areas = length(unique(Grid_Catch$NewAreas))
last_year = 2017.75
Species <- "BET"
save_all <- matrix(0, nrow = 0, ncol = 1+n_areas*2) # save all the LL catch into this matrix
for (c in 1:length(Countries)) {# deal with the allocation by country
 # reformat the gridded and FSR data into quarterly and annual values
 Grid_weight_quarterly <- Grid_Catch %>% filter(FlagAbv==Countries[c],SpeciesAbv==Species) %>%
 mutate(YQ = Yrr + (Quarter-1)/4) %>%
 group_by(YQ,NewAreas) %>% summarise(Tot_Weight_Sum = sum(SumOfWeight,na.rm = TRUE)) %>%
 spread(key = NewAreas, value = Tot_Weight_Sum, fill = 0)

 Grid_number_quarterly <- Grid_Catch %>% filter(FlagAbv==Countries[c],SpeciesAbv==Species) %>%
 mutate(YQ = Yrr + (Quarter-1)/4) %>%
 group_by(YQ,NewAreas) %>% summarise(Tot_Number_Sum = sum(SumOfNumber,na.rm = TRUE)) %>%
 spread(key = NewAreas, value = Tot_Number_Sum, fill = 0)

 Grid_number_annual <- Grid_Catch %>% filter(FlagAbv==Countries[c],SpeciesAbv==Species) %>%
 group_by(Yrr,NewAreas) %>% summarise(Tot_Number_Sum = sum(SumOfNumber,na.rm = TRUE)) %>%
 group_by(Yrr) %>% mutate(EPO = sum(Tot_Number_Sum,na.rm = TRUE)) %>%
 spread(key = NewAreas, value = Tot_Number_Sum, fill = 0)

 Grid_weight_annual <- Grid_Catch %>% filter(FlagAbv==Countries[c],SpeciesAbv==Species) %>%
 group_by(Yrr,NewAreas) %>% summarise(Tot_Weight_Sum = sum(SumOfWeight,na.rm = TRUE)) %>%
 group_by(Yrr) %>% mutate(EPO = sum(Tot_Weight_Sum,na.rm = TRUE)) %>%
 spread(key = NewAreas, value = Tot_Weight_Sum, fill = 0)

 # calculate the prop (in weight and number) by quarter by area
 Grid_prop_quarterly <- Grid_Catch %>% filter(FlagAbv==Countries[c],SpeciesAbv==Species) %>%
 group_by(Yrr,Quarter,NewAreas) %>% summarise(Tot_Weight_Sum = sum(SumOfWeight,na.rm = TRUE)) %>%
 group_by(Yrr) %>% mutate(Prop = Tot_Weight_Sum/sum(Tot_Weight_Sum,na.rm = TRUE)) %>%
 select(Yrr,Quarter,NewAreas,Prop) %>%
 spread(key = NewAreas, value = Prop, fill = 0) %>% mutate(YQ = Yrr + (Quarter-1)/4)

 Grid_prop_num_quarterly <- Grid_Catch %>% filter(FlagAbv==Countries[c],SpeciesAbv==Species) %>%
 group_by(Yrr,Quarter,NewAreas) %>% summarise(Tot_Number_Sum = sum(SumOfNumber,na.rm = TRUE)) %>%
 group_by(Yrr) %>% mutate(Prop = Tot_Number_Sum/sum(Tot_Number_Sum,na.rm = TRUE)) %>%
 select(Yrr,Quarter,NewAreas,Prop) %>%
 spread(key = NewAreas, value = Prop, fill = 0) %>% mutate(YQ = Yrr + (Quarter-1)/4)

 # if the data do not include some areas for the entire period, add 0 catch to those areas
 # to make the format of the dataset consistent among countries
 if(ncol(Grid_number_annual)<(2+n_areas)) {
 for (a in 1:n_areas) {
 if(! toString(a) %in% names(Grid_number_annual)) {
 Grid_number_annual[[toString(a)]] <- 0
 Grid_number_quarterly[[toString(a)]] <- 0
 Grid_weight_annual[[toString(a)]] <- 0
 Grid_weight_quarterly[[toString(a)]] <- 0
 Grid_prop_quarterly[[toString(a)]] <- 0
 Grid_prop_num_quarterly[[toString(a)]] <- 0
 }
 }
 }

 # CHN has one PS catch data in 2001, assume it is LL catch
```

```
FSR_annual <- FSR_Catch %>% filter(FlagAbv==Countries[c],SpeciesAbv==Species) %>%
group_by(Year) %>% summarise(mt=sum(mt))

# flag = 0 (have gridded number data); 1 (gridded weight data < FSR, need to do allocation);
# 2 (gridded weight data > FSR, use gridded weight data); 3 (no gridded number or weight data, need to do allowcation);

allocation_flag <- rep(3,nrow(FSR_annual))
flag_id <- FSR_annual$Year %in% Grid_number_annual$Yrr
if(Countries[c] %in% Special_Coutries) {
allocation_flag[flag_id==TRUE] <- ifelse(Grid_number_an-
nual$EPO>0,ifelse(Grid_weight_annual$EPO>0&Grid_weight_annual$EPO<FSR_annual[which(FSR_annual$Year %in% Grid_weight_an-
nual$Yrr),"mt"],1,0),
ifelse(Grid_weight_annual$EPO>0,
ifelse(Grid_weight_annual$EPO<FSR_annual[which(FSR_annual$Year %in% Grid_weight_annual$Yrr),"mt"],1,2),3))
}
else {
allocation_flag[flag_id==TRUE] <- ifelse(Grid_number_annual$EPO>0,0,
ifelse(Grid_weight_annual$EPO>0,
ifelse(Grid_weight_annual$EPO<FSR_annual[which(FSR_annual$Year %in% Grid_weight_annual$Yrr),"mt"],1,2),3))
}
# a quick look at the allocation flag vector
# plot(FSR_annual$Year,allocation_flag,main=Countries[c])
print(Countries[c])
print(allocation_flag)

# create a new data.frame to store the allocation values
YQ = seq(FSR_annual$Year[1],last_year,0.25)
allocation <- data.frame("YQ" = rep(YQ), "Year" = floor(YQ), "Quarter" = rep(1:4,length(YQ)/4))

allocation_weight <- data.frame(matrix(NA,nrow = length(YQ), ncol = n_areas))
names(allocation_weight) <- paste0("W",seq(1,n_areas))
allocation <- cbind(allocation,allocation_weight)

for (i in 1:length(FSR_annual$Year)) { # do the allocation for each year

year <- FSR_annual$Year[i]

# if FSR does not exist for last year, use the previous year's value
if(is.na(as.numeric(FSR_annual[which(FSR_annual$Year==year),"mt"]))==FALSE) FSR <- as.nu-
meric(FSR_annual[which(FSR_annual$Year==year),"mt"])
else FSR <- as.numeric(FSR_annual[which(FSR_annual$Year==(year-1)),"mt"])

if (allocation_flag[i]==1) {
# allocate using FSR and weight prop by quarter by area
allocation[which(allocation$Year==year),paste0("W",seq(1,n_areas))] <- FSR * Grid_prop_quarterly[which(alloca-
tion$Year==year),paste0("",seq(1,n_areas))]
}

if (allocation_flag[i]==2) {
# use the gridded weight data directly
allocation[which(allocation$Year==year),paste0("W",seq(1,n_areas))] <- Grid_weight_quarterly[which(floor(Grid_weight_quar-
terly$YQ)==year),paste0("",seq(1,n_areas))]
}

if (allocation_flag[i]==3) {
# allocate using FSR and weight prop by quarter by area from the nearest year that has data
if(sum(Grid_prop_quarterly[paste0("",seq(1,n_areas))])>0) { # use the prop in weight for allocation
for (year_diff in 1:40) { # this loop is used to find the reference year (year_new) for allocation

if((year-year_diff) %in% Grid_number_annual$Yrr) {
if(Grid_weight_annual[which(Grid_weight_annual$Yrr==(year-year_diff)),"EPO"]>0) {
year_new <- year-year_diff
break
}
}

if((year+year_diff) %in% Grid_number_annual$Yrr) {
if(Grid_weight_annual[which(Grid_weight_annual$Yrr==(year+year_diff)),"EPO"]>0) {
year_new <- year+year_diff
break
}
}
}

prop <- Grid_prop_quarterly[which(Grid_prop_quarterly$Yrr==year_new),c("Quarter",paste0("",seq(1,n_areas)))]
prop_final <- matrix(0,nrow=4,ncol=n_areas)
for(q in 1:4) { # if no catch in some quarter, add 0 for those quarters to make dataset consistent among quarters
if(q %in% prop$Quarter) prop_final[q,] <- data.matrix(prop[which(prop$Quarter==q),2:(n_areas+1)])
}
# print(year_new)
allocation[which(allocation$Year==year),paste0("W",seq(1,n_areas))] <- FSR * prop_final

}

else { # use the prop in number for allocation
for (year_diff in 1:40) {

if((year-year_diff) %in% Grid_number_annual$Yrr) {
if(Grid_number_annual[which(Grid_number_annual$Yrr==(year-year_diff)),"EPO"]>0) {
year_new <- year-year_diff
break
}
}

if((year+year_diff) %in% Grid_number_annual$Yrr) {
if(Grid_number_annual[which(Grid_number_annual$Yrr==(year+year_diff)),"EPO"]>0) {
```

```
 year_new <- year+year_diff
 break
 }
 }

 }
 prop_num <- Grid_prop_num_quarterly[which(Grid_prop_num_quarterly$Yrr==year_new),c("Quarter",paste0("",seq(1,n_areas)))]
 prop_final <- matrix(0,nrow=4,ncol=n_areas)
 for(q in 1:4) {
 if(q %in% prop_num$Quarter) prop_final[q,] <- data.matrix(prop_num[which(prop_num$Quarter==q),2:(n_areas+1)])
 }
 # print(year_new)
 allocation[which(allocation$Year==year),paste0("W",seq(1,n_areas))] <- FSR * prop_final

 }

 }
 }

 save <- right_join(Grid_number_quarterly[,c("YQ",paste0("",seq(1,n_areas)))],allocation[,c(1,seq(4,n_areas+3))])

 # if no data is available in the last year, copy the data in the previous year
 if(sum(!is.na(save[seq(nrow(save)-3,nrow(save)),2:(1+2*n_areas)]))==0) {
 # print(Countries[c])
 save[seq(nrow(save)-3,nrow(save)),2:(1+2*n_areas)] <- save[seq(nrow(save)-3-4,nrow(save)-4),2:(1+2*n_areas)]
 }

 # remove those numbers where weight allocation exist (see rule#2 in the word file)
 save[,paste0("",seq(1,n_areas))] <- save[,paste0("",seq(1,n_areas))] * ifelse(is.na(save[,paste0("W",seq(1,n_areas))]),1,NA)

 write.csv(save,paste0(Countries[c],".csv"),row.names=FALSE)

 save_all <- rbind(save_all,data.matrix(save))
}
colnames(save_all) <- c("YQ",paste0("N",seq(1,n_areas)),paste0("W",seq(1,n_areas)))
write.csv(save_all,"save_all.csv",row.names=FALSE)

LL_Catch <- data.frame(save_all) %>% gather(c(paste0("N",seq(1,n_areas)),paste0("W",seq(1,n_areas))), key = "term", value =
"catch") %>%
 group_by(YQ,term) %>% summarise(tot_catch=sum(catch,na.rm=T)) %>% spread(key = term, value = tot_catch) %>%
 filter(YQ>=1975)


###################### Coastal countries
Coastal_Countries <- as.character(unique(FSR_Catch$FlagAbv))[!as.character(unique(FSR_Catch$FlagAbv)) %in% Countries]
Coastal_Countries <- sort(Coastal_Countries)
Area_Flag <- c(6,3,3,4,3,3,6,4,3)

Coastal_Catch <- matrix(0,nrow=nrow(LL_Catch),ncol=n_areas)
Coastal_Catch <- cbind(floor(LL_Catch$YQ),Coastal_Catch)

for (c in 1:length(Coastal_Countries)) {
 FSR_annual <- FSR_Catch %>% filter(FlagAbv==Coastal_Countries[c],SpeciesAbv==Species) %>%
 group_by(Year) %>% summarise(mt=sum(mt))

 for (y in 1:nrow(FSR_annual)) {
 Coastal_Catch[which(Coastal_Catch[,1]==FSR_annual$Year[y]),Area_Flag[c]+1] <-
Coastal_Catch[which(Coastal_Catch[,1]==FSR_annual$Year[y]),Area_Flag[c]+1] + FSR_annual$mt[y]/4
 }
}

if(sum(Coastal_Catch[(nrow(LL_Catch)-3):nrow(LL_Catch),2:(n_areas+1)])==0) {
 Coastal_Catch[(nrow(LL_Catch)-3):nrow(LL_Catch),2:(n_areas+1)] <- Coastal_Catch[(nrow(LL_Catch)-3-4):(nrow(LL_Catch)-
4),2:(n_areas+1)]
}

write.csv(Coastal_Catch,"Coastal_Catch.csv",row.names=FALSE)

# totla catch
LL_Catch[,paste0("W",seq(1,n_areas))] <- LL_Catch[,paste0("W",seq(1,n_areas))] + Coastal_Catch[,2:(n_areas+1)]
write.csv(LL_Catch,"LL_Catch.csv",row.names=FALSE)
```