

REPORT OF THE 2019 ICCAT YELLOWFIN TUNA STOCK ASSESSMENT MEETING
(Grand-Bassam, Cote d'Ivoire, 8-16 July 2019)

1. Opening, adoption of agenda and meeting arrangements

The meeting was held at Afrikland Hotel Grand-Bassam, Cote d'Ivoire July 8 to 16, 2019. Dr. Shannon L. Cass-Calay (USA), the Yellowfin Tuna Species Group ("the Group") rapporteur and meeting Chair, opened the meeting and welcomed participants. Dr. Justin Amade and Professor Datté J. Yao (Côte d'Ivoire) welcomed the participants and highlighted the importance of the work to be developed by the Group aiming at the preparation for the management advice to the Commission. At the opening of the session, the general inspector, Dr. Diawara Siriman, representing the Ministry of Livestock and Fisheries Resources, stated that the health of the tuna industry in Côte d'Ivoire, which is a flagship of the fisheries industry, is essential as the supply for the tuna companies of the country who depends on it. The Group thanked the Ministry of Animal Resources and Fisheries, supporting staff and Côte d'Ivoire scientist for kindly hosting the meeting and having arranged all necessary logistics for its success. The Chair proceeded to review the Agenda, which was adopted with changes (**Appendix 1**).

The List of Participants is included in **Appendix 2**. The List of Documents presented at the meeting is attached as **Appendix 3**. The abstracts of all SCRS documents and presentations provided at the meeting are included in **Appendix 4**. The following served as rapporteurs:

| <i>Sections</i> | <i>Rapporteur</i> |
|-----------------|--|
| Item 1 | M. Ortiz, |
| Item 2 | S. Cass-Calay, M. Ortiz, L. Ailloud |
| Item 3 | L. Ailloud, A. Kimoto, S. Cass-Calay, M. Ortiz |
| Item 4 | A. Kimoto, D. Die, C. Brown, M. Narvaez |
| Item 5 | A. Kimoto, J. Walter |
| Item 6 | S. Cass-Calay, G. Melvin, D. Die |
| Item 7 | S. Cass-Calay, D. Die |
| Item 8 | M. Ortiz |

And the following served as assessment modelers;

| <i>Model</i> | <i>Modelers</i> |
|-----------------|--|
| Stock Synthesis | J. Walter, A. Kimoto, K. Sato, T. Matsumoto, H. Yokio, H. Winker |
| JABBA | R. Sant'Ana |
| MPB | G. Merino |

2. Summary of available data for assessment

2.1 Biology

A presentation was made (SCRS_P_2019_037) regarding the age composition of yellowfin tuna captured in the Ascension Islands. Large yellowfin tuna are often observed. Captures (n = 341) were made by rod and reel and spear fishing modes during 2014-2017. Individuals from 50 to 192 cm, and 0 to 18 years were observed (**Figure 1**). Evidence of sexually dimorphic growth was also noted (**Figure 2**).

The group determined that the maximum age of yellowfin observed in this study (18 years) was consistent with a previous study in the Gulf of Mexico and USA Atlantic east coast (SCRS/2019/025), further supporting the change from Max Age = 11 to Max Age = 18 which was recommended at the data preparatory meeting. Furthermore, this study also confirms that individuals as old as 18 occur outside of the US, and closer to the areas where fishing pressure is higher (e.g. Gulf of Guinea).

The Group discussed the available length at age observations from Ascension, USA and South Africa, and noted that the variability in the length at age of young fish appears larger than the variability in the length at age of older fish (**Figure 3**.) The Group suggested that the unusual variability in length at age of young fish could arise as an artifact of birthdate assignment. For example, in the US study, birthdate is assumed to be July 1, but yellowfin born outside US waters may have been sampled in the US study. These fish could

have true birthdates much earlier, leading to an error in age assignment. Errors could also occur because spawning season is protracted, so a fish born early in the spawning season would appear much larger at assigned age than a fish born late in the same spawning season. An assumed birthdate was not applied to the Ascension Island data. Therefore, the ages from that study are simply the number of annuli observed, and no adjustment is made to account for birthdate.

The Group also observed that studies in various areas (South Africa, USA, Ascension Island) suggest dissimilar growth patterns (**Figure 3**) but noted that this could arise as a function of differential fishing selectivity. The Group also discussed that there was strong bimodality in the length composition of the Ascension data, and that this data included older fish which were larger, on average, than those sampled in other areas. The Group concluded that the bimodality occurred because two types of sampling gear were used (rod and reel, and spear). The Group also concluded that most of the largest fish were captured by spear fishers, who frequently target the largest fish for sport. If such targeting creates a bias toward larger fish at age, this could explain the differences observed between the US and Ascension Island data.

The Group agreed that the Ascension dataset was appropriate for use in age-structured stock assessments (e.g. stock synthesis) but recommended that age assignment for the Ascension dataset be adjusted to consider birthdate to maximize the comparability of the datasets. Unfortunately, not all samples had edge type, so the adjustment could not be made during the meeting. Should these data be made available, the adjustment could be made. Also, stock synthesis requires age composition data to be assigned to a fleet or survey. The Group noted that the current fleet structure of the stock synthesis model does not include a fleet comparable to the Ascension spear fishery. Therefore, the Group recommended excluding the spear fishing data from the stock synthesis model inputs. The Group agreed that the rod and reel gear could be assumed to have similar selectivity as the longline fleets.

AOTTP Information

The working requested a summary of the information concerning growth from the Atlantic Ocean Tropical tuna Tagging Programme (AOTTP). Two analyses were presented. The first analysis was developed using data from recaptured yellowfin tuna released between 40-90 cm, with length data quality of “MEAS”, with 46 to 74 days at sea. Fish were assigned an assumed age according to the Von Bertalanffy equation ($L_{inf} = 155.7$; $k=0.443$, $t_0 = 0.0148$). The age was calculated for the midpoint of the length between the release length and the recapture length. For the purposes of visualizing the data, 215 fish were randomly selected from the available observations (**Figure 4**).

The second similar analysis (**Figure 5**) produced a vector plot of the growth increments of AOTTP fish measured upon recovery. The relative age of each fish at the time of tagging was estimated from the length at tagging by inverting the von Bertalanffy (top panel) and Richards (bottom panel) growth equations using parameters estimated by stock synthesis. The age at recapture is then taken to be the age at tagging plus the time at liberty.

The results indicate that tagged fish released with lengths of less than 65 cm tend to grow slower (than the von Bertalanffy equation ($L_{inf} = 155.7$; $k=0.443$, $t_0 = 0.0148$) while fish above 65 cm tend to grow faster (**Figure 4**). The results suggest that the growth of yellowfin tuna is better estimated using a Richards function than a von Bertalanffy function. Therefore, the Group recommended that age-structured models use that functional shape (**Figure 5b**).

2.2 Catch, effort, size and CAS estimates

The Secretariat reported on the intersessional work done following the workplan from the data preparatory meeting. Task 1 Nominal Catch (NC) was updated and provided to the modelers ahead of the meeting. Total YFT catch (**Table 1**) included the estimates of the Ghana tropical tunas 2012-2018 (SCRS/2019/124), the data submitted by CPCs until June 26, 2019 and estimated 2018 catches. The 2018 reports of catches by CPC was incomplete, only about 58% of the total (**Table 2**). For those CPCs that did not report catch in 2018, and estimated YFT catch was calculated as the average of the 3 previous years (2015-2017). **Table 3 and Figure 6** show the total catches of YFT 1950-2018 by main gear used as input for the stock assessment models).

Catch distribution (CatDis) was also estimated for YFT extending the distribution to match the fleet distribution for the Stock Synthesis. **Table 6** shows the fleet structure used for the Stock Synthesis model, and **Table 4** shows the catch for each of the fleet as estimated from the CatDis. The Secretariat also provided the size samples composition for each fleet ID base on the Task 2 size data, SCRS/2019/66 document provides details and methods for estimating the size sample frequencies 1968-2017, no sufficient size information was available for 2018. During the meeting, review of preliminary runs and diagnostics were used to correct some of the fleet size information, see section 3.1.4 for further details. At the meeting is was noted that the size data from Venezuela contained in the ICCAT database for the 2006 PS and BB fleets was incorrect. It will be updated after the meeting. For this assessment this size data was excluded.

SCRS/2019/124 presented the estimates of the Ghanaian total tropical tuna catches from the purse seine and baitboat fisheries 2012-2018. These estimates included the catches for YFT, the size composition of the catch (Task 2 SZ), and catch and effort for the tropical tunas (Task 2 CE). The estimates are based exclusively on the AVDTH Ghana database, as it was concluded that sampling and coverage of the two main Ghanaian fleets is sufficient and appropriate to estimates total catch, catch composition, size distribution of catch and catch-effort distribution since 2012. To estimate the catch, catch-effort, and catch composition from the Ghanaian sampling program, the species composition and size sampling by fleet/vessel, year, month, gear, fishing mode and 1x1 lat-lon grid were used. The new estimates for YFT were lower in general compared to previous estimates presented for the bigeye stock assessment in 2018 (**Figure 7**). The differences resulted from the method used to estimate catch composition. In 2018 estimates were based on the EU and Ghana fleet composition data, while in 2019 only the Ghana sampling data was used.

A presentation (SCRS/P/2019/039) reviewed the fisheries trends of the Venezuelan purse seine, longline and baitboat fleets for 1987-2018. Catch and effort trends of these fleets has decreased from peak catches in the early 1990's, from about 8 to 2 thousand tons in recent years, for all three main gears. It was noted that the main fishing grounds are the eastern Caribbean region, with some expansion to the Guyana-Amazon area during the 2010s for the longline fleet only. The size distribution of the catch ranges from 30 to 190 cm FL YFT, with larger fish caught by the longline fleet, and small and medium size caught by the baitboat and purse seine fleets. It was noted that the sampling in all 3 fleets is done by trained observers, for the longline sampling is done by observers onboard, while for purse seine and baitboat is done at port.

Document SCRS/2019/100 was submitted on the EU-Spain Canary Islands fisheries for 1975-2018. During the data preparatory meeting document SCRS/2019/076 with similar information was presented and discussed by the Group, therefore document SCRS/2019/100 was not discussed at this meeting.

2.3 Relative abundance estimates

Three documents describing abundance indicators (CPUE) were submitted that had been previously discussed during the yellowfin tuna data preparatory meeting in April 2019. The changes made to these documents had been recommended by the Group. Therefore, these documents were made available intersessionally for review and were presented at the meeting but were not discussed in detail. These documents included:

- SCRS/2019/066: An index of yellowfin tuna in free schools for the EU purse seine fleet (EUPSFS index).
- SCRS/2019/075: An index of juvenile yellowfin tuna derived from echosounder buoys (BAI index).
- SCRS/2019/122: Regional indices of abundance for the Japanese Longline.

Two new abundance series were presented to the Group, summarizing CPUE series for the Venezuelan and Chinese Taipei longline fisheries. These are described below. The revised and new CPUE series are summarized **Table 5** and **Figure 8**.

SCRS/2019/123 document describes a standardized index of relative abundance for the Venezuelan longline fishery during the period 1991-2018. The index was estimated using generalized linear models and a delta lognormal approach. Two data sources were used, the Venezuelan Pelagic Longline Observer Program (1991-2011) and the National Observer Program (2012-2018). The index showed relatively

constant values from 1992-2004, then increased to a maximum in 2007. Thereafter, the index showed a declining trend until 2010, after which it is stable at that level (**Figure 8**).

The Group discussed some technical aspects of the standardization, including the approach used to model a number of influential interaction terms. In the current standardization, the Group noted that year interaction terms were modeled using fixed effects and recommended that these be modeled using random effects. Generally, ICCAT has recommended the use of random effects because it produces expanded confidence intervals that may better represent scientific uncertainty. This change in the calculation of the index was carried out during the meeting and the updated index is shown in **Figure 9** and was provided to the modeling team for use in sensitivity analyses. The Group also noted that there are some important outliers in the lognormal component. These had not been removed because there was no evidence that they were erroneous.

The Group observed that the Venezuelan fleet operations have shifted over time toward the Atlantic Ocean, off the Guianas Shelf (**Figure 10**) and recommended that regional indices could be constructed (i.e. regions 1-3 used for the joint index) to better account for the movement of the fleet over time.

SCRS/2019/120 document describes a development of standardized indices of abundance from the Chinese Taipei distant water longline fishery during the period 1967-2018. Regional abundance indices of yellowfin tuna were developed by period using generalized linear models. The entire period (1967-2018) and three separate periods from 1967-1989, 1990-2005, and 2006-2018 were considered, with information on operation type (i.e., the number of hooks per basket, HPB) available for the latter period. The standardized indices showed almost identical trends between whole and separate periods. However, the trends differed amongst regions, especially since 2010, with an increase for the western tropical Atlantic Ocean but a slight decrease in the eastern tropical waters (**Figure 11**).

The Group observed that the spatial extent of this fishery is large, and that effort and nominal CPUE have shifted between areas over time (**Figures 12 and 13**), in large part due to changes in the target species (**Figure 14**). The author also noted that the substantial increase in the standardized CPUE in the mid 2000s may have resulted from ICCAT regulations to limit the catch of bigeye tuna, which caused some fishermen to target yellowfin tuna (Sun *et al.* 2014). The Group also noted that there are substantial changes in the size composition of the Chinese Taipei longline fishery which may result, in part, from changes in targeting and other fishing behaviors due to regulations imposed to limit the catch of bigeye. Because the joint longline index (SCRS/2019/081) already included the operational level data from the Chinese Taipei longline fleets, the Group had recommended the use of the joint indices in the stock assessment models, rather than the indices developed solely from the data of Chinese Taipei.

Due to changes in targeting, regulations and reporting, the Group expressed some concerns about the use of the Chinese Taipei data in the development of the joint longline CPUE index. Data were presented to the Group which indicated potential high-grading in the Chinese Taipei longline fleets after 2004. This date corresponds to a change in national regulations and the presenter noted that the observed change in the mean size of fish could potentially be due to discarding. The Group noted that discards are not included in the logbooks and that this could cause problems in the standardization of the joint index. For instance, there could be problems if the discard rate changes over time, and the selectivity of the index could be biased.

The Group requested that the author clarify the information used in the development of the joint index. The author responded to this request and following these discussions, the Group generally agreed to use the joint CPUE indices, as recommended by the data preparatory meeting. However, the potential impact of discards on the joint longline index warrants further investigation.

3. Stock assessment methods and other data relevant to the assessment

3.1 Stock Synthesis

3.1.1 Model setup and data inputs

An initial assessment of the Atlantic yellowfin tuna stock using Stock Synthesis 3.3 (Methot and Wetzel, 2013) was conducted prior to the 2019 Yellowfin Tuna Stock Assessment Meeting as agreed in the 2019

Yellowfin Tuna Data Preparatory Meeting. The full assumptions and data inputs to this model are described in SCRS/2019/121. Model inputs were discussed in detail at the 2019 data preparatory meeting (Anon, 2019).

The key assumptions and configurations of the initial “preliminary reference model” were as follows. The preliminary reference model was constructed as a model with 4 seasons and a timeframe from 1950 – 2018. Fleets are partitioned to represent homogenous fishing areas. However, this model does not have explicit movement between the areas and hence functions as a non-spatial, one-area model. The model starts in 1950 and assumes that the stock starts at virgin or near virgin conditions.

3.1.2 Natural mortality

Natural mortality (M) was parameterized by age according to Lorenzen (2005), scaling to the growth curve (section 3.1.3). This was conducted internally to the model to be consistent with the growth treatment in the model by assuming a value of natural mortality of 0.35 assigned to age 5 (baseline M), consistent with the Then et al. (2017) estimator of M, and assuming a maximum age of 18. This treatment differs from the 2016 assessment where growth was scaled externally with a baseline M=0.55 based on a maximum age of 11 and scaled according to the Gascuel *et al.* (1992) size at age. The resulting M-at-age vector is defined below:

| Age | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6 | Age 7 | Age 8 | Age 9+ |
|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| M | 1.3 | 0.66 | 0.48 | 0.4 | 0.37 | 0.35 | 0.34 | 0.34 | 0.34 | 0.33 |

Natural mortality was initially included in the grid of uncertainty, and during the data preparatory meeting two alternative values, upper and lower M vector were proposed (Anon 2019). However, these values were considered very low and high for yellowfin biology dynamics, and during the meeting the Working Group restricted this range to values of 20% above and below the baseline M (0.28 and 0.42, respectively). Still, however, these more extreme values of M were eliminated from the final stock synthesis model uncertainty grid because the low M scenario had poor diagnostic performance, and the high M scenario produced model estimates that were not consistent with the known biology (i.e. maximum age) of yellowfin tuna. The difficulty in using the low and high M may have been in part due to the fact that both steepness (*h*) and M were fixed in stock synthesis. The Group decided to use only the baseline M value (0.35) and recommended that further analyses be done to determine an appropriate range of M values based on simulation analyses and other biological information. A likelihood profile on M suggested that all values of M greater than 0.35 were equally probable.

3.1.3 Growth, morphometric relationships and reproduction

Following an evaluation of the growth of yellowfin recaptured in the AOTTP (**section 2.1**), the Group elected to use a Richards functional form for the growth model but decided to fix the parameters at the values estimated internally by stock synthesis using the US/GOM age data. Parameters were fixed to avoid introducing additional instability in the model. The weight of Atlantic yellowfin tuna in kilograms was estimated from straight fork length in centimeters as:

$$W_L = (2.1527 \times 10^{-5}) \text{SFL}^{2.976} \quad (\text{Caverivière 1976})$$

Fecundity was modeled as a direct function of female body weight. The maturity at length was based on Diaha *et al.* (2016), with 50% maturity at 115 cm SFL. The sex ratio was assumed to be 50:50 males-females. Birth date was adjusted to the first month of each season (January, April, July, October).

Growth for yellowfin was estimated using recent otoliths sampling (GOM/US East Coast), that included age validation based on bomb-radiocarbon techniques (see section 2.1 from Anon. 2019 for more details). A major difference in the biological information is the new maximum age assumption of Age 18 for Atlantic yellowfin tuna, compared to the assumptions in previous assessments where maximum age was assumed to be 11. This has important implications for the estimate of natural mortality. Growth was estimated internally in stock synthesis using the US/GOM age data, assuming a Richards growth model, and a given size at minimum size of age sampling (0.38 year) of 25 cm SFL.

Regarding the use of age data for conditional age at length, the Group originally favored its use in stock synthesis, but model diagnostics were poor. A cross sectional catch curve applied to the age data estimated Z at 0.45. It was the Group's feeling that the Z experienced by the large fish found in the GOM and off the Eastern US could be lower and possibly not representative of the bulk of the exploited population. The Group therefore elected not to use the age data for conditional age at length.

3.1.4 Fleet structure

For the 2019 assessment, the model used 25 different fleets (**Table 6**). Fleet structure was largely the same as in 2016 with some exceptions. First a new fleet was assigned to the emerging handline fishery off northern Brazil. Next, the longline fleet-areas were adjusted to coincide with the geographical areas of the joint longline index (SCRS/2019/121 Figure 2). This change applies to both catch by area/fleet and the size information.

During the meeting, a more detailed review of the size composition of each fleet and feedback from scientists familiar with the fisheries, suggested a need to restructure of some of the fleets. These changes included:

1. Fleet 11_GhanaBB_PS: The Group decided to impose four selectivity time blocks: 1981-1987 (mixed BB and PS), 1988-1995 (mostly BB), 1996-2018 (mixed BB and increasing PS) and prior to 1981 selectivity will match that estimated for 1988-1995 (mostly BB). For the most recent time block 1996-2018 the Group recommended removing the length composition data from 1996-2008 (blue box in **Figure 15**) where sampling for the expanding purse seine fishery was incomplete and likely not representative. These decisions were based on evaluation of the length composition inputs (**Figure 15**) and changes in the relative fraction of the catch landed by BB vs. PS (**Figure 16**).
2. Fleet 12_BB_area2_SDakar: The Group noted an increase in large fish in the size composition of the fleet in the last decade (**Figure 17**, recent years) and upon inspection of the data realized that it was being caused by the South African HL fishery which targets much larger fish than other BB. The decision was therefore taken to move South Africa HL catch and length data from Fleet 12_BB_area2_Sdak to Fleet 25_OTH_OTH.
3. Fleet 13_BB_DAKAR_62_80 and Fleet 14_BB_DAKAR_81+: clear outliers were present in the size data of the Venezuela BB (particularly 2006). The Group decided to remove all size data from Venezuela BB pending a more thorough evaluation of these records.
4. Fleet 24_PS_WEST: This fleet included the US PS and Venezuelan PS. Given that the majority of US PS catches prior to 1990 occurred in the Eastern Tropical Atlantic, the Group proposed to move US catch and size data prior to 1990 from Fleet 24_PS_WEST to Fleet 1_PS_ESFR2_6585 and Fleet 2_PS_ESFR2_8690. As with BB, clear outliers were present in the 2006 size data of the Venezuela PS. Given the limited time available to evaluate the problem, the decision was taken to remove Venezuela PS size data for 2006. The Venezuelan scientist confirmed that their original submission for 2006 by BB and PS was correct, the Group recommended to check and revise the ICCAT database.
5. Fleet 25_OTH_OTH: The length composition of Cabo Verde HL (originally assigned to Fleet 25_OTH_OTH) was similar to the Cabo Verde BB (included in Fleet 14_BB_DAKAR_81_18). The Group therefore decided to move catch and length data from Cabo Verde HL from Fleet 25_OTH_OTH (green line in **Figure 18**) to Fleet 14_BB_DAKAR_81_18. Due to this fleet being a 'catch-all' fleet, the selectivity is not well defined and there is a risk that the model will interpret the occasional spike in catches of 50 cm fish as large recruitment events when in fact the presence of these fish is most likely linked to internal changes in fleet dynamics and local availability. The Group therefore recommended to down-weight the influence of this data using a much lower lambda (0.001).
6. Fleet 17_Japan_LL_TRO and Fleet 20_Other_LL_TRO: These fleets exhibit a shift in mean size at age through time. The Group discussed the possibility that these shifts in selectivity could be produced by increased discarding or by changes in fleet composition. Time blocks were proposed based on the Hoyle et al. (2019) influence plots which indicate a substantial shift in fleet composition, likely associated with the observed changes in selectivity. Time blocks on selectivity will be as follows 1950-1979 (early shallow sets), 1980-1991 (transition to deeper sets and BET targeting), 1992-2004 (deep sets) and

between 2005-2018 to coincide with the apparent change in selectivity to target larger BET. Size composition data from the Chinese Taipei longline fishery was removed from 2005-2018 due to difficulties in interpretation of the increasing mean size (See **section 2.3**).

7. Fleet 22_HL_Braz_N: Lack of size composition data for the BRA HL fishery means the selectivity is poorly informed. The Group elected that selectivity of Brazil HL be estimated using prior distributions derived from the AOTTP tagging estimates, rather than mirrored to the Fleet 14_BB_DAKAR_81_18. Length composition data for 1994 (dominated by larger fish) was removed.

These changes led to a better prediction of mean lengths and improved the Pearson residuals from the fit to the length composition.

3.1.5 Abundance Index inputs

A major advance in this assessment was the development of a joint longline index using high resolution catch and effort information from the main longline fleets operating in the Atlantic (Japan, US, Brazil, Korea and Chinese Taipei). The index was developed for 3 regions; North Atlantic, tropical area and South Atlantic based on the size distribution of the catches for these fleets. This index was linked to the Japan longline fleet composition size data for estimating selectivity, as this fleet represents the majority of the size composition in region 2 after removal of the Chinese Taipei data from 2005-2018, and because it has had consistent size sampling. One index was used in the initial stock synthesis reference run, the Joint LL Region 2 index (SCRS/2019/121). Three time blocks (section 3.1.4) were applied to the selectivity assumed for this index to account for changes in targeting to bigeye tuna. To obtain the interannual variance for the joint index the geometric mean of each seasonal CV was obtained and used as input for the annual index. Indices were input as annual values.

The bouy associated index (BAI) index was modelled as linked to respective seasonal PS FAD fleets, which improved fit to the index. The EUPSFS index was linked to the PS EU FSC 91 season 1 where much of the catch comes from. Indices were input as annual indices, except the BAI index that maintained their seasonal information, with a mean CV=0.2 for the LL indices and 0.3 for the BAI and EUPSFS indices but allowed to vary with the interannual variability in the estimated standard error of the index.

The hindcasting diagnostic indicated better predictions of CPUE trend when the model included all indices of abundance.

3.1.6 Length composition

Length composition data were initially processed by the Secretariat (SCRS/P/2018/46) to remove outlier and to achieve generally homogenous fleet structure. After removal of outliers, no fish above 220 cm remained in the dataset. Size composition data was estimated following the same fleet structure described above (**section 3.2.4**) and it was updated during the meeting to also reflect the changes described in this document in terms of fleet restructuring.

Length composition was input with an initial sample size equal to the $\ln(N)$ to decrease the weight of multiple samples within a fleet, season, and year combination. Preliminary results indicated that size composition data has a large influence in the model fit and results. During the meeting further downweighting of the size composition to $0.5 \cdot \ln(N)$ resulted in similar results but showed improvement in the fits and diagnostic test results. Thus, a lambda of $0.5 \cdot \ln(N)$ was used to weight the size composition data in all accepted runs.

3.1.7 Stock recruitment parameterization

A Beverton-Holt stock recruitment relation was assumed to model the number of recruits as a function of spawning stock biomass. Virgin recruitment (R_0) was freely estimated and steepness (h) was fixed at a value of 0.8 for the preliminary reference model and at 0.9 for the uncertainty grid. Profiling on steepness indicated that there was insufficient information in the data to freely estimate it. Annual variation in recruitment (SigmaR) was estimated in the stock synthesis models on the basis of a likelihood profile which supported estimation. The estimated total annual recruitment was distributed across the four seasons according to seasonal allocations estimated in the model. Deviations in annual recruitment were estimated

from 1979 to 2017. The lognormal bias correction ($-0.5\sigma^2$) for the mean of the stock recruit relationship was applied during the period 1972 to 2017 with the recommended bias correction ramp applied to each model according to Methot and Taylor (2011).

During the meeting analyses showed that the reference model fit tended to produce unusually large recruitment peaks in 2017 and 2018, due primarily to the information from the BAI index that is treated as a recruitment index. Noting that there is no size composition data in 2018 in this model to corroborate or contrast with these high recruitment estimates, the Group decided to fix the 2018 estimates of recruitment to the stock recruitment curve rather than estimate them. Not estimating the recruitment deviation for 2018 substantially improved the reference model diagnostics.

3.1.8 Selectivity

Length-based selectivity was estimated for the fleets. **Table 7** outlines the functional forms chosen and time blocks imposed on each fleet.

3.1.9 Data weighting

Input variance adjustments were iteratively adjusted according to recommendations in Francis (2011).

3.1.10 Diagnostics

The Group discussed the initial models (SCRS/2019/121, runs 1-23) presented by the authors and a number of additional model runs were proposed, conducted and discussed (**Table 8**). A set of diagnostics were run to evaluate model performance including fits to indices of abundance, length composition residuals, retrospective analysis, hindcasting, likelihood profiling, Age Structured Production Model (ASPM) analysis, jitter analysis and sensitivity runs on influential parameters. The details of these runs are provided in **Table 8** and the following presentations: YFT stock synthesis.2019_Part1.inputs and diagnostics, YFT stock synthesis.2019_Part II reference grid development and sensitivity runs, YFT stock synthesis.2019_Part III reference grid developmentV3. Diagnostics on preliminary runs are available in presentation SCRS/P/2019/043. Diagnostics on the accepted runs are described in **section 4.1**.

3.1.11 Base case and sensitivity runs

The list of accepted runs is detailed in **Table 9**. The following characteristics were common to all runs: the Richards growth function was fixed to parameter values estimated internally by stock synthesis using age data from US/GOM, no conditional age at length data was used, M was scaled according to the growth curve using $M_{age\ 5}=0.35$, recruitment deviations were not estimated for 2018, a lambda of 0.5 was used to downweigh the length composition data. Sensitivity runs tested the influence of h (0.8 vs. 0.9) and the BAI index (including vs. excluding the index).

3.2 Surplus production model MPB

Document SCRS/2019/115 presented preliminary results from fitting the biomass production model mpb (Kell, 2016) to the YFT data using catch data and the joint LL R2 index for 1979-2018 (run 1). Updating the data from what was available in the 2019 Data Preparatory meeting with the most recent catch data made available by the Secretariat caused notable changes in the perception of stock status. Overall, the model had difficulty converging and diagnostics were relatively poor.

The Group expressed concerns over the fact that the model appears unstable. The model finds a solution only if strict constraints are imposed on the search space for r (intrinsic growth rate) and K (carrying capacity), and when the model did find a solution, that solution does not correspond to the minimum in the likelihood profile, suggesting poor convergence (**Figure 19**).

The Group discussed the following points: a) mpb has difficulty explaining the observed catch given the continuous decline in the CPUE, b) there are population dynamics and selectivity components that a biomass model simply cannot accommodate.

Unconstrained, the model tends to go to values of intrinsic growth rates r that are extremely low. It is therefore necessary to impose some level of constraint on the parameters. However, the Group felt that it was more defensible on a biological standpoint to constrain K on the left-hand side and leave r unconstrained, and expected that would improve the estimation of r (**Table 10**, run2). The Group also recommended to free up the B_0 parameter as a potential solution for improving the fit (**Table 10**, run3). Freeing up B_0 had almost no impact. Another proposal to improve fit was to include the EUPFS index. Adding the PS index led to a slight improvement in the pattern of residuals for the indices in the most recent years and showed more stability in the jackknife analysis (**Figure 20**), with almost no change to the hindcasting and retrospective analyses. The Group asked to see if the r and K estimates change a lot retrospectively. The result showed no change in the retrospective pattern for r with a slight change for K and MSY . The LL region 1 index was later added to see if it would further improve the fit, but the model could not converge.

Finally, the Group agreed on a reference case (run 2) using two indices: Joint LL R2 and EUPFS, as this was the scenario with better diagnostics.

3.3 Bayesian surplus production model JABBA

Document SCRS/2019/125 presented results from JABBA, a Bayesian surplus production model. Four scenarios were presented: a) base case (joint LL R2 with stock synthesis 2016 r prior), b) run 1 (joint LL R2 with FishLife r prior), c) run 2 (joint LL R2 + BAI with stock synthesis 2016 r prior), d) run 3 (joint LL R2 + BAI with FishLife r prior). FishLife r prior refers to a prior estimated using biological parameters available at FishLife database (www.fishbase.se/yellowfin_tuna) and size composition data used in stock synthesis in a model approach to derive surplus biomass parameters from age structure population dynamic model (Winker et al., 2018). This approach has been used in other ICCAT and tRFMOs assessments previously, with the objective of making comparable the runs between biomass surplus production models and length-age based integrated models such stock synthesis. In all scenarios, the model appeared to converge properly, though the inclusion of the BAI index worsened the diagnostics. Overall, the management quantities estimated were comparable across runs.

During the meeting, the JABBA base case run from SCRS 2019/119 was updated using an r prior based on the 2019 stock synthesis run results. The Group decided to exclude the 2 scenarios that use 2016 priors (runs 1 and 3) since they contain outdated information on the biology of the stock. All runs presented at the meeting are listed in **Table 11**.

The Group raised concern that the priors may be having too much influence on the results. Even the “uninformative” prior chosen for run 5 appeared to have information due to its lognormal shape. The Group therefore recommended to create a new run using the FishLife prior but with increased CV (run 14). Increasing the CV from 0.3 to 0.6 allowed the model more freedom to adapt to the data and the model converged on a value of r close to the one estimated by stock synthesis (**Figure 21**). This gave the Group confidence that the value estimated for r in the JABBA model is consistent with the information present in the integrated assessment. However, noting that this run had a higher RMSE in the fit to the index and a strong retrospective pattern (which is to be expected when giving more flexibility to the prior) the Group elected not to use a CV of 0.6 in the final selection of accepted runs. The Group did discuss the issue of taking results from a model fit and using it as data (as is the case with the stock synthesis prior). However, it considered that comparing JABBA results using FishLife prior with the expanded CV with runs that use the stock synthesis prior was a valuable exercise for checking that the model results are consistent with the data going into the assessment.

Following the observation that K and r appear highly correlated and that r is consistently being estimated at a value that is lower than that indicated by the prior, a question was raised on whether there is something inherent to mbp and JABBA that causes these models to favor lower values of r . The Group does not know if this observed propensity to favor lower r values is a true property of the model or simply a result of the data. The Group recommended to try a sensitivity run with ASPIC, whose properties are well studied, to check if the model results in similar estimates for r . ASPIC is not able to control the estimation of r the same way as JABBA or mbp, and when used with the available indices it leads to implausibly low estimates of r .

Regarding indices, the Group questioned the appropriateness of using the echosounder CPUE (BAI) in a production model as it reflects only the dynamics of recruits. On this basis, the Group elected to remove this

run and instead test the impact of adding three new indices: EUPSFS, joint LL R1 and joint LL R3 over the Joint R2 index. All other indices except for the EUPSFS, showed evidence of lack of randomness of time-series residuals (**Figure 22**). Still, anytime more than one index was used, the conflict between indices consistently translated into a positive trend in the residuals in the earlier years and a negative trend in the residuals in the most recent years. The Group discussed the shortcomings of each index. Both LL and PS indices have shortcomings, such as changes in targeting, and technological advances that are difficult to properly account for. But, based on the diagnostics, the quality of the fit was best when using only the Joint LL R2 index (**Figure 22**) so the Group decided to use run 6 as the base case and include the other indices (except for BAI) in sensitivity analyses (run 13). Two additional sensitivity runs were selected to contrast results using the stock synthesis prior vs. the FishLife prior (runs 16 and 17).

The JABBA runs utilizing the Venezuelan longline index (VEN LL) showed a poor fit to VEN LL index, with a residual trend in the index fit as well as an increase in RMSE for the overall model fit. The Group agreed that runs including the VEN LL index should not be used for the uncertainty matrix. The Group affirmed, however, its recommendation these data should be included, if possible, in the next development of a multi-national joint LL CPUE index.

Another issue common to all runs was the increasing trend observed in the process error over the last decade (**Figure 23**). In state-space models, like JABBA, the observation error is accounted for in the fit to the indices, but the process error component represents all other processes that are not directly controlled or observed in the data used to modelling (e.g. growth, recruitment, catchability, catch, etc.). The Group noted that the increasing trend in the process error occurred the same year that stock synthesis has a selectivity change imposed. If the change in selectivity is indeed causing this pattern in the process error one could attempt to solve this in the production model by accounting for some autoregressive structure in q . Though this issue deserves to be further explored, resolving it is beyond the scope of the current assessment meeting.

Lastly, the Group compared results from mpb and JABBA. Though the Bayesian model showed better model convergence and diagnostics, both models resulted in similar parameter estimates, giving the Group confidence in the population dynamics being estimated.

4. Stock status results

4.1 Stock Synthesis

Following the development of the reference case described in **section 3.1** the Group determined the major axes of uncertainty to develop the uncertainty grid. The axes of uncertainty included:

1. To use/not use the Juvenile Index from Echosounder Buoys (BAI).
2. Steepness (0.8 and 0.9)

In preliminary model runs, the lambda on length composition (1, 0.5) and the natural mortality (0.28, 0.35, 0.42) had also been included as possible axes of uncertainty, but they were ultimately excluded from the final uncertainty grid for reasons indicated in sections 3.1. Briefly, the low natural mortality had poor diagnostic performance, and the high mortality produced results that appeared biologically implausible although the retrospective and hindcast analyses revealed no unusual behavior. The results from weighting the length composition with a lambda set to 1 or 0.5 were nearly identical, but the lambda 0.5 had improved model performance. The final stock synthesis uncertainty grid was composed of the 4 combinations of items above. *Note: the reference case is a member of the uncertainty grid.* The full listing of model runs, likelihoods and some diagnostic criteria are in **Tables 8** and **9**.

Diagnostic performance for the Stock Synthesis runs

All uncertainty grid runs had positive definite Hessians and maximum gradient components less than 0.0001. Parameter estimates for the uncertainty grid models are shown in **Table 12**, and had relatively low standard errors except some of the spline parameters, the Richards K parameters and the descending limb of the PS-West, though some of the CVs are misleading as the parameters themselves were estimated to be very close to zero, inflating the CV. Also, there were relatively few highly correlated parameters with a few

notable exceptions being K and the Richards growth parameter. There were no bound parameters in the uncertainty grid runs.

A full suite of diagnostic evaluations (likelihood profiles, jitter, retrospective, hindcast) were conducted for each model run. The jitter analyses (n=50) indicated that the models were stable (i.e. all MLE estimates were within one likelihood unit; **Figure 24**). Profiling of the key parameters (R0, steepness, sigmaR and M) for the reference case indicated that R0 was estimable (**Figure 25**) but that steepness was not (**Figure 26**). Regarding R0, there was conflict between the various data components, where the survey data favored a higher value of R0, relative to the length data. However, the survey data had little influence on the maximum likelihood estimate for that parameter. Profiles for natural mortality (M) at age 5 indicated that values of 0.35 and higher are equally probable (**Figure 27**), but that values below 0.35 are not supported. Due to the rather high correlation between steepness and R0, fixing certain values of steepness largely predetermined R0 (**Figure 28**). Hence it was necessary to fix steepness. Sigma R appears estimable (**Figure 29**) using the Methot and Taylor (2011) bias correction ramping. Hence it was considered unnecessary to include different values of sigmaR as part of the uncertainty grid.

Retrospective analyses showed no strong pattern for any uncertainty grid model (**Figure 30**). Hindcasting is a similar approach that can be used to evaluate multiple measures of prediction skill. In a hindcast a model is fit to the first part of a time series and then projected over the period omitted in the original fit. Prediction skill can then be evaluated by comparing the predictions from the projection with the observations (Kell et al. 2016). The hindcast results indicated that the uncertainty grid models had population dynamics that were able to predict the CPUE series used (Joint Longline Area 2, EU_PS_Free School) except for the Echosounder Buoy (BAI) index of juvenile yellowfin, which cannot be hindcast because there is no data in the hindcast to predict deviations from the stock recruitment relationship (**Figure 31**).

An Age Structured Production Model (ASPM) diagnostic was also conducted (**Figure 32**). This analysis was used to determine whether the stock synthesis results were consistent with age-structured production model population dynamics. The treatments for this analysis were: **base case** (the stock synthesis model run), **aspm**: running stock synthesis like ASPM using the selectivity parameters from integrated model, the recruitment deviation is not used, **aspm_est**: same as **aspm** but estimated recruitment deviation, **aspm_fix**: same as **aspm_est** but with fixed recruitment deviation from the integrated model). The results suggest that the Stock Synthesis runs behave much like ASPM when structured similarly.

Model Results

The fits to the indices (**Figure 33 – 36**) and the length composition aggregated by fleet (**Figure 37 – 40**) were examined and were considered acceptable. The Total Biomass, SSB, F and recruitment trends are shown in **Figures 41 to 44** and **Tables 13 and 14**. The recruitment deviations showed little trend in residuals, although some very large recruitment events were noted, including a large recruitment event in 2017 in the runs that included the juvenile index (EUPSFS). The model estimated selectivity values are shown in **Figure 45**.

The estimated stock recruitment relationships showed little evidence of a relationship between SSB and recruits (**Figure 46**) and there was insufficient contrast in the data to estimate steepness from the profiles (see **Figure 26**). Recruitment by season indicates that the highest fraction of recruits was estimated to be born in seasons 1 and 2 (Jan-June) and the lowest in season 4 (Oct-Dec) (**Figure 47**). Time series of the numbers at age shows little evidence of strong cohort structure and a decline in the mean age in the population over time (**Figure 48**).

The estimated maximum sustainable yield (MSY) in 2018 for the uncertainty grid models ranged from 101,779 to 120,468 t (**Table 15**). These values were similar to those reported in the 2016 assessment (123,139 to 123,382). Calculations of the time-varying benchmarks show a long-term increase in SSB_{MSY} and a general long term decrease in F_{MSY} and MSY (**Figure 49**).

In general, the estimated SSB/SSB_{MSY} and F/F_{MSY} trajectories showed very similar trends for all stock synthesis uncertainty grid models (**Figure 50**). The SSB/SSB_{MSY} has shown a significant decreasing trend since the 1960s, and the SSB_{2018}/SSB_{MSY} value was the lowest in the time series, with values that ranged from (1.17 to 1.39). These values were generally higher than the estimated biomass levels estimated in the 2016 stock synthesis model runs (0.81 to 1.38). Fishing mortality (exploitation in biomass) increased to a

maximum in the early 1980s and 1990s then declined until the mid 2000s before increasing again to high levels by 2018 (**Figure 50**). Fishing mortality in 2018 was at or near the highest level in the time series. The estimated values of F_{2018}/F_{MSY} ranged from (0.86 to 1.19).

Combined results of the stock synthesis uncertainty grid

A Kobe plot was developed using the stock synthesis results from all uncertainty grid models. According to the Stock Synthesis results, the estimated SSB/SSB_{MSY} indicates that the 2018 stock is not overfished (1.32 with 90% CI: 1.02 – 1.69); **Figure 50**, top and **Figure 51**) The F/F_{MSY} in 2018 varied by model run, but on aggregate suggests that the stock was near the overfishing threshold (0.93 with 90% CI: 0.56 – 1.43); **Figure 50**, bottom and **Figure 51**). In 2018, the probability of overfishing and overfished (red) was 3.4% the probability of being overfished but not overfishing (yellow) was 0.5%, the probability of not being overfished but overfishing (orange) was 36.9% and the probability of being neither overfished nor overfishing (green) was 59.3%.

4.2 Surplus production model MPB

After the Group discussed Document SCRS/2019/115, the updated MPB results were provided. For MPB, the Group agreed on a reference case using two indices of abundance: joint longline index Region 02 and EU purse seine free school (EUPSFS) index. 500 bootstraps were run to characterize the statistical uncertainty for this Reference Case. **Table 16** shows the estimated parameters and MSY based benchmarks summarized by means, medians and 90% confidence intervals.

The trajectory of the estimated biomass (**Figure 52**, upper panel) showed a continuous decreasing trend from 1950 to the early 2000s, and a slightly increasing trend afterwards (**Table 17**). The fishing mortality increased gradually from 1950 and reached the historical highest value in early 2000s (**Figure 52**, lower panel, **Table 17**). It was gradually decreased to the late 2000s and remained flat, however some increase was observed in the recent years (2005-2018). The retrospective analysis (**Figure 53**) shows a pattern where the model tends to overestimate biomass and underestimate fishing mortality as a new year of data is added. The retrospective runs were projected forward with catch observations (hindcast diagnostic) and new trends of biomass were compared with the reference case. The results (**Figure 54**) shows relatively good prediction skill, as indicated by predicted biomass falling within the confidence intervals of the bootstrapped estimate, except for the 10-year retrospective case.

Figures 55 and **56** show the estimated trajectory of the stock on a Kobe diagram and the marginal density distributions of the bootstraps for the relative stock status estimates in 2018. **Figure 56** also shows the probabilities of the stock being in the different quadrants of the Kobe plot. According to the estimates of the MPB-Reference Case, Atlantic yellowfin stock is currently not overexploited and not undergoing overexploitation (green area of the Kobe plot) with probability (56%).

4.3 Bayesian surplus production model JABBA

After the Group reviewed Document SCRS/2019/125 and discussed various additional scenarios (**Table 11**), it was agreed that the following 4 scenarios (Base Case, S2, S3, and S5) are the final Reference Cases for JABBA.

- Base Case: Joint longline index Region 02, and use r prior from the stock synthesis setting in 2019
- S2: Joint longline index Region 02, and use r prior from Generic FishLife
- S3: Joint longline index Regions 02 and 01 and EU purse seine free school (EUPSFS), and use r prior from the stock synthesis setting in 2019
- S5: Joint longline index Regions 02 and 01 and EU purse seine free school (EUPSFS), and use r prior from Generic FishLife

The Group agreed to carry out two sensitivity runs (S6 and S7) based on the Base Case and S2 scenarios to evaluate the effect of Venezuelan longline index provided during the stock assessment meeting.

- Sensitivity S6: Base Case + Venezuelan longline index
- Sensitivity S7: S2 + Venezuelan longline index

The estimated parameters and values of biomass and fishing mortality for all Reference Cases are shown in **Tables 18** and **19**. The trajectory of B/B_{MSY} in the Reference Base Case showed a continuous decreasing trend from 1950 to 2018 (**Figure 57**, right panel). In the 2010s, the trend became relatively flat but reached the historical lowest level and remained below B_{MSY} (base case $B_{2018}/B_{MSY} = 1.02$). The trajectory of F/F_{MSY} (**Figure 57**, left panel) showed an overall increasing trend from the beginning of the time series to its end of the time series, except several years in the mid-2000s. F/F_{MSY} in 2016 was quickly increased to the historical highest value (1.02), and remained at close to 1.0 afterwards but not overfishing ($F_{2018}/F_{MSY} = 0.95$). A retrospective analysis for eight years was also examined which showed no retrospective patterns and very consistent estimates (**Figure 58**).

All Reference Cases generally showed similar trends in B/B_{MSY} and F/F_{MSY} (**Figure 59**), but the values showed two parallel patterns except B/K ; Base Case and S3, and S2 and S5 were very similar. The estimated K values in Base Case and S3 were larger than those in S2 and S5 (**Table 18**), that caused by the different assumption on prior distribution of r (use r prior from the stock synthesis setting in 2019 or from Generic FishLife). These differences produced the higher B/B_{MSY} values and smaller F/F_{MSY} values in Base Case and S3 compared to those in S2 and S5.

Hindcasting (Kell *et al.*, 2016) was conducted for the four Reference Cases by projecting over the period omitting the last 8 years from the time series and comparing to the models that utilized the complete time series (**Figure 60**). The prediction skill of joint longline index Region 02 performs better for the Base Case than for S2 run. When multiple CPUEs were used in S3 and S5, the model did not forecast joint longline index Region 02 well, while the projections for the other indices performed better. All predicted indices remained within the 95% credibility intervals of 10,000 MCMC iterations.

The Group explored the sensitivity analyses including the Venezuelan longline index on the S3 and S5 runs (Sensitivity S6 and S7). Residual diagnostic (**Figure 61**) and the randomness of the time series of CPUE residuals (**Figure 62**) showed strong trend and pattern on the Venezuelan longline index. The RMSE increased from 9% in the Reference Base Case to 47% with this index. Given that the use of the Venezuelan index did not improve the JABBA models, the group did not recommend its use at this time. Instead, the group recommended that the Venezuela longline index data be included in the standardization method of the joint longline index for Atlantic fisheries.

The Group reviewed the trajectories of B_{2018}/B_{MSY} and F_{2018}/F_{MSY} from each JABBA Reference Cases (**Figure 63**). The Group was concerned that some of the Kobe plots did not show a typical anti-clockwise pattern with the stock status moving from underexploited level through a period of unsustainable fishing to the overexploited phase. This could be related to the changes in selectivity over the time series, that surplus production models commonly do not take into account. This pattern is more sensitive in JABBA that estimates the process error (see Section 3.3) which may explain the distinction between JABBA's and MPB models.

The combined posteriors of B_{2018}/B_{MSY} and F_{2018}/F_{MSY} from the four JABBA Reference Cases (**Figure 64**) predicted 48.9% probability that the stock remains overfished and that overfishing is still occurring (red quadrant), while being in the green quadrant with 42.6%, 6% in the yellow quadrant, and 2.5% in the orange quadrant (i.e. overfishing but not overfished).

4.4 Synthesis of assessment results

Data inputs and model structure

During the data preparatory meeting the Group agreed on the data inputs to be used with the two modelling platforms deemed to be appropriate for the evaluation of stock status: production models (JABBA and MPV) and a statistically integrated assessment model (Stock Synthesis). A subset of the data inputs had to be prepared/updated after the data preparatory meeting (e.g. VEN LL, buoy BAI and EU free school (EUPFS) indices of abundance, catch per fleet, size data). At the data meeting, the Group also agreed on the main axes of uncertainty associated with the different data inputs and model structures: natural mortality, growth, stock productivity (r or steepness), sub-sets of indices of abundance, statistical weight of different data inputs.

During the meeting, the Group investigated an initial set of models fitted during the intersessional period together with the appropriate diagnostics (residuals of fit to each data set, hindcast predictions, retrospective analysis, likelihood profiles for each parameter and data input, ASPM diagnostic for stock synthesis, differences between posterior and prior for Bayesian models). Model runs that were deemed to have inappropriate diagnostics, were eliminated from the data set. The failure of the diagnostics of certain model runs was also used to revise the axes of uncertainty and final model specifications.

The following production model runs were retained for management advice:

- JABBA with joint longline index of tropical area (region 2), and r prior consistent with Stock Synthesis 2019 estimates
- JABBA with joint longline index of region 2 and r prior based on inputs from FISHLIFE
- JABBA with joint longline indices of region 2 and northern area (region 1) and purse seine free school index, and r prior consistent with Stock Synthesis 2019 estimates
- JABBA with joint longline index of region 2 and region 1 and purse seine free schools index and r prior based on inputs from FISHLIFE
- MPB with joint longline index region 2 and purse seine free school index

Four Stock Synthesis model runs were retained for management advice, obtained by the combination of two values of steepness and two sets of abundance indices:

- without buoy index of abundance (BAI) and with steepness 0.8 (run 1)
- without buoy index of abundance and with steepness 0.9 (run 2)
- with buoy index of abundance and with steepness 0.8 (run 3)
- with buoy index of abundance and with steepness 0.9 (run 4)

All other specifications of Stock Synthesis were the same for the four model runs. The most important specifications of Stock Synthesis that need to be highlighted are:

- natural mortality changes with age, and for age 5 is 0.35
- Richard's growth model was initially estimated with age composition data and its parameters fixed for the final stock synthesis runs
- all models included the joint longline index for region 2 and the purse seine free school index
- the buoy index (BAI) was used as a quarterly abundance index for FAD fisheries
- the statistical weight of length composition data was fixed to 0.5 for all runs
- a few changes to structure of fleets agreed during the data preparatory meeting, including adding new periods of change in selectivity for some fleets
- eliminated some sets of size data for certain fisheries that could not be accommodated with the final fleet structure of the model
- data is not sufficient to estimate recruitment deviations in 2018, the last year of assessment.

Stock status

The trend in the estimated biomass for all models shows a general continuous decline in biomass through time. Stock Synthesis runs suggest a few periods of large increases in spawning biomass associated with episodes of high recruitment. Such very high recruitments have only happened three times in the period 1960 to 2017. Production models show much less pronounced increases in total biomass at the equivalent times. Note, however, that for all models there are large uncertainties in the value of biomass at any point in the history, including 2018 (**Figure 65**). Most model runs lead to biomasses at the end of 2018 above the level that produces MSY (**Figure 66**).

Estimates of historical fishing mortality show similar trends for all models. For most model runs, fishing mortality increased progressively until the early 1980s, it varied in level until the mid 1990s, after which it declined gradually until the mid 2000s. Since the mid-2000s, the fishing mortality has had a generally increasing trend with fluctuations until 2018. Overall the models estimate that the fishing mortality in 2018 was near the fishing mortality that would produce MSY, with the majority of the models estimating fishing mortality to be below that level. Again, for all models there are large uncertainties in the value of fishing mortality at any point in the history, including 2018 (**Figure 67**).

It is important to note that the Stock Synthesis model is the only one that can provide estimates of recent recruitment. Recruitments were not estimated to vary from the stock-recruit relationship for 2018, due to

the large uncertainty in terminal year recruitment estimates. The estimate of recruitment in 2017 is also more uncertain than for previous years, in part because there is no 2018 size frequency data to corroborate or contrast with it. Stock Synthesis models which use the buoy index suggest very high recruitment in 2017, whereas models that do not use the buoy index suggest that recruitment in 2017 was above average but not particularly high. The alternative assumptions about recruitment produce some differences in estimates of historical trends and current status, but the largest differences are seen in the projections, which will be discussed in the next section.

In considering how to synthesize management advice (e.g. current [2018] stock status), the Group considered a number of factors. In a general sense, Stock Synthesis may be considered to be a more appropriate model for the situation observed in the YFT fisheries, where overall selectivity has changed over time mostly towards an increase in the probability of catching small fish. The surplus production models do not take this into account. This was a basis for developing the final status and projection advice for BET in 2018 only with stock synthesis. However, in this YFT assessment, Stock Synthesis results were deemed to be very sensitive to the alternative data inputs and model structures considered. The Group considered that the accepted runs from surplus production models reflected different, reasonable hypotheses for the YFT population dynamics and thus were included in the management advice.

The four Stock Synthesis model runs, were regarded as representing alternative recruitment, and steepness hypotheses. Likewise, the JABBA runs addressed different hypotheses about initial priors for r , and about which indices of abundance were representing the population. Finally, the base case selected for MPB estimated biomass and fishing mortality trends that varied somewhat from JABBA. The Group decided that, in order to capture this uncertainty in the population dynamics for developing the management advice, it was best to incorporate results from all of the accepted model runs.

The Group decided to give equal weight to surplus production model and integrated assessment model results. Within surplus production models, JABBA and MPB were also given equal weight. Each run within a modeling platform (JABBA, and Stock Synthesis) were given equal weight. All benchmarks were calculated following this weighting scheme. A distribution of estimates for each benchmark was calculated by combining the following number of random estimates from the various models: 100 for each of the four JABBA models, 400 for the MPB model and 200 for each Stock Synthesis model. This provided a set of 1600 iterations. Median, 5 and 95 percentiles were then calculated from each distribution.

For the combined results (MPB, JABBA, SS) used to develop management advice, the median estimate of B_{2018}/B_{MSY} is 1.17 (0.75, 1.62) and the median estimate of F_{2018}/F_{MSY} is 0.96 (0.56, 1.50). The median MSY estimated is 127,558 tons with 90% confidence intervals of 98,268 and 267,350 tons (**Table 20**). Combining the results of all models provides a way to estimate the probability of the stock being in each quadrant of the Kobe plot in 2018 (**Figure 68**). The corresponding probabilities are 54% in the green (not being overfished not subject to overfishing), 21% in the orange (subject to overfishing but not being overfished) 2% in the yellow (being overfished but not subject to overfishing) and 22% in the red (being overfished and subject to overfishing).

5. Projections

The Group agreed to project each of the models (i.e. stock synthesis, MPB, and JABBA) using the following general specifications.

- Projection interval: The Group agreed to make projections over a 14-year interval, 2020-2033, which corresponds to two generation times of yellowfin tuna.
- 2019 Catch: Fixed at 131,042 t, the same catch as was estimated for 2018.
- Constant catch projections were made at 0 t, and 60,000 – 150,000 t, by 10,000 t intervals: 11 catch scenarios in total.

For stock synthesis setting,

- Recruitment: Based on the estimated stock recruitment relationship with no recruitment deviations.

- Selectivity and fleet allocations: It is necessary to specify the selectivity pattern for projections. The appropriate pattern is model specific. Use average of the last three years of the model (2016-2018).

5.1 Stock synthesis

For stock synthesis uncertainty grid, the statistical uncertainty of catch projections were estimated using 2,500 multivariate normal (MVN) iterations for each model of the grid (run1 (Reference Case), run 2, run 3, and run 4) for each constant catch scenario. Due to the technical problem in MVN approach, the values of F/F_{MSY} more than 4 or B/B_{MSY} less than 0.2 were replaced to 4 or 0.2 (SCRS/2019/145). The trajectories for relative biomass and fishing mortality using the median of MVN iterations are shown in **Figure 69**. The projections in runs 1, 2 and 3, and 4 (**Figure 69**) showed that the median of MVN iterations could maintain the stock above B_{MSY} level and below F_{MSY} by 2033 with the constant catches less than 110,000 t, 120,000 t, and 130,000 t, respectively. However, the projections in runs 1 and 2 clearly indicate that constant catch higher than 140,000 t leads to population crash in later years.

5.2 MPB

Catch projections from the 5000 iterations developed from the MPB-Reference Case were carried out. The deterministic trajectories for relative biomass and fishing mortality are shown in **Figure 70**. The projections with MPB (**Figure 70**) showed that according to the the median of 5000 bootstrap iterations, constant catches less than 130,000 t could maintain the stock at or above B_{MSY} level and below F_{MSY} though 2033

5.3 JABBA

Catch projections from 36,000 MCMC iterations were conducted for each JABBA Reference Cases (Base Case, S2, S3, and S5). The trajectories for relative biomass and fishing mortality using the median of MCMC iterations are shown in **Figure 71**. The projections with JABBA in Base Case, S3, and S5 (**Figure 71**) showed that according to the the median of MCMC iterations, constant catches less than 130,000 t. could rebuild (S5) or maintain the stock at or above B_{MSY} level and below F_{MSY} through 2033. However, the projection with S2 could rebuild the stock at or above B_{MSY} level and below F_{MSY} by 2033 with the constant catches less than 120,000 t.

5.1 Synthesis of projections

Combined catch projections from 9 runs (JABBA (Base Case, S2, S3, and S5), MPB, Stock Synthesis (runs 1, 2, 3 and 4) were provided at constant catches ranging 0 t and from 60,000 to 150,000 t. The method used to combine the projection results is described in section 4.4. In the projections results from the Stock Synthesis and JABBA models, some iterations were predicted with exceptionally small biomass ratios and extremely high F ratios indicating the potential for stock collapse. Thus, probability of biomass being less than 20% of the biomass that supports MSY was calculated for each projection year and catch scenario (**Table 21**). The probability increased with higher catch levels and in later projected years. The probabilities more than 1% or 10% were observed with the constant catch more than 110,000 t or 140,000 t, respectively. The highest probability was 23.3% with 150,000 t constant catch in 2033. It should be noted that the reference chosen, 20% of biomass that supports MSY, was selected for informational purposes and has not been adopted formally by the SCRS for tropical tunas.

The combined projections show that 120,000 t constant catch will maintain more than 50% probability of being in green quadrant by 2033 (**Figure 72** and **Table 22**: Kobe II matrix).

6. Recommendations

Management

Based on the 2019 stock assessment, the Atlantic yellowfin tuna stock biomass was estimated to be above the biomass that can support MSY on a continuing basis (not overfished; 1.17 B/B_{MSY} in 2018), and that the current fishing mortality was at or near the overfishing threshold (0.96 F/F_{MSY} in 2018). The Group noted

that catch reports for 2018 were incomplete, with 42% of the estimated total catch being estimated using the average from the previous three years by CPC and gear type. Furthermore, no size data for 2018 were available at the time of the assessment. This may add uncertainty to the terminal year stock status estimates for 2018, and the Group recommends that final SCRS advice take into consideration any difference between these current estimates and the reported 2018 catches available for the Plenary meeting.

Projections results indicated that catch levels at or below the 120,000 t were expected to maintain healthy stock biomass through 2033. However, the Group noted that the most recent catch estimates suggest that overall catches have exceeded 120,000 t every year since 2015, the Group expressed strong concern that such overages are expected to further degrade the condition of the yellowfin stock if they continue. Furthermore, given that significant overages continue to occur, existing conservation and management measures appear to be insufficient, and the Committee recommends that the Commission strengthen such measures.

The Commission should also be aware that increased harvests on small yellowfin, and the increased catches of bigeye tuna if such harvests are taken on FADs, could have negative consequences to both long-term sustainable yield and stock status. Should the Commission wish to increase long-term sustainable yield, the Committee continues to recommend that effective measures be found to reduce fishing mortality on small yellowfin and bigeye tuna (e.g. FAD-related and other fishing mortality of small yellowfin tuna).

Research and Statistics

- A number of issues related to discards from the longline fleets of Chinese Taipei, ongoing practices and their impact on the joint longline index were discussed during the assessment meeting. **The Group recommended that the potential impact associated with discards in the joint longline index be further investigated and revisions made as were done for the BET stock assessment.**
- In 2018 there was no funding provided to carry out work on yellowfin tuna MSE in 2019. However, if MSE is going to be used to provide advice on tropical tunas in 2022 it is time to reactivate the process. **The Group recommended that the MSE workplan be revised and requests funding to continue the process.** It was also suggested that other sources of funding for work be explored as well.
- **The Group recommended evaluation of approaches to improve the estimates of M, and to develop uncertainty grids that consider the correlations between key biological parameters for example, M and steepness so that biologically implausible combinations can be identified and eliminated.**
- **The Group recommended increasing the sampling and ageing of small (≤ 65 SFL, particularly < 30 cm SFL) yellowfin using daily ring counts and otolith weight to better understand the dynamics of growth for earlier years, and the apparent slow initial growth/two-stanza pattern.**
- **The Group recommended that Venezuela scientist and the Secretariat review the size data for 2006 and other years as outliers were identified for this particular year in several fleets.**
- **The Group recommended that the Venezuela catch and effort data from the longline fisheries should be included, if possible, in the next development of a multi-national joint LL CPUE index.**
- As presentations are an increasingly important part of the SCRS meetings, the Group request that the SCRS discuss possible changes to the process used to manage and storage such presentations during the plenary meeting to:
 - improve the ability of scientists to access such material in the future
 - properly reference the material presented
 - make it clear to presentation authors whether material can or cannot be cited in ICCAT reports

- **It was recommended that the Ghanaian scientists provide a review of the data available through the EMS project, comparing those data with the data coming from at-sea observers and port samplers to the SCRS.**

7. Other matters

The ICCAT Secretariat provided a summary of the active requests from the Commission regarding tropical tunas (**Appendix 5**). During the meeting, information was presented, and discussions ensued related to two of these requests. The following text is a summary of these discussions and is intended to help the Group develop the responses during the September meeting of the species group.

Evaluate the efficacy of the area/time closure referred to in paragraph 13 for the reduction of catches of tropical tuna juveniles. Rec. 16-01, paragraph 15

In 2018, the SCRS recommended that the efficacy of longer and larger closures should be evaluated.

SCRS/2019/107 presents an alternative approach to manage purse seine fisheries for tropical tuna stocks, which uses fisheries closures instead of catch limits for the purse seine fishery. The length of the closures is estimated according to an expected reduction in catch, through a model that uses fisheries data and inputs from the latest assessments of tropical tuna stocks. The proposal is to set two closures to achieve the reduction in activity that is sought, allowing that each fishing unit selects the closure during which it will remain in port, so as to not compromise supply to the market. The approach is similar to the one used at the IATTC, which has proved successful over many years.

It is proposed that full closures are more efficient than TACs, or time-area closures, because: they are fully inclusive in terms of the fishing units and stocks covered (target and bycatch); do not lead to catch misreporting; and are not undermined by changes in targeting or selectivity through effort redistribution or changes in gear configuration or fishing mode. The authors hypothesize that they will be more effective in achieving the targets set by the Commission than stock-based TACs, which have been exceeded for several years in both the ICCAT and IOTC.

The model includes a tool that can express the reduction sought in terms of the number of days of closure required and the number of closures that could be implemented to achieve that target. In addition, the model is multi-species and can be set to achieve targets for both target and bycatch stocks, preventing the detrimental effects that TACs set on individual stocks may have on multi-species fisheries.

During the discussion, it was noted that in SCRS/2019/107 the catches of immature/mature fish by fishing mode estimated by the model for bigeye did not reflect the values calculated from the present fisheries.

The authors pointed out that the purpose of the analysis presented was to demonstrate the tool and to show how achievement of any goal expressed as a percent reduction in catch of immature/mature fish could be evaluated with such tool. The authors intend to modify input values to be more in line with current estimates for the Atlantic fisheries and present the new analysis at the next SCRS plenary.

Various points were discussed regarding the model assumptions in relation to the effort pattern during the open fishing periods. The authors assumed that there was little chance for effort to increase in the open period. Arguments were made that current purse seine operations are already very efficient and there is little room for vessels to increase their efficiency by shortening their periods when they are landing or by timing their maintenance and refit to the closure period. One of the constraints for the latter is the fact that there are limited sites available for vessel maintenance. However, it was noted, that in the case of the IATTC closure at least one fleet was able to increase effort by increasing efficiency and redistributing maintenance to the closed period.

Another question was whether there would be some chance of effort redistribution of purse seine to other oceans (Pacific and/or Indian) during such closures. The perception from authors was that this would be unlikely given the length of closures considered. In the Pacific, such effort distribution from the East to the Central Pacific is constrained by the lack of fishing opportunities provided by PNA countries to access their

waters. Most tRFMOs have capacity restrictions that could limit such movement of seiners. Clearly, it is difficult to predict what effects new Atlantic closures may have on trans-oceanic movement of purse seine effort. All tRFMOs should be aware of such possible effects when they make the decisions of imposing new lengthy closures and consider strengthening capacity constraints to such movement.

Part of why catches exceeded TACs in recent times was CPCs exercising their rights to develop purse seine fleets. It was questioned whether closures would affect such pattern or not in the future. The authors responded that the incentive to enter the fishery or increase the catch of new/recent entrants would remain, however, new entrants would have to accept that they would be subject to the closures as well.

The authors also made the point that such closures would have to be reviewed continuously and the allocation of open days should be changed in response to the condition of the stock(s). It was pointed out that the analysis assumes the closures do not impact the potential CPUE in the open period, but such assumption may not be correct. It is possible that the accumulation of biomass during the closures could lead to increases in CPUE once the area is re-opened. It was discussed that seasonal closures in the IATTC have not shown any evidence of substantial increases in CPUE after the opening, although it needs to be noted that IATTC vessels can choose which closure to abide with. Therefore fishing effort never goes to zero during closures, it is only reduced.

One important point made was that closures without some measure of capacity constraints are unlikely to be beneficial in term of economics. It was understood that the closure will also be applied to supply vessels. In the IATTC effort capacity is adjusted with a multiplier that is calculated every year and links the number of fishing days of the closure to the state of stocks. A possible mechanism to control capacity may be requiring CPCs to inform ICCAT of any proposed increase in the number of fishing vessels with enough time so that the allowable days of opening could be recalculated. These closures should have benefits in terms of reductions in bycatch because it is expected that they will reduce overall purse seine effort.

It was noted, that the current system of stock-specific TACs constrains fleets for which the species under a TAC may not be the primary objective but rather a bycatch. Recently, small-scale fleets from some CPCs have had to stop fishing because the national BET catch limit was reached, when in fact BET was not their primary target. Another limitation of the current system is that it requires real time monitoring of catch so as not to exceed quotas. Such monitoring is not always effective, furthermore when it relies on the monitoring of species composition at the landing place, a challenging endeavor.

The Group discussed the fact that such closures can assist in achieving a TAC. The Group agreed that this analysis was informative and that it should be transmitted to the SCRS for their consideration in the September meeting.

Provide performance indicators for skipjack, bigeye and yellowfin tuna, with the perspective to develop management strategy evaluations for tropical tunas. Rec. 16-01, paragraph 49 (b)

Phase one of a research project in support of the MSE process on tropical tunas was completed in 2018 (Merino *et al.*, 2018) but no further funding was provided for phases two and three. Phase one included:

- Workplan development
- Initiate design and implementation of MSE
- Participate in workshops
 - Bigeye stock assessment (16-20 July, Pasaia)
 - Panel 1 (23-25 July Bilbao)
 - SCRS species (26-28 September, Madrid)
 - Specific MSE workshop (December, Pasaia)
- Liaise with ICCAT experts for stock assessment methods, uncertainties, data formats etc.

The preliminary workplan developed for phases two and three include:

- Develop stock synthesis for eastern SKJ
- Condition OMs
- Develop Observation Error Model

- Identify candidate MPs
- Performance statistics
- Simulations
- Evaluation of MPs
- Summary and presentation of results
- Dissemination to SCRS, WGs, Panel 1 and Commission at request
- Peer review publication of results

The Group reviewed a proposal (**Figure 73**) for activities for phases two and three in order to be ready to implement the project. The initial estimate of such activities is of €250,000. Phase two and three of such project would be completed during 2020 and 2021.

The Group discussed the importance of considering these activities given: the need to maintain the momentum of progress on MSE for tropical tunas and take advantage that 2019 is the beginning of a new budget cycle for ICCAT. Furthermore, the SCRS plans to conduct an assessment of skipjack tuna in 2020, so it would be appropriate to work on MSE in 2020 and 2021 to be in a position to provide advice on MSE to the Commission by 2022. It was pointed out that the proposed budget supports the technical and scientific work related to MSE, and although input from stakeholders is an important part of the process, this proposed budget does not provide support for such activities. It was noted that the FAO ABNJ tuna project and some other funding agencies are in the process of developing activities in support of broader capacity building related to MSE.

The Group recommended that this proposed list of activities and associated budget be considered by the SCRS to be passed to the Commission when needed. The Group was reminded of the benefits of continued Commission discussions regarding operational management objectives for tropical tunas. The more specific these objectives are the easier it will be for the MSE technical group to develop and calculate performance indicators within the MSE. To that end, the calendar and proposed workplan should explicitly indicate that input from the Commission is expected.

8. Adoption of the report and closure

The major part of the report was adopted during the meeting, sections 4.4, 5.3 and 5.4 are pending for adoption. The Group agreed to adopt these sections by correspondence by 2 September 2019. Dr Cass-Calay thanked the Ministry of Fisheries of Côte d'Ivoire for hosting and their logistic and technical support to the meeting as well their attentions and social gatherings provided to the Group. The meeting was adjourned.

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Table 1 (continuation). Final YFT Task I nominal catch (T1NC, t) by region, major gear, flag and year.

| Catch type | Area | Flag | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | | | | | |
|----------------------------|-----------|----------------------------|-------|-------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|--------|--------|--|--|--|
| ATW | Caribbean | Belize | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Cuba | 2,084 | 2,070 | 2,244 | 2,149 | 2,047 | 1,837 | 2,266 | 2,152 | 2,513 | 1,758 | 1,818 | 4,238 | 5,131 | 4,169 | 4,021 | 2,767 | 2,705 | 2,514 | 4,337 | 6,145 | 6,239 | 6,172 | 3,503 | 6,085 | 7,233 | 3,790 | 5,468 | 2,749 | 3,232 | 3,677 | 3,653 | 4,639 | 2,277 | 11,643 | 16,462 | 16,214 | | | |
| | | Costa Rica | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Guatemala | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | El Salvador | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Honduras | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Nicaragua | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Panama | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | St. Vincent and Grenadines | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Turkey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | USA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | UK-British Virgin Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Other | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Discards | ATW | Belize | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Cuba | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Costa Rica | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Guatemala | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | El Salvador | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Honduras | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Nicaragua | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Panama | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| St. Vincent and Grenadines | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Turkey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| USA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| UK-British Virgin Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Other | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Discards | ATW | | | Belize | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Cuba | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Costa Rica | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Guatemala | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | El Salvador | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Honduras | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Nicaragua | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | Panama | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | St. Vincent and Grenadines | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Turkey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | USA | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | UK-British Virgin Islands | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | Other | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table 2. YFT reported catches (Report CPC) and estimates for 2018 total catch using the 3 prior years (2015-2018 average).

| Catch | Est 3 yr Avg | Report CPC | Total |
|----------------------------|---------------------|-------------------|----------------|
| Flag | 2018 | 2018 | |
| Barbados | 263 | | |
| Belize | 4,588 | | |
| Brazil | 16,214 | | |
| Canada | | 15 | |
| Cape Verde | | 5,584 | |
| China PR | 405 | | |
| Chinese Taipei | | 992 | |
| Côte d'Ivoire | 463 | | |
| Curaçao | 6,980 | | |
| Dominica | 194 | | |
| El Salvador | 5,911 | | |
| EU.España | 177 | 10,742 | |
| EU.France | 315 | 24,611 | |
| EU.Portugal | | 638 | |
| Ghana | | 23,160 | |
| Guatemala | | 2,539 | |
| Guyana | 126 | | |
| Japan | 3,325 | | |
| Korea Rep. | | 455 | |
| Liberia | 84 | | |
| Maroc | | 108 | |
| Mexico | | 895 | |
| Mixed flags (EU tropical) | 1,567 | | |
| Namibia | 49 | | |
| Panama | 5,803 | | |
| S. Tomé e Príncipe | 289 | | |
| Senegal | 57 | 5,016 | |
| South Africa | | 389 | |
| St. Vincent and Grenadines | 429 | | |
| Sta. Lucia | 199 | | |
| Trinidad and Tobago | | 1,214 | |
| U.S.A. | 2,894 | | |
| UK.Bermuda | | 32 | |
| UK.Sta Helena | | 199 | |
| Venezuela | 4,125 | | |
| Total | 54,455 | 76,587 | 131,042 |

Table 3. Total nominal catch YFT 1950 – 2018 used as input for the 2019 stock assessment. 2018 is a combination of CPC reported catches and Group estimates.

| YearC | Bait boat | Longline | Other surf. | Purse seine | Total |
|-------|-----------|----------|-------------|-------------|---------|
| 1950 | 1,176 | | 24 | | 1,200 |
| 1951 | 1,176 | | 182 | | 1,358 |
| 1952 | 2,548 | | 239 | | 2,787 |
| 1953 | 3,528 | | 72 | | 3,600 |
| 1954 | 3,332 | | 75 | | 3,407 |
| 1955 | 4,218 | | 82 | | 4,300 |
| 1956 | 5,723 | 612 | 262 | | 6,597 |
| 1957 | 9,187 | 13,886 | 625 | | 23,698 |
| 1958 | 10,304 | 29,949 | 328 | | 40,581 |
| 1959 | 5,775 | 51,882 | 112 | | 57,769 |
| 1960 | 11,247 | 57,121 | 125 | | 68,493 |
| 1961 | 9,839 | 48,762 | 202 | | 58,803 |
| 1962 | 10,557 | 46,692 | 274 | | 57,523 |
| 1963 | 17,785 | 45,254 | 60 | 1,499 | 64,598 |
| 1964 | 21,116 | 40,427 | 34 | 7,351 | 68,928 |
| 1965 | 18,486 | 40,943 | 13 | 8,279 | 67,721 |
| 1966 | 15,050 | 28,016 | 12 | 15,658 | 58,736 |
| 1967 | 16,761 | 24,523 | 1 | 18,940 | 60,225 |
| 1968 | 22,135 | 32,329 | | 29,859 | 84,323 |
| 1969 | 15,645 | 34,579 | 5 | 44,362 | 94,591 |
| 1970 | 9,787 | 31,094 | 314 | 33,525 | 74,720 |
| 1971 | 10,701 | 31,334 | 320 | 32,391 | 74,746 |
| 1972 | 13,304 | 30,820 | 309 | 51,029 | 95,462 |
| 1973 | 14,773 | 33,613 | 311 | 47,238 | 95,935 |
| 1974 | 20,977 | 32,430 | 305 | 53,520 | 107,232 |
| 1975 | 10,041 | 29,838 | 277 | 84,359 | 124,515 |
| 1976 | 12,814 | 25,839 | 418 | 85,871 | 124,942 |
| 1977 | 10,949 | 27,832 | 556 | 91,998 | 131,335 |
| 1978 | 10,002 | 21,237 | 765 | 102,013 | 134,017 |
| 1979 | 14,832 | 16,636 | 1,120 | 94,979 | 127,568 |
| 1980 | 9,411 | 20,129 | 456 | 100,772 | 130,769 |
| 1981 | 11,935 | 19,610 | 6,323 | 118,163 | 156,031 |
| 1982 | 16,181 | 20,492 | 4,203 | 124,415 | 165,291 |
| 1983 | 15,110 | 14,597 | 6,221 | 129,491 | 165,419 |
| 1984 | 18,455 | 18,330 | 2,905 | 74,801 | 114,491 |
| 1985 | 21,664 | 20,801 | 6,398 | 107,964 | 156,827 |
| 1986 | 17,644 | 25,522 | 7,960 | 95,701 | 146,827 |
| 1987 | 22,181 | 21,268 | 7,078 | 95,171 | 145,698 |
| 1988 | 21,856 | 28,819 | 5,043 | 80,357 | 136,076 |
| 1989 | 17,050 | 25,419 | 4,695 | 115,302 | 162,465 |
| 1990 | 24,343 | 30,002 | 3,295 | 135,944 | 193,584 |
| 1991 | 23,052 | 24,707 | 4,879 | 114,884 | 167,523 |
| 1992 | 21,371 | 25,613 | 3,154 | 113,632 | 163,770 |
| 1993 | 24,850 | 22,754 | 4,005 | 111,838 | 163,447 |
| 1994 | 22,740 | 27,502 | 7,132 | 116,365 | 173,739 |
| 1995 | 18,867 | 25,495 | 6,564 | 103,751 | 154,677 |
| 1996 | 15,961 | 27,098 | 6,795 | 99,334 | 149,187 |
| 1997 | 16,914 | 22,637 | 6,230 | 91,538 | 137,318 |
| 1998 | 19,772 | 26,297 | 5,397 | 93,047 | 144,513 |
| 1999 | 21,922 | 27,484 | 6,365 | 80,383 | 136,154 |
| 2000 | 16,718 | 27,751 | 7,139 | 80,707 | 132,315 |
| 2001 | 19,590 | 23,272 | 7,058 | 103,519 | 153,439 |
| 2002 | 17,497 | 17,790 | 5,388 | 94,096 | 134,770 |
| 2003 | 13,863 | 19,349 | 8,754 | 80,614 | 122,580 |
| 2004 | 19,641 | 29,703 | 7,665 | 62,549 | 119,558 |
| 2005 | 13,637 | 25,377 | 6,936 | 59,117 | 105,067 |
| 2006 | 15,530 | 22,702 | 8,311 | 59,341 | 105,885 |
| 2007 | 15,218 | 29,541 | 5,370 | 50,302 | 100,431 |
| 2008 | 10,439 | 22,340 | 2,890 | 76,198 | 111,868 |
| 2009 | 10,182 | 22,102 | 3,157 | 82,467 | 117,908 |
| 2010 | 10,806 | 20,052 | 3,494 | 83,692 | 118,043 |
| 2011 | 14,694 | 18,271 | 3,483 | 77,152 | 113,599 |
| 2012 | 10,477 | 20,278 | 5,645 | 78,537 | 114,937 |
| 2013 | 8,405 | 17,524 | 9,315 | 71,043 | 106,288 |
| 2014 | 9,963 | 13,685 | 13,428 | 75,785 | 112,861 |
| 2015 | 10,097 | 13,147 | 15,106 | 89,222 | 127,572 |
| 2016 | 11,281 | 16,318 | 18,448 | 101,996 | 148,043 |
| 2017 | 8,931 | 15,001 | 21,675 | 89,193 | 134,800 |
| 2018 | 8,162 | 15,200 | 18,391 | 89,289 | 131,042 |

Table 4. Catch of YFT by fleet ID for input in the stock synthesis model. See Table 6 for the definition of the fleet ID structure and details

Table with 25 columns (Year, Fleet ID 1-25) and 25 rows (1950-2018). Values represent catch data for each fleet ID over time. Many cells contain dashes, indicating zero catch.

Table 5. Recommended annual abundance indices for the Atlantic yellowfin tuna stock assessment reference case. This table reflects revisions made following the data preparatory meeting.

| <i>series</i> | | Joint LL- Region1 | | Joint LL- Region2 | | Joint LL- Region3 | | FR_PS | | Ven_LL | | <i>series</i> | | Buoy-derived | |
|---------------|-----------|-------------------|-----------|-------------------|-----------|-------------------|-----------|---------------|-----------|-----------------|------|---------------|-----------|-----------------|--|
| <i>units</i> | | Number | | Number | | Number | | | | Number | | <i>units</i> | | Abundance Index | |
| <i>area</i> | | North Temprate | | Tropical | | South Temprate | | Tropical | | North Temprate | | <i>area</i> | | Tropical | |
| <i>method</i> | | Delta lognormal | | Delta lognormal | | Delta lognormal | | | | Delta lognormal | | <i>method</i> | | Delta lognormal | |
| <i>source</i> | | SCRS/2019/081 | | SCRS/2019/081 | | SCRS/2019/081 | | SCRS/2019/066 | | SCRS/2019/117 | | <i>source</i> | | SCRS/2019/075 | |
| Year | Std. CPUE | CV | Std. CPUE | CV | Std. CPUE | CV | Std. CPUE | CV | Std. CPUE | CV | Year | Quarter | Std. CPUE | CV | |
| 1979 | 1.12 | 0.10 | 1.29 | 0.08 | 1.35 | 0.20 | | | | | 2010 | 1 | 0.44 | 0.15 | |
| 1980 | 0.89 | 0.10 | 1.25 | 0.06 | 0.62 | 0.14 | | | | | 2010 | 2 | 0.44 | 0.15 | |
| 1981 | 0.81 | 0.08 | 1.23 | 0.05 | 0.72 | 0.12 | | | | | 2010 | 3 | 0.41 | 0.16 | |
| 1982 | 0.74 | 0.09 | 1.18 | 0.04 | 0.90 | 0.10 | | | | | 2010 | 4 | 0.63 | 0.16 | |
| 1983 | 1.01 | 0.09 | 1.02 | 0.06 | 0.85 | 0.11 | | | | | 2011 | 1 | 0.45 | 0.16 | |
| 1984 | 1.12 | 0.09 | 1.29 | 0.05 | 1.07 | 0.12 | | | | | 2011 | 2 | 0.51 | 0.15 | |
| 1985 | 0.86 | 0.09 | 1.15 | 0.04 | 0.86 | 0.10 | | | | | 2011 | 3 | 0.37 | 0.16 | |
| 1986 | 1.06 | 0.08 | 1.41 | 0.05 | 0.99 | 0.10 | | | | | 2011 | 4 | 0.33 | 0.16 | |
| 1987 | 1.06 | 0.07 | 1.52 | 0.04 | 0.91 | 0.11 | | | | | 2012 | 1 | 0.23 | 0.15 | |
| 1988 | 1.19 | 0.07 | 1.37 | 0.04 | 1.35 | 0.10 | | | | | 2012 | 2 | 0.34 | 0.15 | |
| 1989 | 1.16 | 0.06 | 1.31 | 0.04 | 1.00 | 0.10 | | | | | 2012 | 3 | 0.22 | 0.16 | |
| 1990 | 1.36 | 0.07 | 1.32 | 0.04 | 1.00 | 0.09 | | | | | 2012 | 4 | 0.17 | 0.15 | |
| 1991 | 1.23 | 0.06 | 1.11 | 0.04 | 1.03 | 0.07 | 0.32 | 0.15 | 1.03 | 0.62 | 2013 | 1 | 0.12 | 0.14 | |
| 1992 | 1.25 | 0.06 | 0.86 | 0.04 | 1.07 | 0.09 | 0.31 | 0.14 | 0.77 | 0.46 | 2013 | 2 | 0.17 | 0.14 | |
| 1993 | 0.96 | 0.07 | 1.02 | 0.04 | 0.88 | 0.09 | 0.98 | 0.11 | 0.59 | 0.50 | 2013 | 3 | 0.17 | 0.13 | |
| 1994 | 1.22 | 0.07 | 1.07 | 0.04 | 1.06 | 0.07 | 0.79 | 0.14 | 0.55 | 0.43 | 2013 | 4 | 0.22 | 0.13 | |
| 1995 | 1.26 | 0.06 | 1.13 | 0.04 | 1.22 | 0.07 | 1.07 | 0.11 | 0.42 | 0.68 | 2014 | 1 | 0.17 | 0.13 | |
| 1996 | 1.01 | 0.06 | 0.98 | 0.04 | 1.09 | 0.08 | 0.93 | 0.12 | 0.62 | 0.43 | 2014 | 2 | 0.18 | 0.13 | |
| 1997 | 1.04 | 0.06 | 0.88 | 0.04 | 0.98 | 0.08 | 0.85 | 0.11 | 0.51 | 0.46 | 2014 | 3 | 0.22 | 0.12 | |
| 1998 | 1.08 | 0.06 | 0.94 | 0.04 | 1.15 | 0.06 | 1.30 | 0.10 | 0.66 | 0.48 | 2014 | 4 | 0.22 | 0.12 | |
| 1999 | 1.10 | 0.06 | 0.95 | 0.04 | 1.05 | 0.07 | 1.07 | 0.10 | 0.89 | 0.35 | 2015 | 1 | 0.15 | 0.12 | |
| 2000 | 1.07 | 0.05 | 0.94 | 0.04 | 1.08 | 0.06 | 0.77 | 0.10 | 0.59 | 0.49 | 2015 | 2 | 0.17 | 0.12 | |
| 2001 | 1.00 | 0.05 | 0.87 | 0.04 | 1.11 | 0.07 | 1.00 | 0.10 | 0.56 | 0.65 | 2015 | 3 | 0.22 | 0.09 | |
| 2002 | 0.86 | 0.05 | 0.78 | 0.04 | 1.18 | 0.08 | 0.97 | 0.10 | 0.61 | 0.72 | 2015 | 4 | 0.22 | 0.10 | |
| 2003 | 0.93 | 0.05 | 0.82 | 0.04 | 1.16 | 0.07 | 1.55 | 0.09 | 0.73 | 0.85 | 2016 | 1 | 0.14 | 0.11 | |
| 2004 | 1.04 | 0.05 | 0.94 | 0.04 | 1.13 | 0.08 | 1.13 | 0.08 | 0.82 | 0.95 | 2016 | 2 | 0.19 | 0.12 | |
| 2005 | 1.34 | 0.05 | 1.18 | 0.03 | 1.29 | 0.06 | 0.80 | 0.10 | 1.42 | 0.76 | 2016 | 3 | 0.22 | 0.12 | |
| 2006 | 1.14 | 0.06 | 0.98 | 0.03 | 1.07 | 0.05 | 0.97 | 0.08 | 1.02 | 0.73 | 2016 | 4 | 0.21 | 0.11 | |
| 2007 | 0.90 | 0.06 | 0.87 | 0.04 | 1.02 | 0.05 | 0.80 | 0.09 | 2.19 | 0.32 | 2017 | 1 | 0.17 | 0.12 | |
| 2008 | 0.69 | 0.07 | 0.67 | 0.04 | 0.85 | 0.06 | 1.03 | 0.09 | 1.68 | 0.24 | 2017 | 2 | 0.24 | 0.11 | |
| 2009 | 0.77 | 0.07 | 0.69 | 0.03 | 0.81 | 0.06 | 1.11 | 0.07 | 1.41 | 0.39 | 2017 | 3 | 0.34 | 0.11 | |
| 2010 | 0.72 | 0.07 | 0.64 | 0.03 | 0.90 | 0.06 | 0.88 | 0.10 | 1.19 | 0.33 | 2017 | 4 | 0.46 | 0.11 | |
| 2011 | 0.79 | 0.07 | 0.65 | 0.03 | 1.02 | 0.06 | 0.81 | 0.09 | 1.19 | 0.12 | | | | | |
| 2012 | 0.84 | 0.06 | 0.66 | 0.03 | 1.21 | 0.06 | 0.80 | 0.10 | 1.13 | 0.23 | | | | | |
| 2013 | 0.87 | 0.06 | 0.72 | 0.04 | 1.24 | 0.05 | 0.86 | 0.08 | 1.17 | 0.31 | | | | | |
| 2014 | 0.80 | 0.08 | 0.64 | 0.04 | 0.89 | 0.06 | 0.84 | 0.10 | 1.29 | 0.17 | | | | | |
| 2015 | 0.78 | 0.07 | 0.67 | 0.04 | 0.99 | 0.06 | 0.85 | 0.09 | 1.35 | 0.23 | | | | | |
| 2016 | 0.86 | 0.07 | 0.64 | 0.04 | 0.98 | 0.06 | 1.10 | 0.11 | 1.24 | 0.19 | | | | | |
| 2017 | 0.92 | 0.07 | 0.67 | 0.04 | 1.04 | 0.06 | 0.87 | 0.11 | 1.19 | 0.06 | | | | | |
| 2018 | 0.86 | 0.09 | 0.55 | 0.05 | 0.91 | 0.09 | 0.98 | 0.09 | 1.17 | 0.15 | | | | | |

Table 6. Stock synthesis fleet structure definition for the 2019 YFT stock assessment for catch and size composition.

| Stock Synthesis ID | Name | Season | Gear | Area_ID_TT | Yr_Start | Yr_End |
|--------------------|-----------------|--------|-------|--------------|----------|--------|
| 1 | PS EU 63-85 | | PS | 1, 2n, 2s, 3 | 1963 | 1985 |
| 2 | PS EU 86-90 | | PS | 1, 2n, 2s, 3 | 1986 | 1990 |
| 3 | PS EU FSC 91 | 1 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 4 | PS EU FSC 91 | 2 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 5 | PS EU FSC 91 | 3 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 6 | PS EU FSC 91 | 4 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 7 | PS EU FAD 91 | 1 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 8 | PS EU FAD 91 | 2 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 9 | PS EU FAD 91 | 3 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 10 | PS EU FAD 91 | 4 | PS | 1, 2n, 2s, 3 | 1991 | 2018 |
| 11 | PSBB Ghana | | PS+BB | 1, 2n, 2s, 3 | 1972 | 2018 |
| 12 | BB South Dakar | | BB | 2n, 3 | 1950 | 2018 |
| 13 | BB Dakar 62-80 | | BB | 2n | 1955 | 1980 |
| 14 | BB Dakar 81+ | | BB | 2n | 1981 | 2018 |
| 15 | BB North 25 lat | | BB | 1 | 1962 | 2018 |
| 16 | LL JPN North 25 | | LL | North_LL | 1957 | 2018 |
| 17 | LL JPN Trop | | LL | Trop_LL | 1956 | 2018 |
| 18 | LL JPN South | | LL | South_LL | 1959 | 2018 |
| 19 | LL North Oth | | LL | North_LL | 1959 | 2018 |
| 20 | LL Trop Oth | | LL | Trop_LL | 1957 | 2018 |
| 21 | LL South Oth | | LL | South_LL | 1962 | 2018 |
| 22 | HL Brazil | | HL | 1 | 1985 | 2018 |
| 23 | RR USA | | RR | 1 | 1951 | 2018 |
| 24 | PS West | | PS | 2n | 1979 | 2018 |
| 25 | Others | | OTH | 1, 2n, 2s, 3 | 1950 | 2018 |

Table 7. Description of selectivity shapes, time blocks and data decisions for the accepted runs. Time blocks are described as the beginning and ending years for blocks.

| Fleet | Selectivity | Time block(s) | Note |
|--------------|--|--|---|
| 1 | 5 node cubic spline | | Include US PS Catch and Size |
| 2 | 5 node cubic spline | | Include US PS Catch and Size |
| 3 | 5 node cubic spline | | |
| 4 | mirrored to 3 | | |
| 5 | mirrored to 3 | | |
| 6 | mirrored to 3 | | |
| 7 | 5 node cubic spline | 2003 2018 (switch to FADs) | |
| 8 | mirrored to 7 | 2003 2018 (switch to FADs) | |
| 9 | mirrored to 7 | 2003 2018 (switch to FADs) | |
| 10 | mirrored to 7 | 2003 2018 (switch to FADs) | |
| 11 | 5 node cubic spline | 1981 1987 1988 1995 1996 2018 (selex change) | Exclude Size 1996-2008 |
| 12 | double normal, smooth inc/dec | 2010 2018 (selex change) | Exclude South Africa Catch and Size |
| 13 | double normal, smooth inc/dec | | Exclude Venezuela BB Size |
| 14 | double normal, smooth inc/dec | | Exclude Venezuela BB Size |
| 15 | mirrored to 14 | | |
| 16 | double normal, smooth increase | | |
| 17 | logistic | 1979 1991 1992 2004 2005 2018 (selex change) | |
| 18 | mirrored to 16 | | |
| 19 | double normal, smooth increase | 2003 2018 | Exclude Chinese Taipei Size after 2005 |
| 20 | logistic | 1979 1991 1992 2004 2005 2018 (selex change) | Exclude Chinese Taipei Size after 2005 |
| 21 | mirror 19 | | Exclude Chinese Taipei Size after 2005 |
| 22 | double normal with AOTTP tagging estimates as priors | | Exclude 1994 Brazil HL Size |
| 23 | double normal, smooth inc/dec | 1998 2018 (69 cm size limit) | |
| 24 | double normal | | Exclude US PS Catch and Size before 1990, remove 2006 Size from Venezuelan PS |
| 25 | double normal | | Include South Africa Catch and Size, exclude Cabo Verde Catch and Size. Lower lambda (0.001). |

Table 8. Description of reference and sensitivity runs carried out prior to and at the 2019 stock assessment meeting. Runs 29 and up use the data decisions listed in section 3.2.4.

| Run | Description |
|-----|---|
| 1 | Growth fit internally (Richards), Joint LL R2, Conditional Age at Length (CAL), $M_{age\ 5}=0.35$ with Lorenzen scaling, h fixed at 0.8 |
| 2 | Like 1 but with von Bertalanffy form |
| 3 | No CAL, fixed growth to estimates from 1 (preliminary reference run) |
| 4 | No CAL, convert to Lorenzen scaling of M ($M_{age\ 5}=0.318$) |
| 5 | Like 3 but ASPM, fix all selectivity parameters, estimate R_0 , σ_R , recruitment deviations |
| 6 | Like 3 but no recruitment deviations |
| 7 | Like 3 but with continuity M from 2016 assessment |
| 8 | Like 3 but with reduce weight on length composition (0.5) |
| 9 | Like 3 + BAI (CV 0.3, scaled as above) |
| 10 | Like 3 + EUPSFS + BAI (CV 0.3, scaled as above) |
| 11 | Like 3 + EUPSFS (CV 0.3, scaled according to interannual variability in precision) |
| 12 | Like 3 + 3 Joint LL indices |
| 13 | Like 3 but h fixed at 0.7 |
| 14 | Like 3 but h fixed at 0.9 |
| 15 | Like 3 but h fixed at 0.99 |
| 16 | Like 3 but estimate M , fix growth no CAL |
| 17 | Like 3 but estimate M , fix growth, CAL |
| 18 | Like 3 but Low $M_{age\ 5}=0.28$; or other low M |
| 19 | Like 3 but High $M_{age\ 5} = 0.42$, or other high M |
| 20 | Like 3 but with CAL |
| 21 | Like 5 but with 2016 new M |
| 22 | Like 5 but with 2016 + only joint LL |
| 23 | Like 3 but time block LL JPN and LL tropical at 1979 |
| 24 | Like 3 but fix 2017 recruitment deviations at zero |
| 25 | Like 23 but split JLL and Trop at 2004, downweigh OTHER_OTHER length composition data |
| 26 | Like 25 but with new data file |
| 27 | Like 25 same data file, but control file mods |
| 28 | Like 27 but removing BR HL prior to 1992 and Ghana BB/PS 1996-2008 |
| 29 | no CAL, $M=0.35$, Lorenzen scaled (final reference run) |
| 30 | Like 29 + EUPSFS and BAI |
| 31 | Like 29 but with CAL |
| 32 | Like 29 + EUPSFS and BAI |
| 33 | Like 30 but with M and growth like 2016 assessment |
| 34 | Like 30 but with low $M_{age\ 5}=0.28$ |
| 35 | Like 30 but with high $M_{age\ 5}=0.42$ |
| 36 | Like 29 but ASPM, fix all selectivities, estimate R_0 , σ_R , recruitment deviations |
| 37 | Like 30 but with λ on length composition (0.5) |
| 38 | Like 30 but $h=0.7$ |
| 39 | Like 30 but $h=0.9$ |
| 40 | Like 29 + all indices |
| 41 | Like 29 but with only the 3 LL indices (region 1,2,3) |
| 42 | Like 29 but with only EUPSFS index |
| 43 | Like 30 but no recruitment deviations in 2017 and 2018 |
| 44 | Like 30 but no recruitment deviation in 2018 |

Table 9. Characteristics of the reference and sensitivity runs from stock synthesis model used for the uncertainty grid and management advice.

| Run | Indices | <i>h</i> |
|---------------|--|----------|
| 1 (Reference) | joint LL R2 + EUPSFS | 0.8 |
| 2 | joint LL R2 + EUPSFS | 0.9 |
| 3 | joint LL R2 + EUPSFS + BAI linked to seasonal fleets | 0.8 |
| 4 | joint LL R2 + EUPSFS + BAI linked to seasonal fleets | 0.9 |

Table 10. List of model runs carried out in *MPB*.

| Run | Indice(s) | Other assumptions/restrictions |
|-----|---|---------------------------------------|
| 1 | Joint LL R2 (1979-2018) | Search space constrained for r and k |
| 2 | Joint LL R2 (1979-2018) + EU PS (1993-2018) | Unconstrained search space |
| 3 | Joint LL R2 (1979-2018) + EU PS (1993-2018) | Unconstrained search space Free B0 |

Table 11. List of model runs carried out in JABBA. Runs 1-4 were presented in the submitted SCRS document. All other runs were conducted during the assessment meeting. Models in **bold** were used for projections and stock status.

| Run | Indice(s) | Prior on r | Reference |
|---------------------|--|----------------------------|--|
| 1 | Joint LL R2 | SS3 2016 | Base Case in SCRS/2019/119; S1 in YFT_JABBA2019_v3 slides 2 and 29 |
| 2 | Joint LL R2 | FishLife (CV = 0.3) | S1 in SCRS/2019/119; S2 in YFT_JABBA2019_v3 slides 2 and 29 |
| 3 | Joint LL R2 + BAI | SS3 2016 | S2 in SCRS/2019/119 |
| 4 | Joint LL R2 + BAI | FishLife (CV = 0.3) | S3 in SCRS/2019/119 |
| 5 | Joint LL R2 | Uninformative lognormal | S3 in YFT_JABBA2019_v3 slide 2 |
| 6 (base) | Joint LL R2 | SS3 2019 | Base case in YFT_JABBA2019_v3 slides 2, 14, 29, 61 and 68 |
| 7 | Joint LL R2 + Joint LL R1 | SS3 2019 | S1 in YFT_JABBA2019_v3 slide 14 |
| 8 | Joint LL R2 + Joint LL R3 | SS3 2019 | S2 in YFT_JABBA2019_v3 slide 14 |
| 9 | Joint LL R2 + EUPSFS | SS3 2019 | S3 in YFT_JABBA2019_v3 slide 14 |
| 10 | Joint LL R2 + Joint LL R1 + Joint LL R3 | SS3 2019 | S4 in YFT_JABBA2019_v3 slide 14 |
| 11 | Joint LL R2 + Joint LL R1 + Joint LL R3 + EUPSFS | SS3 2019 | S5 in YFT_JABBA2019_v3 slide 14 |
| 12 | Joint LL R2 + Joint LL R1 + Joint LL R3 + EUPSFS + BAI | SS3 2019 | S6 in YFT_JABBA2019_v3 slide 14 |
| 13 | Joint LL R2 + Joint LL R1 + EUPSFS | SS3 2019 | S3 in YFT_JABBA2019_v3 slides 29, 61 and 68 |
| 14 | Joint LL R2 | FishLife (CV = 0.6) | S2 in YFT_JABBA2019_v3 slide 68 |
| 15 | Joint LL R2 + Joint LL R1 + EUPSFS | FishLife (CV = 0.6) | S5 in YFT_JABBA2019_v3 slide 68 |
| 16 | Joint LL R2 | FishLife (CV = 0.3) | S2 in YFT_JABBA2019_v3 slide 61 |
| 17 | Joint LL R2 + Joint LL R1 + EUPSFS | FishLife (CV = 0.3) | S5 in YFT_JABBA2019_v3 slide 61 |
| 18 | Joint LL R2 + Joint LL R1 + EUPSFS | SS3 2016 | S4 in YFT_JABBA2019_v3 slide 29 |
| 19 | Joint LL R2 + Ven LL | SS3 2019 | S6 in YFT_JABBA2019_v3 slide 69 |
| 20 | Joint LL R2 + Ven LL | FishLife (CV=0.3) | S7 in YFT_JABBA2019_v3 slide 69 |

Table 12. Stock synthesis parameter estimates of the for the reference model Run 1. Most parameter estimates are similar. Recruitment deviations not shown for brevity.

| Name | Value | Phase | Min | Max | CV | Grad | Pr type | Prior | Pr SD |
|--|-------|-------|-----|-----|---------|--------|---------|-------|-------|
| NatM_p_1_Fem_GP_1 | 0.35 | -4 | | | | - | | | |
| L_at_Amax_Fem_GP_1 | 153.0 | -2 | 120 | 190 | - | - | no | - | - |
| VonBert_K_Fem_GP_1 | 0.67 | -4 | 0.1 | 0.9 | - | - | no | - | - |
| Richards_Fem_GP_1 | 0.11 | -4 | -2 | 2 | - | - | no | - | - |
| CV_young_Fem_GP_1 | 0.21 | -4 | 0.1 | 0.3 | - | - | no | - | - |
| CV_old_Fem_GP_1 | 0.07 | -5 | 0.1 | 0.3 | - | - | no | - | - |
| RecrDist_month_4 | -0.06 | 3 | -4 | 4 | -509.6% | -2E-05 | Sbet | 0.17 | 2.00 |
| RecrDist_month_7 | -0.41 | 3 | -4 | 4 | -35.8% | 2E-05 | Sbet | -0.72 | 2.00 |
| RecrDist_month_10 | -1.81 | 4 | -4 | 4 | -39.6% | 1E-05 | Sbet | -0.23 | 2.00 |
| SR_LN(R0) | 11.33 | 1 | 9 | 13 | 0.6% | 8E-05 | no | - | - |
| SR_BH_flat_steep | 0.80 | -3 | 0.2 | 1 | - | - | no | - | - |
| SR_sigmaR | 0.35 | 6 | 0.2 | 1 | 15.6% | 4E-06 | no | - | - |
| SizeSpline_Val_2_1_PS_ESFR2_6585(1) | 0.01 | 5 | -2 | 2 | 324.9% | 1E-05 | Sbet | 0.18 | 2 |
| SizeSpline_Val_4_1_PS_ESFR2_6585(1) | 0.06 | 4 | -2 | 2 | 268.8% | 2E-06 | Sbet | -0 | 2 |
| SizeSpline_Val_5_1_PS_ESFR2_6585(1) | 0.80 | 4 | -2 | 2 | 17.7% | 1E-05 | Sbet | 0.68 | 2 |
| SizeSpline_Val_2_2_PS_ESFR2_8690(2) | -0.01 | 2 | -3 | 3 | -907.6% | 3E-08 | no | - | - |
| SizeSpline_Val_4_2_PS_ESFR2_8690(2) | -0.44 | 2 | -3 | 3 | -95.6% | -3E-06 | no | - | - |
| SizeSpline_Val_5_2_PS_ESFR2_8690(2) | 1.88 | 2 | -2 | 5 | 17.5% | 7E-06 | no | - | - |
| SizeSpline_Val_2_3_PS_ESFR2_9118_S1(3) | 0.07 | 5 | -2 | 2 | 116.8% | 2E-07 | Sbet | 0.38 | 2 |
| SizeSpline_Val_4_3_PS_ESFR2_9118_S1(3) | -0.39 | 4 | -2 | 2 | -70.8% | -3E-06 | Sbet | -0.8 | 2 |
| SizeSpline_Val_5_3_PS_ESFR2_9118_S1(3) | 2.46 | 4 | -2 | 5 | 8.1% | 6E-06 | Sbet | 1.79 | 2 |
| SizeSpline_Val_2_7_ESFR_FADS_PS_9118_S1(7) | 0.92 | 5 | -2 | 2 | 3.0% | 3E-06 | no | - | - |
| SizeSpline_Val_4_7_ESFR_FADS_PS_9118_S1(7) | -1.11 | 4 | -5 | 2 | -14.9% | 5E-06 | no | - | - |
| SizeSpline_Val_5_7_ESFR_FADS_PS_9118_S1(7) | -0.77 | 5 | -5 | 2 | -20.8% | 9E-06 | no | - | - |
| SizeSpline_Val_1_11_BB_PS_Ghana_6518(11) | -8.00 | 4 | -10 | 7 | -14.1% | 5E-07 | no | - | - |
| SizeSpline_Val_2_11_BB_PS_Ghana_6518(11) | 0.77 | 5 | -1 | 1 | 5.0% | 2E-06 | Sbet | 0.24 | 1 |
| SizeSpline_Val_4_11_BB_PS_Ghana_6518(11) | -4.92 | 4 | -10 | 2 | -17.1% | 2E-07 | Sbet | -5.7 | 1 |
| SizeSpline_Val_5_11_BB_PS_Ghana_6518(11) | -4.26 | 4 | -10 | 2 | -27.2% | -7E-08 | Sbet | -3 | 1 |
| Size_DbIN_peak_12_BB_area2_Sdak(12) | 46.08 | 3 | 30 | 180 | 3.9% | 6E-06 | Sbet | 46.5 | 0.5 |
| Size_DbIN_ascend_se_12_BB_area2_Sdak(12) | 3.74 | 5 | -5 | 9 | 11.8% | 7E-07 | Sbet | 3.78 | 1 |
| Size_DbIN_descend_se_12_BB_area2_Sdak(12) | 7.66 | 4 | -5 | 9 | 2.0% | 1E-05 | no | 0 | 0 |
| Size_DbIN_ascend_se_13_BB_DAKAR_62_80(13) | 4.46 | 5 | -5 | 9 | 3.6% | -3E-06 | Sbet | 4.39 | 1 |
| Size_DbIN_descend_se_13_BB_DAKAR_62_80(13) | 7.33 | 4 | -5 | 9 | 1.4% | 4E-06 | no | - | - |
| Size_DbIN_ascend_se_14_BB_DAKAR_81_18(14) | 4.61 | 5 | -5 | 9 | 2.3% | -7E-06 | Sbet | 4.81 | 1 |
| Size_DbIN_descend_se_14_BB_DAKAR_81_18(14) | 8.81 | 5 | -5 | 9 | 1.6% | 4E-06 | Sbet | 6.76 | 0.2 |
| Size_DbIN_peak_16_Japan_LL_N(16) | 118.9 | 3 | 70 | 130 | 1.7% | 8E-06 | Sbet | 119 | 0.5 |
| Size_DbIN_ascend_se_16_Japan_LL_N(16) | 6.35 | 5 | -5 | 9 | 2.1% | -1E-05 | Sbet | 6.49 | 0.5 |
| Size_DbIN_descend_se_16_Japan_LL_N(16) | 5.14 | 4 | -5 | 10 | 8.5% | 9E-06 | no | - | - |
| Size_DbIN_end_logit_16_Japan_LL_N(16) | -1.43 | 4 | -9 | 15 | -18.5% | 1E-05 | no | - | - |
| Size_inflection_17_Japan_LL_TRO(17) | 118.1 | 3 | 70 | 180 | 2.5% | 2E-05 | no | - | - |
| Size_95%width_17_Japan_LL_TRO(17) | 29.33 | 3 | 10 | 60 | 12.0% | -3E-06 | no | - | - |
| Size_DbIN_peak_19_Other_LL_N(19) | 125.4 | 3 | 70 | 150 | 0.8% | 3E-05 | Sbet | 125 | 1 |
| Size_DbIN_ascend_se_19_Other_LL_N(19) | 6.89 | 5 | -5 | 9 | 0.7% | -4E-05 | Sbet | 6.49 | 1 |
| Size_DbIN_descend_se_19_Other_LL_N(19) | 5.06 | 4 | -5 | 10 | 3.9% | 3E-05 | no | - | - |
| Size_DbIN_end_logit_19_Other_LL_N(19) | -2.27 | 4 | -9 | 15 | -11.2% | 2E-05 | no | - | - |
| Size_inflection_20_Other_LL_TRO(20) | 85.93 | 3 | 40 | 180 | 2.4% | 1E-05 | Sbet | 85.9 | 0.2 |
| Size_95%width_20_Other_LL_TRO(20) | 14.01 | 3 | 10 | 60 | 18.6% | 2E-07 | Sbet | 13.5 | 0.2 |
| Size_DbIN_peak_22_HL_Braz_N(22) | 54.47 | 5 | 40 | 100 | 3.4% | -2E-06 | Norm | 60 | 10 |
| Size_DbIN_descend_se_22_HL_Braz_N(22) | 5.88 | 5 | -5 | 9 | 7.9% | 6E-07 | Norm | 4.5 | 2 |
| Size_DbIN_ascend_se_23_US_RR(23) | 4.95 | 5 | -5 | 9 | 2.7% | -6E-06 | Sbet | 5.64 | 1 |
| Size_DbIN_descend_se_23_US_RR(23) | 7.02 | 4 | -5 | 9 | 1.8% | 7E-06 | no | - | - |
| Size_DbIN_ascend_se_24_PS_WEST(24) | 4.96 | 4 | -5 | 9 | 4.4% | 3E-06 | Sbet | 5.34 | 2 |
| Size_DbIN_descend_se_24_PS_WEST(24) | 5.13 | 4 | -5 | 10 | 15.1% | 5E-07 | Sbet | 5.18 | 2 |
| Size_DbIN_end_logit_24_PS_WEST(24) | -0.98 | 6 | -9 | 15 | -61.1% | 2E-06 | Sbet | -0.5 | 2 |
| Size_DbIN_peak_25_OTH_OTH(25) | 78.33 | 3 | 50 | 130 | 8.3% | -6E-06 | Sbet | 71.2 | 0.2 |
| Size_DbIN_descend_se_25_OTH_OTH(25) | 8.93 | 4 | -5 | 10 | 12.8% | -8E-06 | Sbet | 8.06 | 0.2 |
| SizeSpline_Val_1_7_ESFR_FADS_PS_9118_S1(7)_BLK1repl_2003 | -6.70 | 6 | -10 | 7 | -7.1% | 2E-06 | no | - | - |
| SizeSpline_Val_4_7_ESFR_FADS_PS_9118_S1(7)_BLK1repl_2003 | -2.44 | 6 | -5 | 2 | -9.3% | 6E-07 | no | - | - |
| SizeSpline_Val_5_7_ESFR_FADS_PS_9118_S1(7)_BLK1repl_2003 | -3.12 | 6 | -5 | 2 | -10.3% | -1E-06 | no | - | - |
| SizeSpline_Val_1_11_BB_PS_Ghana_6518(11)_BLK3repl_1981 | -8.51 | 6 | -10 | 7 | -8.3% | 5E-07 | Sbet | -7.8 | 0.2 |

| Name | Value | Phase | Min | Max | CV | Grad | Pr type | Prior | Pr SD |
|--|-------|-------|-----|-----|--------|--------|---------|-------|-------|
| SizeSpline_Val_1_11_BB_PS_Ghana_6518(11)_BLK3repl_1988 | -8.36 | 6 | -10 | 7 | -6.9% | -4E-07 | Sbet | -7.8 | 0.2 |
| SizeSpline_Val_1_11_BB_PS_Ghana_6518(11)_BLK3repl_1996 | -7.87 | 6 | -10 | 7 | -12.9% | -5E-08 | Sbet | -7.8 | 0.2 |
| SizeSpline_Val_4_11_BB_PS_Ghana_6518(11)_BLK3repl_1981 | -2.07 | 6 | -5 | 2 | -21.1% | -1E-06 | Sbet | -0.3 | 0.1 |
| SizeSpline_Val_4_11_BB_PS_Ghana_6518(11)_BLK3repl_1996 | 0.28 | 6 | -5 | 2 | 80.5% | 5E-07 | Sbet | -0.3 | 0.1 |
| SizeSpline_Val_5_11_BB_PS_Ghana_6518(11)_BLK3repl_1981 | -0.77 | 6 | -2 | 2 | -43.7% | 4E-07 | Sbet | -1.4 | 0.2 |
| SizeSpline_Val_5_11_BB_PS_Ghana_6518(11)_BLK3repl_1988 | -2.83 | 6 | -3 | 2 | -11.7% | 7E-07 | Sbet | -1.4 | 0.2 |
| SizeSpline_Val_5_11_BB_PS_Ghana_6518(11)_BLK3repl_1996 | -0.78 | 6 | -2 | 2 | -35.7% | -3E-06 | Sbet | -1.4 | 0.2 |
| Size_inflection_17_Japan_LL_TRO(17)_BLK7add_1979 | 2.67 | 6 | -10 | 30 | 147.6% | -1E-06 | no | - | - |
| Size_inflection_17_Japan_LL_TRO(17)_BLK7add_1992 | 13.04 | 6 | -10 | 30 | 29.4% | 4E-06 | no | - | - |
| Size_inflection_17_Japan_LL_TRO(17)_BLK7add_2005 | 20.86 | 6 | -10 | 30 | 20.9% | 2E-06 | no | - | - |
| Size_95%width_17_Japan_LL_TRO(17)_BLK7add_1979 | -3.43 | 6 | -15 | 25 | 0.0% | 4E-06 | no | - | - |
| Size_95%width_17_Japan_LL_TRO(17)_BLK7add_1992 | -2.96 | 6 | -15 | 25 | 0.0% | -3E-06 | no | - | - |
| Size_95%width_17_Japan_LL_TRO(17)_BLK7add_2005 | 8.27 | 6 | -15 | 25 | 0.0% | -2E-07 | no | - | - |
| Size_DbIN_peak_19_Other_LL_N(19)_BLK1repl_2003 | 130.4 | 6 | 30 | 180 | 0.0% | 3E-05 | no | - | - |
| Size_inflection_20_Other_LL_TRO(20)_BLK7add_1979 | 15.51 | 6 | -10 | 30 | 0.0% | 2E-06 | no | - | - |
| Size_inflection_20_Other_LL_TRO(20)_BLK7add_1992 | 4.93 | 6 | -10 | 30 | 0.0% | -3E-06 | no | - | - |
| Size_inflection_20_Other_LL_TRO(20)_BLK7add_2005 | 24.47 | 6 | -10 | 30 | 0.0% | -2E-07 | no | - | - |
| Size_95%width_20_Other_LL_TRO(20)_BLK7add_1979 | 14.27 | 6 | -15 | 25 | 0.0% | -2E-06 | no | - | - |
| Size_95%width_20_Other_LL_TRO(20)_BLK7add_1992 | 9.10 | 6 | -15 | 25 | 0.0% | 2E-07 | no | - | - |
| Size_95%width_20_Other_LL_TRO(20)_BLK7add_2005 | 20.57 | 6 | -15 | 25 | 0.0% | 3E-06 | no | - | - |

Table 13. Estimates of SSB relative to SSB_{MSY}, and fishing mortality relative to F_{MSY} between 1951 and 2018 from SS Grid runs 1-4. Confidence intervals are 95% and based on the hessian standard errors.

| Year | SSB/SSB _{msy} | | | | | | | | | | | | F/F _{msy} | | | | | | | | | | | | |
|------|------------------------|------|------|-------|------|------|-------|------|------|-------|------|------|--------------------|------|------|-------|------|--------|-------|------|------|-------|------|------|------|
| | Run 1 | | | Run 2 | | | Run 3 | | | Run 4 | | | Run 1 | | | Run 2 | | | Run 3 | | | Run 4 | | | |
| | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci | |
| 1951 | 3.39 | 3.34 | 3.45 | 3.82 | 3.72 | 3.91 | 3.38 | 3.33 | 3.42 | 3.79 | 3.71 | 3.86 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1952 | 3.39 | 3.34 | 3.44 | 3.81 | 3.72 | 3.90 | 3.37 | 3.33 | 3.42 | 3.78 | 3.71 | 3.85 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1953 | 3.38 | 3.33 | 3.43 | 3.80 | 3.71 | 3.89 | 3.37 | 3.32 | 3.41 | 3.77 | 3.70 | 3.85 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1954 | 3.37 | 3.32 | 3.43 | 3.79 | 3.70 | 3.88 | 3.36 | 3.31 | 3.40 | 3.76 | 3.69 | 3.84 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1955 | 3.36 | 3.31 | 3.41 | 3.78 | 3.69 | 3.87 | 3.35 | 3.30 | 3.39 | 3.75 | 3.68 | 3.82 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1956 | 3.35 | 3.30 | 3.40 | 3.76 | 3.67 | 3.86 | 3.34 | 3.29 | 3.38 | 3.74 | 3.66 | 3.81 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| 1957 | 3.33 | 3.28 | 3.39 | 3.75 | 3.65 | 3.84 | 3.32 | 3.28 | 3.37 | 3.72 | 3.65 | 3.80 | 0.08 | 0.07 | 0.09 | 0.07 | 0.06 | 0.08 | 0.07 | 0.06 | 0.08 | 0.06 | 0.06 | 0.07 | 0.07 |
| 1958 | 3.29 | 3.23 | 3.34 | 3.69 | 3.60 | 3.79 | 3.28 | 3.23 | 3.33 | 3.67 | 3.59 | 3.75 | 0.14 | 0.12 | 0.16 | 0.12 | 0.10 | 0.14 | 0.12 | 0.11 | 0.14 | 0.11 | 0.10 | 0.12 | 0.12 |
| 1959 | 3.21 | 3.15 | 3.27 | 3.60 | 3.50 | 3.70 | 3.20 | 3.15 | 3.26 | 3.58 | 3.50 | 3.67 | 0.20 | 0.17 | 0.23 | 0.18 | 0.15 | 0.20 | 0.18 | 0.16 | 0.20 | 0.16 | 0.14 | 0.18 | 0.18 |
| 1960 | 3.10 | 3.04 | 3.17 | 3.48 | 3.37 | 3.58 | 3.11 | 3.04 | 3.17 | 3.47 | 3.37 | 3.56 | 0.25 | 0.21 | 0.28 | 0.21 | 0.18 | 0.24 | 0.22 | 0.19 | 0.25 | 0.19 | 0.17 | 0.22 | 0.22 |
| 1961 | 3.01 | 2.93 | 3.08 | 3.36 | 3.25 | 3.48 | 3.02 | 2.95 | 3.09 | 3.36 | 3.26 | 3.46 | 0.22 | 0.19 | 0.25 | 0.19 | 0.16 | 0.22 | 0.19 | 0.17 | 0.22 | 0.17 | 0.15 | 0.19 | 0.19 |
| 1962 | 2.94 | 2.86 | 3.03 | 3.29 | 3.17 | 3.41 | 2.96 | 2.88 | 3.04 | 3.29 | 3.18 | 3.40 | 0.22 | 0.19 | 0.25 | 0.19 | 0.16 | 0.22 | 0.19 | 0.17 | 0.22 | 0.17 | 0.15 | 0.20 | 0.20 |
| 1963 | 2.85 | 2.69 | 3.01 | 3.19 | 2.99 | 3.38 | 2.88 | 2.73 | 3.03 | 3.21 | 3.03 | 3.39 | 0.25 | 0.21 | 0.30 | 0.22 | 0.18 | 0.26 | 0.23 | 0.19 | 0.26 | 0.20 | 0.16 | 0.23 | 0.23 |
| 1964 | 2.73 | 2.43 | 3.04 | 3.05 | 2.70 | 3.40 | 2.78 | 2.49 | 3.07 | 3.09 | 2.76 | 3.42 | 0.28 | 0.23 | 0.34 | 0.25 | 0.19 | 0.30 | 0.25 | 0.20 | 0.30 | 0.22 | 0.18 | 0.26 | 0.26 |
| 1965 | 2.60 | 2.20 | 2.99 | 2.90 | 2.45 | 3.35 | 2.66 | 2.28 | 3.04 | 2.96 | 2.53 | 3.39 | 0.29 | 0.22 | 0.36 | 0.26 | 0.19 | 0.32 | 0.26 | 0.20 | 0.31 | 0.23 | 0.18 | 0.28 | 0.28 |
| 1966 | 2.45 | 2.00 | 2.89 | 2.73 | 2.23 | 3.24 | 2.53 | 2.10 | 2.95 | 2.81 | 2.33 | 3.29 | 0.26 | 0.20 | 0.33 | 0.23 | 0.17 | 0.29 | 0.23 | 0.18 | 0.28 | 0.20 | 0.15 | 0.25 | 0.25 |
| 1967 | 2.39 | 1.92 | 2.86 | 2.67 | 2.14 | 3.19 | 2.47 | 2.02 | 2.92 | 2.75 | 2.24 | 3.25 | 0.28 | 0.20 | 0.35 | 0.24 | 0.18 | 0.31 | 0.24 | 0.18 | 0.30 | 0.21 | 0.16 | 0.26 | 0.26 |
| 1968 | 2.33 | 1.85 | 2.82 | 2.61 | 2.06 | 3.15 | 2.42 | 1.95 | 2.89 | 2.69 | 2.16 | 3.21 | 0.40 | 0.29 | 0.50 | 0.34 | 0.25 | 0.44 | 0.34 | 0.26 | 0.43 | 0.30 | 0.22 | 0.38 | 0.38 |
| 1969 | 2.22 | 1.73 | 2.70 | 2.48 | 1.93 | 3.02 | 2.31 | 1.84 | 2.78 | 2.57 | 2.04 | 3.09 | 0.45 | 0.33 | 0.58 | 0.40 | 0.28 | 0.51 | 0.39 | 0.29 | 0.49 | 0.35 | 0.26 | 0.44 | 0.44 |
| 1970 | 2.17 | 1.68 | 2.67 | 2.42 | 1.87 | 2.98 | 2.26 | 1.79 | 2.74 | 2.51 | 1.98 | 3.05 | 0.36 | 0.26 | 0.46 | 0.31 | 0.22 | 0.40 | 0.31 | 0.23 | 0.39 | 0.27 | 0.20 | 0.35 | 0.35 |
| 1971 | 2.15 | 1.65 | 2.65 | 2.41 | 1.84 | 2.97 | 2.24 | 1.76 | 2.73 | 2.50 | 1.96 | 3.04 | 0.32 | 0.24 | 0.41 | 0.28 | 0.20 | 0.35 | 0.28 | 0.21 | 0.35 | 0.25 | 0.18 | 0.31 | 0.31 |
| 1972 | 2.40 | 1.89 | 2.90 | 2.69 | 2.12 | 3.26 | 2.46 | 1.98 | 2.95 | 2.75 | 2.21 | 3.30 | 0.35 | 0.26 | 0.44 | 0.30 | 0.22 | 0.38 | 0.31 | 0.23 | 0.38 | 0.27 | 0.20 | 0.34 | 0.34 |
| 1973 | 2.99 | 2.40 | 3.58 | 3.37 | 2.70 | 4.05 | 3.01 | 2.44 | 3.57 | 3.38 | 2.74 | 4.02 | 0.31 | 0.23 | 0.39 | 0.27 | 0.20 | 0.34 | 0.28 | 0.21 | 0.35 | 0.24 | 0.18 | 0.30 | 0.30 |
| 1974 | 3.43 | 2.78 | 4.09 | 3.89 | 3.15 | 4.64 | 3.42 | 2.79 | 4.04 | 3.86 | 3.14 | 4.57 | 0.34 | 0.25 | 0.42 | 0.29 | 0.21 | 0.36 | 0.30 | 0.23 | 0.38 | 0.26 | 0.20 | 0.33 | 0.33 |
| 1975 | 3.50 | 2.86 | 4.15 | 3.98 | 3.24 | 4.72 | 3.48 | 2.85 | 4.10 | 3.93 | 3.23 | 4.64 | 0.40 | 0.30 | 0.50 | 0.34 | 0.26 | 0.43 | 0.36 | 0.27 | 0.45 | 0.31 | 0.24 | 0.39 | 0.39 |
| 1976 | 3.33 | 2.73 | 3.94 | 3.79 | 3.10 | 4.49 | 3.31 | 2.72 | 3.90 | 3.75 | 3.08 | 4.41 | 0.43 | 0.32 | 0.53 | 0.37 | 0.28 | 0.46 | 0.39 | 0.29 | 0.48 | 0.33 | 0.25 | 0.41 | 0.41 |
| 1977 | 3.06 | 2.51 | 3.61 | 3.49 | 2.85 | 4.12 | 3.05 | 2.51 | 3.58 | 3.45 | 2.84 | 4.06 | 0.49 | 0.37 | 0.61 | 0.42 | 0.32 | 0.52 | 0.44 | 0.34 | 0.55 | 0.38 | 0.29 | 0.48 | 0.48 |
| 1978 | 2.74 | 2.26 | 3.23 | 3.13 | 2.57 | 3.69 | 2.74 | 2.26 | 3.22 | 3.10 | 2.57 | 3.64 | 0.56 | 0.43 | 0.70 | 0.48 | 0.36 | 0.60 | 0.51 | 0.39 | 0.62 | 0.44 | 0.33 | 0.54 | 0.54 |
| 1979 | 2.43 | 2.00 | 2.86 | 2.77 | 2.27 | 3.26 | 2.44 | 2.01 | 2.87 | 2.76 | 2.28 | 3.24 | 0.61 | 0.46 | 0.76 | 0.52 | 0.39 | 0.65 | 0.55 | 0.42 | 0.68 | 0.47 | 0.36 | 0.59 | 0.59 |
| 1980 | 2.09 | 1.71 | 2.47 | 2.38 | 1.95 | 2.82 | 2.12 | 1.74 | 2.50 | 2.39 | 1.97 | 2.82 | 0.71 | 0.54 | 0.88 | 0.60 | 0.46 | 0.75 | 0.63 | 0.48 | 0.78 | 0.54 | 0.41 | 0.67 | 0.67 |
| 1981 | 1.80 | 1.46 | 2.13 | 2.04 | 1.66 | 2.43 | 1.83 | 1.49 | 2.17 | 2.07 | 1.69 | 2.45 | 0.93 | 0.71 | 1.16 | 0.79 | 0.60 | 0.99 | 0.82 | 0.62 | 1.02 | 0.71 | 0.54 | 0.88 | 0.88 |
| 1982 | 1.59 | 1.27 | 1.90 | 1.80 | 1.45 | 2.16 | 1.63 | 1.31 | 1.95 | 1.83 | 1.48 | 2.19 | 1.08 | 0.81 | 1.34 | 0.92 | 0.69 | 1.15 | 0.95 | 0.71 | 1.18 | 0.82 | 0.61 | 1.02 | 1.02 |
| 1983 | 1.42 | 1.12 | 1.73 | 1.62 | 1.27 | 1.96 | 1.47 | 1.16 | 1.78 | 1.66 | 1.31 | 2.01 | 1.14 | 0.85 | 1.43 | 0.97 | 0.72 | 1.23 | 1.00 | 0.74 | 1.26 | 0.87 | 0.64 | 1.09 | 1.09 |
| 1984 | 1.33 | 1.03 | 1.63 | 1.51 | 1.17 | 1.85 | 1.38 | 1.07 | 1.69 | 1.55 | 1.21 | 1.90 | 0.79 | 0.58 | 0.99 | 0.67 | 0.49 | 0.85 | 0.69 | 0.51 | 0.87 | 0.60 | 0.44 | 0.76 | 0.76 |
| 1985 | 1.40 | 1.10 | 1.71 | 1.60 | 1.25 | 1.95 | 1.45 | 1.13 | 1.77 | 1.64 | 1.28 | 1.99 | 0.95 | 0.72 | 1.19 | 0.81 | 0.61 | 1.01 | 0.84 | 0.63 | 1.05 | 0.73 | 0.54 | 0.91 | 0.91 |
| 1986 | 1.59 | 1.26 | 1.92 | 1.81 | 1.44 | 2.19 | 1.62 | 1.28 | 1.97 | 1.84 | 1.46 | 2.22 | 0.84 | 0.63 | 1.05 | 0.71 | 0.53 | 0.89 | 0.75 | 0.56 | 0.93 | 0.64 | 0.48 | 0.80 | 0.80 |
| 1987 | 1.78 | 1.41 | 2.14 | 2.03 | 1.61 | 2.45 | 1.81 | 1.43 | 2.18 | 2.05 | 1.63 | 2.47 | 0.81 | 0.61 | 1.01 | 0.69 | 0.51 | 0.86 | 0.72 | 0.54 | 0.90 | 0.62 | 0.46 | 0.77 | 0.77 |
| 1988 | 1.81 | 1.44 | 2.17 | 2.07 | 1.65 | 2.49 | 1.84 | 1.46 | 2.21 | 2.09 | 1.67 | 2.51 | 0.75 | 0.57 | 0.93 | 0.63 | 0.48 | 0.79 | 0.67 | 0.50 | 0.83 | 0.57 | 0.43 | 0.71 | 0.71 |
| 1989 | 1.84 | 1.48 | 2.19 | 2.11 | 1.70 | 2.52 | 1.87 | 1.50 | 2.23 | 2.13 | 1.72 | 2.53 | 0.90 | 0.69 | 1.11 | 0.76 | 0.58 | 0.94 | 0.80 | 0.61 | 0.99 | 0.68 | 0.52 | 0.85 | 0.85 |
| 1990 | 1.79 | 1.45 | 2.13 | 2.06 | 1.67 | 2.45 | 1.82 | 1.47 | 2.17 | 2.07 | 1.68 | 2.46 | 1.12 | 0.86 | 1.39 | 0.95 | 0.72 | 1.18 | 1.00 | 0.76 | 1.24 | 0.85 | 0.65 | 1.06 | 1.06 |
| 1991 | 1.62 | 1.29 | 1.95 | 1.86 | 1.48 | 2.24 | 1.66 | 1.32 | 1.99 | 1.89 | 1.51 | 2.26 | 1.03 | 0.79 | 1.28 | 0.87 | 0.66 | 1.08 | 0.92 | 0.70 | 1.14 | 0.79 | 0.60 | 0.98 | 0.98 |
| 1992 | 1.53 | 1.22 | 1.84 | 1.75 | 1.40 | 2.10 | 1.56 | 1.24 | 1.88 | 1.78 | 1.42 | 2.13 | 1.02 | 0.78 | 1.26 | 0.87 | 0.66 | 1.07 | 0.91 | 0.69 | 1.13 | 0.78 | 0.59 | 0.97 | 0.97 |
| 1993 | 1.54 | 1.24 | 1.84 | 1.76 | 1.42 | 2.11 | 1.56 | 1.25 | 1.87 | 1.78 | 1.44 | 2.12 | 1.02 | 0.79 | 1.26 | 0.87 | 0.66 | 1.07 | 0.91 | 0.70 | 1.13 | 0.78 | 0.60 | 0.97 | 0.97 |
| 1994 | 1.54 | 1.25 | 1.83 | 1.77 | 1.43 | 2.10 | 1.56 | 1.26 | 1.87 | 1.78 | 1.44 | 2.12 | 1.09 | 0.84 | 1.34 | 0.92 | 0.71 | 1.14 | 0.97 | 0.75 | 1.20 | 0.83 | 0.64 | 1.03 | 1.03 |
| 1995 | 1.52 | 1.22 | 1.81 | 1.74 | 1.41 | 2.08 | 1.54 | 1.24 | 1.84 | 1.76 | 1.42 | 2.09 | 1.00 | 0.76 | 1.23 | 0.84 | 0.64 | 1.04 | 0.89 | 0.67 | 1.10 | 0.76 | 0.58 | 0.94 | 0.94 |
| 1996 | 1.51 | 1.21 | 1.80 | 1.73 | 1.40 | 2.07 | 1.53 | 1.23 | 1.84 | 1.75 | 1.41 | 2.09 | 0.99 | 0.75 | 1.23 | 0.84 | 0.63 | 1.04 | 0.88 | 0.66 | 1.10 | 0.75 | 0.57 | 0.94 | 0.94 |
| 1997 | 1.46 | 1.16 | 1.76 | 1.68 | 1.34 | 2.01 | 1.49 | 1.18 | 1.79 | 1.69 | 1.35 | 2.03 | 0.95 | 0.71 | 1.18 | 0.80 | 0.60 | 1.00 | 0.84 | 0.63 | 1.05 | 0.72 | 0.54 | 0.90 | 0.90 |
| 1998 | 1.41 | 1.11 | 1.70 | 1.62 | 1.28 | 1.95 | 1.44 | 1.13 | 1.74 | 1.64 | 1.30 | 1.98 | 1.01 | 0.76 | 1.27 | 0.86 | 0.64 | 1.08 | 0.90 | 0.67 | 1.13 | 0.77 | 0.57 | 0.97 | 0.97 |
| 1999 | 1.35 | 1.05 | 1.64 | 1.55 | 1.20 | 1.89 | 1.38 | 1.07 | 1.69 | 1.57 | 1.23 | 1.92 | 0.92 | 0.69 | 1.16 | 0.78 | 0.58 | 0.98 | 0.82 | 0.61 | 1.03 | 0.70 | 0.52 | 0.88 | 0.88 |
| 2000 | 1.40 | 1.09 | 1.71 | 1.61 | 1.26 | 1.96 | 1.44 | 1.12 | 1.75 | 1.64 | 1.28 | 1.99 | 0.82 | 0.61 | 1.03 | 0.69 | 0.52 | 0.87</ | | | | | | | |

Table 14. Estimates of SSB 1950 – 2018 from the stock synthesis grid runs 1-4. Confidence intervals are 95% and based on the Hessian standard errors.

| Year | Run 1 | | | Run 2 | | | Run 3 | | | Run 4 | | |
|------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci | MLE | lci | uci |
| 1950 | 1,433,860 | 1,244,168 | 1,623,552 | 1,370,660 | 1,178,805 | 1,562,515 | 1,527,430 | 1,313,853 | 1,741,007 | 1,452,100 | 1,241,978 | 1,662,222 |
| 1951 | 1,433,100 | 1,243,401 | 1,622,799 | 1,369,910 | 1,178,048 | 1,561,772 | 1,526,680 | 1,313,095 | 1,740,265 | 1,451,340 | 1,241,212 | 1,661,468 |
| 1952 | 1,431,490 | 1,241,803 | 1,621,177 | 1,368,290 | 1,176,440 | 1,560,140 | 1,525,060 | 1,311,487 | 1,738,633 | 1,449,720 | 1,239,602 | 1,659,838 |
| 1953 | 1,428,550 | 1,238,884 | 1,618,216 | 1,365,360 | 1,173,531 | 1,557,189 | 1,522,100 | 1,308,546 | 1,735,654 | 1,446,770 | 1,236,672 | 1,656,868 |
| 1954 | 1,424,420 | 1,234,795 | 1,614,045 | 1,361,240 | 1,169,452 | 1,553,028 | 1,517,950 | 1,304,433 | 1,731,467 | 1,442,620 | 1,232,559 | 1,652,681 |
| 1955 | 1,419,730 | 1,230,171 | 1,609,289 | 1,356,560 | 1,164,838 | 1,548,282 | 1,513,210 | 1,299,754 | 1,726,666 | 1,437,910 | 1,227,910 | 1,647,910 |
| 1956 | 1,414,770 | 1,225,276 | 1,604,264 | 1,351,630 | 1,159,973 | 1,543,287 | 1,508,220 | 1,294,823 | 1,721,617 | 1,432,950 | 1,223,009 | 1,642,891 |
| 1957 | 1,408,500 | 1,219,062 | 1,597,938 | 1,345,410 | 1,153,808 | 1,537,012 | 1,501,910 | 1,288,562 | 1,715,258 | 1,426,690 | 1,216,798 | 1,636,582 |
| 1958 | 1,388,390 | 1,199,007 | 1,577,773 | 1,325,370 | 1,133,823 | 1,516,917 | 1,481,740 | 1,268,443 | 1,695,037 | 1,406,600 | 1,196,757 | 1,616,443 |
| 1959 | 1,355,210 | 1,165,932 | 1,544,488 | 1,292,300 | 1,100,861 | 1,483,739 | 1,448,480 | 1,235,277 | 1,661,683 | 1,373,450 | 1,163,705 | 1,583,195 |
| 1960 | 1,310,960 | 1,121,851 | 1,500,069 | 1,248,210 | 1,056,945 | 1,439,475 | 1,404,110 | 1,191,060 | 1,617,160 | 1,329,240 | 1,119,651 | 1,538,829 |
| 1961 | 1,270,380 | 1,081,389 | 1,459,371 | 1,207,850 | 1,016,712 | 1,398,988 | 1,363,410 | 1,150,468 | 1,576,352 | 1,288,770 | 1,079,297 | 1,498,243 |
| 1962 | 1,243,510 | 1,054,362 | 1,432,658 | 1,181,390 | 990,145 | 1,372,635 | 1,336,710 | 1,123,633 | 1,549,787 | 1,262,480 | 1,052,911 | 1,472,049 |
| 1963 | 1,205,240 | 1,005,300 | 1,405,180 | 1,144,730 | 944,126 | 1,345,334 | 1,302,020 | 1,079,229 | 1,524,811 | 1,229,200 | 1,011,048 | 1,447,352 |
| 1964 | 1,153,670 | 921,061 | 1,386,279 | 1,095,730 | 865,994 | 1,325,466 | 1,255,230 | 1,001,043 | 1,509,417 | 1,184,840 | 938,417 | 1,431,263 |
| 1965 | 1,096,680 | 837,821 | 1,355,919 | 1,041,430 | 787,949 | 1,294,911 | 1,201,810 | 921,426 | 1,482,194 | 1,133,900 | 863,849 | 1,403,951 |
| 1966 | 1,033,980 | 762,508 | 1,305,452 | 981,260 | 716,911 | 1,245,609 | 1,141,820 | 848,622 | 1,435,018 | 1,076,590 | 795,277 | 1,357,903 |
| 1967 | 1,009,050 | 729,458 | 1,288,642 | 957,558 | 685,973 | 1,229,143 | 1,117,190 | 815,550 | 1,418,830 | 1,053,220 | 764,471 | 1,341,969 |
| 1968 | 985,510 | 699,981 | 1,271,039 | 935,303 | 658,455 | 1,212,151 | 1,093,250 | 785,783 | 1,400,717 | 1,030,630 | 736,793 | 1,324,467 |
| 1969 | 936,854 | 655,341 | 1,218,367 | 888,915 | 616,097 | 1,161,733 | 1,043,550 | 740,242 | 1,346,858 | 983,444 | 693,776 | 1,273,112 |
| 1970 | 917,664 | 632,731 | 1,202,597 | 870,518 | 594,252 | 1,146,784 | 1,022,840 | 716,092 | 1,329,588 | 963,698 | 670,700 | 1,256,696 |
| 1971 | 909,130 | 622,370 | 1,195,890 | 863,759 | 585,598 | 1,141,920 | 1,014,340 | 705,709 | 1,322,971 | 957,127 | 662,259 | 1,251,995 |
| 1972 | 1,011,860 | 710,506 | 1,313,214 | 966,014 | 672,839 | 1,259,189 | 1,113,380 | 788,843 | 1,437,917 | 1,055,670 | 745,135 | 1,366,205 |
| 1973 | 1,261,610 | 901,979 | 1,621,241 | 1,211,210 | 859,876 | 1,562,544 | 1,358,180 | 972,628 | 1,743,732 | 1,295,230 | 925,211 | 1,665,249 |
| 1974 | 1,449,720 | 1,046,479 | 1,852,961 | 1,397,390 | 1,002,446 | 1,792,334 | 1,543,650 | 1,111,509 | 1,975,791 | 1,478,150 | 1,062,740 | 1,893,560 |
| 1975 | 1,480,160 | 1,074,436 | 1,885,884 | 1,430,050 | 1,032,103 | 1,827,997 | 1,571,560 | 1,135,648 | 2,007,472 | 1,508,340 | 1,089,139 | 1,927,541 |
| 1976 | 1,408,370 | 1,022,644 | 1,794,096 | 1,362,130 | 983,423 | 1,740,837 | 1,495,600 | 1,079,617 | 1,911,583 | 1,436,750 | 1,036,765 | 1,836,735 |
| 1977 | 1,293,290 | 939,436 | 1,647,144 | 1,251,510 | 903,857 | 1,599,163 | 1,376,970 | 993,467 | 1,760,473 | 1,323,200 | 954,546 | 1,691,854 |
| 1978 | 1,159,460 | 842,408 | 1,476,512 | 1,122,150 | 810,471 | 1,433,829 | 1,238,930 | 892,943 | 1,584,917 | 1,190,330 | 857,847 | 1,522,813 |
| 1979 | 1,026,490 | 743,354 | 1,309,626 | 993,301 | 714,924 | 1,271,678 | 1,101,760 | 790,459 | 1,413,061 | 1,057,950 | 759,003 | 1,356,897 |
| 1980 | 884,225 | 636,028 | 1,132,422 | 855,263 | 611,394 | 1,099,132 | 956,096 | 680,745 | 1,231,447 | 917,259 | 653,204 | 1,181,314 |
| 1981 | 759,276 | 541,324 | 977,228 | 733,965 | 520,002 | 947,928 | 827,903 | 583,632 | 1,072,174 | 793,424 | 559,549 | 1,027,299 |
| 1982 | 669,706 | 470,374 | 869,038 | 646,785 | 451,201 | 842,369 | 734,806 | 509,414 | 960,198 | 703,253 | 487,710 | 918,796 |
| 1983 | 600,930 | 412,549 | 789,311 | 579,840 | 395,066 | 764,614 | 664,392 | 450,019 | 878,765 | 635,013 | 430,144 | 839,882 |
| 1984 | 562,215 | 378,923 | 745,507 | 542,440 | 362,617 | 722,263 | 623,862 | 414,446 | 833,278 | 596,104 | 395,978 | 796,230 |
| 1985 | 593,061 | 405,237 | 780,885 | 573,845 | 389,378 | 758,312 | 655,341 | 440,903 | 869,779 | 628,164 | 423,015 | 833,313 |
| 1986 | 671,442 | 466,442 | 876,442 | 651,382 | 449,647 | 853,117 | 734,064 | 500,951 | 967,177 | 705,837 | 482,466 | 929,208 |
| 1987 | 750,207 | 524,146 | 976,268 | 729,436 | 506,694 | 952,178 | 816,312 | 560,632 | 1,071,992 | 786,929 | 541,555 | 1,032,303 |
| 1988 | 762,763 | 535,191 | 990,335 | 742,736 | 518,404 | 967,068 | 829,607 | 572,090 | 1,087,124 | 801,017 | 553,794 | 1,048,240 |
| 1989 | 776,761 | 552,862 | 1,000,660 | 757,497 | 536,734 | 978,260 | 843,599 | 590,014 | 1,097,184 | 815,868 | 572,371 | 1,059,365 |
| 1990 | 756,827 | 539,988 | 973,666 | 738,274 | 524,467 | 952,081 | 821,477 | 575,519 | 1,067,435 | 794,688 | 558,518 | 1,030,858 |
| 1991 | 685,668 | 480,293 | 891,043 | 668,273 | 465,852 | 870,694 | 748,259 | 514,845 | 981,673 | 722,921 | 498,844 | 946,998 |
| 1992 | 644,989 | 452,334 | 837,644 | 628,819 | 438,983 | 818,655 | 704,623 | 484,901 | 924,345 | 680,831 | 470,000 | 891,662 |
| 1993 | 648,847 | 459,810 | 837,884 | 633,086 | 446,736 | 819,436 | 705,673 | 490,293 | 921,053 | 682,395 | 475,737 | 889,053 |
| 1994 | 650,386 | 463,151 | 837,621 | 634,947 | 450,308 | 819,586 | 706,127 | 492,959 | 919,295 | 683,194 | 478,686 | 887,702 |
| 1995 | 640,529 | 454,147 | 826,911 | 625,316 | 441,525 | 809,107 | 695,720 | 483,462 | 907,978 | 672,993 | 469,402 | 876,584 |
| 1996 | 637,080 | 449,676 | 824,484 | 621,905 | 437,112 | 806,698 | 692,249 | 478,852 | 905,646 | 669,479 | 464,790 | 874,168 |
| 1997 | 616,345 | 430,200 | 802,490 | 601,384 | 417,837 | 784,931 | 671,557 | 459,430 | 883,684 | 649,004 | 445,515 | 852,493 |
| 1998 | 594,285 | 410,688 | 777,882 | 579,737 | 398,699 | 760,775 | 649,264 | 439,897 | 858,631 | 627,224 | 426,346 | 828,102 |
| 1999 | 568,665 | 386,370 | 750,960 | 554,615 | 374,845 | 734,385 | 624,232 | 416,376 | 832,088 | 602,763 | 403,264 | 802,262 |
| 2000 | 591,719 | 402,955 | 780,483 | 577,583 | 391,341 | 763,825 | 649,503 | 434,711 | 864,295 | 627,743 | 421,441 | 834,045 |
| 2001 | 680,132 | 471,337 | 888,927 | 664,922 | 458,777 | 871,067 | 741,079 | 504,875 | 977,283 | 717,651 | 490,560 | 944,742 |
| 2002 | 735,881 | 510,383 | 961,379 | 720,209 | 497,547 | 942,871 | 799,681 | 545,749 | 1,053,613 | 775,269 | 530,984 | 1,019,554 |
| 2003 | 748,127 | 519,319 | 976,935 | 733,031 | 507,141 | 958,921 | 812,618 | 555,386 | 1,069,850 | 788,613 | 541,096 | 1,036,130 |
| 2004 | 769,542 | 538,609 | 1,000,475 | 754,795 | 526,827 | 982,763 | 833,251 | 574,272 | 1,092,230 | 809,332 | 560,094 | 1,058,570 |
| 2005 | 763,959 | 534,492 | 993,426 | 749,629 | 523,100 | 976,158 | 826,826 | 570,111 | 1,083,541 | 803,069 | 555,972 | 1,050,166 |
| 2006 | 719,032 | 500,619 | 937,445 | 705,636 | 490,001 | 921,271 | 780,020 | 535,741 | 1,024,299 | 757,318 | 522,171 | 992,465 |
| 2007 | 693,117 | 482,864 | 903,370 | 680,181 | 472,582 | 887,780 | 752,231 | 517,147 | 987,315 | 729,957 | 503,673 | 956,241 |
| 2008 | 688,492 | 482,106 | 894,878 | 675,614 | 471,835 | 879,393 | 746,075 | 515,422 | 976,728 | 723,688 | 501,702 | 945,674 |
| 2009 | 651,183 | 453,541 | 848,825 | 638,771 | 443,647 | 833,895 | 706,712 | 485,440 | 927,984 | 684,949 | 472,054 | 897,844 |
| 2010 | 603,356 | 415,579 | 791,133 | 591,594 | 406,218 | 776,970 | 657,759 | 446,845 | 868,673 | 636,866 | 433,988 | 839,744 |
| 2011 | 578,770 | 395,844 | 761,696 | 567,404 | 386,806 | 748,002 | 633,549 | 427,820 | 839,278 | 613,038 | 415,168 | 810,908 |
| 2012 | 580,649 | 396,257 | 765,041 | 569,394 | 387,324 | 751,464 | 651,616 | 442,680 | 860,552 | 630,404 | 429,461 | 831,347 |
| 2013 | 595,234 | 405,565 | 784,903 | 584,038 | 396,743 | 771,333 | 687,554 | 471,303 | 903,805 | 665,017 | 457,069 | 872,965 |
| 2014 | 621,142 | 424,915 | 817,369 | 610,082 | 416,317 | 803,847 | 697,100 | 480,085 | 914,115 | 674,080 | 465,428 | 882,732 |
| 2015 | 639,491 | 437,368 | 841,614 | 628,665 | 429,135 | 828,195 | 670,885 | 459,858 | 881,912 | 648,133 | 445,269 | 850,997 |
| 2016 | 624,059 | 420,286 | 827,832 | 613,782 | 412,739 | 814,825 | 630,732 | 425,512 | 835,952 | 608,194 | 410,936 | 805,452 |
| 2017 | 569,324 | 369,135 | 769,513 | 559,988 | 362,645 | 757,331 | 579,610 | 378,545 | 780,675 | 557,280 | 364,022 | 750,538 |
| 2018 | 506,273 | 308,672 | 703,874 | 498,006 | 303,393 | 692,619 | 528,253 | 330,142 | 726,364 | 506,320 | 315,853 | 696,787 |

Table 15. Stock synthesis grid runs 1 – 4 estimated benchmarks for Atlantic YFT stock.

| Benchmark | Run 1 | | | Run 2 | | |
|--------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| | MLE | lci | uci | MLE | lci | uci |
| SSB_unfished | 1,433,860 | 1,244,168 | 1,623,552 | 1,370,660 | 1,178,805 | 1,562,515 |
| Totbio_unfished | 1,847,760 | 1,603,285 | 2,092,235 | 1,766,280 | 1,519,006 | 2,013,554 |
| SmryBio_unfished | 1,847,500 | 1,603,061 | 2,091,939 | 1,766,040 | 1,518,802 | 2,013,278 |
| Recr_unfished | 83,296 | 71,503 | 95,089 | 79,580 | 67,712 | 91,447 |
| SSB_Btgt | 430,157 | 373,249 | 487,065 | 411,199 | 353,643 | 468,755 |
| SPR_Btgt | 0.344 | 0.344 | 0.344 | 0.319 | 0.319 | 0.319 |
| Fstd_Btgt | 0.161 | 0.148 | 0.175 | 0.175 | 0.161 | 0.189 |
| Dead_Catch_Btgt | 101,768 | 88,245 | 115,291 | 106,738 | 92,164 | 121,312 |
| SSB_SPR | 363,244 | 315,189 | 411,299 | 383,785 | 330,066 | 437,504 |
| Fstd_SPR | 0.186 | 0.171 | 0.201 | 0.187 | 0.172 | 0.202 |
| Dead_Catch_SPR | 101,030 | 87,609 | 114,451 | 107,170 | 92,537 | 121,803 |
| SSB_MSY | 422,487 | 367,459 | 477,515 | 359,054 | 310,133 | 407,975 |
| SPR_MSY | 0.339 | 0.334 | 0.343 | 0.282 | 0.276 | 0.289 |
| Fstd_MSY | 0.164 | 0.151 | 0.177 | 0.198 | 0.183 | 0.213 |
| Dead_Catch_MSY | 101,779 | 88,255 | 115,303 | 107,301 | 92,650 | 121,952 |
| Ret_Catch_MSY | 101,779 | 88,255 | 115,303 | 107,301 | 92,650 | 121,952 |
| B_MSY/SSB_unfished | 0.295 | 0.290 | 0.299 | 0.262 | 0.256 | 0.268 |
| Benchmark | Run 3 | | | Run 4 | | |
| | MLE | lci | uci | MLE | lci | uci |
| SSB_unfished | 1,527,430 | 1,313,853 | 1,741,007 | 1,452,100 | 1,241,978 | 1,662,222 |
| Totbio_unfished | 1,966,670 | 1,691,521 | 2,241,819 | 1,869,710 | 1,599,012 | 2,140,408 |
| SmryBio_unfished | 1,966,420 | 1,691,309 | 2,241,531 | 1,869,480 | 1,598,820 | 2,140,140 |
| Recr_unfished | 86,978 | 73,715 | 100,241 | 82,734 | 69,744 | 95,723 |
| SSB_Btgt | 458,229 | 394,156 | 522,302 | 435,629 | 372,592 | 498,666 |
| SPR_Btgt | 0.344 | 0.344 | 0.344 | 0.319 | 0.319 | 0.319 |
| Fstd_Btgt | 0.169 | 0.158 | 0.180 | 0.184 | 0.172 | 0.195 |
| Dead_Catch_Btgt | 114,826 | 102,512 | 127,140 | 119,899 | 106,601 | 133,197 |
| SSB_SPR | 386,949 | 332,843 | 441,055 | 406,587 | 347,753 | 465,421 |
| Fstd_SPR | 0.195 | 0.183 | 0.207 | 0.196 | 0.184 | 0.208 |
| Dead_Catch_SPR | 113,930 | 101,649 | 126,211 | 120,353 | 106,974 | 133,732 |
| SSB_MSY | 452,022 | 389,789 | 514,255 | 383,482 | 329,596 | 437,368 |
| SPR_MSY | 0.340 | 0.336 | 0.344 | 0.285 | 0.280 | 0.289 |
| Fstd_MSY | 0.171 | 0.160 | 0.182 | 0.206 | 0.193 | 0.219 |
| Dead_Catch_MSY | 114,833 | 102,513 | 127,153 | 120,468 | 107,048 | 133,888 |
| Ret_Catch_MSY | 114,833 | 102,513 | 127,153 | 120,468 | 107,048 | 133,888 |
| B_MSY/SSB_unfished | 0.296 | 0.292 | 0.300 | 0.264 | 0.259 | 0.269 |

Table 16. MSY based benchmarks, stock status and estimated model parameters for the MPB-Reference Case for Atlantic yellowfin tuna.

| Variable | Mean | Median | 90%LCI | 90%UCI |
|-------------------------------------|-------------|---------------|---------------|---------------|
| MSY (x 1,000 t) | 128.06 | 128.09 | 121.79 | 134.16 |
| B _{MSY} (x 1,000 t) | 814.42 | 757.20 | 690.75 | 1065.76 |
| F _{MSY} | 0.16 | 0.17 | 0.11 | 0.19 |
| F ₂₀₁₈ /F _{MSY} | 0.981 | 0.979 | 0.776 | 1.194 |
| B ₂₀₁₈ /B _{MSY} | 1.060 | 1.057 | 0.844 | 1.287 |
| B ₂₀₁₈ /K | 0.390 | 0.389 | 0.321 | 0.464 |
| r (yr-1) | 0.162 | 0.169 | 0.115 | 0.188 |
| K (x 1,000 t) | 2212.708 | 2057.258 | 1876.713 | 2895.589 |

Table 17. The MPB-Reference Case estimates of biomass, fishing mortality, biomass relative to B_{MSY} , and fishing mortality relative to F_{MSY} between 1950 and 2018 for Atlantic yellowfin tuna.

| Year | Biomass | | | Fishing mortality | | | B/ B_{MSY} | | | F/ F_{MSY} | | |
|------|---------|---------|---------|-------------------|--------|--------|--------------|--------|--------|--------------|--------|--------|
| | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI |
| 1950 | 1954396 | 1782878 | 2750810 | 0.001 | 0.000 | 0.001 | 2.581 | 2.581 | 2.581 | 0.004 | 0.003 | 0.004 |
| 1951 | 1970173 | 1798648 | 2765402 | 0.001 | 0.000 | 0.001 | 2.602 | 2.594 | 2.606 | 0.004 | 0.004 | 0.004 |
| 1952 | 1983247 | 1811471 | 2778282 | 0.001 | 0.001 | 0.002 | 2.619 | 2.605 | 2.625 | 0.008 | 0.008 | 0.009 |
| 1953 | 1992766 | 1820578 | 2788354 | 0.002 | 0.001 | 0.002 | 2.632 | 2.614 | 2.639 | 0.011 | 0.010 | 0.011 |
| 1954 | 1999915 | 1827237 | 2796531 | 0.002 | 0.001 | 0.002 | 2.641 | 2.622 | 2.649 | 0.010 | 0.010 | 0.011 |
| 1955 | 2006083 | 1832889 | 2804019 | 0.002 | 0.002 | 0.002 | 2.649 | 2.628 | 2.657 | 0.013 | 0.012 | 0.013 |
| 1956 | 2010341 | 1836626 | 2809804 | 0.003 | 0.002 | 0.004 | 2.655 | 2.634 | 2.662 | 0.019 | 0.018 | 0.021 |
| 1957 | 2011598 | 1837388 | 2812664 | 0.012 | 0.008 | 0.013 | 2.657 | 2.637 | 2.663 | 0.070 | 0.066 | 0.074 |
| 1958 | 1995546 | 1820910 | 2798113 | 0.020 | 0.015 | 0.022 | 2.635 | 2.624 | 2.639 | 0.120 | 0.115 | 0.127 |
| 1959 | 1965258 | 1790529 | 2768256 | 0.029 | 0.021 | 0.032 | 2.596 | 2.591 | 2.601 | 0.174 | 0.166 | 0.183 |
| 1960 | 1922716 | 1748380 | 2724420 | 0.036 | 0.025 | 0.039 | 2.540 | 2.527 | 2.561 | 0.210 | 0.201 | 0.220 |
| 1961 | 1876246 | 1702868 | 2674506 | 0.031 | 0.022 | 0.035 | 2.478 | 2.459 | 2.518 | 0.185 | 0.177 | 0.193 |
| 1962 | 1846707 | 1674781 | 2639476 | 0.031 | 0.022 | 0.034 | 2.440 | 2.418 | 2.487 | 0.184 | 0.176 | 0.192 |
| 1963 | 1822950 | 1652636 | 2609309 | 0.035 | 0.025 | 0.039 | 2.409 | 2.386 | 2.460 | 0.209 | 0.200 | 0.218 |
| 1964 | 1795681 | 1627031 | 2575112 | 0.038 | 0.027 | 0.042 | 2.374 | 2.349 | 2.430 | 0.226 | 0.216 | 0.235 |
| 1965 | 1768106 | 1601205 | 2539987 | 0.038 | 0.027 | 0.042 | 2.338 | 2.312 | 2.399 | 0.226 | 0.216 | 0.234 |
| 1966 | 1745736 | 1580655 | 2509512 | 0.034 | 0.023 | 0.037 | 2.309 | 2.283 | 2.371 | 0.198 | 0.190 | 0.206 |
| 1967 | 1735542 | 1572273 | 2490965 | 0.035 | 0.024 | 0.038 | 2.297 | 2.272 | 2.355 | 0.205 | 0.195 | 0.213 |
| 1968 | 1725296 | 1563687 | 2472700 | 0.049 | 0.034 | 0.054 | 2.284 | 2.262 | 2.338 | 0.288 | 0.275 | 0.300 |
| 1969 | 1692387 | 1532309 | 2432066 | 0.056 | 0.039 | 0.062 | 2.241 | 2.215 | 2.302 | 0.329 | 0.314 | 0.342 |
| 1970 | 1653771 | 1495363 | 2384955 | 0.045 | 0.031 | 0.050 | 2.191 | 2.161 | 2.260 | 0.266 | 0.254 | 0.276 |
| 1971 | 1640365 | 1483670 | 2362016 | 0.046 | 0.032 | 0.050 | 2.173 | 2.146 | 2.239 | 0.268 | 0.256 | 0.279 |
| 1972 | 1628632 | 1473619 | 2341107 | 0.059 | 0.041 | 0.065 | 2.158 | 2.133 | 2.221 | 0.345 | 0.329 | 0.359 |
| 1973 | 1597714 | 1444272 | 2301336 | 0.060 | 0.042 | 0.066 | 2.118 | 2.090 | 2.185 | 0.354 | 0.337 | 0.367 |
| 1974 | 1570445 | 1418525 | 2264790 | 0.068 | 0.047 | 0.076 | 2.082 | 2.053 | 2.153 | 0.402 | 0.383 | 0.418 |
| 1975 | 1535362 | 1384964 | 2221370 | 0.081 | 0.056 | 0.090 | 2.036 | 2.004 | 2.113 | 0.478 | 0.454 | 0.496 |
| 1976 | 1487214 | 1338529 | 2164513 | 0.084 | 0.058 | 0.093 | 1.973 | 1.935 | 2.061 | 0.495 | 0.470 | 0.512 |
| 1977 | 1444320 | 1297518 | 2112116 | 0.091 | 0.062 | 0.101 | 1.917 | 1.875 | 2.012 | 0.535 | 0.508 | 0.553 |
| 1978 | 1399645 | 1255032 | 2057671 | 0.096 | 0.065 | 0.107 | 1.859 | 1.813 | 1.962 | 0.563 | 0.533 | 0.582 |
| 1979 | 1356756 | 1214705 | 2004898 | 0.094 | 0.064 | 0.105 | 1.804 | 1.755 | 1.914 | 0.552 | 0.522 | 0.571 |
| 1980 | 1325627 | 1185176 | 1962632 | 0.099 | 0.067 | 0.110 | 1.762 | 1.713 | 1.875 | 0.579 | 0.547 | 0.600 |
| 1981 | 1293539 | 1155472 | 1920296 | 0.121 | 0.081 | 0.135 | 1.721 | 1.671 | 1.836 | 0.708 | 0.667 | 0.733 |
| 1982 | 1238810 | 1103413 | 1855727 | 0.133 | 0.089 | 0.150 | 1.650 | 1.595 | 1.777 | 0.782 | 0.736 | 0.810 |
| 1983 | 1179763 | 1046858 | 1786305 | 0.140 | 0.093 | 0.158 | 1.574 | 1.512 | 1.713 | 0.820 | 0.769 | 0.853 |
| 1984 | 1125458 | 994829 | 1721197 | 0.102 | 0.067 | 0.115 | 1.504 | 1.436 | 1.654 | 0.594 | 0.554 | 0.620 |
| 1985 | 1127973 | 997502 | 1712203 | 0.139 | 0.092 | 0.157 | 1.506 | 1.444 | 1.641 | 0.813 | 0.759 | 0.849 |
| 1986 | 1088515 | 957657 | 1662174 | 0.135 | 0.088 | 0.153 | 1.452 | 1.386 | 1.592 | 0.790 | 0.734 | 0.827 |
| 1987 | 1060481 | 930383 | 1625081 | 0.137 | 0.090 | 0.157 | 1.414 | 1.346 | 1.555 | 0.805 | 0.746 | 0.845 |
| 1988 | 1035072 | 905820 | 1591174 | 0.131 | 0.086 | 0.150 | 1.380 | 1.310 | 1.521 | 0.771 | 0.712 | 0.811 |
| 1989 | 1023121 | 892177 | 1568679 | 0.159 | 0.104 | 0.182 | 1.360 | 1.291 | 1.499 | 0.934 | 0.861 | 0.983 |
| 1990 | 982900 | 852813 | 1520933 | 0.197 | 0.127 | 0.227 | 1.308 | 1.234 | 1.454 | 1.158 | 1.062 | 1.225 |
| 1991 | 913633 | 784038 | 1442336 | 0.183 | 0.116 | 0.214 | 1.218 | 1.134 | 1.381 | 1.075 | 0.975 | 1.150 |
| 1992 | 874662 | 744859 | 1397446 | 0.187 | 0.117 | 0.220 | 1.165 | 1.075 | 1.336 | 1.099 | 0.990 | 1.184 |
| 1993 | 841042 | 710377 | 1356128 | 0.194 | 0.121 | 0.230 | 1.118 | 1.023 | 1.296 | 1.144 | 1.023 | 1.240 |
| 1994 | 807006 | 676654 | 1316508 | 0.215 | 0.132 | 0.257 | 1.073 | 0.972 | 1.258 | 1.269 | 1.122 | 1.386 |
| 1995 | 764337 | 632920 | 1267441 | 0.202 | 0.122 | 0.244 | 1.015 | 0.905 | 1.211 | 1.194 | 1.042 | 1.319 |
| 1996 | 741322 | 607963 | 1234478 | 0.201 | 0.121 | 0.245 | 0.981 | 0.866 | 1.184 | 1.191 | 1.030 | 1.328 |
| 1997 | 722623 | 588037 | 1207383 | 0.190 | 0.114 | 0.234 | 0.954 | 0.834 | 1.163 | 1.127 | 0.967 | 1.268 |
| 1998 | 717898 | 579399 | 1192339 | 0.201 | 0.121 | 0.249 | 0.943 | 0.817 | 1.154 | 1.201 | 1.027 | 1.360 |
| 1999 | 705715 | 561881 | 1170273 | 0.193 | 0.116 | 0.242 | 0.922 | 0.789 | 1.137 | 1.157 | 0.981 | 1.323 |
| 2000 | 701040 | 550804 | 1156990 | 0.189 | 0.114 | 0.240 | 0.912 | 0.773 | 1.129 | 1.137 | 0.960 | 1.314 |
| 2001 | 696741 | 541807 | 1149188 | 0.220 | 0.134 | 0.283 | 0.907 | 0.761 | 1.125 | 1.325 | 1.114 | 1.547 |
| 2002 | 675290 | 512077 | 1118405 | 0.200 | 0.121 | 0.263 | 0.875 | 0.719 | 1.098 | 1.208 | 1.003 | 1.433 |
| 2003 | 671290 | 500865 | 1105525 | 0.183 | 0.111 | 0.245 | 0.864 | 0.702 | 1.089 | 1.110 | 0.915 | 1.335 |
| 2004 | 675615 | 501411 | 1106003 | 0.177 | 0.108 | 0.238 | 0.868 | 0.701 | 1.089 | 1.075 | 0.884 | 1.307 |
| 2005 | 686515 | 504423 | 1109501 | 0.153 | 0.095 | 0.208 | 0.879 | 0.703 | 1.091 | 0.938 | 0.765 | 1.141 |
| 2006 | 711581 | 523033 | 1126842 | 0.149 | 0.094 | 0.202 | 0.906 | 0.728 | 1.114 | 0.918 | 0.747 | 1.115 |
| 2007 | 734550 | 542354 | 1144888 | 0.137 | 0.088 | 0.185 | 0.934 | 0.751 | 1.148 | 0.845 | 0.683 | 1.027 |
| 2008 | 761720 | 568172 | 1167575 | 0.147 | 0.096 | 0.197 | 0.968 | 0.785 | 1.178 | 0.907 | 0.737 | 1.099 |
| 2009 | 778988 | 583397 | 1178649 | 0.151 | 0.100 | 0.202 | 0.986 | 0.806 | 1.198 | 0.937 | 0.760 | 1.134 |
| 2010 | 791869 | 593075 | 1183579 | 0.149 | 0.100 | 0.199 | 0.999 | 0.816 | 1.211 | 0.927 | 0.751 | 1.123 |
| 2011 | 803064 | 602653 | 1188322 | 0.141 | 0.096 | 0.188 | 1.012 | 0.827 | 1.225 | 0.880 | 0.712 | 1.068 |
| 2012 | 817450 | 614444 | 1199918 | 0.141 | 0.096 | 0.187 | 1.031 | 0.842 | 1.244 | 0.874 | 0.706 | 1.060 |
| 2013 | 830928 | 625287 | 1213851 | 0.128 | 0.088 | 0.170 | 1.047 | 0.853 | 1.263 | 0.798 | 0.641 | 0.963 |
| 2014 | 852928 | 645437 | 1233107 | 0.132 | 0.092 | 0.175 | 1.075 | 0.877 | 1.297 | 0.830 | 0.663 | 0.992 |
| 2015 | 867225 | 660881 | 1239565 | 0.147 | 0.103 | 0.193 | 1.092 | 0.894 | 1.319 | 0.922 | 0.737 | 1.102 |
| 2016 | 866504 | 659255 | 1231154 | 0.171 | 0.120 | 0.225 | 1.092 | 0.889 | 1.321 | 1.071 | 0.854 | 1.286 |
| 2017 | 845982 | 638368 | 1205832 | 0.159 | 0.112 | 0.211 | 1.066 | 0.859 | 1.295 | 0.999 | 0.794 | 1.208 |
| 2018 | 838353 | 629487 | 1194778 | 0.156 | 0.110 | 0.208 | 1.057 | 0.844 | 1.287 | 0.979 | 0.776 | 1.194 |

Table 18. Summary, including MSY based benchmarks, of posterior quantiles denoting the median and the 95% credibility intervals of parameter estimates for the JABBA Reference Cases for Atlantic yellowfin stock.

| Model | Base Case | | | S2 | | | |
|--------------------|-----------|---------|---------|---------|---------|---------|---------|
| | Estimates | Median | 2.50% | 97.50% | Median | 2.50% | 97.50% |
| K | | 2272092 | 1602534 | 4512552 | 1736979 | 1098577 | 3350110 |
| r | | 0.154 | 0.112 | 0.211 | 0.229 | 0.141 | 0.369 |
| ψ (psi) | | 0.992 | 0.817 | 1.197 | 0.993 | 0.820 | 1.194 |
| σ_{proc} | | 0.084 | 0.045 | 0.134 | 0.089 | 0.055 | 0.145 |
| m | | 0.867 | 0.867 | 0.867 | 1.127 | 1.127 | 1.127 |
| F_{MSY} | | 0.178 | 0.129 | 0.244 | 0.203 | 0.125 | 0.327 |
| B_{MSY} (t) | | 776970 | 548006 | 1543123 | 677555 | 428529 | 1306801 |
| MSY (t) | | 134815 | 108978 | 267350 | 134429 | 111991 | 245473 |
| B_{1950}/K | | 0.987 | 0.761 | 1.242 | 0.99 | 0.754 | 1.258 |
| B_{2018}/K | | 0.343 | 0.195 | 0.599 | 0.324 | 0.195 | 0.583 |
| B_{2018}/B_{MSY} | | 1.003 | 0.571 | 1.753 | 0.830 | 0.499 | 1.495 |
| F_{2018}/F_{MSY} | | 0.977 | 0.297 | 1.915 | 1.190 | 0.368 | 2.112 |

| Model | S3 | | | S5 | | | |
|--------------------|-----------|---------|---------|---------|---------|---------|---------|
| | Estimates | Median | 2.50% | 97.50% | Median | 2.50% | 97.50% |
| K | | 2146591 | 1541241 | 3417437 | 1591346 | 1017798 | 2965343 |
| r | | 0.161 | 0.117 | 0.221 | 0.255 | 0.153 | 0.400 |
| ψ (psi) | | 0.995 | 0.819 | 1.197 | 0.994 | 0.82 | 1.197 |
| σ_{proc} | | 0.077 | 0.045 | 0.122 | 0.089 | 0.055 | 0.134 |
| m | | 0.867 | 0.867 | 0.867 | 1.127 | 1.127 | 1.127 |
| F_{MSY} | | 0.186 | 0.135 | 0.254 | 0.226 | 0.136 | 0.354 |
| B_{MSY} (t) | | 734053 | 527046 | 1168635 | 620747 | 397019 | 1156712 |
| MSY (t) | | 135118 | 111155 | 205339 | 136810 | 115105 | 222251 |
| B_{1950}/K | | 0.991 | 0.768 | 1.246 | 0.99 | 0.757 | 1.256 |
| B_{2018}/K | | 0.371 | 0.227 | 0.564 | 0.365 | 0.228 | 0.603 |
| B_{2018}/B_{MSY} | | 1.085 | 0.665 | 1.649 | 0.936 | 0.585 | 1.547 |
| F_{2018}/F_{MSY} | | 0.901 | 0.409 | 1.619 | 1.035 | 0.393 | 1.772 |

Table 19. Estimates of biomass, fishing mortality, biomass relative to B_{MSY} , and fishing mortality relative to F_{MSY} between 1950 and 2018 from JABBA Reference Cases (a: Base Case, b: S2, c: S3, and d: S5) for Atlantic yellowfin tuna with 95% credibility intervals.

| Base Case | | | | | | | | | | | | |
|-----------|---------|---------|---------|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| JABBA | Biomass | | | Fishing mortality | | | B/Bmsy | | | F/Fmsy | | |
| Year | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI |
| 1950 | 2260547 | 1441730 | 4535648 | 0.001 | 0.000 | 0.001 | 2.885 | 2.225 | 3.631 | 0.003 | 0.002 | 0.004 |
| 1951 | 2250309 | 1426115 | 4536344 | 0.001 | 0.000 | 0.001 | 2.875 | 2.181 | 3.644 | 0.003 | 0.002 | 0.005 |
| 1952 | 2240517 | 1413573 | 4529405 | 0.001 | 0.001 | 0.002 | 2.866 | 2.137 | 3.647 | 0.007 | 0.004 | 0.010 |
| 1953 | 2228794 | 1398683 | 4513944 | 0.002 | 0.001 | 0.003 | 2.858 | 2.102 | 3.641 | 0.009 | 0.005 | 0.013 |
| 1954 | 2220862 | 1383577 | 4492138 | 0.002 | 0.001 | 0.002 | 2.850 | 2.086 | 3.636 | 0.009 | 0.004 | 0.013 |
| 1955 | 2217873 | 1371496 | 4514154 | 0.002 | 0.001 | 0.003 | 2.840 | 2.064 | 3.624 | 0.011 | 0.006 | 0.016 |
| 1956 | 2218129 | 1376886 | 4505434 | 0.003 | 0.001 | 0.005 | 2.839 | 2.056 | 3.637 | 0.017 | 0.008 | 0.025 |
| 1957 | 2207412 | 1367964 | 4483919 | 0.011 | 0.005 | 0.017 | 2.832 | 2.043 | 3.642 | 0.061 | 0.030 | 0.091 |
| 1958 | 2190205 | 1348194 | 4454079 | 0.019 | 0.009 | 0.030 | 2.804 | 2.019 | 3.619 | 0.105 | 0.052 | 0.157 |
| 1959 | 2158370 | 1323503 | 4423292 | 0.027 | 0.013 | 0.044 | 2.764 | 1.986 | 3.593 | 0.152 | 0.075 | 0.228 |
| 1960 | 2113355 | 1279972 | 4360039 | 0.032 | 0.016 | 0.054 | 2.708 | 1.936 | 3.553 | 0.184 | 0.090 | 0.280 |
| 1961 | 2071155 | 1241169 | 4289917 | 0.028 | 0.014 | 0.047 | 2.648 | 1.891 | 3.501 | 0.162 | 0.078 | 0.247 |
| 1962 | 2041807 | 1210113 | 4239868 | 0.028 | 0.014 | 0.048 | 2.615 | 1.840 | 3.479 | 0.160 | 0.078 | 0.247 |
| 1963 | 2020354 | 1201827 | 4249408 | 0.032 | 0.015 | 0.054 | 2.586 | 1.817 | 3.453 | 0.182 | 0.087 | 0.281 |
| 1964 | 1992917 | 1179027 | 4221892 | 0.035 | 0.016 | 0.058 | 2.554 | 1.782 | 3.427 | 0.197 | 0.093 | 0.306 |
| 1965 | 1967143 | 1151778 | 4219707 | 0.034 | 0.016 | 0.059 | 2.520 | 1.752 | 3.389 | 0.196 | 0.091 | 0.307 |
| 1966 | 1942848 | 1133700 | 4196913 | 0.030 | 0.014 | 0.052 | 2.491 | 1.730 | 3.382 | 0.172 | 0.080 | 0.270 |
| 1967 | 1939109 | 1128034 | 4166031 | 0.031 | 0.014 | 0.053 | 2.484 | 1.723 | 3.387 | 0.177 | 0.082 | 0.278 |
| 1968 | 1926912 | 1122391 | 4201239 | 0.044 | 0.020 | 0.075 | 2.472 | 1.708 | 3.372 | 0.250 | 0.114 | 0.392 |
| 1969 | 1893179 | 1091387 | 4192196 | 0.050 | 0.023 | 0.087 | 2.431 | 1.671 | 3.337 | 0.285 | 0.129 | 0.451 |
| 1970 | 1856254 | 1062376 | 4185264 | 0.040 | 0.018 | 0.070 | 2.388 | 1.632 | 3.294 | 0.230 | 0.102 | 0.367 |
| 1971 | 1844014 | 1059786 | 4166807 | 0.041 | 0.018 | 0.071 | 2.377 | 1.631 | 3.289 | 0.231 | 0.102 | 0.370 |
| 1972 | 1836333 | 1053753 | 4193798 | 0.052 | 0.023 | 0.091 | 2.364 | 1.630 | 3.282 | 0.298 | 0.129 | 0.473 |
| 1973 | 1805291 | 1032418 | 4201286 | 0.053 | 0.023 | 0.093 | 2.328 | 1.602 | 3.265 | 0.304 | 0.130 | 0.485 |
| 1974 | 1777462 | 1015018 | 4227944 | 0.060 | 0.025 | 0.106 | 2.300 | 1.577 | 3.254 | 0.344 | 0.144 | 0.550 |
| 1975 | 1746785 | 989494 | 4245721 | 0.071 | 0.029 | 0.126 | 2.261 | 1.541 | 3.236 | 0.408 | 0.168 | 0.654 |
| 1976 | 1702495 | 950056 | 4275713 | 0.073 | 0.029 | 0.132 | 2.208 | 1.491 | 3.215 | 0.419 | 0.167 | 0.682 |
| 1977 | 1660918 | 916821 | 4293143 | 0.079 | 0.031 | 0.143 | 2.158 | 1.442 | 3.176 | 0.452 | 0.175 | 0.745 |
| 1978 | 1616287 | 884491 | 4283439 | 0.083 | 0.031 | 0.152 | 2.104 | 1.396 | 3.139 | 0.474 | 0.178 | 0.786 |
| 1979 | 1575025 | 852265 | 4306768 | 0.081 | 0.030 | 0.150 | 2.055 | 1.350 | 3.110 | 0.463 | 0.169 | 0.775 |
| 1980 | 1546965 | 834861 | 4325359 | 0.085 | 0.030 | 0.157 | 2.025 | 1.321 | 3.114 | 0.484 | 0.170 | 0.812 |
| 1981 | 1523867 | 824591 | 4344908 | 0.102 | 0.036 | 0.189 | 2.000 | 1.301 | 3.105 | 0.584 | 0.203 | 0.983 |
| 1982 | 1486440 | 794718 | 4290605 | 0.111 | 0.039 | 0.208 | 1.949 | 1.251 | 3.063 | 0.636 | 0.218 | 1.085 |
| 1983 | 1454307 | 769122 | 4270412 | 0.114 | 0.039 | 0.215 | 1.908 | 1.213 | 3.052 | 0.649 | 0.219 | 1.118 |
| 1984 | 1459065 | 762753 | 4376217 | 0.078 | 0.026 | 0.150 | 1.918 | 1.202 | 3.124 | 0.447 | 0.147 | 0.783 |
| 1985 | 1508104 | 797776 | 4474920 | 0.104 | 0.035 | 0.197 | 1.976 | 1.262 | 3.184 | 0.594 | 0.198 | 1.028 |
| 1986 | 1544213 | 814993 | 4690763 | 0.095 | 0.031 | 0.180 | 2.029 | 1.285 | 3.320 | 0.542 | 0.178 | 0.943 |
| 1987 | 1569723 | 831390 | 4764419 | 0.093 | 0.031 | 0.175 | 2.062 | 1.301 | 3.387 | 0.529 | 0.174 | 0.920 |
| 1988 | 1551248 | 822740 | 4681014 | 0.088 | 0.029 | 0.165 | 2.038 | 1.292 | 3.332 | 0.501 | 0.164 | 0.867 |
| 1989 | 1523239 | 816061 | 4542365 | 0.107 | 0.036 | 0.199 | 2.005 | 1.275 | 3.252 | 0.608 | 0.201 | 1.046 |
| 1990 | 1460996 | 781343 | 4384973 | 0.133 | 0.044 | 0.248 | 1.922 | 1.228 | 3.125 | 0.755 | 0.250 | 1.302 |
| 1991 | 1341161 | 704571 | 4057427 | 0.125 | 0.041 | 0.238 | 1.763 | 1.113 | 2.889 | 0.713 | 0.233 | 1.236 |
| 1992 | 1259706 | 658946 | 3777001 | 0.130 | 0.043 | 0.249 | 1.657 | 1.039 | 2.701 | 0.741 | 0.244 | 1.289 |
| 1993 | 1245272 | 655173 | 3780443 | 0.131 | 0.043 | 0.249 | 1.638 | 1.034 | 2.690 | 0.749 | 0.244 | 1.302 |
| 1994 | 1238612 | 652808 | 3794566 | 0.140 | 0.046 | 0.266 | 1.632 | 1.029 | 2.693 | 0.798 | 0.257 | 1.380 |
| 1995 | 1211532 | 634458 | 3779383 | 0.128 | 0.041 | 0.244 | 1.596 | 0.994 | 2.674 | 0.728 | 0.231 | 1.279 |
| 1996 | 1167449 | 606964 | 3598673 | 0.128 | 0.041 | 0.246 | 1.535 | 0.960 | 2.555 | 0.729 | 0.233 | 1.285 |
| 1997 | 1126149 | 586414 | 3461920 | 0.122 | 0.040 | 0.234 | 1.478 | 0.924 | 2.457 | 0.696 | 0.223 | 1.223 |
| 1998 | 1120400 | 587629 | 3444571 | 0.129 | 0.042 | 0.246 | 1.474 | 0.921 | 2.451 | 0.735 | 0.236 | 1.293 |
| 1999 | 1105791 | 577796 | 3415179 | 0.123 | 0.040 | 0.236 | 1.457 | 0.904 | 2.422 | 0.701 | 0.225 | 1.236 |
| 2000 | 1090981 | 571567 | 3381162 | 0.121 | 0.039 | 0.231 | 1.436 | 0.894 | 2.389 | 0.691 | 0.223 | 1.220 |
| 2001 | 1068095 | 560038 | 3297793 | 0.144 | 0.047 | 0.274 | 1.405 | 0.881 | 2.325 | 0.818 | 0.267 | 1.442 |
| 2002 | 1033797 | 533983 | 3193281 | 0.130 | 0.042 | 0.252 | 1.358 | 0.839 | 2.258 | 0.744 | 0.239 | 1.323 |
| 2003 | 1042583 | 535456 | 3255014 | 0.118 | 0.038 | 0.229 | 1.370 | 0.837 | 2.291 | 0.671 | 0.214 | 1.204 |
| 2004 | 1084357 | 557225 | 3389672 | 0.110 | 0.035 | 0.215 | 1.422 | 0.873 | 2.400 | 0.629 | 0.199 | 1.130 |
| 2005 | 1114626 | 576820 | 3528600 | 0.094 | 0.030 | 0.182 | 1.469 | 0.894 | 2.499 | 0.536 | 0.168 | 0.969 |
| 2006 | 1072684 | 557605 | 3351941 | 0.099 | 0.032 | 0.190 | 1.410 | 0.867 | 2.367 | 0.563 | 0.178 | 1.006 |
| 2007 | 995677 | 519848 | 3079430 | 0.101 | 0.033 | 0.193 | 1.311 | 0.810 | 2.186 | 0.574 | 0.183 | 1.020 |
| 2008 | 919109 | 481752 | 2790038 | 0.122 | 0.040 | 0.232 | 1.208 | 0.754 | 1.971 | 0.694 | 0.225 | 1.225 |
| 2009 | 875449 | 457039 | 2646128 | 0.135 | 0.045 | 0.258 | 1.148 | 0.716 | 1.876 | 0.771 | 0.250 | 1.356 |
| 2010 | 836480 | 434925 | 2521217 | 0.141 | 0.047 | 0.271 | 1.100 | 0.682 | 1.791 | 0.807 | 0.263 | 1.424 |
| 2011 | 819645 | 424596 | 2483110 | 0.139 | 0.046 | 0.268 | 1.078 | 0.667 | 1.765 | 0.791 | 0.257 | 1.400 |
| 2012 | 816444 | 426217 | 2487244 | 0.141 | 0.046 | 0.270 | 1.073 | 0.669 | 1.769 | 0.803 | 0.258 | 1.415 |
| 2013 | 819753 | 427737 | 2537758 | 0.130 | 0.042 | 0.248 | 1.080 | 0.672 | 1.800 | 0.738 | 0.236 | 1.303 |
| 2014 | 818750 | 427449 | 2516596 | 0.138 | 0.045 | 0.264 | 1.077 | 0.670 | 1.790 | 0.785 | 0.252 | 1.383 |
| 2015 | 819250 | 429728 | 2502837 | 0.156 | 0.051 | 0.297 | 1.077 | 0.673 | 1.783 | 0.887 | 0.285 | 1.563 |
| 2016 | 804313 | 418182 | 2479273 | 0.184 | 0.060 | 0.354 | 1.060 | 0.658 | 1.759 | 1.045 | 0.335 | 1.864 |
| 2017 | 780734 | 388563 | 2472886 | 0.173 | 0.055 | 0.347 | 1.027 | 0.612 | 1.751 | 0.981 | 0.307 | 1.827 |
| 2018 | 762050 | 362706 | 2492665 | 0.172 | 0.053 | 0.361 | 1.003 | 0.571 | 1.753 | 0.977 | 0.297 | 1.915 |

Table 19. Continued.

| S2 | | | | | | | | | | | | |
|-------|---------|---------|---------|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| JABBA | Biomass | | | Fishing mortality | | | B/Bmsy | | | F/Fmsy | | |
| Year | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI |
| 1950 | 1725687 | 1008159 | 3378993 | 0.001 | 0.000 | 0.001 | 2.539 | 1.934 | 3.226 | 0.003 | 0.002 | 0.005 |
| 1951 | 1719686 | 1001763 | 3368642 | 0.001 | 0.000 | 0.001 | 2.529 | 1.905 | 3.216 | 0.004 | 0.002 | 0.006 |
| 1952 | 1715496 | 995396 | 3358613 | 0.002 | 0.001 | 0.003 | 2.525 | 1.886 | 3.207 | 0.008 | 0.004 | 0.011 |
| 1953 | 1709704 | 987871 | 3336217 | 0.002 | 0.001 | 0.004 | 2.517 | 1.870 | 3.191 | 0.011 | 0.006 | 0.015 |
| 1954 | 1703882 | 989348 | 3323107 | 0.002 | 0.001 | 0.003 | 2.511 | 1.862 | 3.188 | 0.010 | 0.005 | 0.014 |
| 1955 | 1700106 | 985716 | 3307008 | 0.003 | 0.001 | 0.004 | 2.506 | 1.857 | 3.189 | 0.013 | 0.007 | 0.018 |
| 1956 | 1701436 | 990332 | 3314908 | 0.004 | 0.002 | 0.007 | 2.507 | 1.855 | 3.194 | 0.019 | 0.011 | 0.027 |
| 1957 | 1698517 | 979969 | 3327567 | 0.014 | 0.007 | 0.024 | 2.502 | 1.849 | 3.197 | 0.070 | 0.038 | 0.099 |
| 1958 | 1678775 | 966808 | 3315795 | 0.024 | 0.012 | 0.042 | 2.476 | 1.825 | 3.167 | 0.121 | 0.065 | 0.172 |
| 1959 | 1646900 | 939697 | 3322509 | 0.035 | 0.017 | 0.061 | 2.430 | 1.787 | 3.132 | 0.175 | 0.094 | 0.251 |
| 1960 | 1609612 | 906172 | 3276369 | 0.043 | 0.021 | 0.076 | 2.372 | 1.735 | 3.086 | 0.213 | 0.112 | 0.306 |
| 1961 | 1566235 | 873837 | 3249632 | 0.038 | 0.018 | 0.067 | 2.310 | 1.673 | 3.033 | 0.188 | 0.098 | 0.272 |
| 1962 | 1542816 | 855346 | 3202200 | 0.037 | 0.018 | 0.067 | 2.275 | 1.646 | 3.014 | 0.186 | 0.096 | 0.271 |
| 1963 | 1524335 | 845778 | 3193869 | 0.042 | 0.020 | 0.076 | 2.252 | 1.616 | 2.993 | 0.212 | 0.108 | 0.310 |
| 1964 | 1504924 | 831647 | 3180098 | 0.046 | 0.022 | 0.083 | 2.220 | 1.602 | 2.962 | 0.229 | 0.115 | 0.336 |
| 1965 | 1482241 | 819161 | 3190911 | 0.046 | 0.021 | 0.083 | 2.189 | 1.576 | 2.946 | 0.228 | 0.113 | 0.336 |
| 1966 | 1466628 | 810865 | 3158764 | 0.040 | 0.019 | 0.072 | 2.168 | 1.549 | 2.917 | 0.200 | 0.099 | 0.297 |
| 1967 | 1463592 | 812491 | 3191311 | 0.041 | 0.019 | 0.074 | 2.163 | 1.547 | 2.925 | 0.205 | 0.101 | 0.305 |
| 1968 | 1461130 | 810510 | 3184853 | 0.058 | 0.026 | 0.104 | 2.155 | 1.542 | 2.926 | 0.289 | 0.142 | 0.430 |
| 1969 | 1432695 | 790884 | 3154678 | 0.066 | 0.030 | 0.120 | 2.119 | 1.501 | 2.898 | 0.330 | 0.160 | 0.493 |
| 1970 | 1400539 | 763486 | 3134739 | 0.053 | 0.024 | 0.098 | 2.071 | 1.457 | 2.853 | 0.267 | 0.128 | 0.402 |
| 1971 | 1394753 | 763116 | 3121430 | 0.054 | 0.024 | 0.098 | 2.063 | 1.451 | 2.852 | 0.268 | 0.127 | 0.404 |
| 1972 | 1392749 | 759490 | 3117373 | 0.069 | 0.031 | 0.126 | 2.059 | 1.456 | 2.848 | 0.343 | 0.161 | 0.517 |
| 1973 | 1366869 | 749624 | 3108017 | 0.070 | 0.031 | 0.128 | 2.022 | 1.428 | 2.822 | 0.352 | 0.163 | 0.528 |
| 1974 | 1346622 | 735087 | 3121077 | 0.080 | 0.034 | 0.146 | 1.993 | 1.404 | 2.795 | 0.400 | 0.183 | 0.604 |
| 1975 | 1317946 | 719872 | 3095313 | 0.094 | 0.040 | 0.173 | 1.952 | 1.375 | 2.760 | 0.475 | 0.211 | 0.716 |
| 1976 | 1277970 | 689920 | 3091135 | 0.098 | 0.040 | 0.181 | 1.892 | 1.327 | 2.711 | 0.492 | 0.213 | 0.747 |
| 1977 | 1241243 | 666521 | 3097258 | 0.106 | 0.042 | 0.197 | 1.841 | 1.291 | 2.674 | 0.533 | 0.223 | 0.806 |
| 1978 | 1203452 | 641578 | 3122272 | 0.111 | 0.043 | 0.209 | 1.790 | 1.246 | 2.642 | 0.562 | 0.227 | 0.852 |
| 1979 | 1173206 | 624968 | 3138196 | 0.109 | 0.041 | 0.204 | 1.742 | 1.213 | 2.622 | 0.552 | 0.213 | 0.837 |
| 1980 | 1148390 | 614939 | 3213199 | 0.114 | 0.041 | 0.213 | 1.710 | 1.193 | 2.611 | 0.576 | 0.216 | 0.871 |
| 1981 | 1131239 | 608829 | 3200550 | 0.138 | 0.049 | 0.256 | 1.686 | 1.175 | 2.600 | 0.698 | 0.256 | 1.053 |
| 1982 | 1093884 | 581282 | 3172072 | 0.151 | 0.052 | 0.284 | 1.636 | 1.128 | 2.565 | 0.763 | 0.272 | 1.161 |
| 1983 | 1067475 | 559029 | 3166863 | 0.155 | 0.052 | 0.296 | 1.595 | 1.084 | 2.539 | 0.784 | 0.276 | 1.206 |
| 1984 | 1069148 | 557832 | 3218253 | 0.107 | 0.036 | 0.205 | 1.597 | 1.076 | 2.603 | 0.542 | 0.185 | 0.843 |
| 1985 | 1111332 | 595742 | 3284122 | 0.141 | 0.048 | 0.263 | 1.663 | 1.138 | 2.658 | 0.714 | 0.248 | 1.098 |
| 1986 | 1145242 | 612020 | 3423828 | 0.128 | 0.043 | 0.240 | 1.715 | 1.157 | 2.799 | 0.648 | 0.222 | 1.011 |
| 1987 | 1169291 | 629867 | 3512256 | 0.125 | 0.041 | 0.231 | 1.748 | 1.181 | 2.879 | 0.629 | 0.214 | 0.984 |
| 1988 | 1152945 | 622220 | 3457783 | 0.118 | 0.039 | 0.219 | 1.728 | 1.171 | 2.840 | 0.595 | 0.203 | 0.927 |
| 1989 | 1134701 | 619909 | 3409011 | 0.143 | 0.048 | 0.262 | 1.704 | 1.168 | 2.777 | 0.720 | 0.247 | 1.109 |
| 1990 | 1085502 | 593691 | 3298946 | 0.178 | 0.059 | 0.326 | 1.629 | 1.122 | 2.659 | 0.898 | 0.306 | 1.374 |
| 1991 | 985023 | 525807 | 3015279 | 0.170 | 0.056 | 0.319 | 1.475 | 1.008 | 2.432 | 0.857 | 0.290 | 1.318 |
| 1992 | 922593 | 487614 | 2800519 | 0.178 | 0.058 | 0.336 | 1.380 | 0.941 | 2.256 | 0.897 | 0.309 | 1.376 |
| 1993 | 917386 | 488737 | 2797416 | 0.178 | 0.058 | 0.334 | 1.373 | 0.936 | 2.263 | 0.899 | 0.305 | 1.384 |
| 1994 | 916576 | 491913 | 2823230 | 0.190 | 0.062 | 0.353 | 1.375 | 0.934 | 2.293 | 0.956 | 0.323 | 1.479 |
| 1995 | 897219 | 475420 | 2811658 | 0.172 | 0.055 | 0.325 | 1.343 | 0.901 | 2.266 | 0.871 | 0.288 | 1.363 |
| 1996 | 861586 | 453817 | 2678540 | 0.173 | 0.056 | 0.329 | 1.289 | 0.865 | 2.155 | 0.876 | 0.290 | 1.372 |
| 1997 | 828546 | 435844 | 2570128 | 0.166 | 0.053 | 0.315 | 1.242 | 0.830 | 2.061 | 0.837 | 0.280 | 1.314 |
| 1998 | 827192 | 437255 | 2558718 | 0.175 | 0.056 | 0.331 | 1.240 | 0.833 | 2.066 | 0.881 | 0.295 | 1.376 |
| 1999 | 815977 | 430987 | 2552323 | 0.167 | 0.053 | 0.316 | 1.225 | 0.815 | 2.053 | 0.840 | 0.279 | 1.323 |
| 2000 | 807038 | 426671 | 2497019 | 0.164 | 0.053 | 0.310 | 1.210 | 0.810 | 2.015 | 0.826 | 0.277 | 1.298 |
| 2001 | 790407 | 420356 | 2430293 | 0.194 | 0.063 | 0.365 | 1.186 | 0.796 | 1.959 | 0.977 | 0.328 | 1.530 |
| 2002 | 757558 | 395201 | 2341912 | 0.178 | 0.058 | 0.341 | 1.137 | 0.756 | 1.898 | 0.898 | 0.298 | 1.418 |
| 2003 | 765157 | 398485 | 2404632 | 0.160 | 0.051 | 0.308 | 1.150 | 0.758 | 1.937 | 0.807 | 0.268 | 1.285 |
| 2004 | 801931 | 421118 | 2526340 | 0.149 | 0.047 | 0.284 | 1.205 | 0.791 | 2.044 | 0.750 | 0.247 | 1.207 |
| 2005 | 833460 | 441252 | 2675900 | 0.126 | 0.039 | 0.238 | 1.255 | 0.812 | 2.166 | 0.635 | 0.204 | 1.038 |
| 2006 | 798418 | 423337 | 2511103 | 0.133 | 0.042 | 0.250 | 1.198 | 0.788 | 2.039 | 0.668 | 0.217 | 1.075 |
| 2007 | 739295 | 390497 | 2299075 | 0.136 | 0.044 | 0.257 | 1.110 | 0.735 | 1.866 | 0.685 | 0.226 | 1.087 |
| 2008 | 677963 | 358531 | 2073733 | 0.165 | 0.054 | 0.312 | 1.016 | 0.682 | 1.673 | 0.834 | 0.281 | 1.303 |
| 2009 | 644267 | 339661 | 1966666 | 0.183 | 0.060 | 0.347 | 0.964 | 0.645 | 1.587 | 0.925 | 0.312 | 1.443 |
| 2010 | 612472 | 323331 | 1876944 | 0.193 | 0.063 | 0.365 | 0.920 | 0.617 | 1.518 | 0.971 | 0.329 | 1.511 |
| 2011 | 600172 | 314834 | 1862014 | 0.189 | 0.061 | 0.361 | 0.901 | 0.603 | 1.502 | 0.955 | 0.318 | 1.492 |
| 2012 | 601560 | 317064 | 1872946 | 0.191 | 0.061 | 0.363 | 0.902 | 0.603 | 1.505 | 0.965 | 0.319 | 1.510 |
| 2013 | 606391 | 317013 | 1894105 | 0.175 | 0.056 | 0.335 | 0.906 | 0.604 | 1.536 | 0.887 | 0.290 | 1.399 |
| 2014 | 604886 | 319628 | 1877876 | 0.187 | 0.060 | 0.353 | 0.907 | 0.607 | 1.515 | 0.943 | 0.313 | 1.474 |
| 2015 | 605845 | 322950 | 1886315 | 0.211 | 0.068 | 0.395 | 0.909 | 0.611 | 1.518 | 1.062 | 0.354 | 1.661 |
| 2016 | 593877 | 315224 | 1854800 | 0.249 | 0.080 | 0.470 | 0.893 | 0.595 | 1.495 | 1.254 | 0.415 | 1.985 |
| 2017 | 571764 | 290697 | 1848171 | 0.236 | 0.073 | 0.464 | 0.859 | 0.548 | 1.489 | 1.186 | 0.378 | 1.969 |
| 2018 | 553023 | 267607 | 1851323 | 0.237 | 0.071 | 0.490 | 0.830 | 0.499 | 1.495 | 1.190 | 0.368 | 2.112 |

Table 19. Continued.

| S3 | | | | | | | | | | | | |
|-------|---------|---------|---------|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| JABBA | Biomass | | | Fishing mortality | | | B/Bmsy | | | F/Fmsy | | |
| Year | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI |
| 1950 | 2135155 | 1396645 | 3556330 | 0.001 | 0.000 | 0.001 | 2.899 | 2.245 | 3.643 | 0.003 | 0.002 | 0.004 |
| 1951 | 2129638 | 1375634 | 3557076 | 0.001 | 0.000 | 0.001 | 2.888 | 2.208 | 3.643 | 0.003 | 0.002 | 0.005 |
| 1952 | 2120792 | 1364357 | 3572352 | 0.001 | 0.001 | 0.002 | 2.881 | 2.172 | 3.646 | 0.007 | 0.004 | 0.010 |
| 1953 | 2112268 | 1355829 | 3577818 | 0.002 | 0.001 | 0.003 | 2.874 | 2.151 | 3.647 | 0.009 | 0.006 | 0.013 |
| 1954 | 2105654 | 1346635 | 3576145 | 0.002 | 0.001 | 0.003 | 2.866 | 2.132 | 3.632 | 0.009 | 0.005 | 0.013 |
| 1955 | 2100989 | 1350556 | 3548849 | 0.002 | 0.001 | 0.003 | 2.863 | 2.129 | 3.643 | 0.011 | 0.007 | 0.016 |
| 1956 | 2094229 | 1345309 | 3546890 | 0.003 | 0.002 | 0.005 | 2.854 | 2.123 | 3.638 | 0.017 | 0.011 | 0.024 |
| 1957 | 2088726 | 1333572 | 3552029 | 0.011 | 0.007 | 0.018 | 2.845 | 2.101 | 3.628 | 0.061 | 0.038 | 0.089 |
| 1958 | 2069874 | 1317580 | 3544255 | 0.020 | 0.011 | 0.031 | 2.819 | 2.076 | 3.606 | 0.105 | 0.066 | 0.154 |
| 1959 | 2036554 | 1286016 | 3500677 | 0.028 | 0.017 | 0.045 | 2.773 | 2.039 | 3.582 | 0.152 | 0.095 | 0.224 |
| 1960 | 1993248 | 1243030 | 3454199 | 0.034 | 0.020 | 0.055 | 2.712 | 1.981 | 3.527 | 0.185 | 0.114 | 0.273 |
| 1961 | 1946439 | 1202158 | 3411689 | 0.030 | 0.017 | 0.049 | 2.646 | 1.925 | 3.467 | 0.163 | 0.099 | 0.242 |
| 1962 | 1914844 | 1170017 | 3387173 | 0.030 | 0.017 | 0.049 | 2.605 | 1.876 | 3.432 | 0.162 | 0.097 | 0.244 |
| 1963 | 1891436 | 1157232 | 3355931 | 0.034 | 0.019 | 0.056 | 2.574 | 1.844 | 3.408 | 0.184 | 0.110 | 0.279 |
| 1964 | 1863999 | 1137736 | 3309070 | 0.037 | 0.021 | 0.061 | 2.536 | 1.811 | 3.372 | 0.199 | 0.118 | 0.304 |
| 1965 | 1832685 | 1113114 | 3272889 | 0.037 | 0.021 | 0.061 | 2.498 | 1.774 | 3.334 | 0.199 | 0.117 | 0.303 |
| 1966 | 1811505 | 1097319 | 3266255 | 0.032 | 0.018 | 0.054 | 2.465 | 1.753 | 3.313 | 0.175 | 0.102 | 0.268 |
| 1967 | 1799813 | 1094202 | 3241426 | 0.033 | 0.019 | 0.055 | 2.451 | 1.744 | 3.303 | 0.181 | 0.105 | 0.276 |
| 1968 | 1785007 | 1087145 | 3228916 | 0.047 | 0.026 | 0.078 | 2.435 | 1.724 | 3.280 | 0.254 | 0.149 | 0.390 |
| 1969 | 1752644 | 1061145 | 3201540 | 0.054 | 0.030 | 0.089 | 2.388 | 1.689 | 3.241 | 0.291 | 0.169 | 0.450 |
| 1970 | 1711245 | 1031409 | 3150852 | 0.044 | 0.024 | 0.072 | 2.335 | 1.644 | 3.189 | 0.235 | 0.135 | 0.364 |
| 1971 | 1700215 | 1023967 | 3119065 | 0.044 | 0.024 | 0.073 | 2.313 | 1.630 | 3.166 | 0.237 | 0.136 | 0.369 |
| 1972 | 1684582 | 1016747 | 3100855 | 0.057 | 0.031 | 0.094 | 2.296 | 1.617 | 3.143 | 0.306 | 0.173 | 0.473 |
| 1973 | 1650025 | 990679 | 3071442 | 0.058 | 0.031 | 0.097 | 2.252 | 1.577 | 3.108 | 0.314 | 0.175 | 0.486 |
| 1974 | 1619638 | 966691 | 3055651 | 0.066 | 0.035 | 0.111 | 2.211 | 1.554 | 3.060 | 0.358 | 0.198 | 0.555 |
| 1975 | 1577512 | 932068 | 3031201 | 0.079 | 0.041 | 0.134 | 2.158 | 1.506 | 2.991 | 0.426 | 0.231 | 0.665 |
| 1976 | 1526496 | 893054 | 2983720 | 0.082 | 0.042 | 0.140 | 2.091 | 1.452 | 2.906 | 0.442 | 0.237 | 0.693 |
| 1977 | 1476670 | 861859 | 2908340 | 0.089 | 0.045 | 0.152 | 2.029 | 1.396 | 2.823 | 0.480 | 0.252 | 0.757 |
| 1978 | 1429410 | 832039 | 2872038 | 0.094 | 0.047 | 0.161 | 1.965 | 1.348 | 2.750 | 0.506 | 0.261 | 0.808 |
| 1979 | 1378997 | 792567 | 2822442 | 0.093 | 0.045 | 0.161 | 1.907 | 1.293 | 2.680 | 0.499 | 0.252 | 0.798 |
| 1980 | 1349894 | 767273 | 2792558 | 0.097 | 0.047 | 0.170 | 1.864 | 1.249 | 2.624 | 0.523 | 0.261 | 0.848 |
| 1981 | 1324108 | 755508 | 2759376 | 0.118 | 0.057 | 0.207 | 1.832 | 1.219 | 2.584 | 0.635 | 0.315 | 1.034 |
| 1982 | 1299481 | 729601 | 2733464 | 0.127 | 0.060 | 0.227 | 1.800 | 1.183 | 2.553 | 0.685 | 0.337 | 1.130 |
| 1983 | 1283323 | 715494 | 2727499 | 0.129 | 0.061 | 0.231 | 1.779 | 1.157 | 2.555 | 0.693 | 0.337 | 1.157 |
| 1984 | 1295934 | 715976 | 2786065 | 0.088 | 0.041 | 0.160 | 1.797 | 1.162 | 2.613 | 0.476 | 0.228 | 0.800 |
| 1985 | 1344466 | 761087 | 2846141 | 0.117 | 0.055 | 0.206 | 1.860 | 1.225 | 2.675 | 0.628 | 0.306 | 1.040 |
| 1986 | 1381830 | 777541 | 2938804 | 0.106 | 0.050 | 0.189 | 1.910 | 1.258 | 2.770 | 0.573 | 0.274 | 0.953 |
| 1987 | 1412490 | 794786 | 3013540 | 0.103 | 0.048 | 0.183 | 1.953 | 1.281 | 2.847 | 0.556 | 0.266 | 0.924 |
| 1988 | 1414549 | 799601 | 3008657 | 0.096 | 0.045 | 0.170 | 1.957 | 1.285 | 2.840 | 0.518 | 0.249 | 0.859 |
| 1989 | 1408077 | 806604 | 2978265 | 0.115 | 0.055 | 0.201 | 1.952 | 1.295 | 2.812 | 0.621 | 0.300 | 1.022 |
| 1990 | 1373841 | 783184 | 2910259 | 0.141 | 0.067 | 0.247 | 1.900 | 1.258 | 2.749 | 0.759 | 0.365 | 1.248 |
| 1991 | 1269784 | 712780 | 2722157 | 0.132 | 0.062 | 0.235 | 1.756 | 1.152 | 2.555 | 0.712 | 0.340 | 1.184 |
| 1992 | 1196711 | 668739 | 2574789 | 0.137 | 0.064 | 0.245 | 1.656 | 1.083 | 2.410 | 0.738 | 0.353 | 1.227 |
| 1993 | 1170652 | 656291 | 2512373 | 0.140 | 0.065 | 0.249 | 1.623 | 1.066 | 2.357 | 0.751 | 0.361 | 1.244 |
| 1994 | 1175451 | 662142 | 2526568 | 0.148 | 0.069 | 0.262 | 1.628 | 1.071 | 2.368 | 0.797 | 0.380 | 1.323 |
| 1995 | 1155500 | 647428 | 2481040 | 0.134 | 0.062 | 0.239 | 1.603 | 1.044 | 2.344 | 0.720 | 0.340 | 1.204 |
| 1996 | 1107954 | 618157 | 2387220 | 0.135 | 0.062 | 0.241 | 1.535 | 1.000 | 2.236 | 0.725 | 0.344 | 1.213 |
| 1997 | 1072939 | 597343 | 2307210 | 0.128 | 0.060 | 0.230 | 1.488 | 0.965 | 2.169 | 0.689 | 0.327 | 1.158 |
| 1998 | 1079825 | 606053 | 2324477 | 0.134 | 0.062 | 0.238 | 1.497 | 0.979 | 2.178 | 0.721 | 0.344 | 1.203 |
| 1999 | 1068562 | 597245 | 2299347 | 0.127 | 0.059 | 0.228 | 1.482 | 0.964 | 2.156 | 0.686 | 0.327 | 1.150 |
| 2000 | 1049966 | 588484 | 2258098 | 0.126 | 0.059 | 0.225 | 1.457 | 0.951 | 2.126 | 0.679 | 0.324 | 1.129 |
| 2001 | 1030508 | 577326 | 2195389 | 0.149 | 0.070 | 0.266 | 1.427 | 0.931 | 2.065 | 0.802 | 0.384 | 1.343 |
| 2002 | 991426 | 549291 | 2141602 | 0.136 | 0.063 | 0.245 | 1.377 | 0.887 | 2.005 | 0.731 | 0.349 | 1.230 |
| 2003 | 1014394 | 565224 | 2205785 | 0.121 | 0.056 | 0.217 | 1.408 | 0.914 | 2.065 | 0.649 | 0.307 | 1.090 |
| 2004 | 1056566 | 591955 | 2290426 | 0.113 | 0.052 | 0.202 | 1.467 | 0.952 | 2.155 | 0.608 | 0.288 | 1.022 |
| 2005 | 1092220 | 617017 | 2369031 | 0.096 | 0.044 | 0.170 | 1.515 | 0.989 | 2.246 | 0.517 | 0.242 | 0.870 |
| 2006 | 1041295 | 585966 | 2249367 | 0.102 | 0.047 | 0.181 | 1.441 | 0.940 | 2.123 | 0.549 | 0.260 | 0.916 |
| 2007 | 956359 | 532222 | 2060782 | 0.105 | 0.049 | 0.189 | 1.323 | 0.859 | 1.939 | 0.566 | 0.270 | 0.952 |
| 2008 | 880802 | 490484 | 1892146 | 0.127 | 0.059 | 0.228 | 1.222 | 0.789 | 1.772 | 0.684 | 0.327 | 1.150 |
| 2009 | 844744 | 472029 | 1809781 | 0.140 | 0.065 | 0.250 | 1.171 | 0.760 | 1.701 | 0.752 | 0.359 | 1.256 |
| 2010 | 806537 | 446777 | 1736425 | 0.146 | 0.068 | 0.264 | 1.118 | 0.723 | 1.625 | 0.788 | 0.377 | 1.328 |
| 2011 | 794650 | 442143 | 1709954 | 0.143 | 0.066 | 0.257 | 1.104 | 0.712 | 1.604 | 0.768 | 0.366 | 1.295 |
| 2012 | 801946 | 445002 | 1727209 | 0.143 | 0.067 | 0.258 | 1.111 | 0.718 | 1.619 | 0.772 | 0.367 | 1.295 |
| 2013 | 810539 | 452193 | 1750477 | 0.131 | 0.061 | 0.235 | 1.124 | 0.725 | 1.637 | 0.705 | 0.335 | 1.189 |
| 2014 | 809968 | 450345 | 1738767 | 0.139 | 0.065 | 0.251 | 1.124 | 0.727 | 1.634 | 0.748 | 0.356 | 1.259 |
| 2015 | 815620 | 455882 | 1744260 | 0.156 | 0.073 | 0.280 | 1.131 | 0.734 | 1.644 | 0.841 | 0.404 | 1.412 |
| 2016 | 812450 | 452773 | 1754677 | 0.182 | 0.084 | 0.327 | 1.128 | 0.734 | 1.648 | 0.979 | 0.464 | 1.651 |
| 2017 | 794315 | 435242 | 1752839 | 0.170 | 0.077 | 0.310 | 1.103 | 0.699 | 1.640 | 0.912 | 0.422 | 1.576 |
| 2018 | 781455 | 413616 | 1760998 | 0.168 | 0.074 | 0.317 | 1.085 | 0.665 | 1.649 | 0.901 | 0.409 | 1.619 |

Table 19. Continued.

| S5 | | | | | | | | | | | | |
|-------|---------|--------|---------|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|
| JABBA | Biomass | | | Fishing mortality | | | B/Bmsy | | | F/Fmsy | | |
| Year | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI | Median | 90%LCI | 90%UCI |
| 1950 | 1576025 | 925558 | 3040825 | 0.001 | 0.000 | 0.001 | 2.537 | 1.942 | 3.221 | 0.003 | 0.002 | 0.005 |
| 1951 | 1573176 | 925921 | 3033786 | 0.001 | 0.000 | 0.001 | 2.533 | 1.929 | 3.207 | 0.004 | 0.002 | 0.005 |
| 1952 | 1570018 | 922601 | 3026898 | 0.002 | 0.001 | 0.003 | 2.533 | 1.916 | 3.201 | 0.008 | 0.005 | 0.011 |
| 1953 | 1566861 | 923280 | 3018663 | 0.002 | 0.001 | 0.004 | 2.527 | 1.911 | 3.205 | 0.010 | 0.006 | 0.014 |
| 1954 | 1563437 | 916429 | 3021698 | 0.002 | 0.001 | 0.004 | 2.521 | 1.908 | 3.193 | 0.010 | 0.006 | 0.014 |
| 1955 | 1560773 | 918256 | 2981636 | 0.003 | 0.001 | 0.005 | 2.520 | 1.900 | 3.191 | 0.012 | 0.007 | 0.017 |
| 1956 | 1555468 | 914922 | 3003404 | 0.004 | 0.002 | 0.007 | 2.516 | 1.896 | 3.191 | 0.019 | 0.011 | 0.027 |
| 1957 | 1552159 | 914170 | 2968619 | 0.015 | 0.008 | 0.026 | 2.511 | 1.890 | 3.179 | 0.068 | 0.041 | 0.096 |
| 1958 | 1532691 | 898078 | 2976895 | 0.026 | 0.014 | 0.045 | 2.478 | 1.858 | 3.157 | 0.118 | 0.071 | 0.167 |
| 1959 | 1503041 | 872241 | 2946378 | 0.038 | 0.020 | 0.066 | 2.427 | 1.817 | 3.115 | 0.172 | 0.102 | 0.245 |
| 1960 | 1462405 | 838269 | 2903194 | 0.047 | 0.024 | 0.082 | 2.362 | 1.766 | 3.061 | 0.210 | 0.122 | 0.300 |
| 1961 | 1421166 | 804781 | 2862925 | 0.041 | 0.021 | 0.073 | 2.296 | 1.696 | 2.998 | 0.185 | 0.106 | 0.267 |
| 1962 | 1403732 | 791024 | 2866983 | 0.041 | 0.020 | 0.073 | 2.264 | 1.667 | 2.983 | 0.184 | 0.104 | 0.266 |
| 1963 | 1385717 | 781967 | 2872044 | 0.047 | 0.022 | 0.083 | 2.240 | 1.651 | 2.959 | 0.209 | 0.118 | 0.302 |
| 1964 | 1366599 | 772724 | 2835786 | 0.050 | 0.024 | 0.089 | 2.208 | 1.623 | 2.927 | 0.226 | 0.127 | 0.329 |
| 1965 | 1347539 | 763426 | 2808916 | 0.050 | 0.024 | 0.089 | 2.179 | 1.593 | 2.891 | 0.225 | 0.126 | 0.330 |
| 1966 | 1332528 | 755505 | 2825470 | 0.044 | 0.021 | 0.078 | 2.155 | 1.574 | 2.871 | 0.197 | 0.109 | 0.290 |
| 1967 | 1330175 | 755310 | 2801951 | 0.045 | 0.021 | 0.080 | 2.148 | 1.567 | 2.878 | 0.203 | 0.111 | 0.298 |
| 1968 | 1326259 | 756771 | 2789536 | 0.064 | 0.030 | 0.111 | 2.146 | 1.562 | 2.876 | 0.285 | 0.155 | 0.419 |
| 1969 | 1299487 | 732280 | 2734580 | 0.073 | 0.035 | 0.129 | 2.098 | 1.516 | 2.829 | 0.326 | 0.175 | 0.486 |
| 1970 | 1268370 | 708115 | 2702401 | 0.059 | 0.028 | 0.106 | 2.045 | 1.464 | 2.781 | 0.265 | 0.141 | 0.397 |
| 1971 | 1260155 | 707875 | 2677736 | 0.059 | 0.028 | 0.106 | 2.037 | 1.461 | 2.770 | 0.266 | 0.141 | 0.398 |
| 1972 | 1252967 | 709766 | 2664922 | 0.076 | 0.036 | 0.134 | 2.028 | 1.452 | 2.765 | 0.342 | 0.179 | 0.512 |
| 1973 | 1226089 | 691009 | 2598836 | 0.078 | 0.037 | 0.139 | 1.987 | 1.421 | 2.719 | 0.351 | 0.182 | 0.527 |
| 1974 | 1204103 | 675850 | 2561173 | 0.089 | 0.042 | 0.159 | 1.952 | 1.387 | 2.676 | 0.400 | 0.205 | 0.605 |
| 1975 | 1170935 | 657746 | 2524141 | 0.106 | 0.049 | 0.189 | 1.900 | 1.348 | 2.633 | 0.478 | 0.239 | 0.724 |
| 1976 | 1129519 | 621621 | 2496168 | 0.111 | 0.050 | 0.201 | 1.831 | 1.288 | 2.563 | 0.498 | 0.242 | 0.761 |
| 1977 | 1091529 | 599492 | 2458864 | 0.120 | 0.053 | 0.219 | 1.766 | 1.244 | 2.521 | 0.544 | 0.256 | 0.831 |
| 1978 | 1048273 | 573930 | 2470255 | 0.128 | 0.054 | 0.234 | 1.703 | 1.194 | 2.463 | 0.577 | 0.262 | 0.881 |
| 1979 | 1010434 | 549590 | 2456262 | 0.126 | 0.052 | 0.232 | 1.644 | 1.146 | 2.400 | 0.572 | 0.250 | 0.875 |
| 1980 | 984662 | 532695 | 2442772 | 0.133 | 0.054 | 0.245 | 1.605 | 1.110 | 2.373 | 0.602 | 0.258 | 0.921 |
| 1981 | 968749 | 522326 | 2461271 | 0.161 | 0.063 | 0.299 | 1.579 | 1.084 | 2.343 | 0.731 | 0.312 | 1.125 |
| 1982 | 947051 | 504775 | 2438577 | 0.175 | 0.068 | 0.327 | 1.542 | 1.054 | 2.327 | 0.793 | 0.332 | 1.225 |
| 1983 | 932824 | 490904 | 2415454 | 0.177 | 0.068 | 0.337 | 1.519 | 1.027 | 2.316 | 0.806 | 0.332 | 1.255 |
| 1984 | 941867 | 491627 | 2483236 | 0.122 | 0.046 | 0.233 | 1.534 | 1.031 | 2.382 | 0.553 | 0.225 | 0.870 |
| 1985 | 985302 | 527328 | 2554195 | 0.159 | 0.061 | 0.297 | 1.603 | 1.093 | 2.457 | 0.724 | 0.299 | 1.123 |
| 1986 | 1016986 | 543099 | 2658223 | 0.144 | 0.055 | 0.270 | 1.655 | 1.121 | 2.562 | 0.657 | 0.267 | 1.028 |
| 1987 | 1042124 | 557676 | 2729757 | 0.140 | 0.053 | 0.261 | 1.694 | 1.150 | 2.632 | 0.636 | 0.257 | 0.994 |
| 1988 | 1045266 | 559513 | 2725542 | 0.130 | 0.050 | 0.243 | 1.697 | 1.155 | 2.624 | 0.593 | 0.241 | 0.924 |
| 1989 | 1044747 | 568663 | 2708546 | 0.156 | 0.060 | 0.286 | 1.699 | 1.167 | 2.609 | 0.709 | 0.291 | 1.092 |
| 1990 | 1017234 | 553584 | 2692740 | 0.190 | 0.072 | 0.350 | 1.653 | 1.139 | 2.546 | 0.867 | 0.353 | 1.334 |
| 1991 | 929894 | 492854 | 2460972 | 0.180 | 0.068 | 0.340 | 1.511 | 1.026 | 2.345 | 0.821 | 0.331 | 1.277 |
| 1992 | 874648 | 460617 | 2304207 | 0.187 | 0.071 | 0.356 | 1.419 | 0.962 | 2.192 | 0.856 | 0.346 | 1.329 |
| 1993 | 857254 | 456785 | 2250347 | 0.191 | 0.073 | 0.358 | 1.395 | 0.950 | 2.160 | 0.868 | 0.350 | 1.351 |
| 1994 | 864818 | 462980 | 2277272 | 0.201 | 0.076 | 0.375 | 1.406 | 0.958 | 2.190 | 0.915 | 0.366 | 1.420 |
| 1995 | 851257 | 451640 | 2273860 | 0.182 | 0.068 | 0.342 | 1.383 | 0.938 | 2.182 | 0.827 | 0.330 | 1.298 |
| 1996 | 812146 | 428709 | 2167524 | 0.184 | 0.069 | 0.348 | 1.320 | 0.891 | 2.075 | 0.837 | 0.333 | 1.315 |
| 1997 | 786801 | 412721 | 2106802 | 0.175 | 0.065 | 0.333 | 1.275 | 0.860 | 2.003 | 0.796 | 0.316 | 1.253 |
| 1998 | 794983 | 421205 | 2124714 | 0.182 | 0.068 | 0.343 | 1.294 | 0.872 | 2.027 | 0.826 | 0.329 | 1.299 |
| 1999 | 787033 | 417291 | 2114457 | 0.173 | 0.064 | 0.326 | 1.282 | 0.864 | 2.020 | 0.787 | 0.311 | 1.236 |
| 2000 | 773101 | 410288 | 2054826 | 0.171 | 0.064 | 0.322 | 1.259 | 0.852 | 1.974 | 0.778 | 0.312 | 1.221 |
| 2001 | 757767 | 404518 | 1988165 | 0.202 | 0.077 | 0.379 | 1.230 | 0.837 | 1.910 | 0.922 | 0.372 | 1.438 |
| 2002 | 724425 | 380622 | 1933092 | 0.186 | 0.070 | 0.354 | 1.177 | 0.793 | 1.841 | 0.846 | 0.338 | 1.333 |
| 2003 | 744874 | 390565 | 2007980 | 0.165 | 0.061 | 0.314 | 1.211 | 0.815 | 1.912 | 0.749 | 0.297 | 1.178 |
| 2004 | 781627 | 416305 | 2109742 | 0.153 | 0.057 | 0.287 | 1.272 | 0.854 | 2.013 | 0.695 | 0.275 | 1.098 |
| 2005 | 816306 | 438908 | 2209590 | 0.129 | 0.048 | 0.239 | 1.329 | 0.886 | 2.126 | 0.585 | 0.231 | 0.935 |
| 2006 | 772331 | 414164 | 2066331 | 0.137 | 0.051 | 0.256 | 1.258 | 0.841 | 2.002 | 0.623 | 0.248 | 0.990 |
| 2007 | 704305 | 374222 | 1868855 | 0.143 | 0.054 | 0.268 | 1.147 | 0.767 | 1.806 | 0.649 | 0.259 | 1.026 |
| 2008 | 645499 | 341512 | 1719975 | 0.173 | 0.065 | 0.328 | 1.049 | 0.702 | 1.635 | 0.790 | 0.315 | 1.246 |
| 2009 | 620643 | 326239 | 1660110 | 0.190 | 0.071 | 0.361 | 1.008 | 0.676 | 1.577 | 0.866 | 0.343 | 1.367 |
| 2010 | 590430 | 308970 | 1573415 | 0.200 | 0.075 | 0.382 | 0.959 | 0.641 | 1.505 | 0.913 | 0.362 | 1.444 |
| 2011 | 581981 | 304889 | 1570840 | 0.195 | 0.072 | 0.373 | 0.947 | 0.634 | 1.491 | 0.890 | 0.353 | 1.402 |
| 2012 | 587861 | 308860 | 1576097 | 0.196 | 0.073 | 0.372 | 0.956 | 0.641 | 1.510 | 0.892 | 0.352 | 1.410 |
| 2013 | 596108 | 313614 | 1614968 | 0.178 | 0.066 | 0.339 | 0.970 | 0.649 | 1.536 | 0.812 | 0.322 | 1.285 |
| 2014 | 598202 | 316749 | 1602024 | 0.189 | 0.070 | 0.356 | 0.972 | 0.651 | 1.533 | 0.859 | 0.342 | 1.357 |
| 2015 | 603302 | 322400 | 1586562 | 0.211 | 0.080 | 0.396 | 0.982 | 0.664 | 1.535 | 0.961 | 0.385 | 1.509 |
| 2016 | 602183 | 321310 | 1600199 | 0.246 | 0.093 | 0.461 | 0.980 | 0.660 | 1.535 | 1.118 | 0.444 | 1.770 |
| 2017 | 585402 | 303424 | 1603922 | 0.230 | 0.084 | 0.444 | 0.954 | 0.622 | 1.534 | 1.047 | 0.404 | 1.708 |
| 2018 | 574586 | 287700 | 1606970 | 0.228 | 0.082 | 0.455 | 0.936 | 0.585 | 1.547 | 1.035 | 0.393 | 1.772 |

Table 20. Combined estimates of Atlantic YFT stock benchmarks from the uncertainty grid.

| Estimates | Mean (90% lower and upper confidence intervals) |
|--|---|
| Maximum Sustainable Yield (MSY) | 127,558 t (98,268-267,350 t) * |
| Relative Biomass**: B_{2018} / B_{MSY} | 1.17 (0.75 - 1.62) |
| Relative Fishing Mortality: F_{2018} / F_{MSY} | 0.96 (0.56 - 1.50) |

*minimum and maximum values of 90%LCI and 90%UCI among all runs by the Stock Synthesis, JABBA, and MPB

**SSB (Stock Synthesis) or exploited biomass (production models)

Table 21. Estimated probabilities of biomass the Atlantic YFT stock levels < 20% of BMSY in the combined projections of JABBA (Base Case, S2, S3, and S5), MPB, Stock Synthesis (runs 1-4) in a given year for a given catch level (0, 60,000 – 150,000 t). This result was used to develop the management advice of Atlantic YFT stock.

| TAC | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 |
|--------|------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|
| 0 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 60000 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 70000 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 80000 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% | 0.1% |
| 90000 | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.1% | 0.1% | 0.1% | 0.2% | 0.2% | 0.2% | 0.2% | 0.2% | 0.3% |
| 100000 | 0.0% | 0.0% | 0.1% | 0.1% | 0.2% | 0.2% | 0.3% | 0.3% | 0.4% | 0.4% | 0.5% | 0.5% | 0.6% | 0.6% |
| 110000 | 0.0% | 0.0% | 0.1% | 0.1% | 0.2% | 0.4% | 0.6% | 0.7% | 0.8% | 0.9% | 1.0% | 1.2% | 1.4% | 1.5% |
| 120000 | 0.0% | 0.0% | 0.1% | 0.3% | 0.5% | 0.7% | 1.0% | 1.2% | 1.5% | 1.8% | 2.1% | 2.4% | 2.6% | 2.9% |
| 130000 | 0.0% | 0.1% | 0.2% | 0.5% | 0.8% | 1.2% | 1.6% | 2.1% | 2.6% | 3.0% | 3.5% | 3.9% | 4.3% | 4.7% |
| 140000 | 0.0% | 0.1% | 0.3% | 0.7% | 1.2% | 1.8% | 2.6% | 3.2% | 4.0% | 4.8% | 10.4% | 12.2% | 12.9% | 13.4% |
| 150000 | 0.0% | 0.1% | 0.3% | 1.0% | 1.7% | 2.7% | 3.7% | 4.8% | 11.9% | 12.7% | 15.9% | 21.3% | 22.1% | 23.3% |

Table 22. Estimated probabilities of the Atlantic YFT stock (a) being below F_{MSY} (overfishing not occurring), (b) above B_{MSY} (not overfished) and (c) above B_{MSY} and below F_{MSY} (green zone) in a given year for a given catch level (0, 60,000 – 150,000 t), based upon the combined projections of JABBA (Base Case, S2, S3, and S5), MPB, Stock Synthesis (runs 1-4). This result was used to develop the management advice of Atlantic YFT stock.

a) Probability that $F \leq F_{MSY}$

| TAC Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 |
|------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 0 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 60000 | 99 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 70000 | 98 | 99 | 99 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 80000 | 96 | 97 | 98 | 98 | 99 | 99 | 99 | 99 | 99 | 100 | 100 | 100 | 100 | 100 |
| 90000 | 93 | 95 | 96 | 97 | 97 | 98 | 98 | 98 | 98 | 99 | 99 | 99 | 99 | 99 |
| 100000 | 88 | 90 | 92 | 93 | 94 | 95 | 95 | 95 | 96 | 96 | 97 | 97 | 97 | 97 |
| 110000 | 81 | 84 | 85 | 86 | 87 | 87 | 88 | 88 | 89 | 90 | 90 | 90 | 90 | 90 |
| 120000 | 71 | 72 | 72 | 73 | 73 | 74 | 74 | 74 | 74 | 74 | 70 | 70 | 70 | 70 |
| 130000 | 60 | 59 | 58 | 56 | 55 | 53 | 50 | 49 | 47 | 46 | 46 | 45 | 39 | 39 |
| 140000 | 48 | 46 | 43 | 39 | 36 | 32 | 30 | 26 | 24 | 23 | 22 | 21 | 21 | 19 |
| 150000 | 39 | 35 | 30 | 25 | 22 | 17 | 15 | 13 | 13 | 12 | 11 | 10 | 10 | 8 |

b) Probability that $B \geq B_{MSY}$

| TAC Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 |
|------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 0 | 64 | 84 | 95 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 60000 | 64 | 75 | 85 | 92 | 96 | 97 | 98 | 99 | 99 | 99 | 100 | 100 | 100 | 100 |
| 70000 | 64 | 74 | 83 | 90 | 94 | 96 | 97 | 98 | 98 | 99 | 99 | 99 | 100 | 100 |
| 80000 | 64 | 72 | 79 | 86 | 91 | 94 | 96 | 97 | 97 | 98 | 98 | 99 | 99 | 99 |
| 90000 | 64 | 70 | 77 | 82 | 87 | 90 | 92 | 94 | 95 | 96 | 97 | 97 | 98 | 98 |
| 100000 | 64 | 68 | 73 | 78 | 82 | 85 | 87 | 89 | 91 | 92 | 93 | 94 | 94 | 95 |
| 110000 | 64 | 67 | 69 | 72 | 75 | 77 | 79 | 81 | 83 | 84 | 85 | 86 | 86 | 87 |
| 120000 | 64 | 65 | 65 | 67 | 68 | 68 | 69 | 70 | 71 | 71 | 68 | 69 | 69 | 69 |
| 130000 | 65 | 63 | 62 | 61 | 60 | 59 | 56 | 56 | 55 | 53 | 52 | 51 | 46 | 45 |
| 140000 | 64 | 61 | 59 | 56 | 54 | 49 | 46 | 40 | 37 | 34 | 31 | 29 | 27 | 25 |
| 150000 | 64 | 60 | 55 | 50 | 45 | 37 | 32 | 27 | 23 | 20 | 18 | 13 | 12 | 8 |

c) Probability that $F \leq F_{MSY}$ and $B \geq B_{MSY}$

| TAC Year | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2033 |
|------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| 0 | 64 | 84 | 95 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 60000 | 64 | 75 | 85 | 92 | 96 | 97 | 98 | 99 | 99 | 99 | 100 | 100 | 100 | 100 |
| 70000 | 64 | 74 | 83 | 90 | 94 | 96 | 97 | 98 | 98 | 99 | 99 | 99 | 100 | 100 |
| 80000 | 64 | 72 | 79 | 86 | 91 | 94 | 96 | 97 | 97 | 98 | 98 | 99 | 99 | 99 |
| 90000 | 64 | 70 | 77 | 82 | 87 | 90 | 92 | 94 | 95 | 96 | 97 | 97 | 98 | 98 |
| 100000 | 64 | 68 | 73 | 77 | 82 | 85 | 87 | 89 | 90 | 92 | 93 | 94 | 94 | 95 |
| 110000 | 64 | 66 | 69 | 72 | 75 | 77 | 79 | 81 | 82 | 83 | 84 | 85 | 86 | 86 |
| 120000 | 63 | 63 | 64 | 65 | 65 | 66 | 66 | 67 | 67 | 68 | 65 | 65 | 66 | 66 |
| 130000 | 58 | 57 | 56 | 54 | 52 | 50 | 47 | 46 | 45 | 44 | 43 | 42 | 38 | 38 |
| 140000 | 48 | 45 | 42 | 38 | 35 | 31 | 29 | 26 | 24 | 22 | 21 | 20 | 20 | 19 |
| 150000 | 39 | 34 | 30 | 25 | 21 | 17 | 15 | 13 | 12 | 12 | 11 | 10 | 9 | 7 |

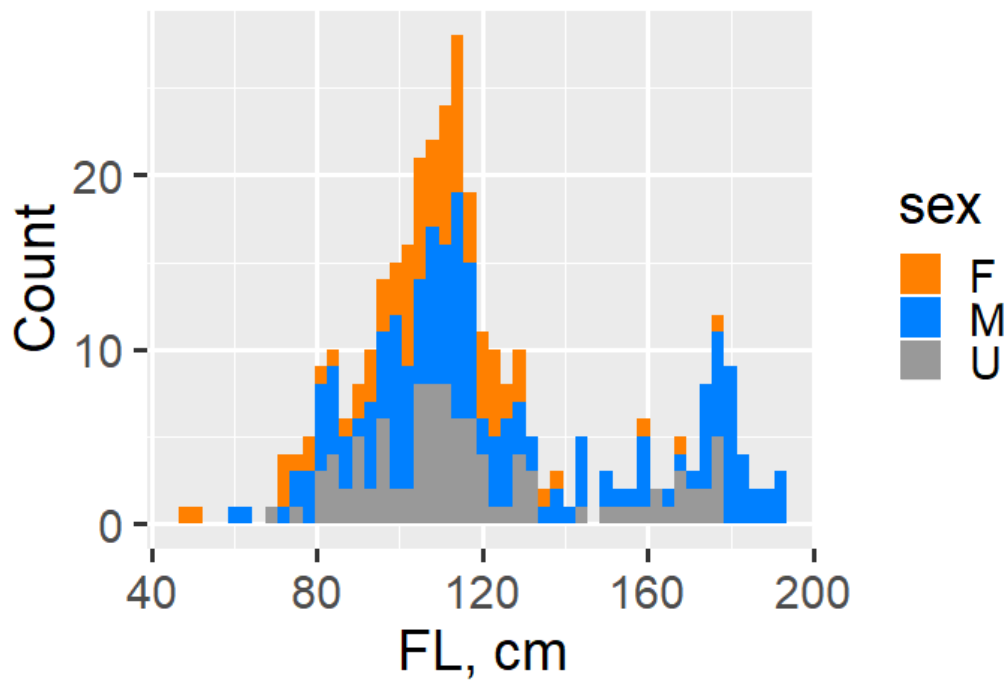


Figure 1. The size composition of YFT fish sampled off Ascension Island, by gender.

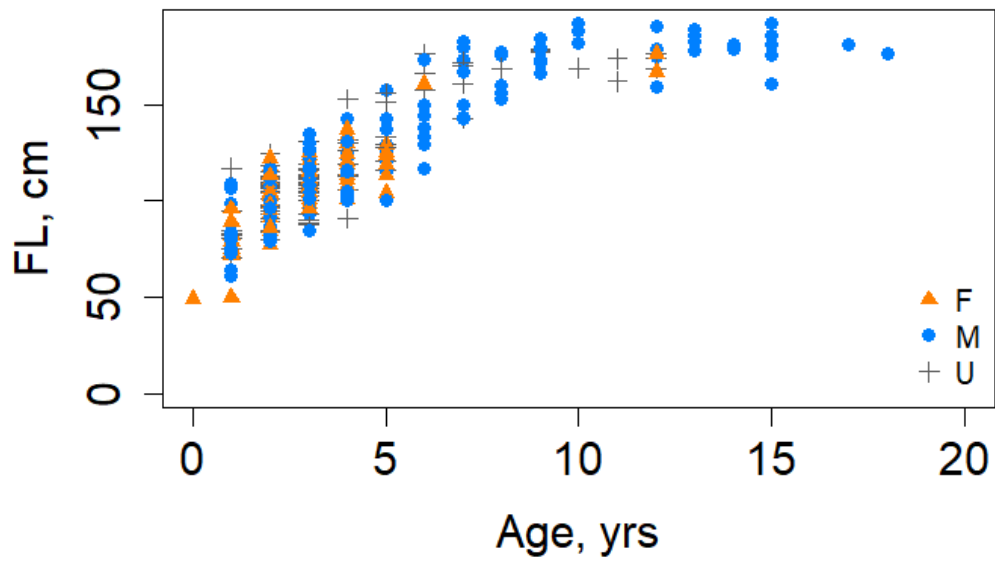


Figure 2. The size at age of YFT fish sampled off Ascension Island, by gender. Some evidence of sex-specific growth is noted. No adjustment was made to annulus count for Ascension data.

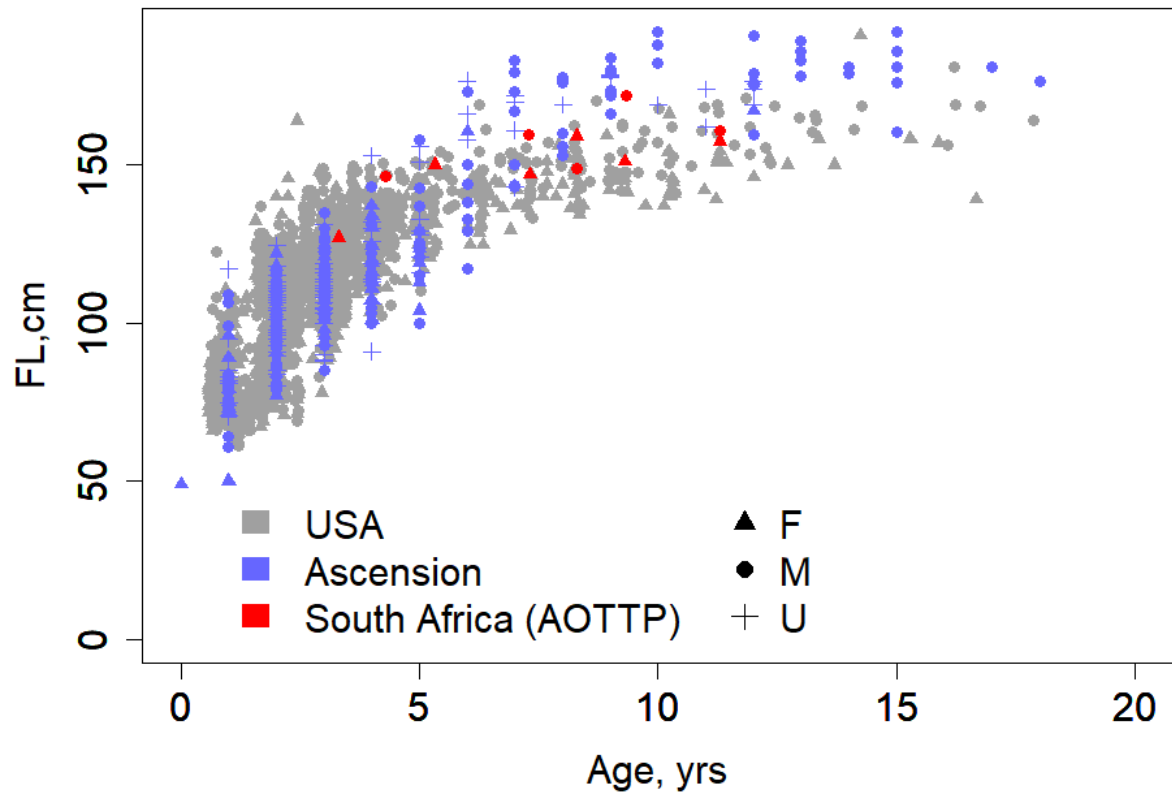


Figure 3. The size at age of YFT fish sampled off Ascension Island, the USA and South Africa (AOTTP), by gender. No adjustment was made to annulus count for Ascension data.

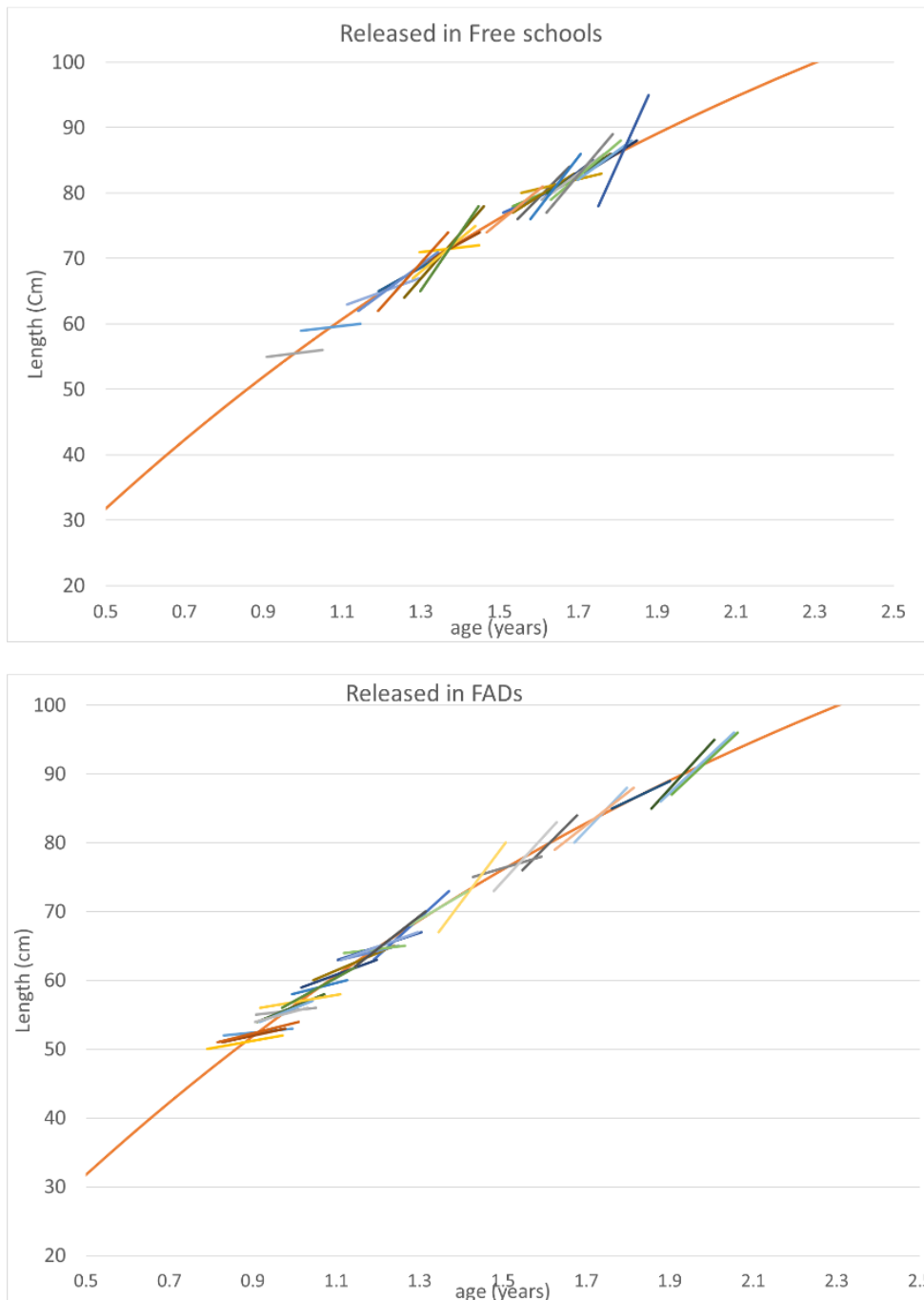
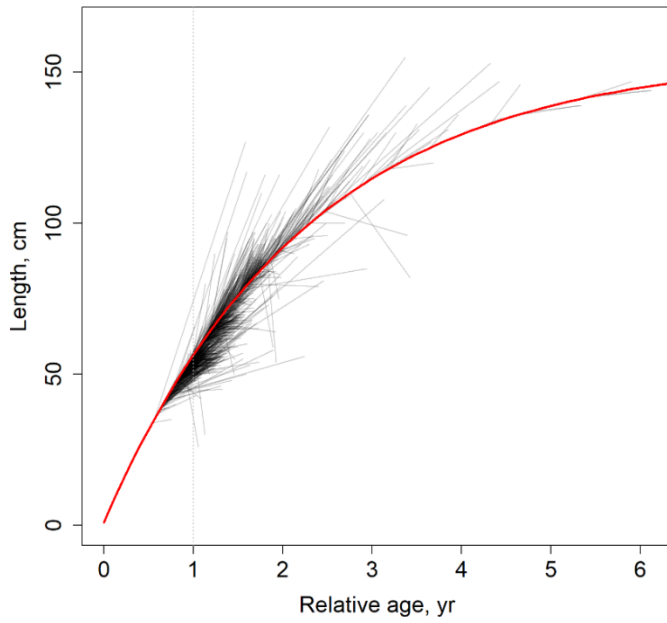


Figure 4. Fit to an assumed von Bertalanffy growth function for recaptured yellowfin tuna in the AOTTP ICCAT database.

a) Von Bertalanffy



b) Richards

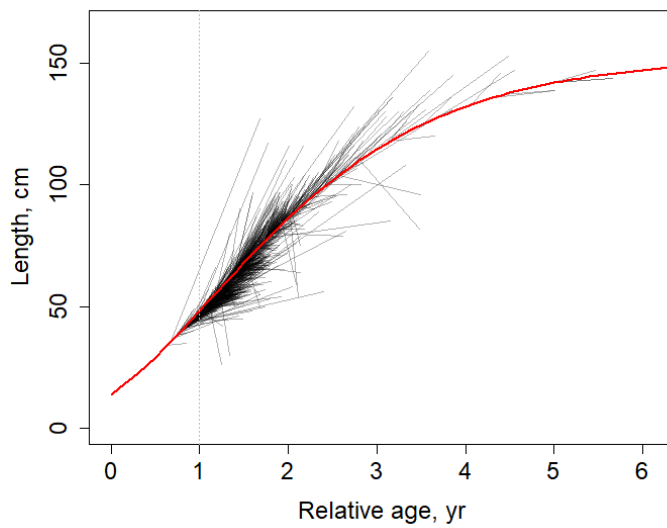


Figure 5. Vector plot of the growth increments of AOTTP fish measured upon recovery. The relative age of each fish at the time of tagging is estimated from the length at tagging by inverting the von Bertalanffy (top panel) and Richards (bottom panel) growth equations using parameters estimated by SS. The age at recapture is then taken to be the age at tagging plus the time at liberty. Each growth trajectory (shown in grey) starts on the fitted curve (shown in red).

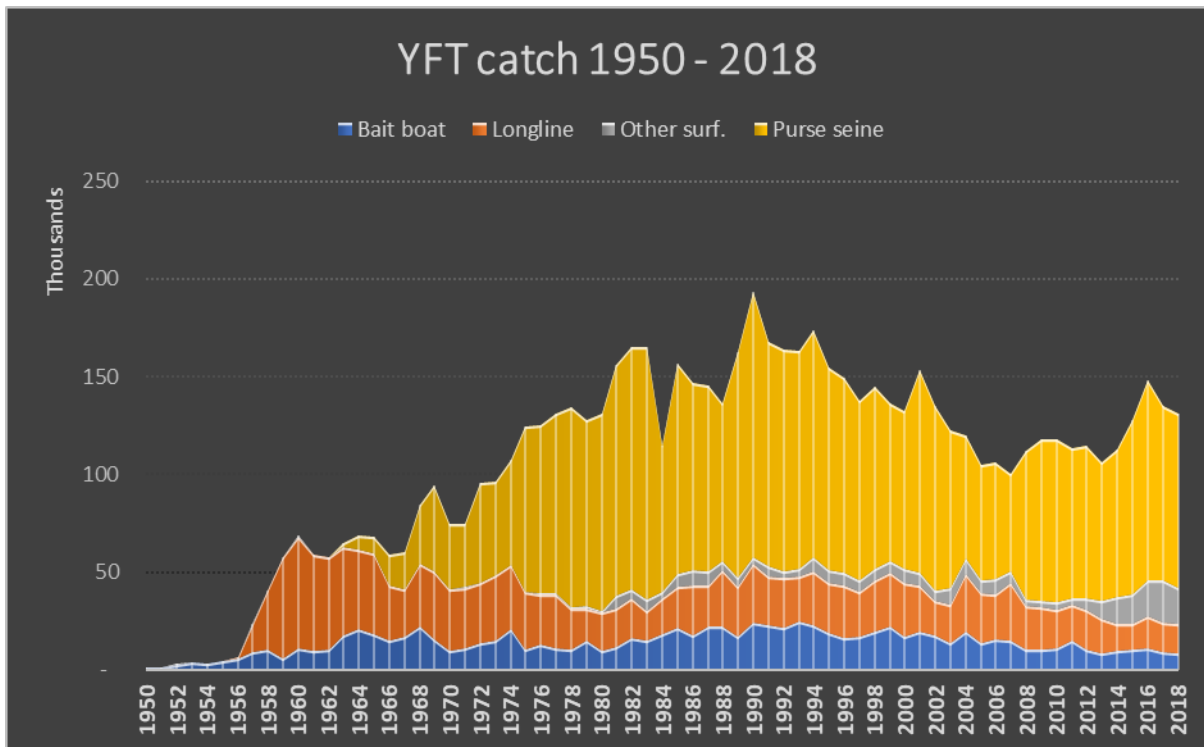


Figure 6. Yellowfin tuna total catch 1950 – 2018 by main fishing gear group. 2018 catch es preliminary.

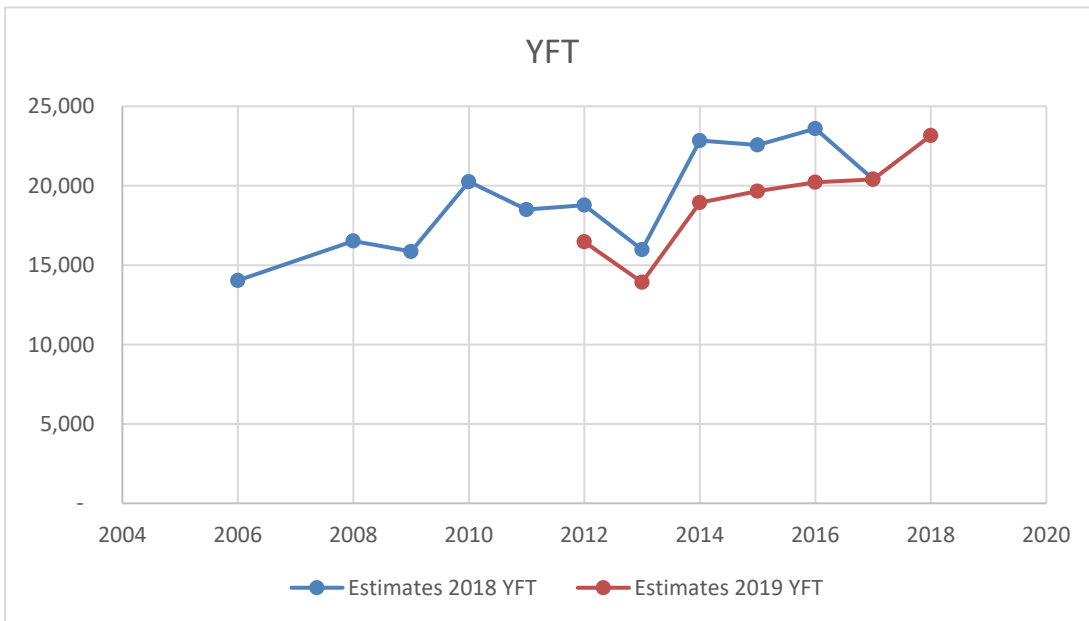


Figure 7. Comparison of YFT estimates of catch by the Ghana tropical fisheries PS and BB for 2018 (2006-2017) and the 2019 YFT stock assessment (2012-2018).

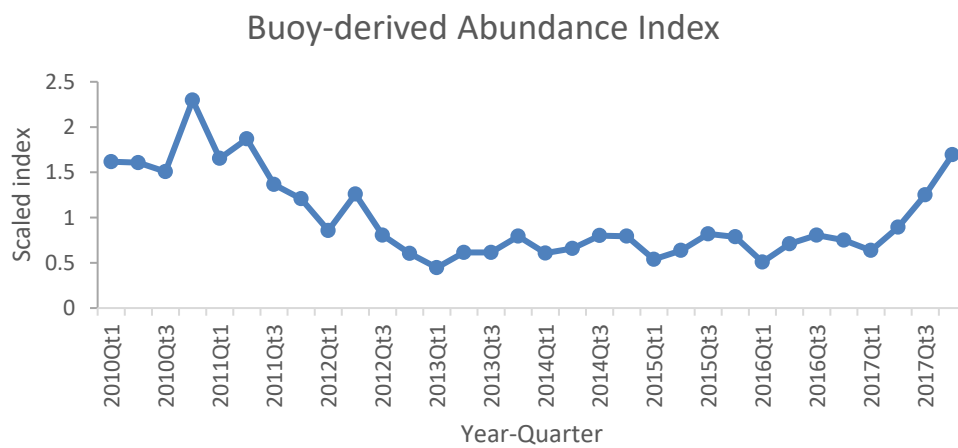
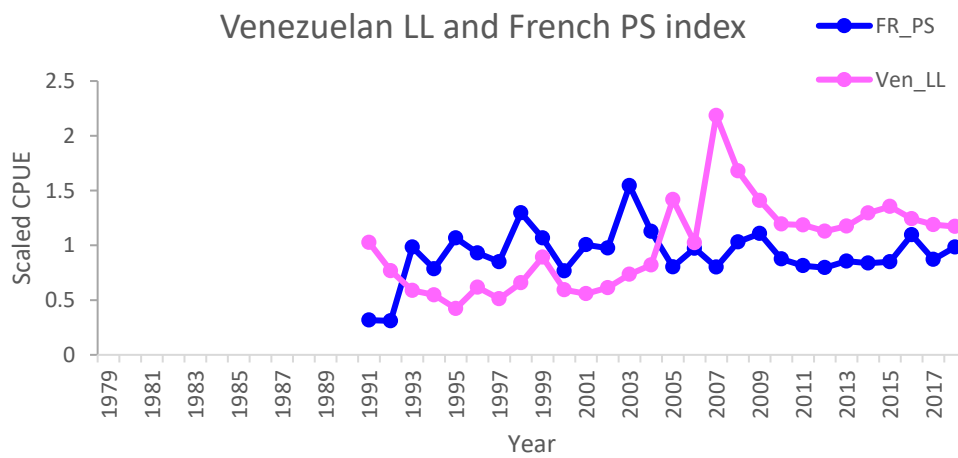
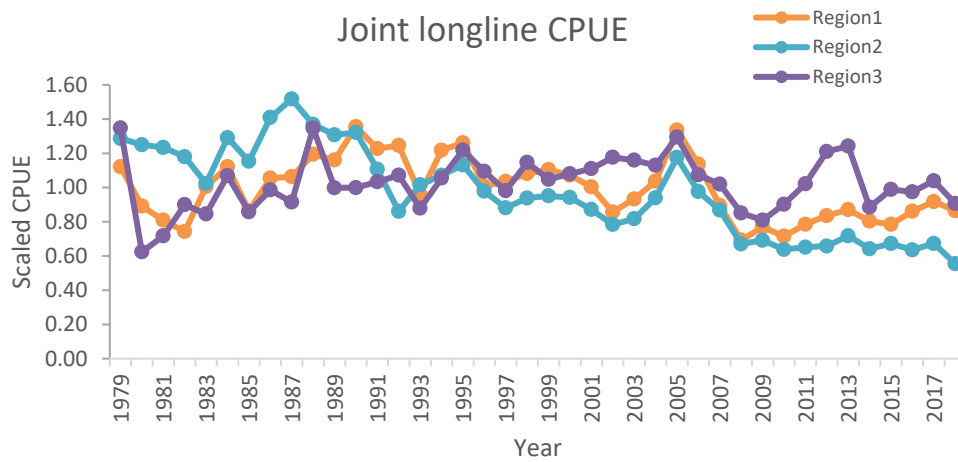


Figure 8 Recommended annual abundance indices for the Atlantic yellowfin tuna stock assessment reference case. This figure reflects revisions made following the data preparatory meeting.

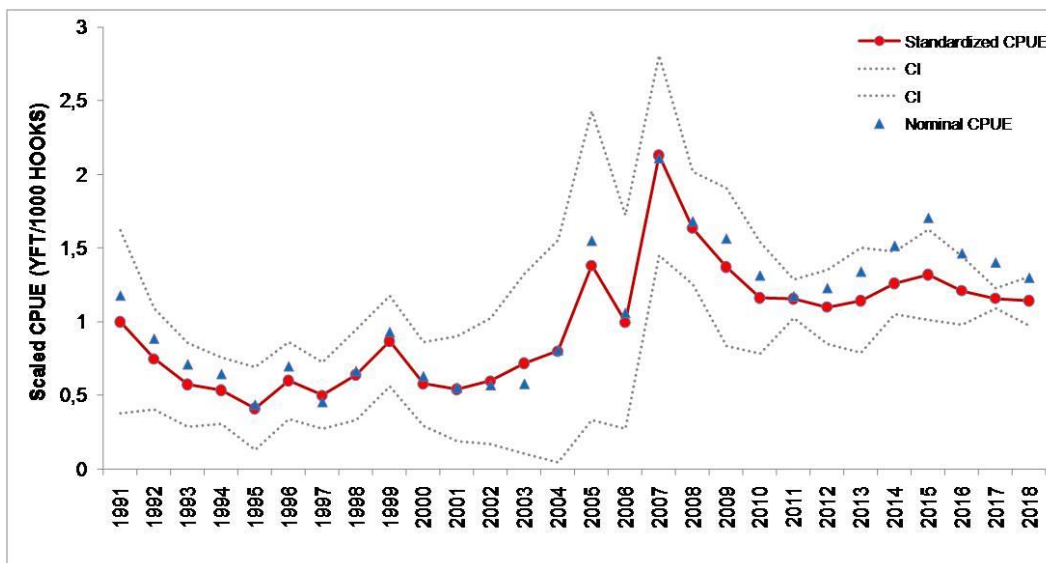


Figure 9. Scaled nominal (blue triangles) and standardized (red circles) CPUE in numbers of yellowfin tuna caught by the Venezuelan longline fleet during the period 1991-2018. The dotted lines represent the 95% confidence intervals.

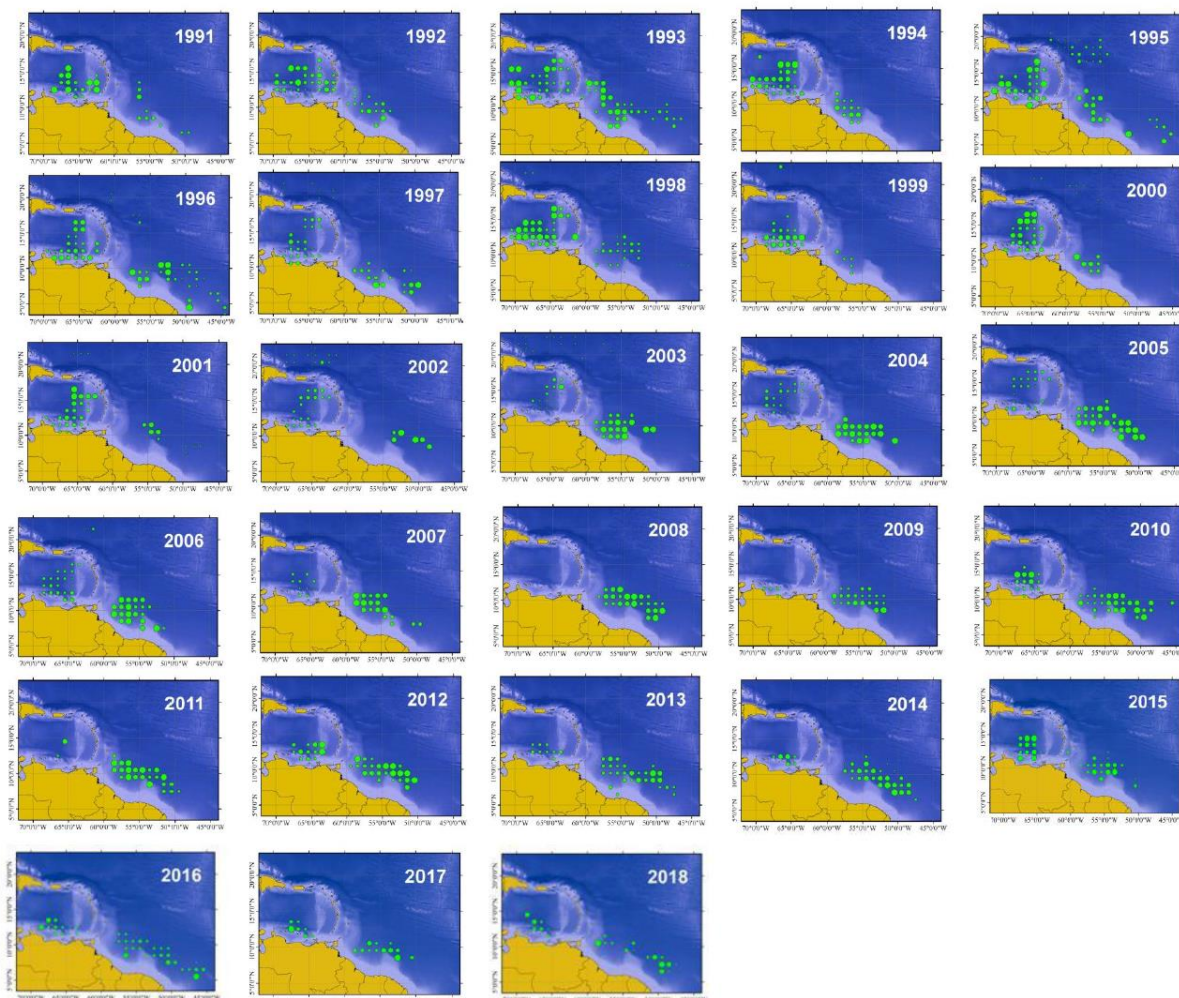


Figure 10. Spatial distribution of nominal CPUE of yellowfin tuna (Number fish/1000 hooks) caught by the Venezuelan pelagic longline fleet during 1991-2018.

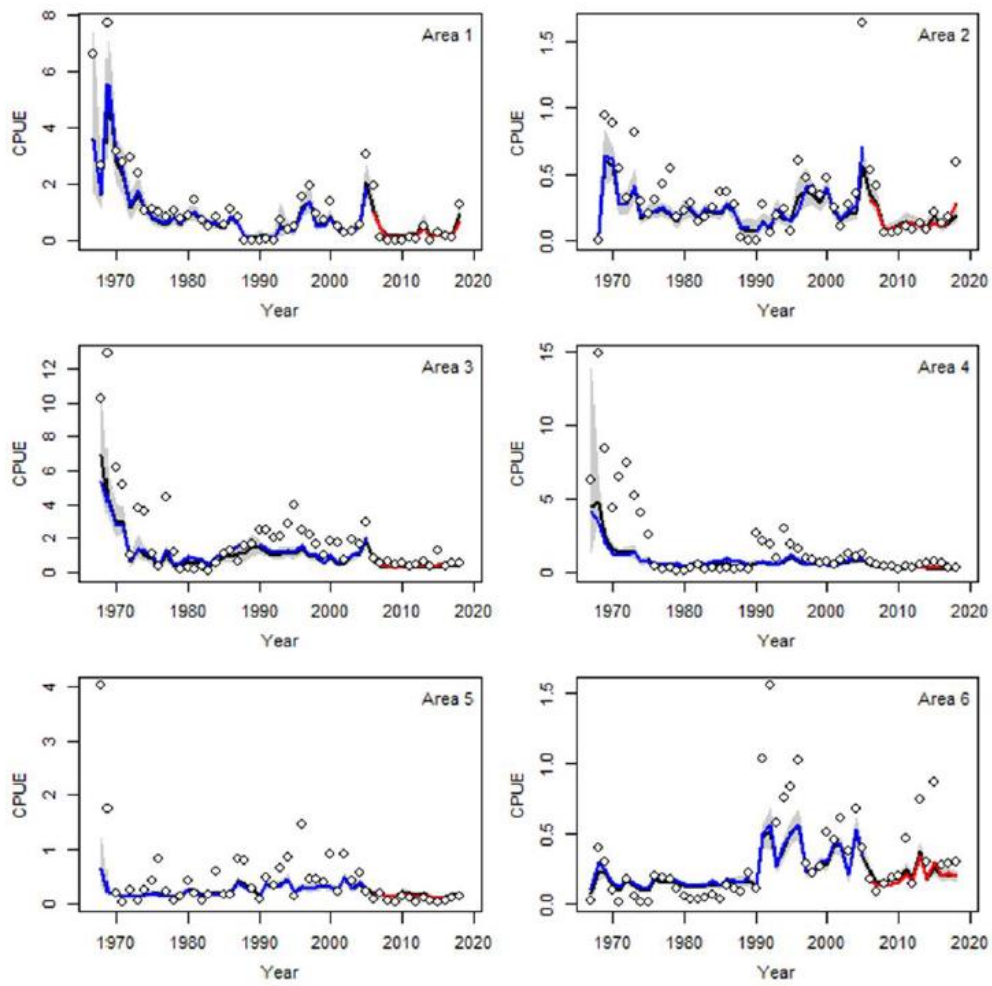


Figure 11. Indices of abundance from the Chinese Taipei distant water longline fishery. Nominal (open circles) and standardized (solid lines) CPUE of yellowfin tuna by period 1967-2018 (black lines), 1967-1989, 1990-2005 (blue lines) and 2006-2018 (red lines). Hooks-per-basket information was available for the latter period. The shaded areas represent the 95% confidence intervals for the entire period (1967-2018).

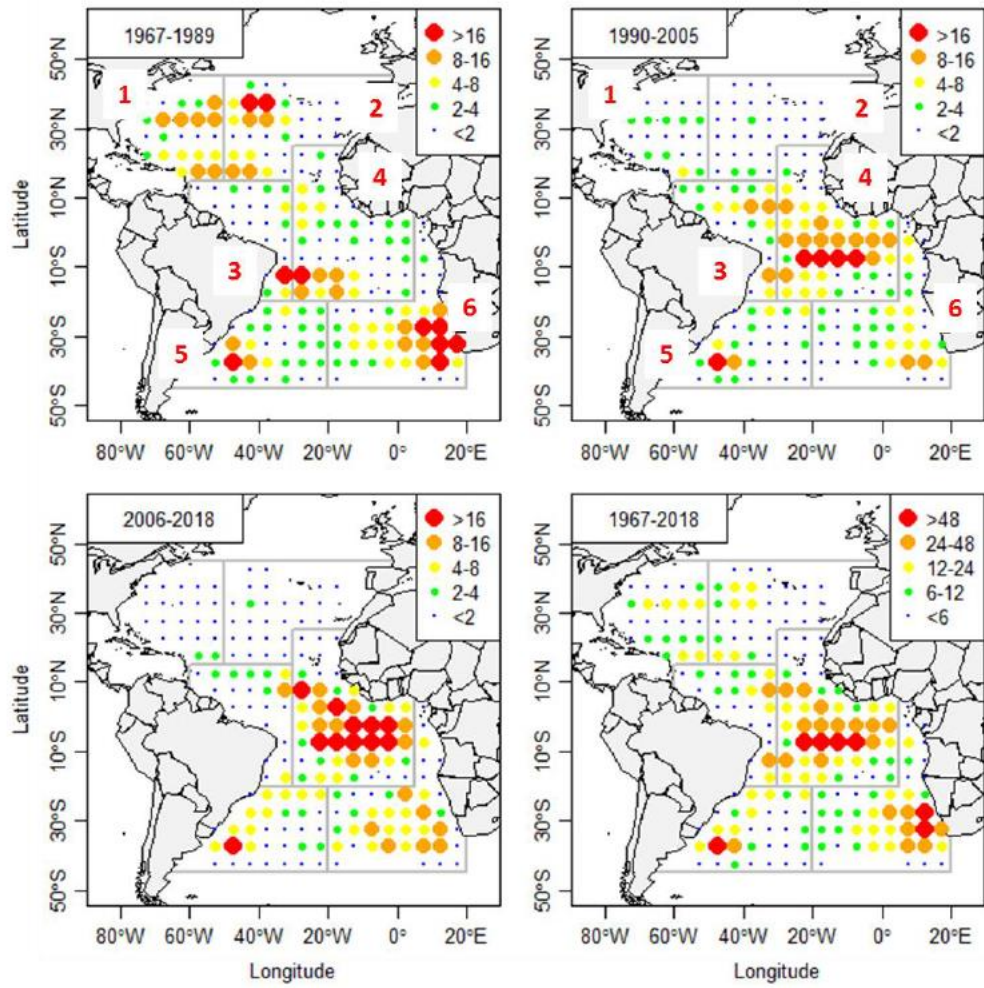


Figure 12. Distributions of fishing effort (million hooks) for the Chinese Taipei distant-water tuna longline fishery for the periods 1967-1989, 1990-2005, 2006-2018 and 1967-2018.

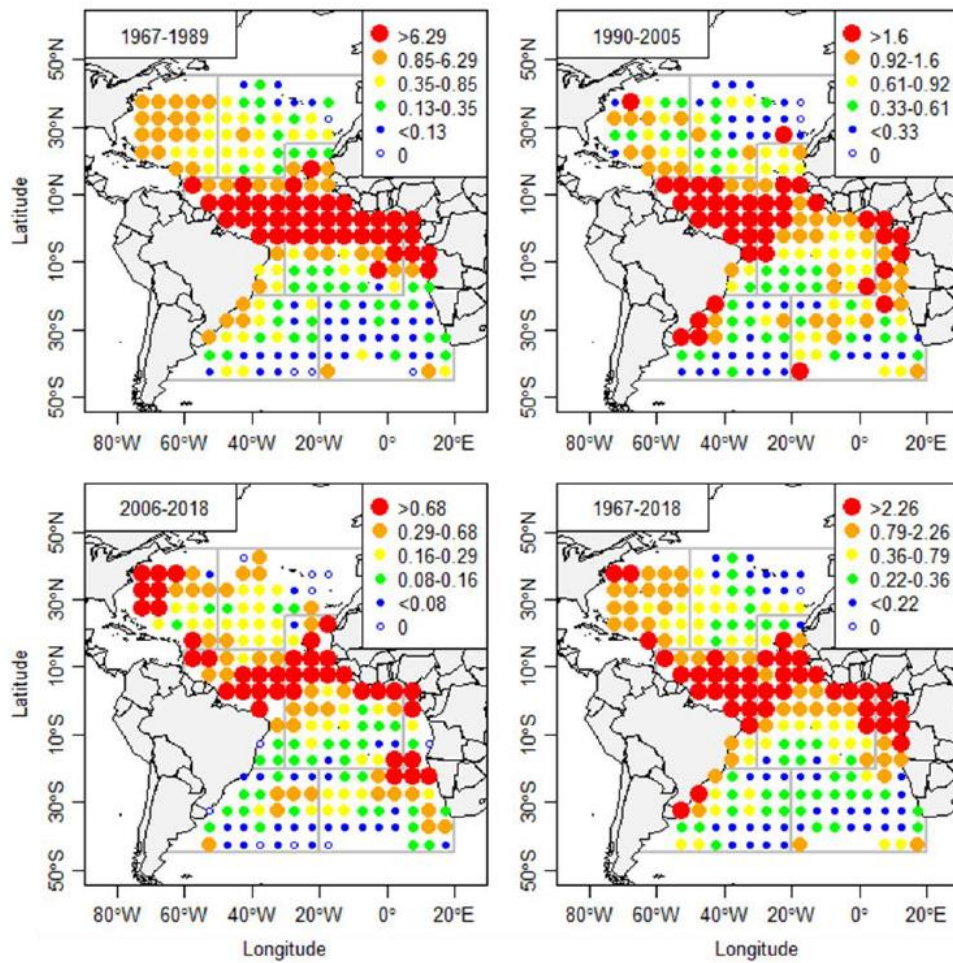


Figure 13. Distribution of nominal CPUE (number of fish caught per 1000 hooks) for yellowfin tuna caught in the Chinese Taipei distant-water tuna longline fishery for the periods of 1967-1989, 1990-2005, 2006-2018 and 1967-2018.

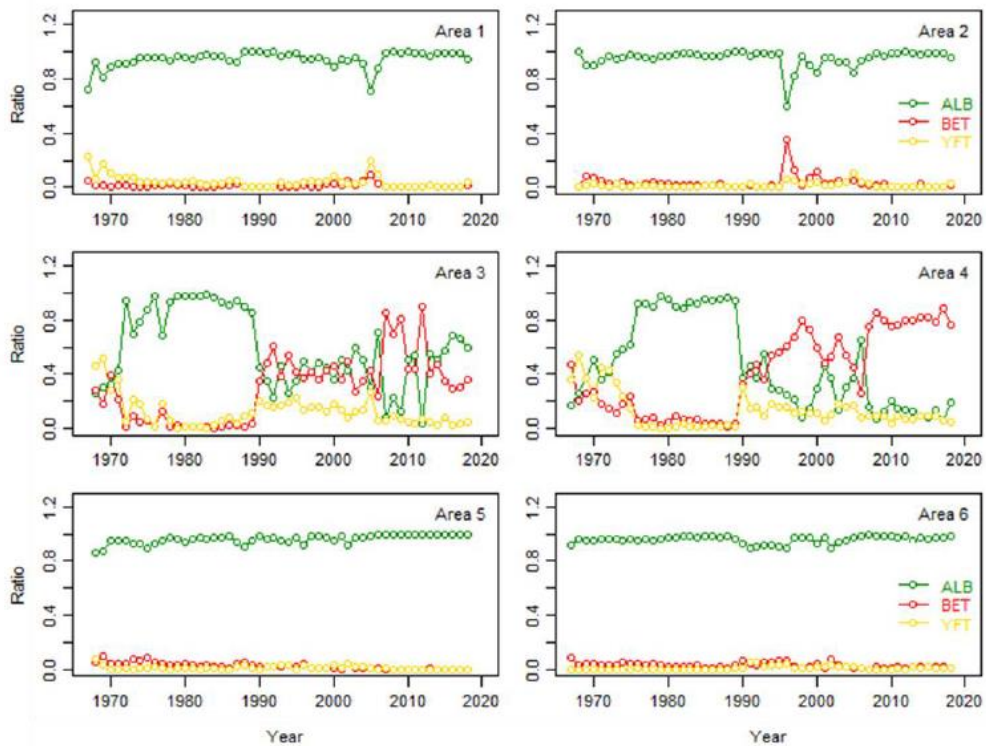


Figure 14. Catch ratios of albacore (ALB), bigeye (BET) and yellowfin tuna (YFT) by area for the China-Taipei distant-water tuna longline fishery. Changes in catch ratio are typically the result of a change in targeting.

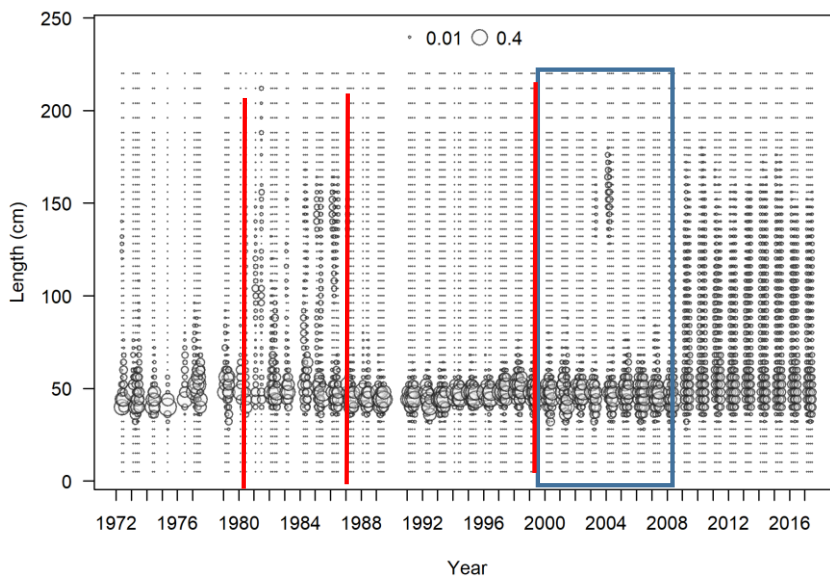


Figure 15. Length composition input for Fleet 11 Ghana BB_PS

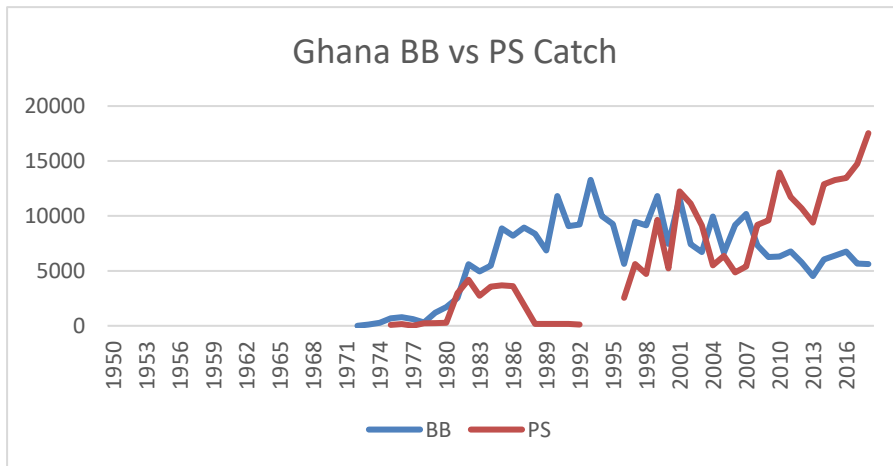


Figure 16. Distribution of catch between PS and BB from Fleet 11 Ghana BB_PS

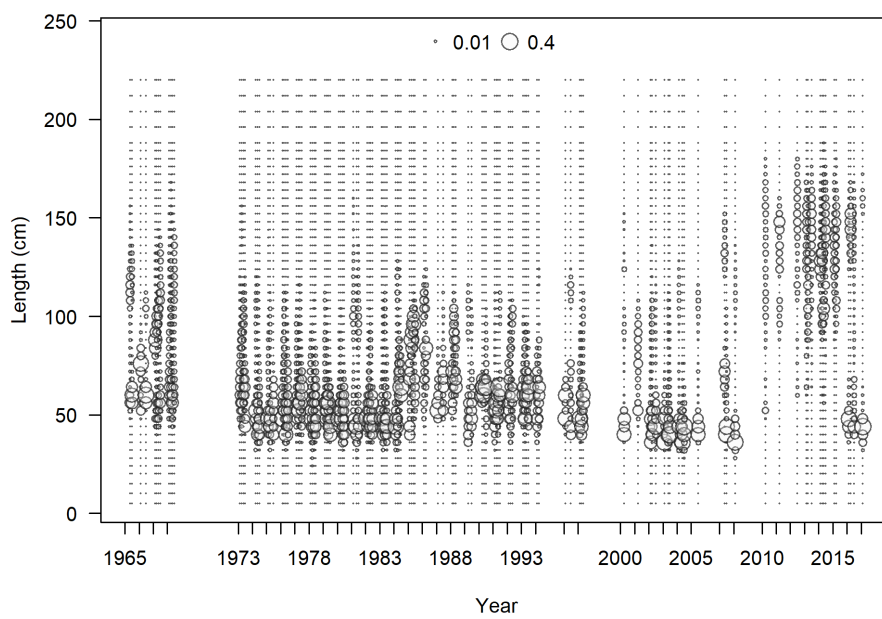


Figure 17. Length composition input for Fleet 12 BB_area2_Sdak before South Africa size data were removed.

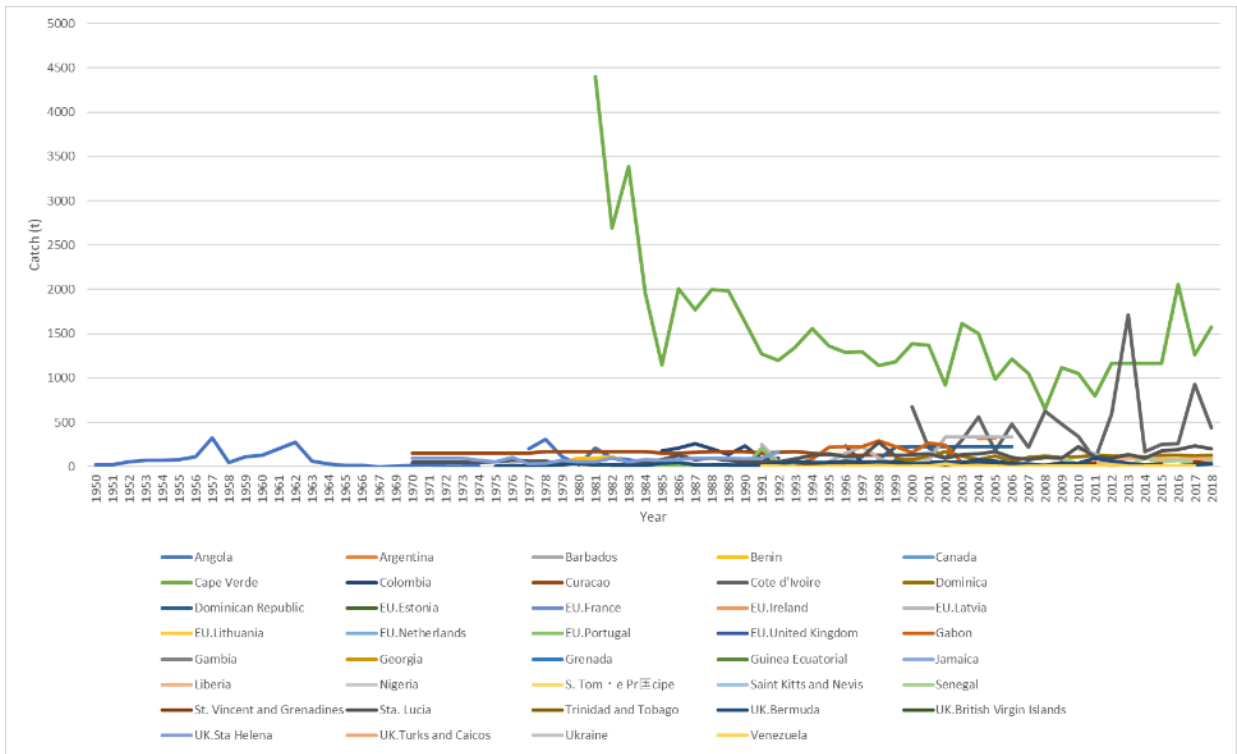


Figure 18. Catch in Fleet 25 other by country before Cape Verde data were removed.

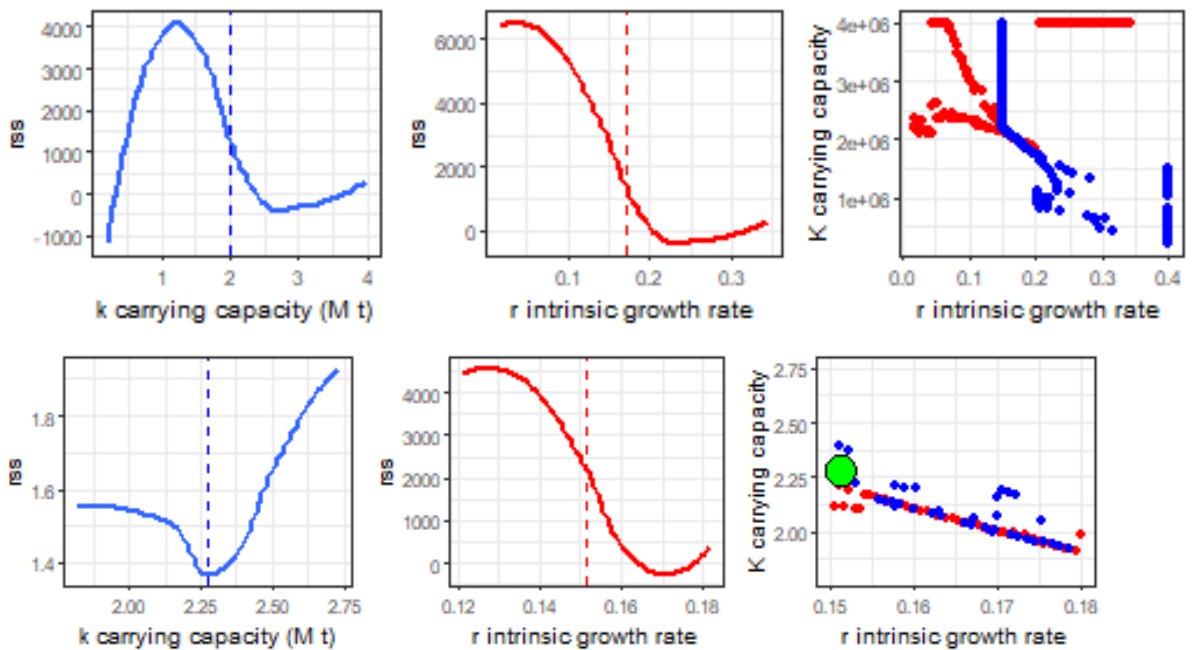


Figure 19. Likelihood profiles for r and K resulting from run 1 of the mpb model (top) vs. run 2 (bottom).

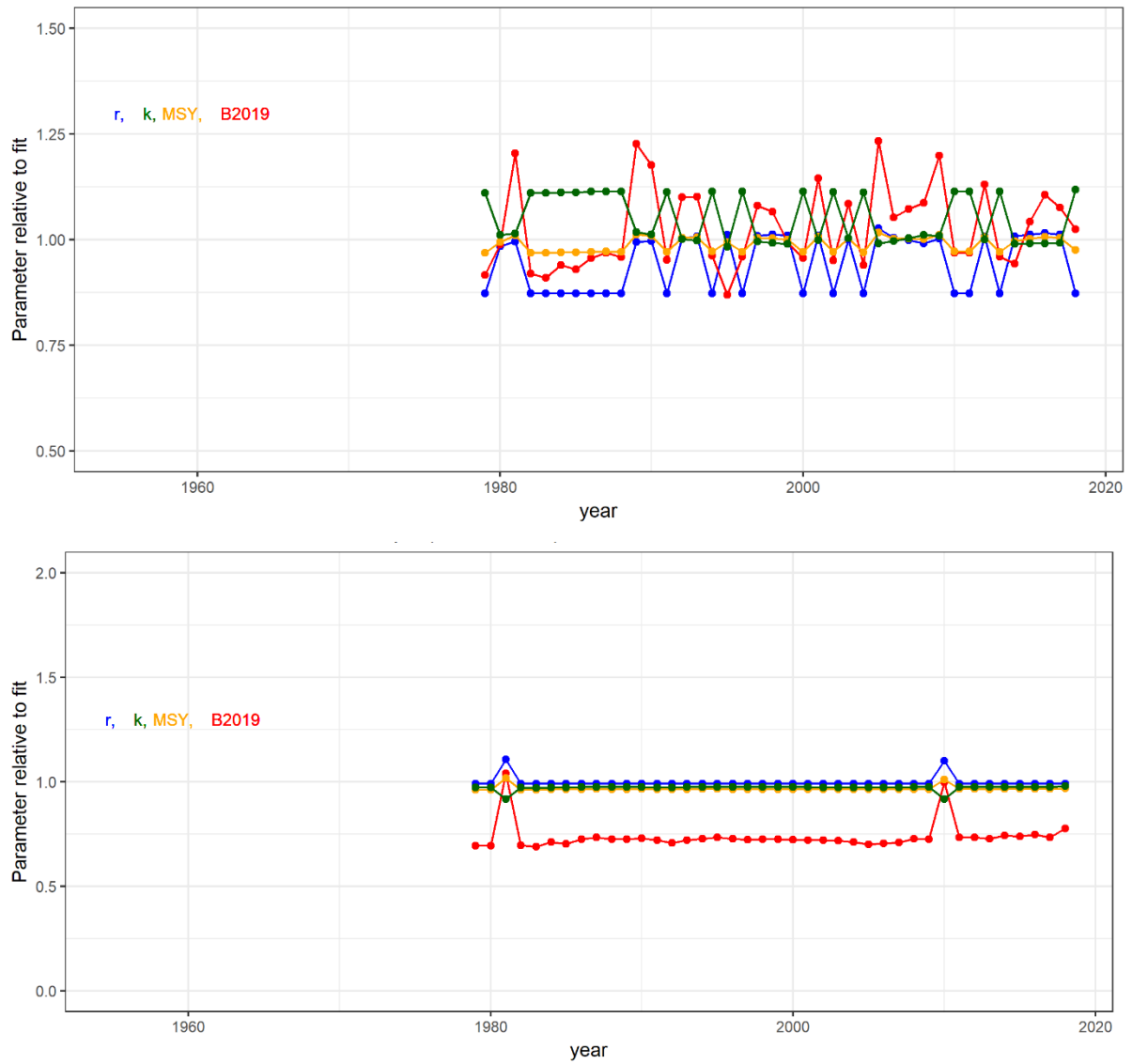


Figure 20. Improvements in the jackknife between run 1 (top) and run 2 (bottom) of *mpb*. Each point represents the change in the parameter estimate resulting from removing that year's data.

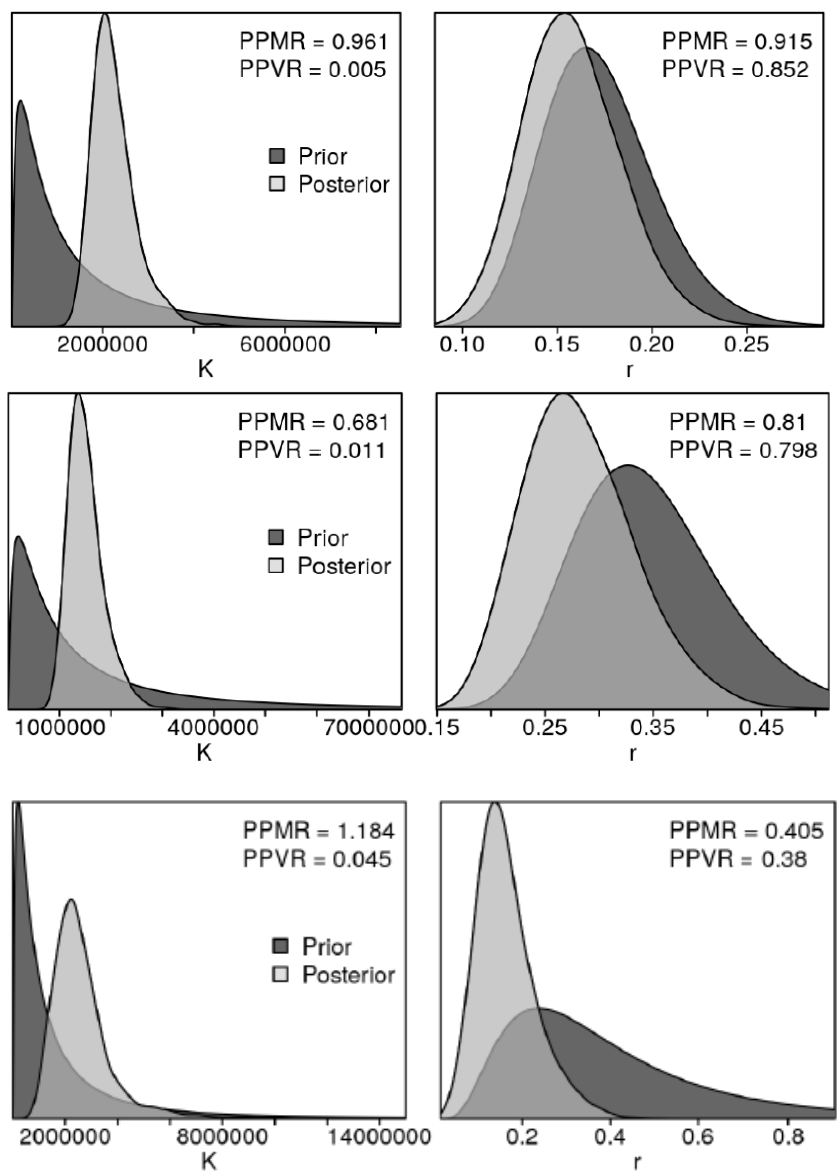


Figure 21. Prior and posterior distributions for K and r resulting from JABBA using an SS3 2019 prior (run 6, top), FishLife prior with a CV = 0.3 (run 2, middle), FishLife prior with a CV = 0.6 (run 14, bottom).

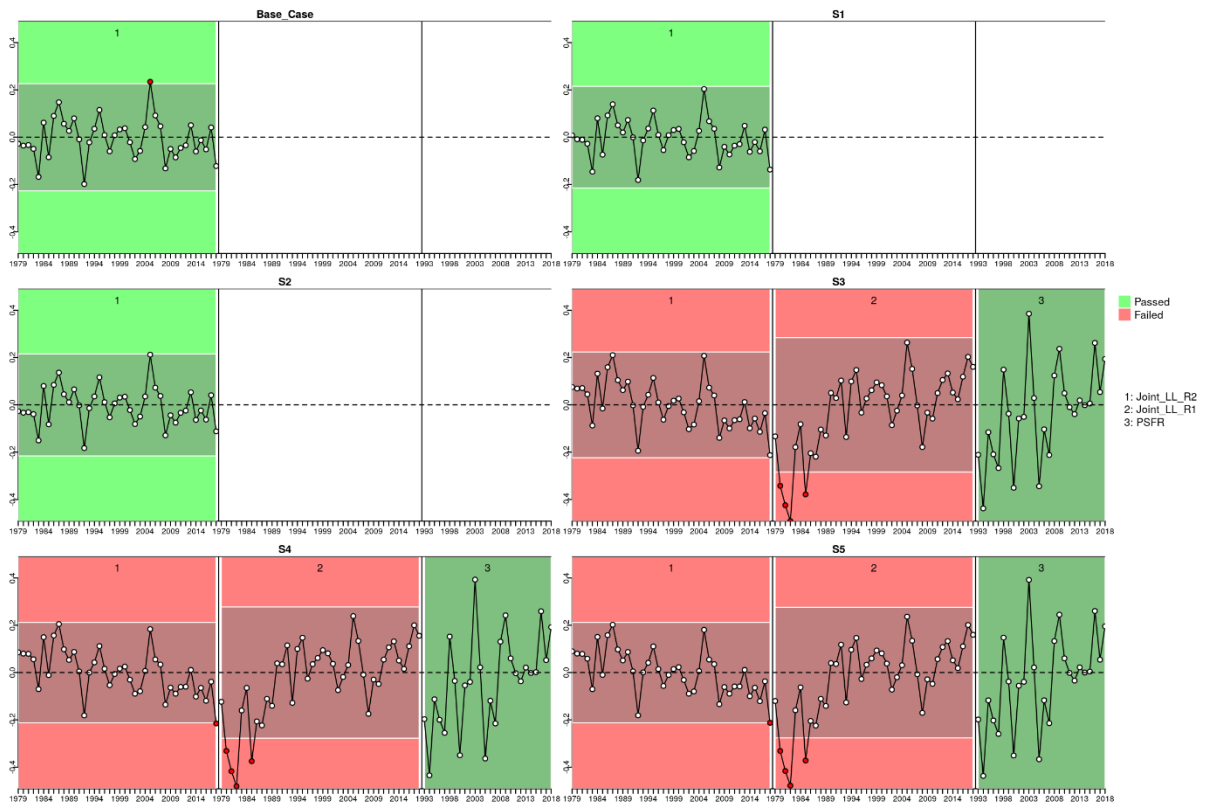


Figure 22. Diagnostic test, quantitative evaluation of the randomness of the time series of CPUE residuals by fleet for runs 6, 1, 16, 13, 18, 17 (from top left to bottom right). Green panels indicate no evidence of lack of randomness of time-series residuals ($p > 0.05$) while red panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

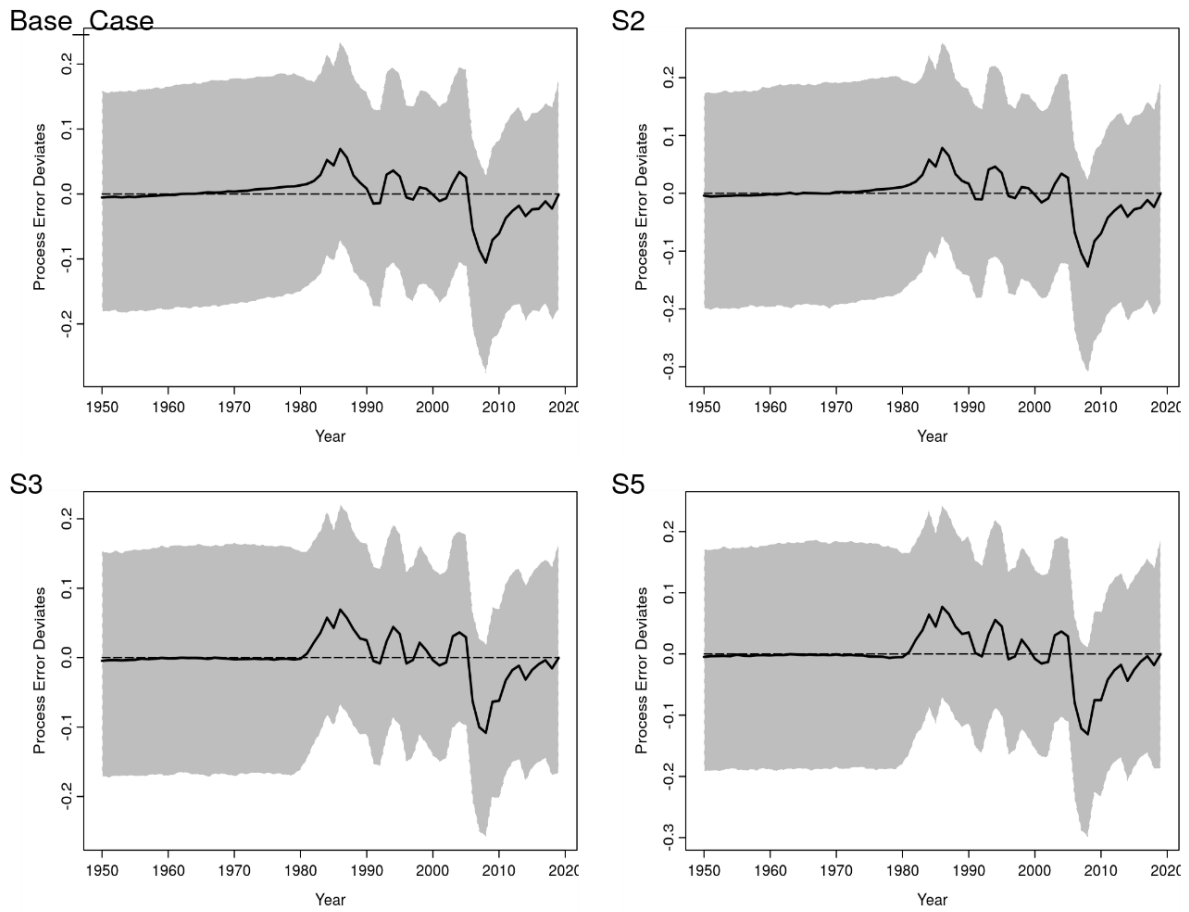


Figure 23. Process error deviations (median: solid line) for the 4 reference runs: (from top left to bottom right) runs 6, 16, 13, 17. Shaded grey area indicates 95% credibility intervals.

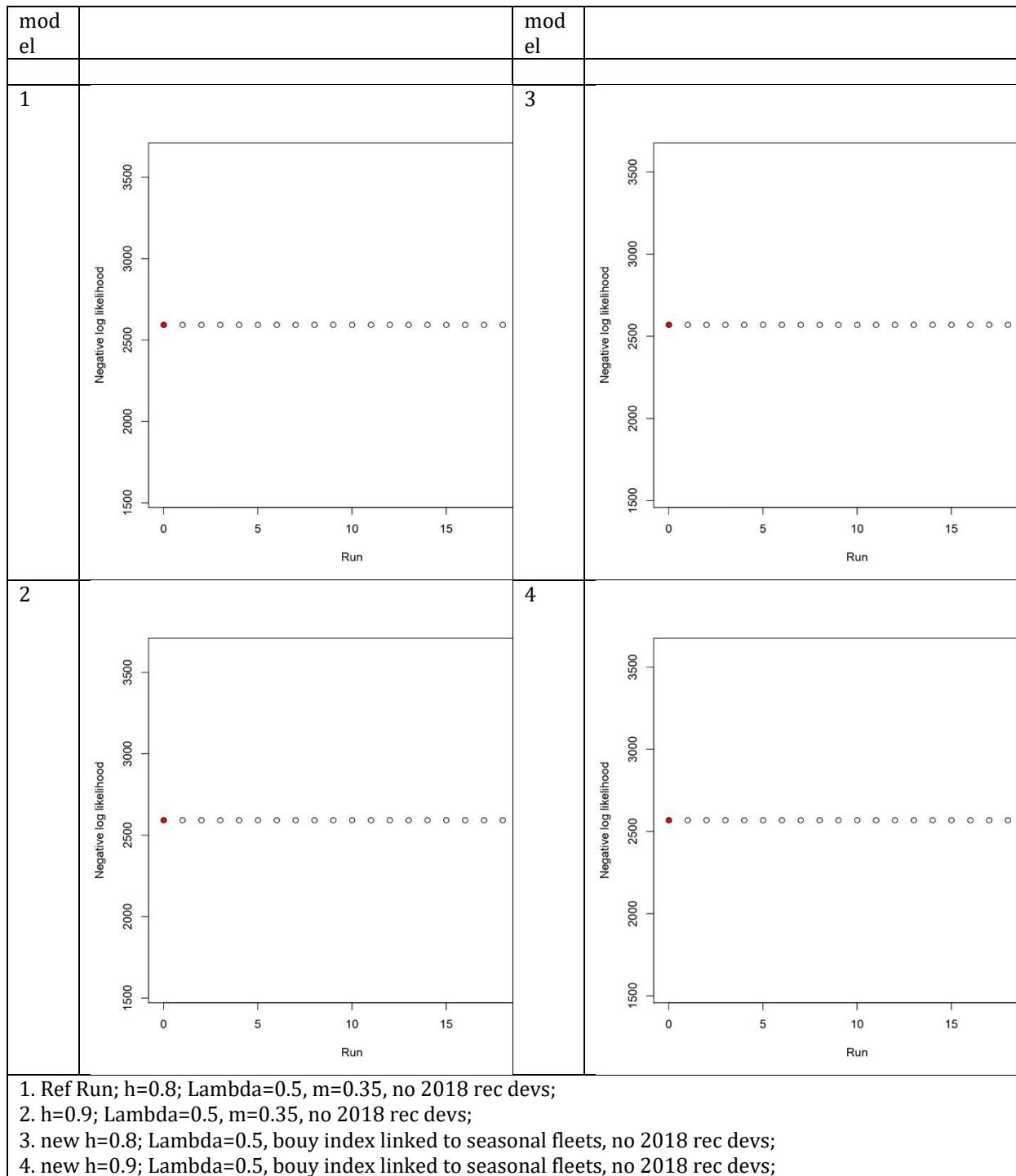


Figure 24. The jitter analysis for the Stock Synthesis runs.

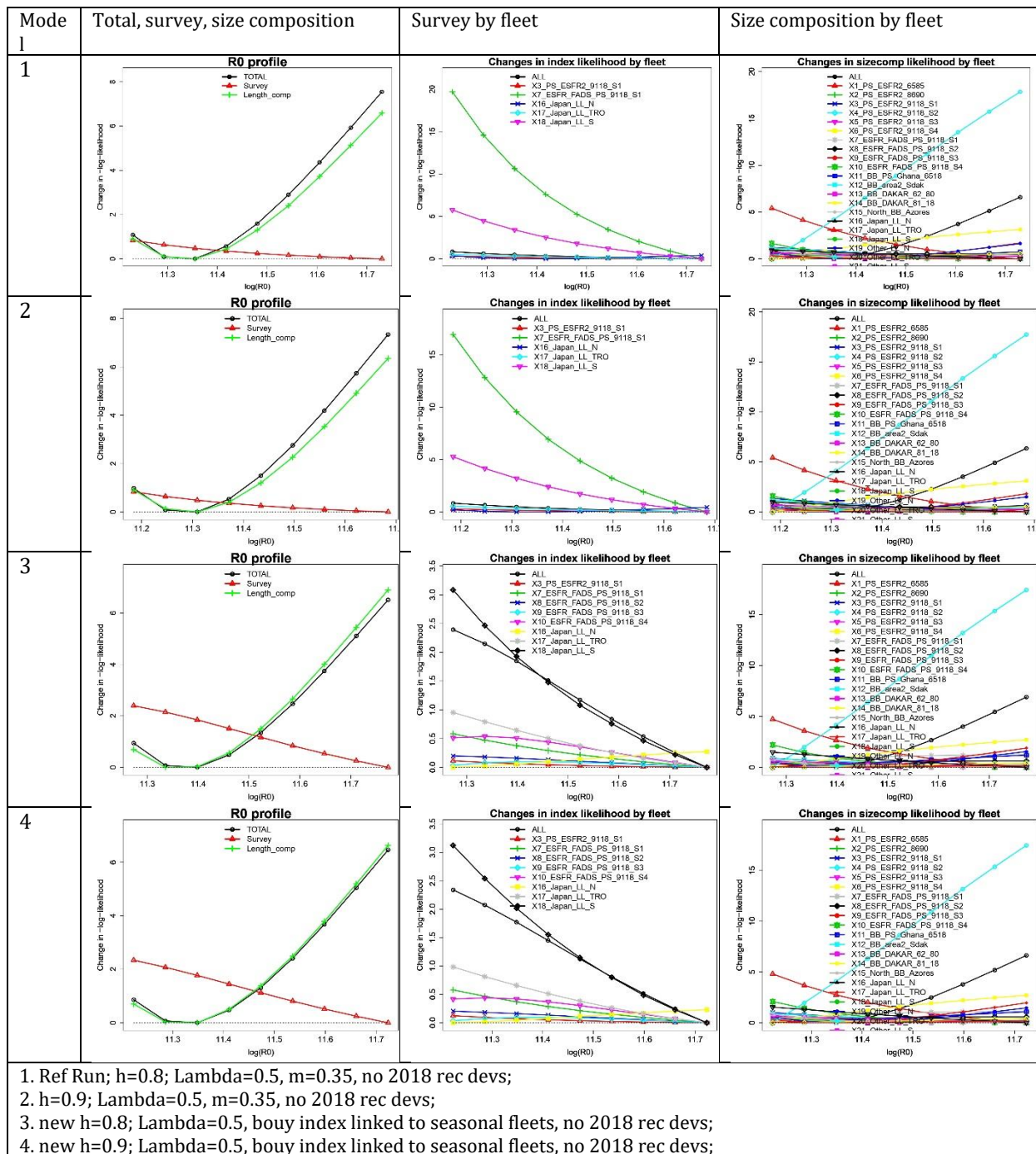


Figure 25. The likelihood profile of R0 for the Stock Synthesis runs.

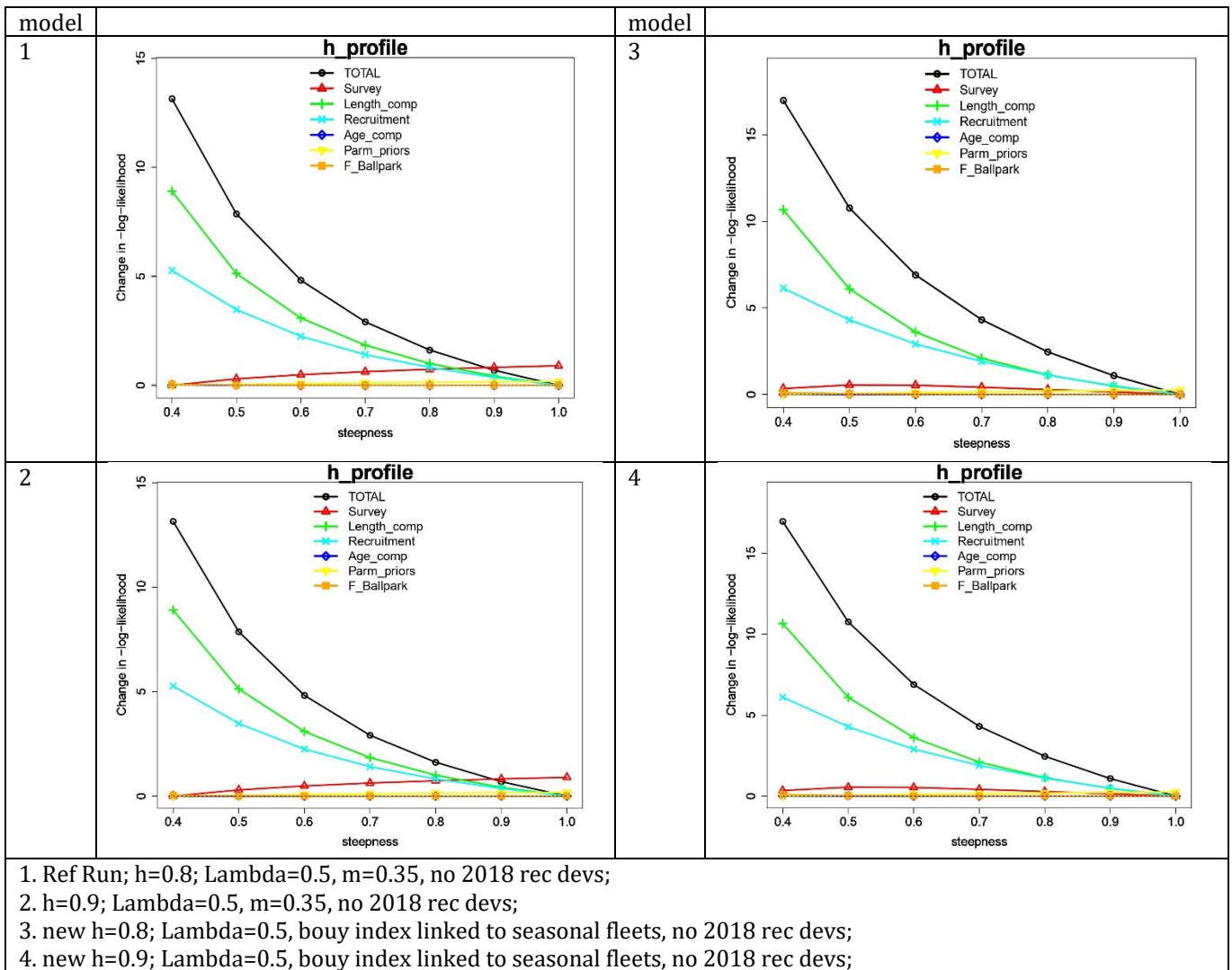


Figure 26. The likelihood profile of steepness (h) for the Stock Synthesis runs.

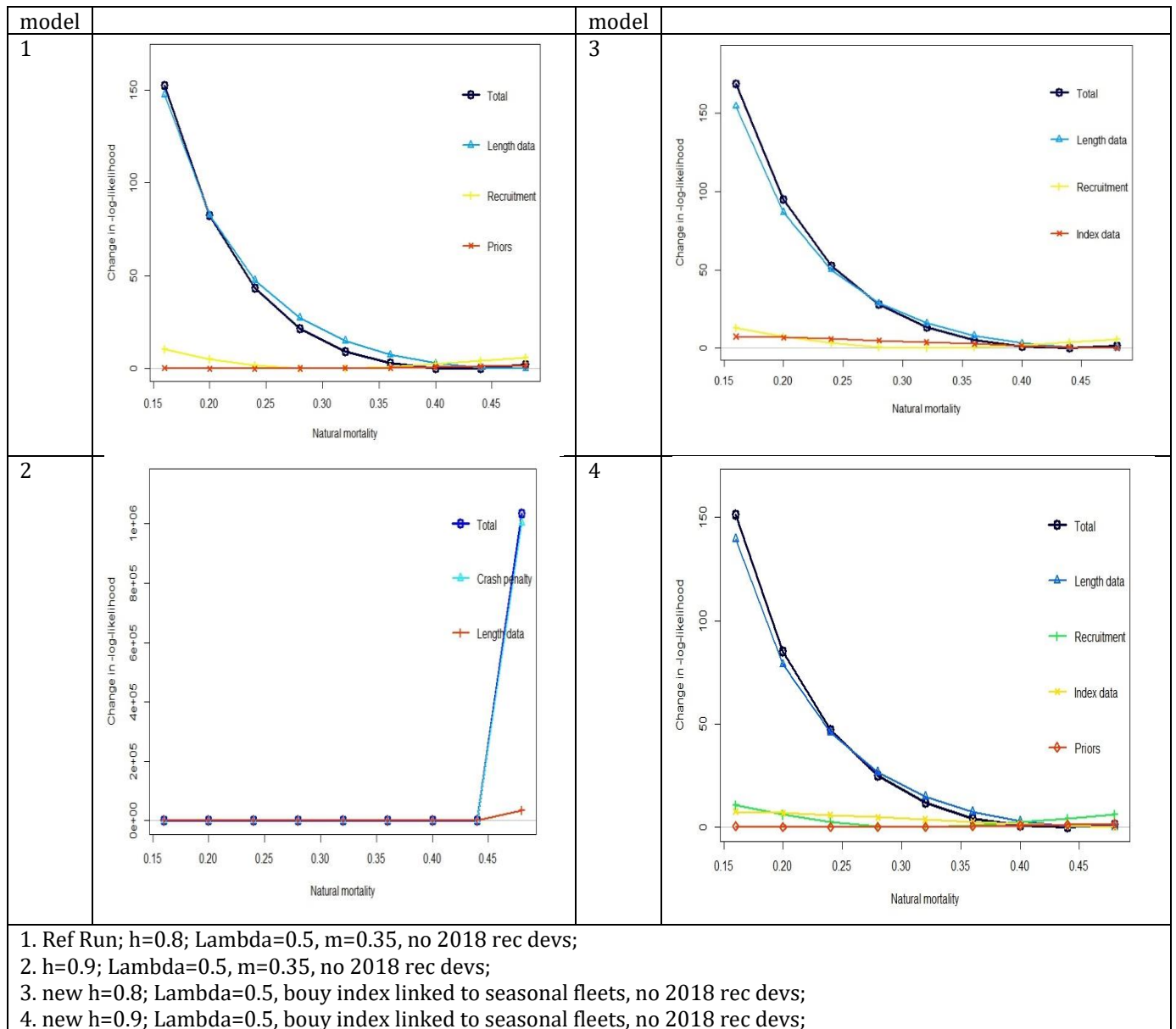


Figure 27. The likelihood profile of natural mortality (M) for the Stock Synthesis runs.

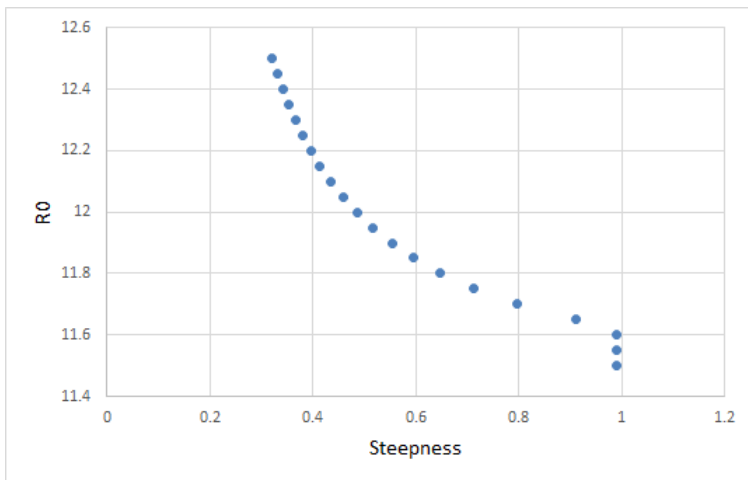


Figure 28. The high correlation between steepness and R_0 . Fixing certain values of steepness largely predetermined R_0 , therefore while R_0 was estimated in the model, steepness was fixed.

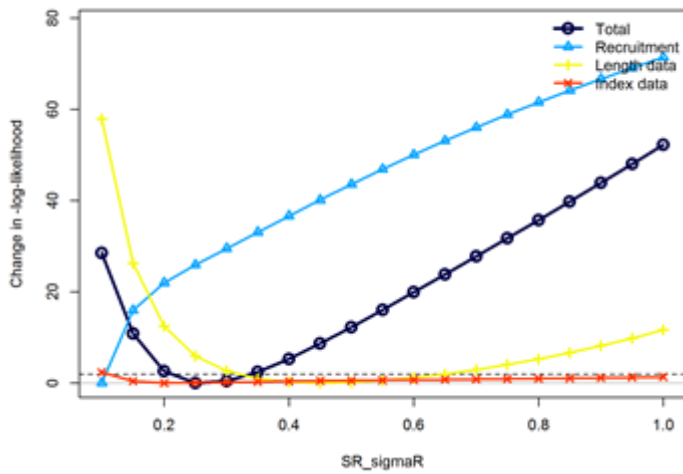


Figure 29. Likelihood profile of the annual variance in recruitment (SigmaR) from the reference case.

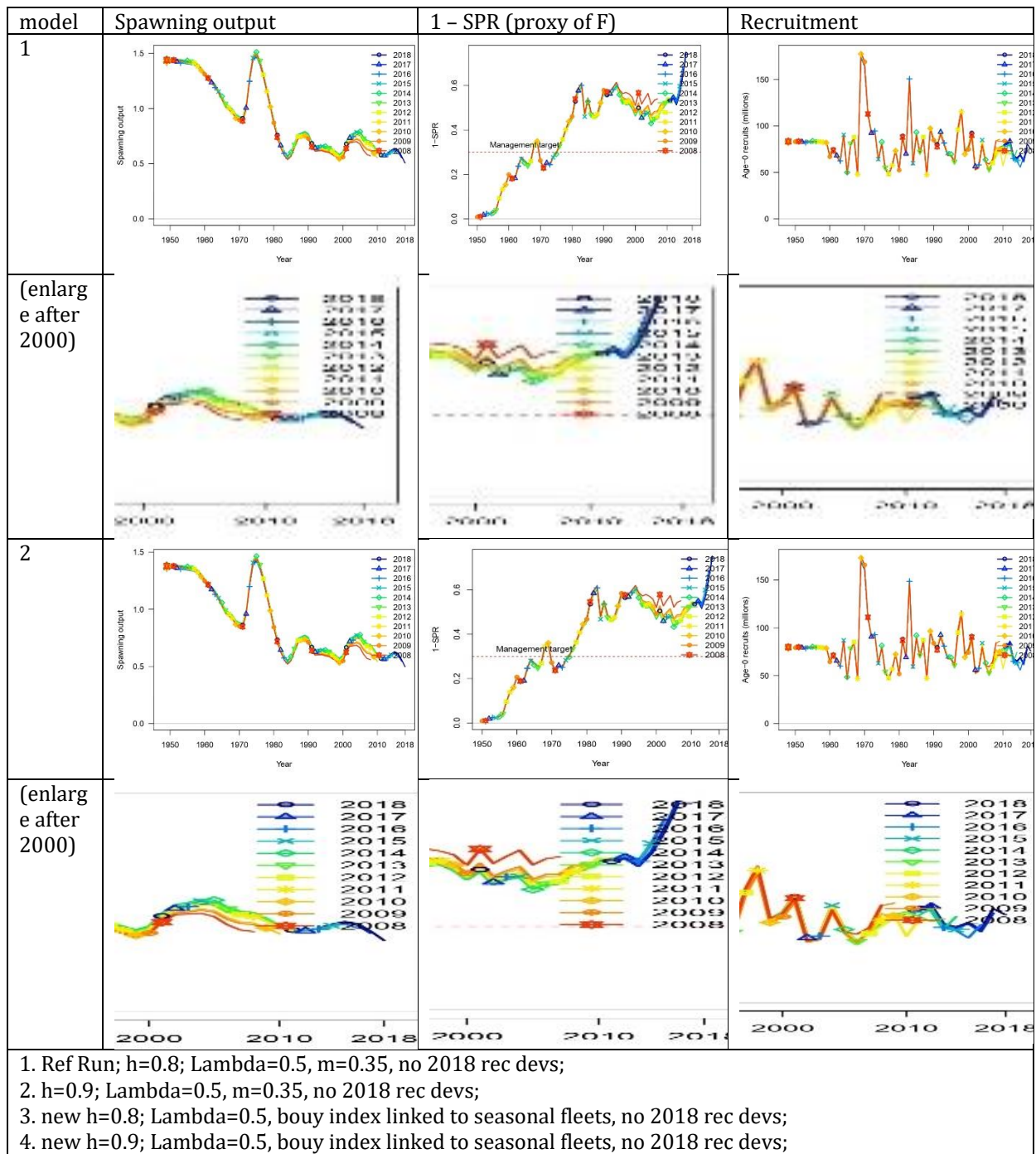


Figure 30. Retrospective analyses on the Stock Synthesis models.

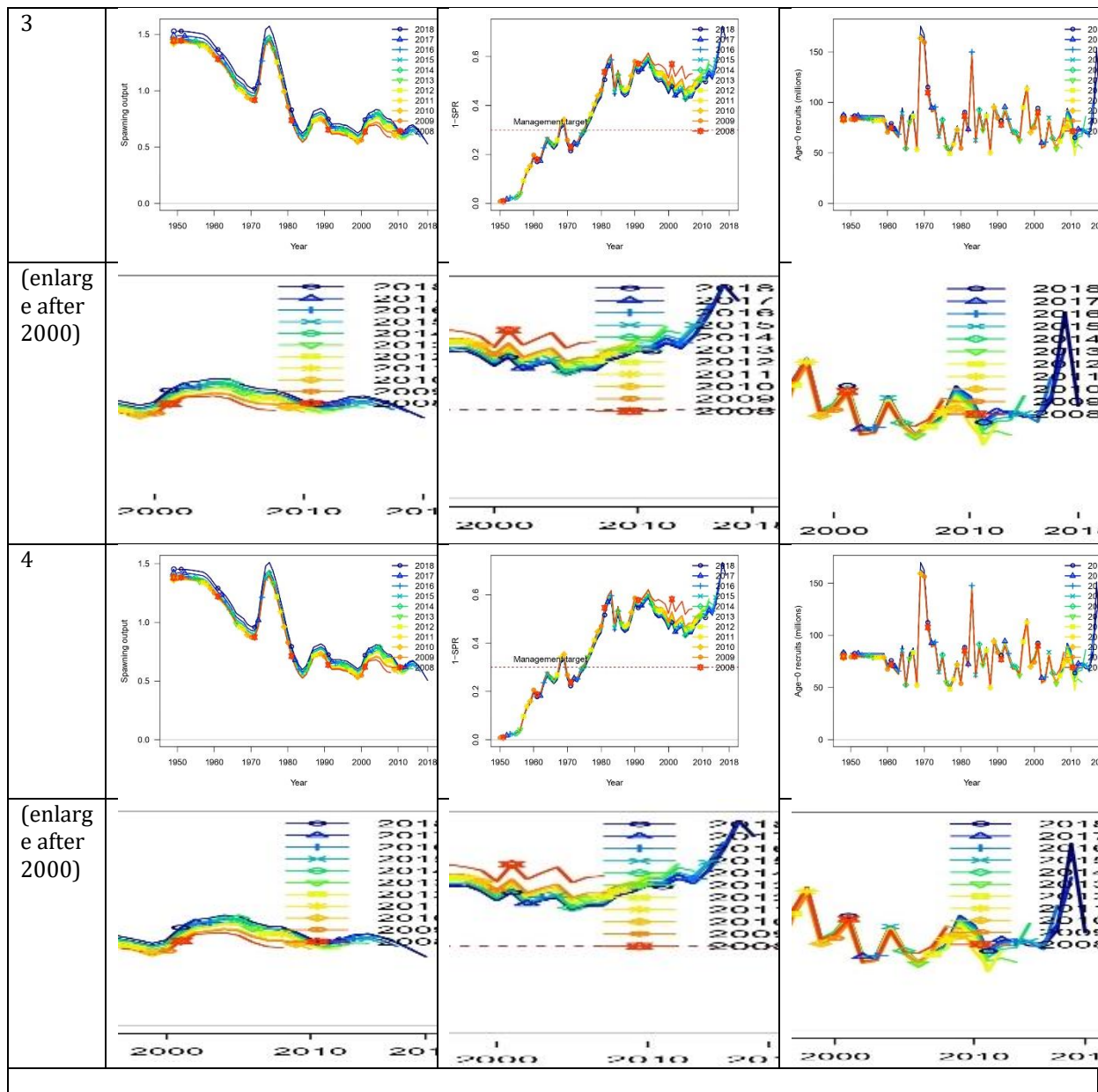


Figure 30 – continued from previous page. Retrospective analyses on the Stock Synthesis models.

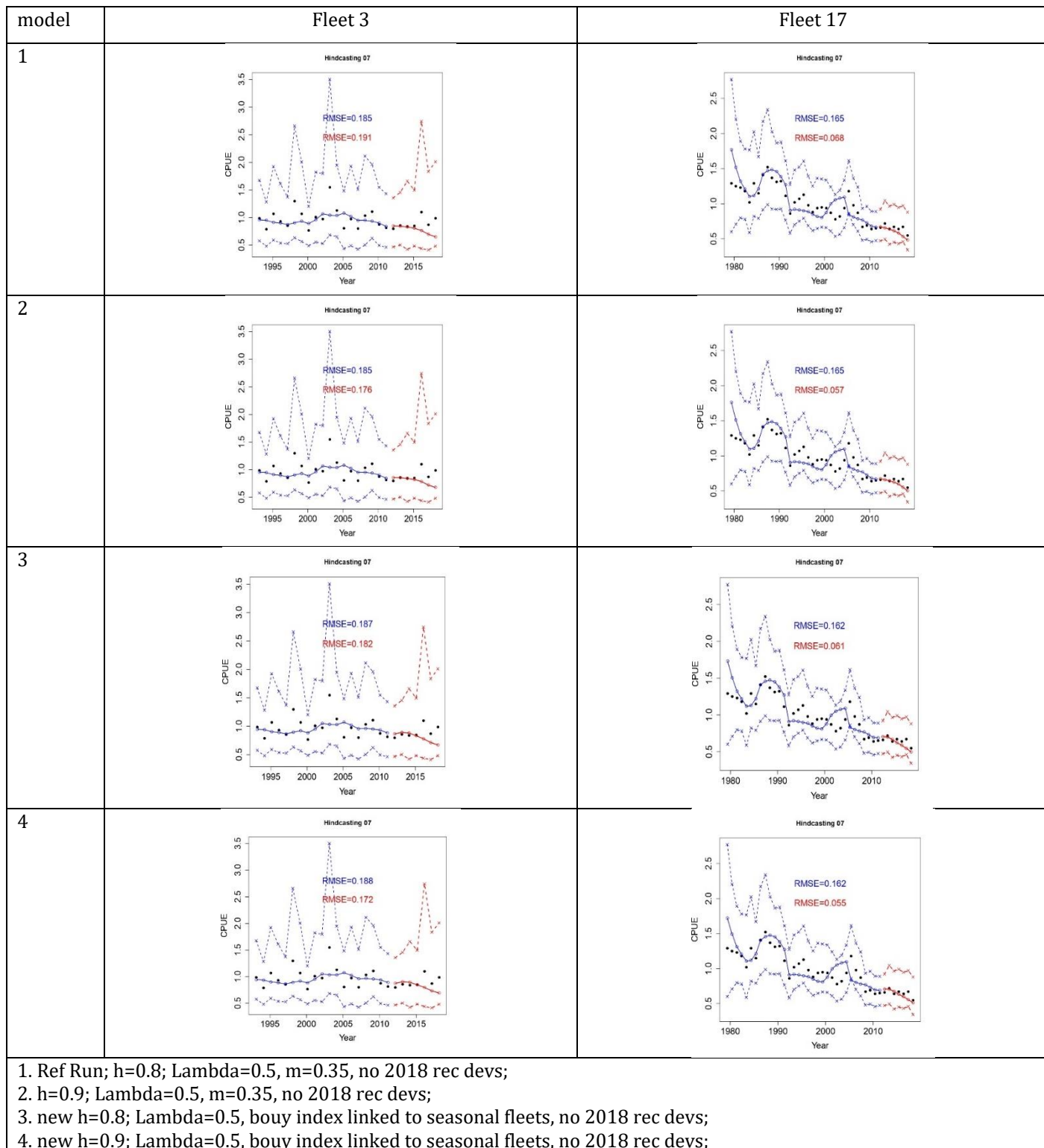


Figure 31. The hindcasting analysis for the Stock Synthesis model runs.

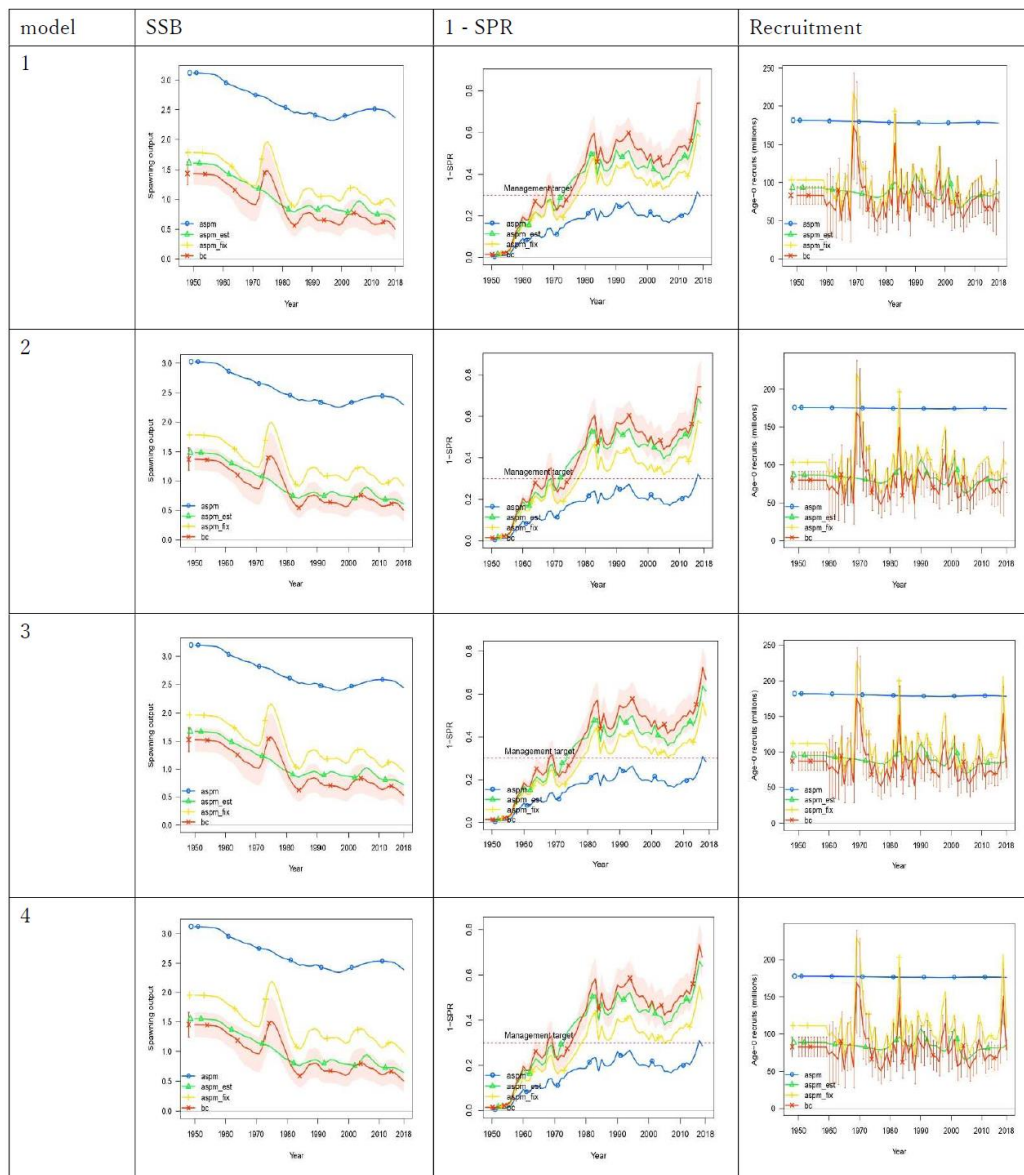


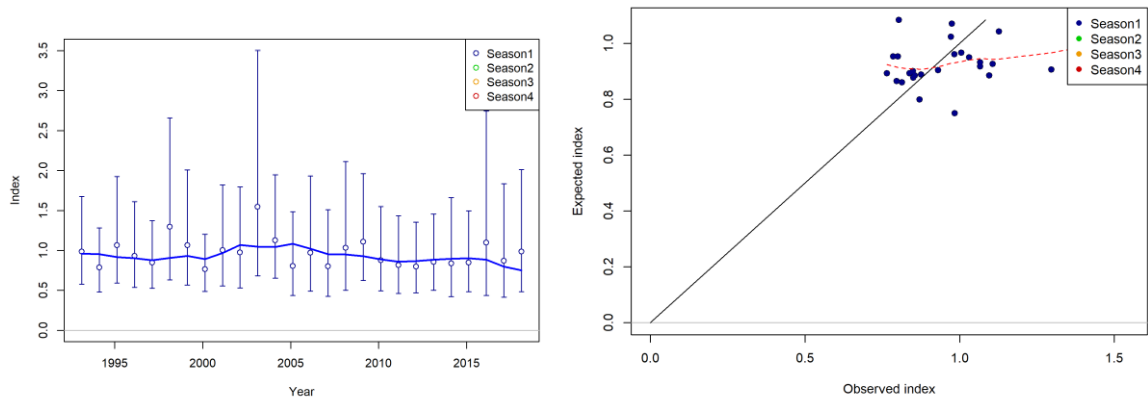
Fig. 8 ASPM analysis for uncertainty grid analysis

(bc: base case (integrated model), aspm: using the selectivity parameters from integrated model, the recruitment deviation is not used, aspm_est: using the selectivity parameters from integrated model, but estimated recruitment deviation, aspm_fix: using the selectivity parameters and recruitment deviation from integrated model).

1. Ref Run; $h=0.8$; $\Lambda=0.5$, $m=0.35$, no 2018 rec devs;
2. $h=0.9$; $\Lambda=0.5$, $m=0.35$, no 2018 rec devs;
3. new $h=0.8$; $\Lambda=0.5$, bouy index linked to seasonal fleets, no 2018 rec devs;
4. new $h=0.9$; $\Lambda=0.5$, bouy index linked to seasonal fleets, no 2018 rec devs;

Figure 32. Age Structured Production Model (ASPM) analysis for Stock Synthesis model. Note: bc: base case (integrated model), aspm: using the selectivity parameters from integrated model, the recruitment deviation is not used, aspm_est: using the selectivity parameters from integrated model, but estimated recruitment deviation, aspm_fix: using the selectivity parameters and recruitment deviation from integrated model).

EU Purse Seine Free School



Joint Longline Index – Region 2

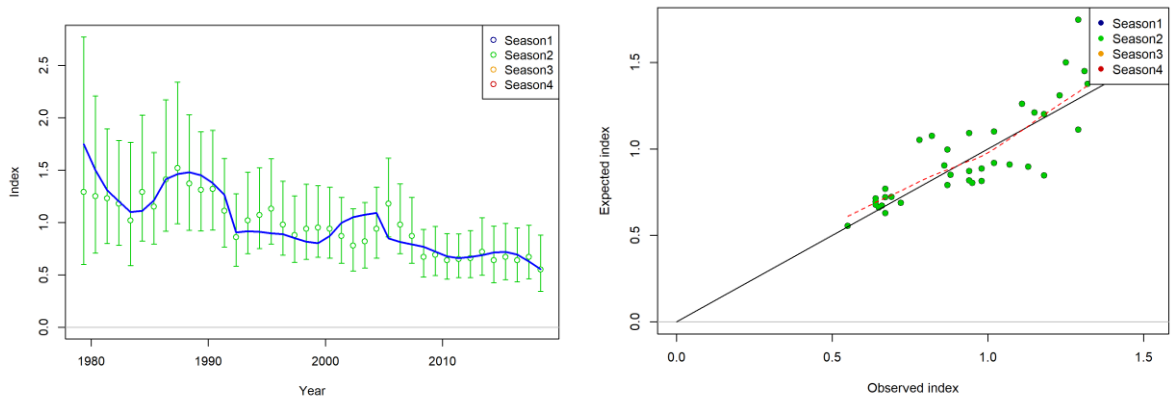
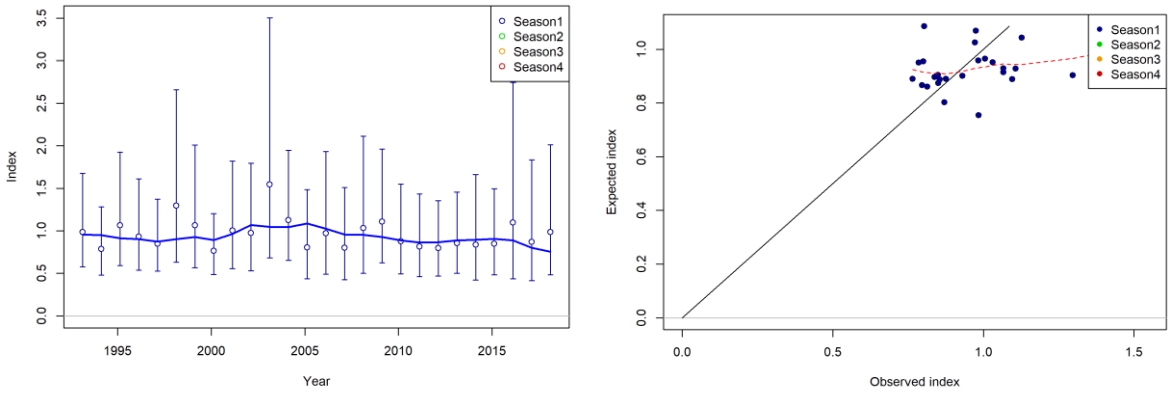


Figure 33. Fits to indices of abundance for Stock Synthesis Run 1.

EU Purse Seine Free School



Joint Longline Index – Region 2

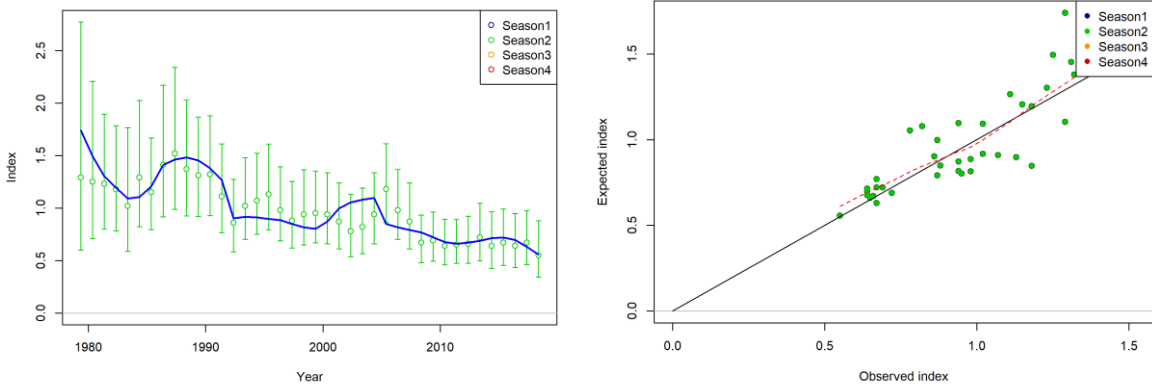
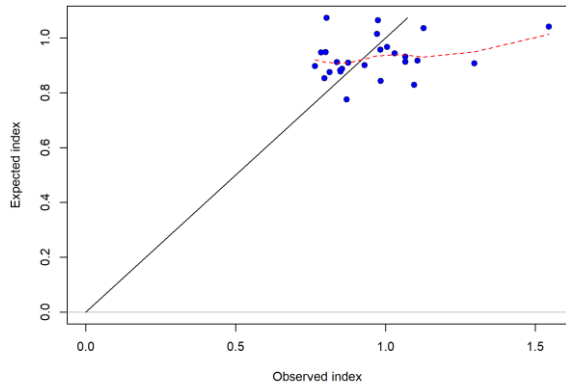
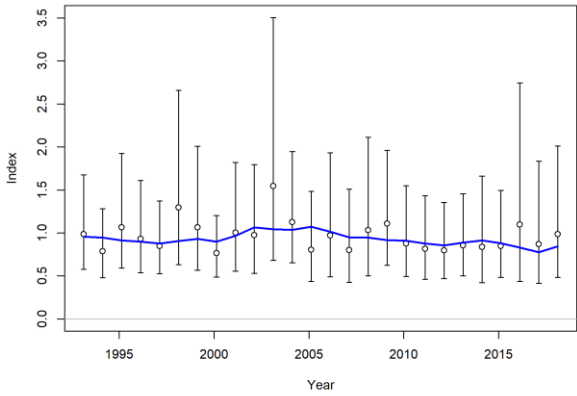
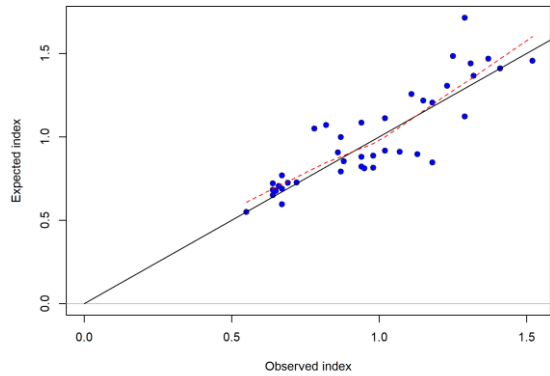
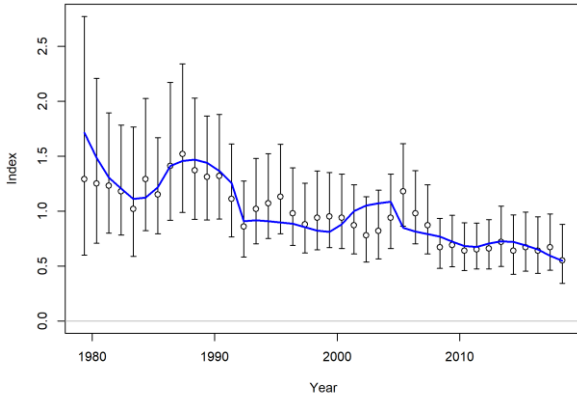


Figure 34. Fits to indices of abundance for Stock Synthesis Run 2.

EU Purse Seine Free School



Joint Longline Index – Region 2



Juvenile Echosounder Buoy Index

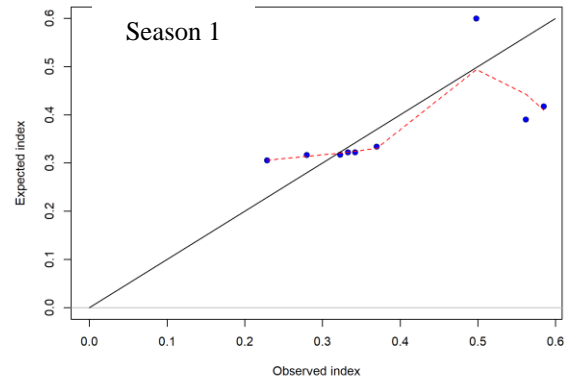
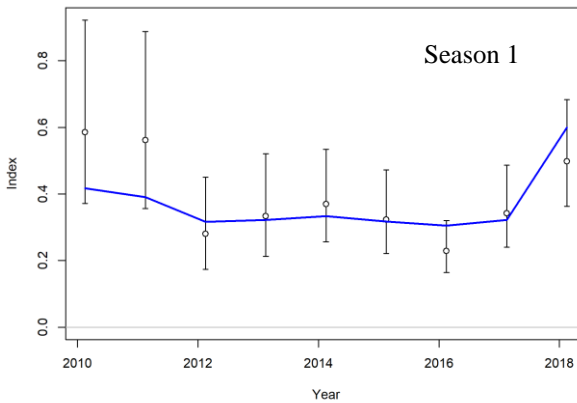


Figure 35. Fits to indices of abundance for Stock Synthesis Run 3 (continues on next page).

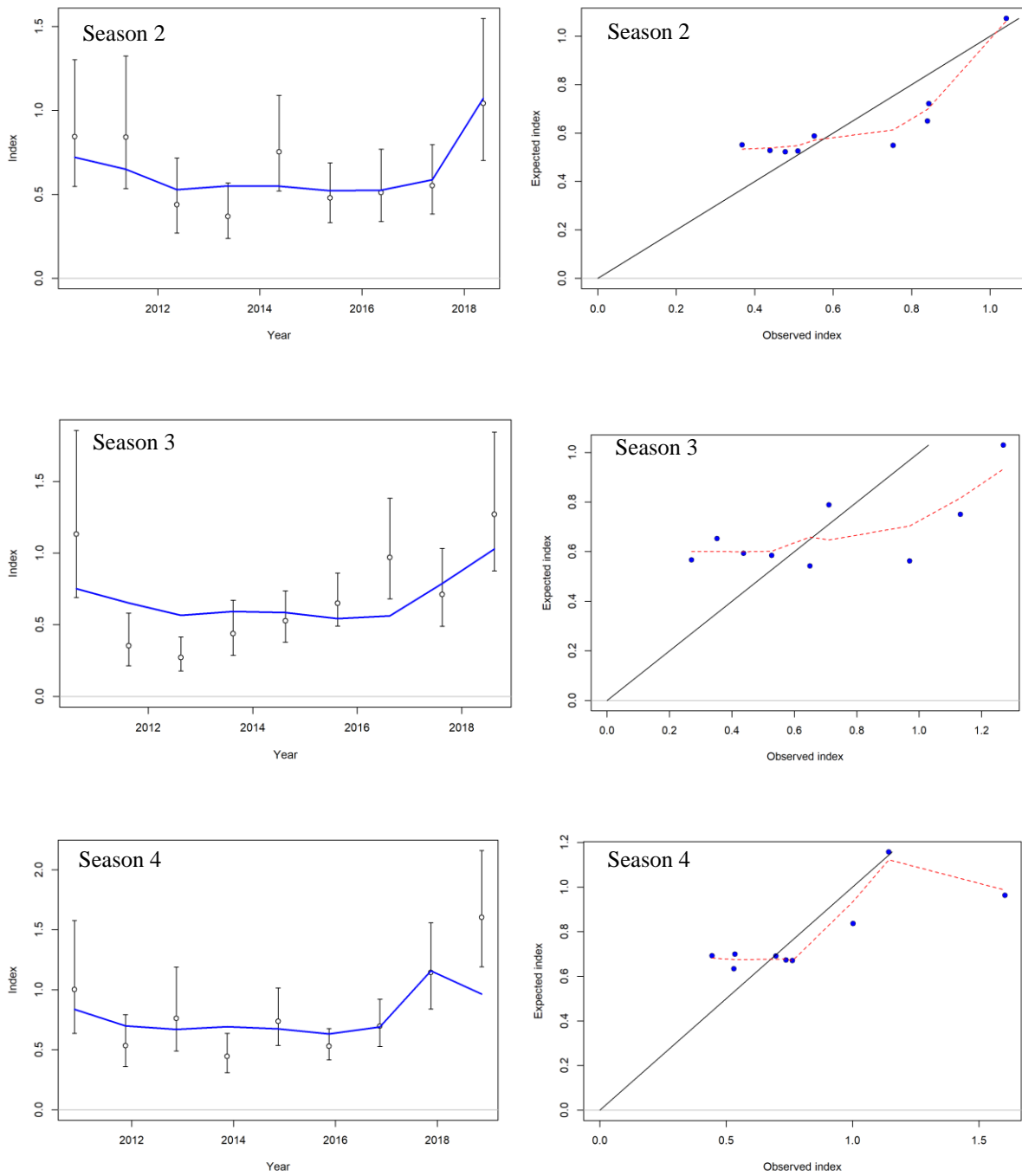
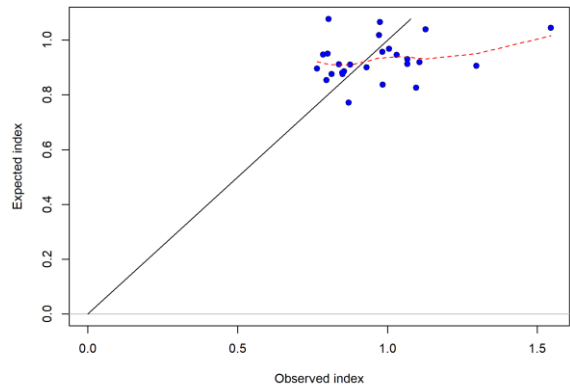
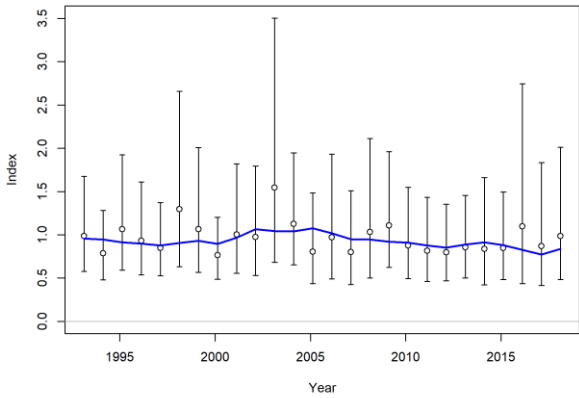
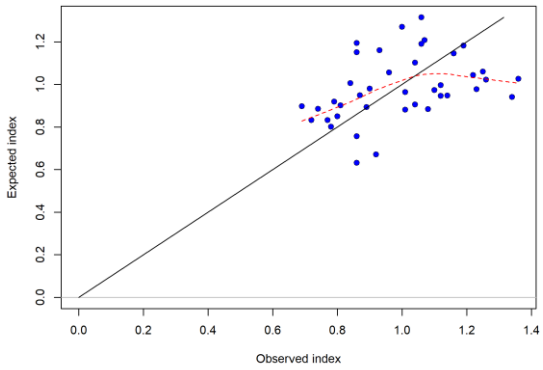
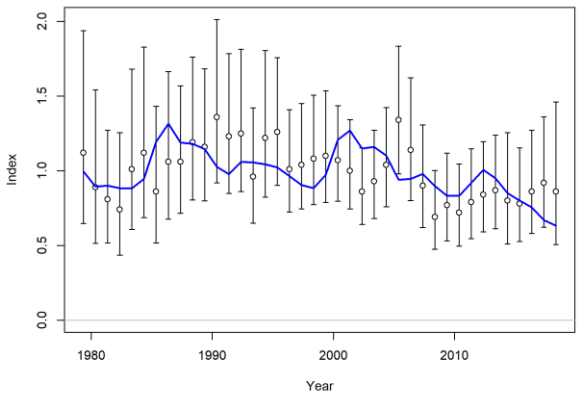


Figure 35 – *continued from previous page.* Fits to indices of abundance for Stock Synthesis Run 3.

EU Purse Seine Free School



Joint Longline Index – Region 2



Juvenile Echosounder Buoy Index

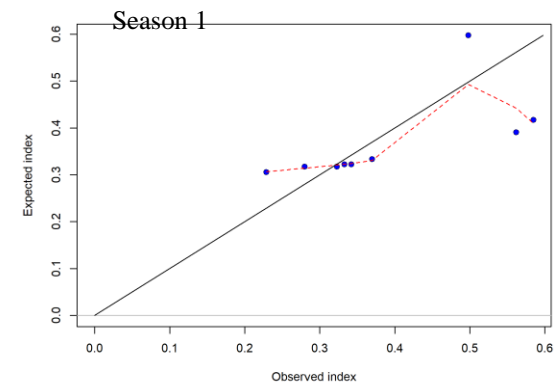
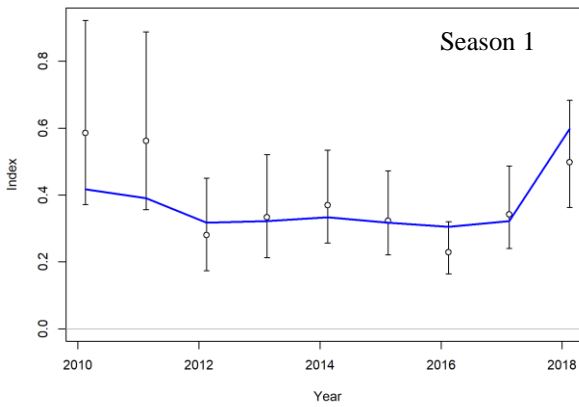


Figure 36. Fits to indices of abundance for Stock Synthesis Run 4 (continues on next page).

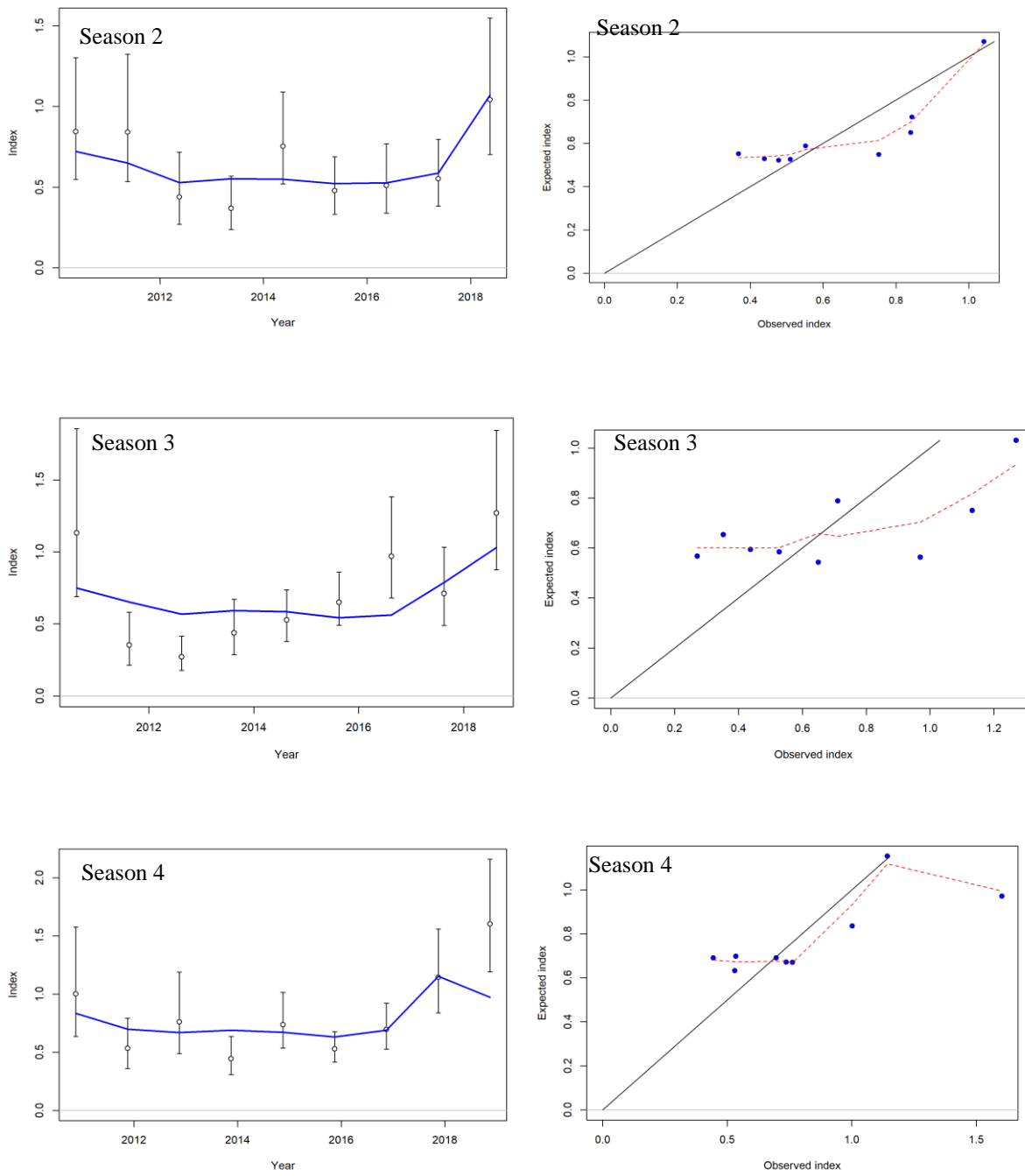


Figure 36- *continued from previous page.* Fits to indices of abundance for Stock Synthesis Run 4.

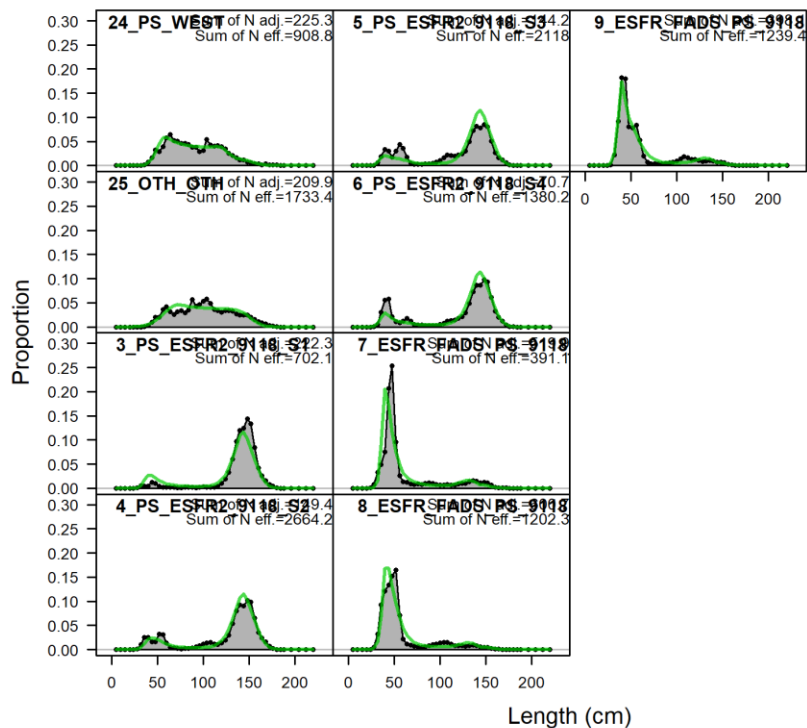
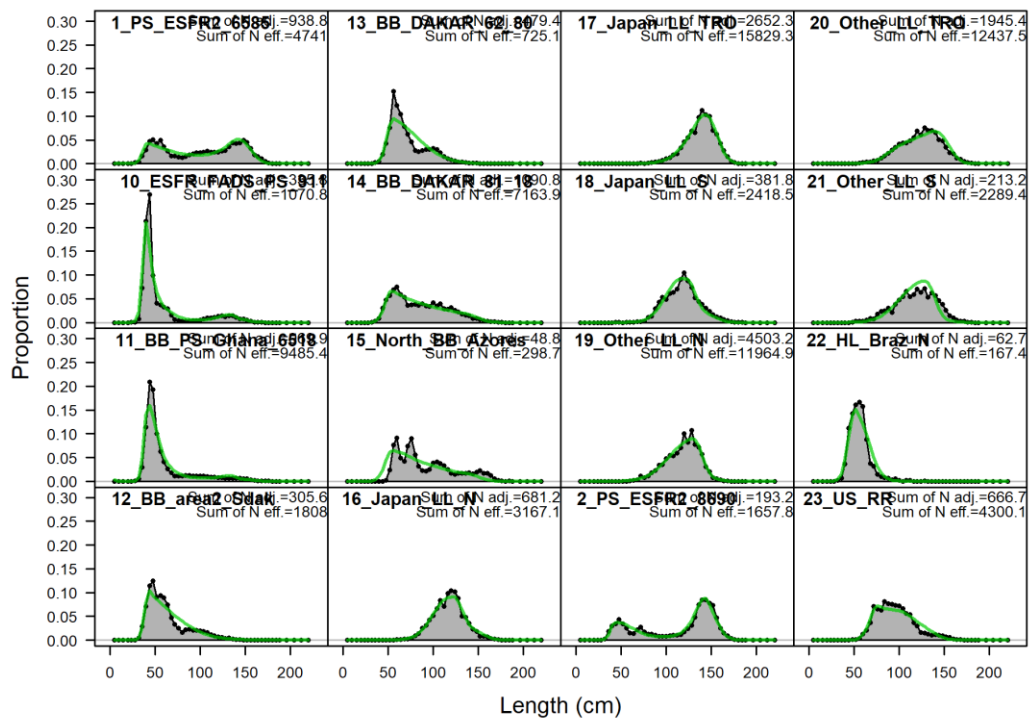


Figure 37. The fits to the length composition, aggregated by fleet for Stock Synthesis Run 1.

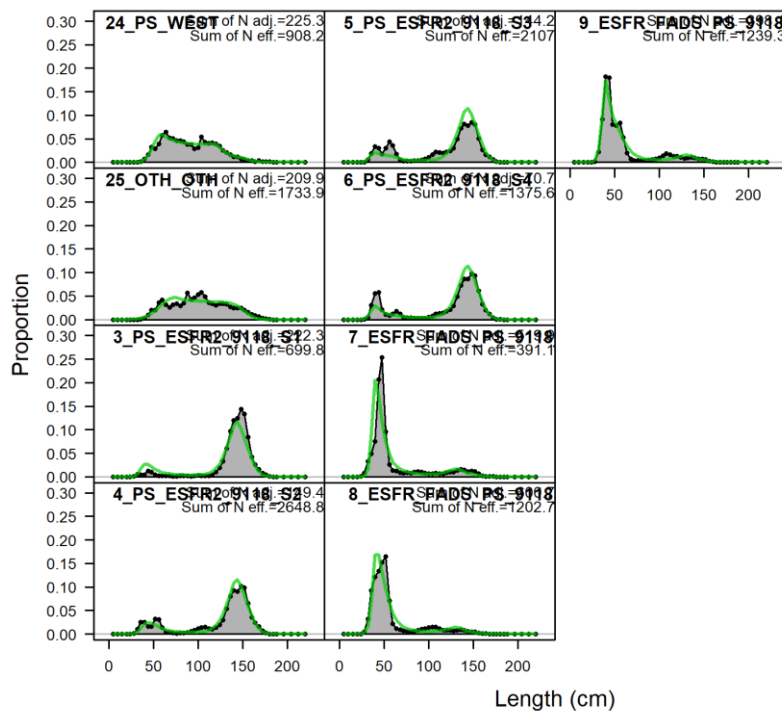
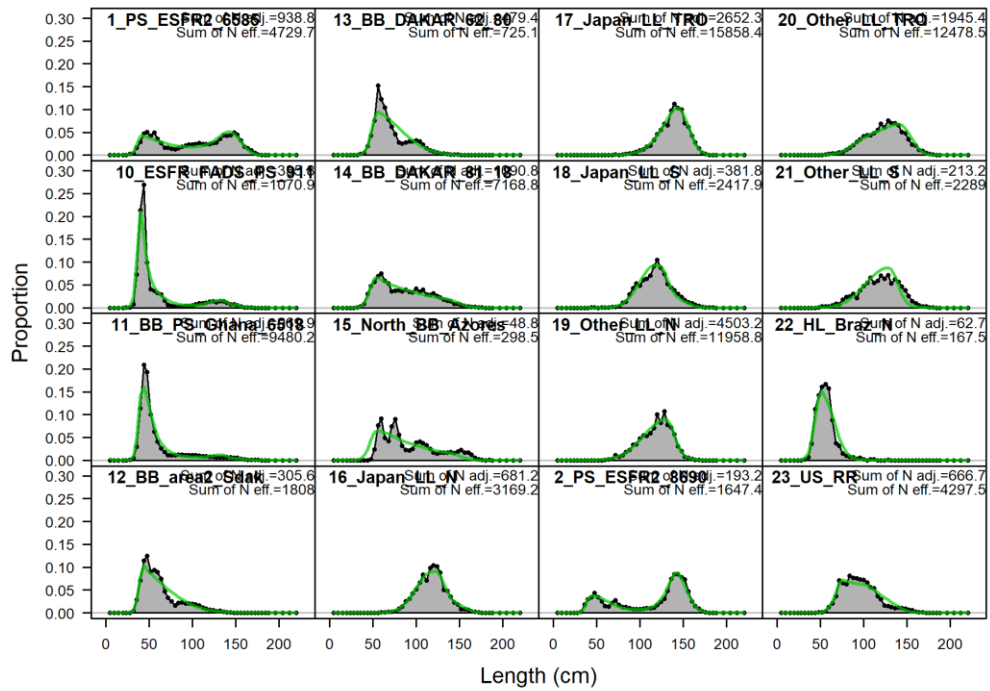


Figure 38. The fits to the length composition, aggregated by fleet for Stock Synthesis Run 2.

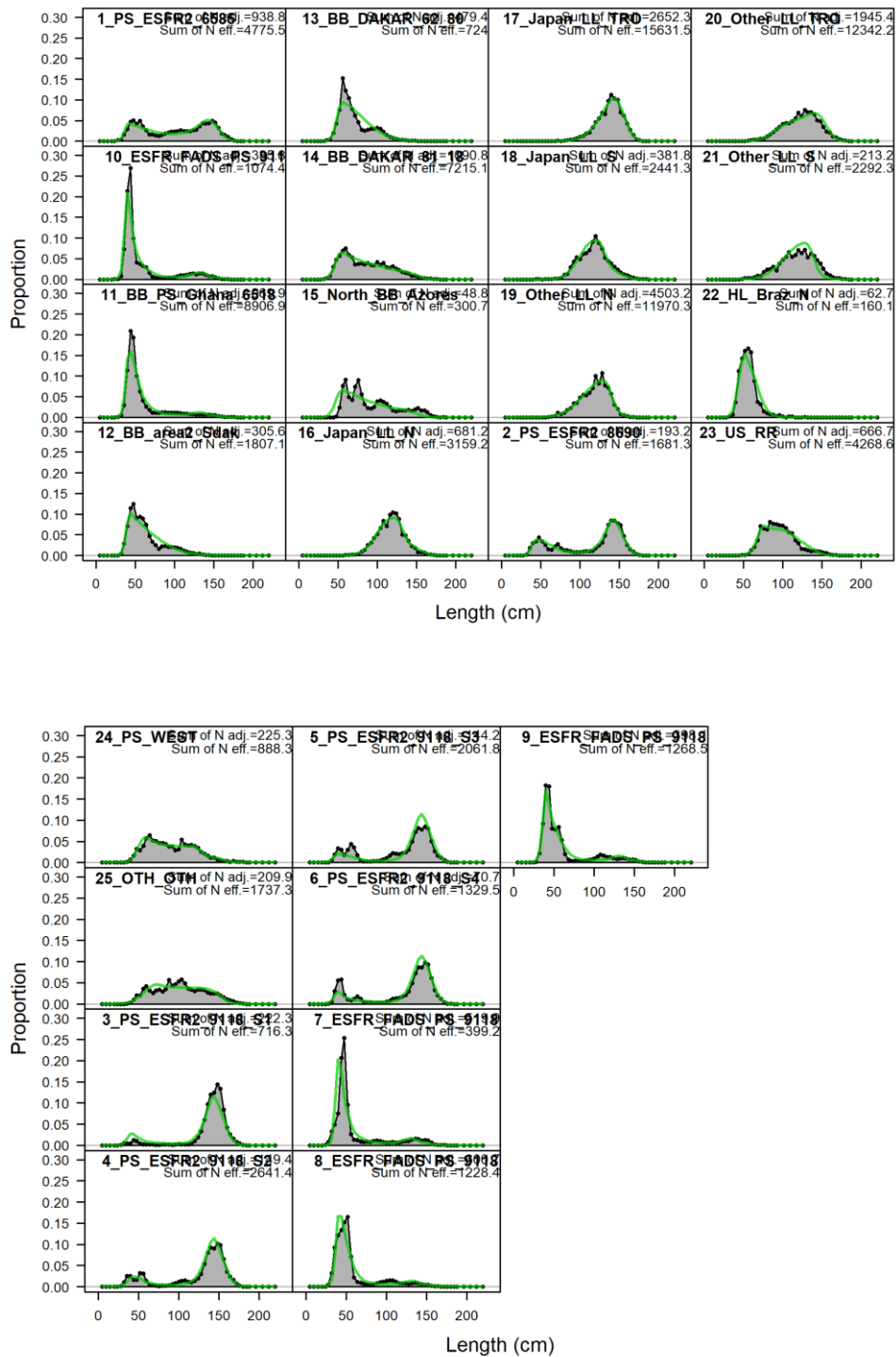


Figure 39. The fits to the length composition, aggregated by fleet for Stock Synthesis Run 3.

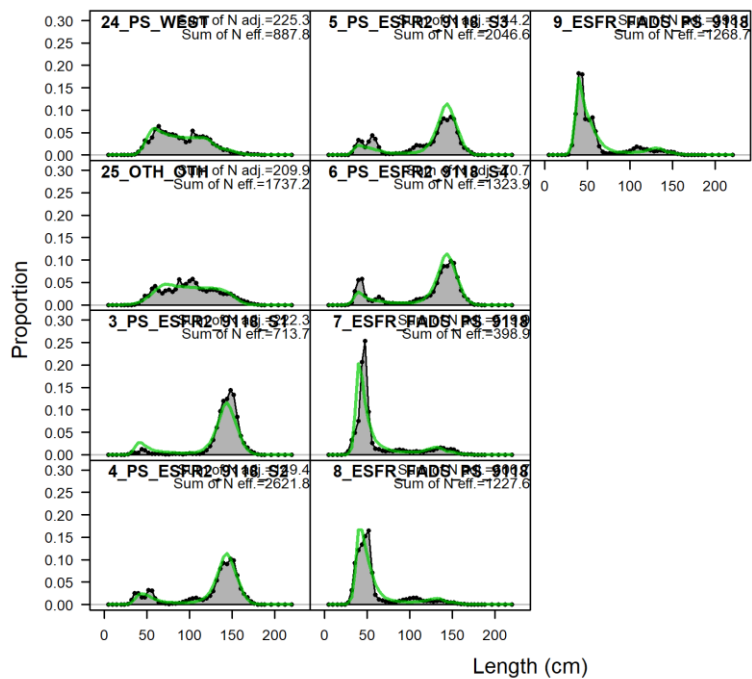
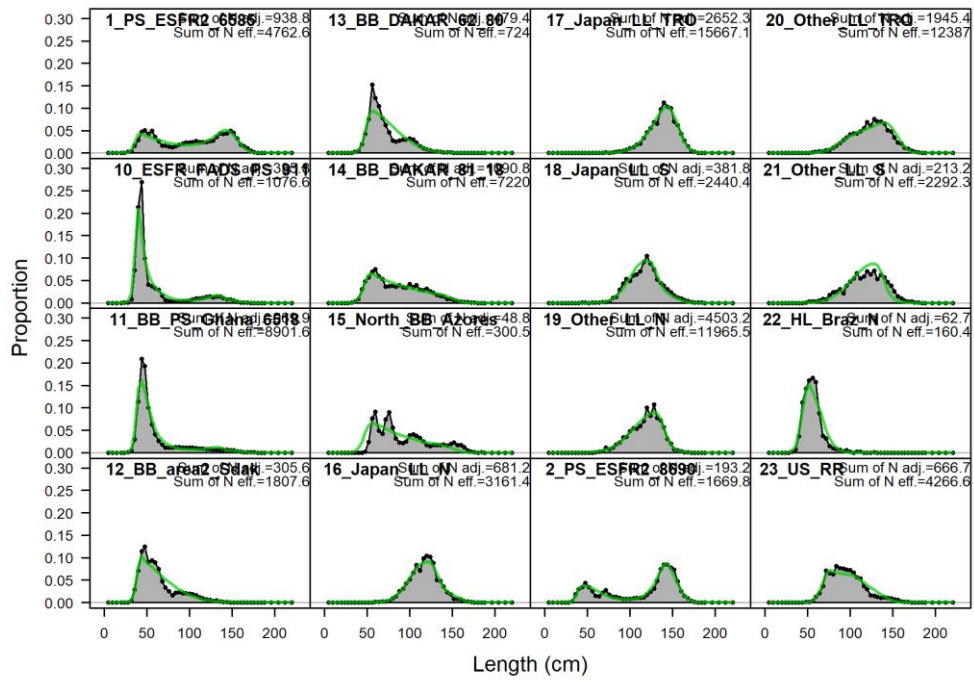


Figure 40. The fits to the length composition, aggregated by fleet for Stock Synthesis Run 4.

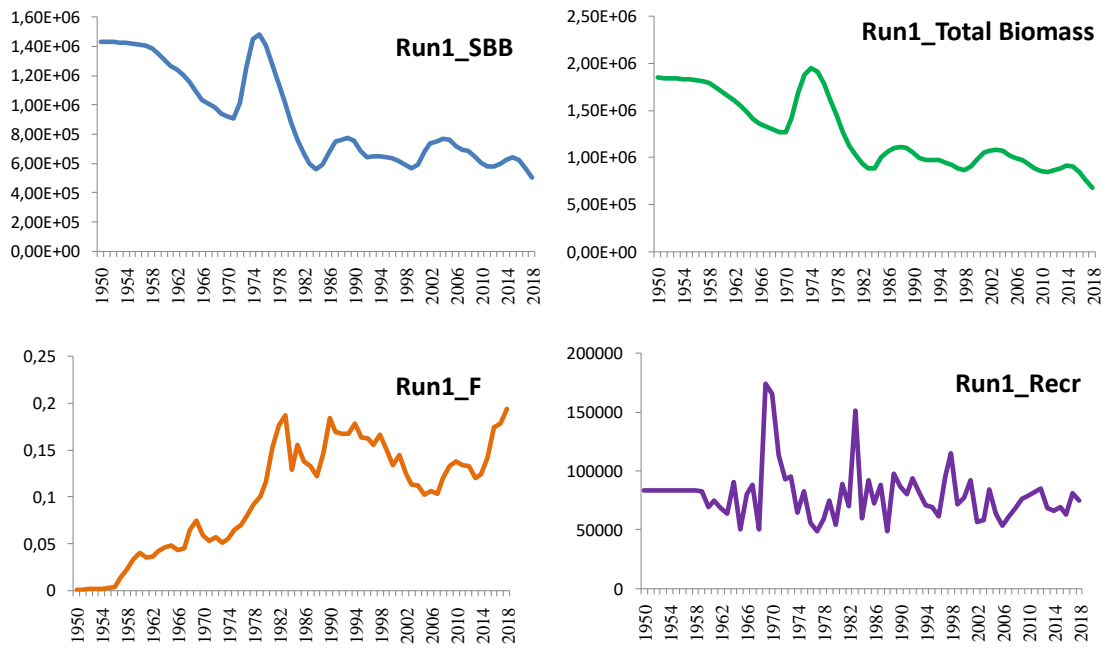


Figure 41. Trends in spawning biomass, total biomass, fishing mortality and recruitment for Stock Synthesis model Run 1.

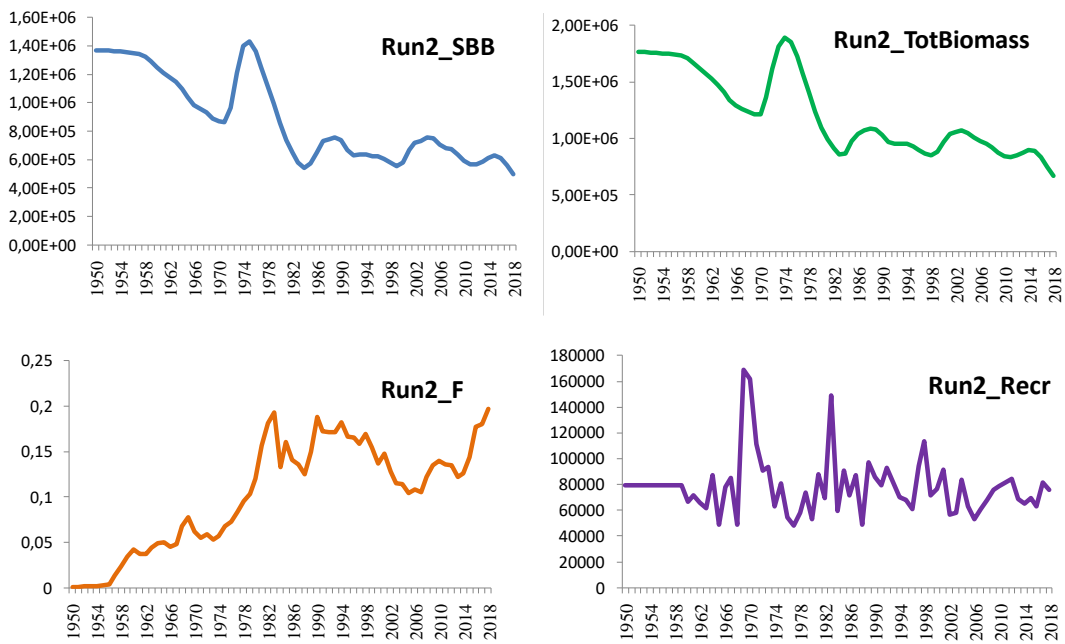


Figure 42. Trends in spawning biomass, total biomass, fishing mortality and recruitment for Stock Synthesis model Run 2.

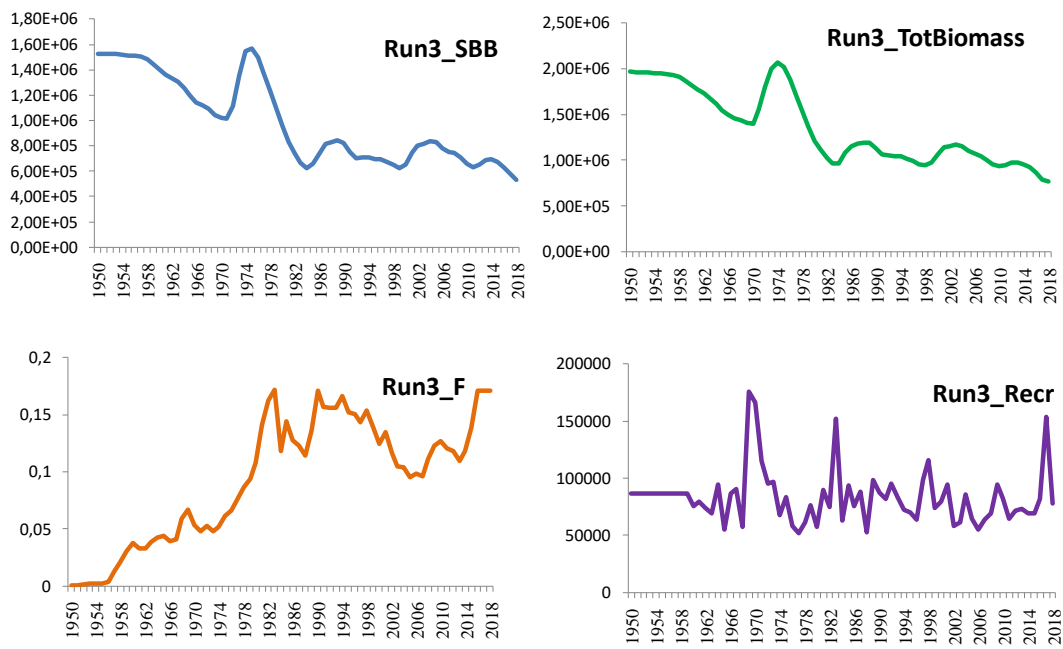


Figure 43. Trends in spawning biomass, total biomass, fishing mortality and recruitment for Stock Synthesis model Run 3.

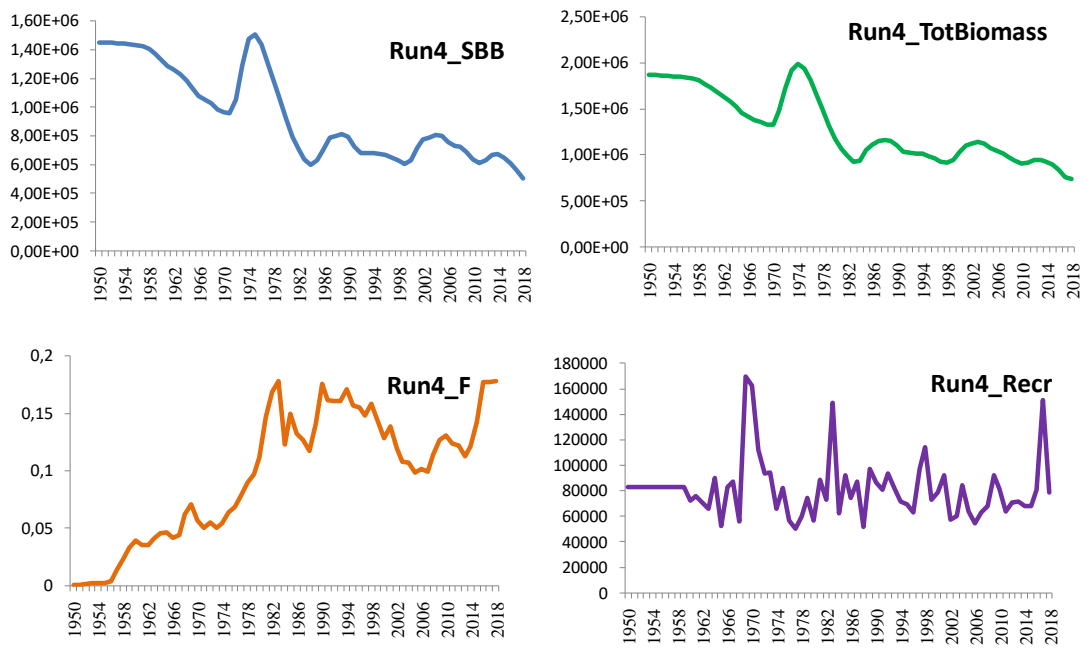


Figure 44. Trends in spawning biomass, total biomass, fishing mortality and recruitment for Stock Synthesis model Run 4

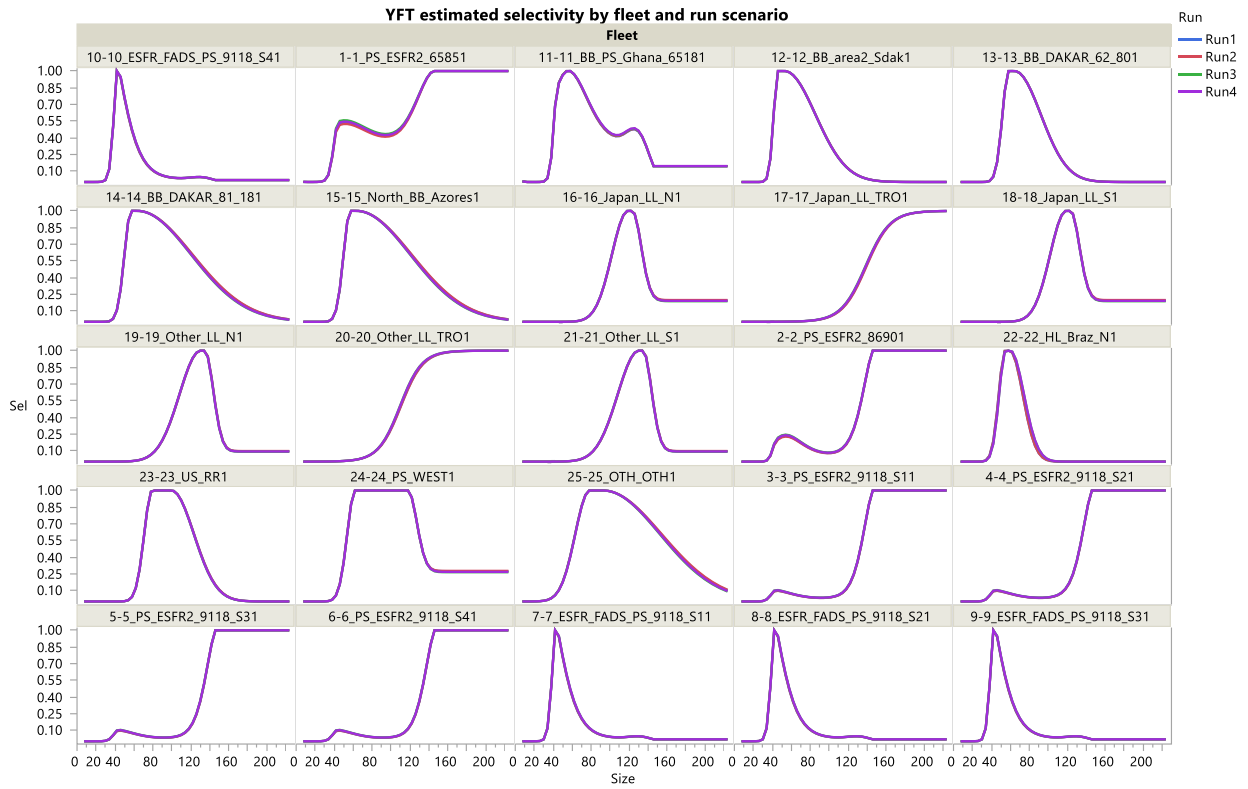
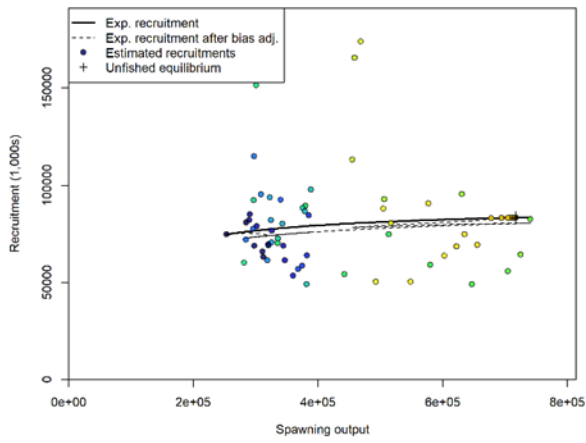
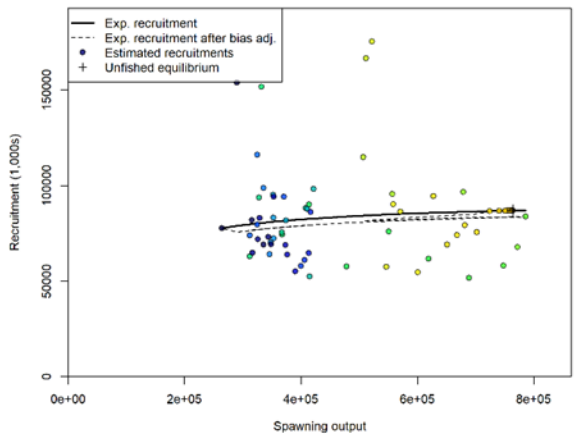
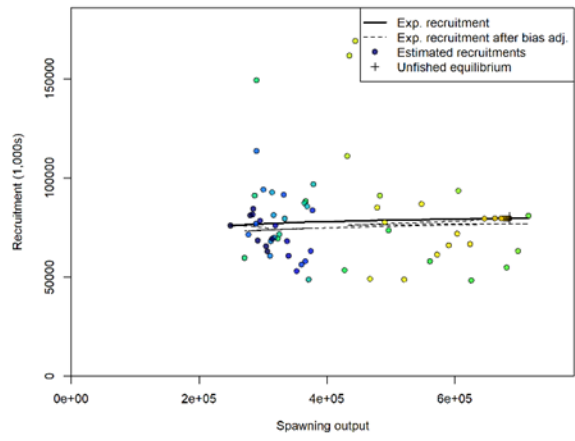


Figure 45. The model estimated selectivity values by fleet ID for the Stock Synthesis runs.

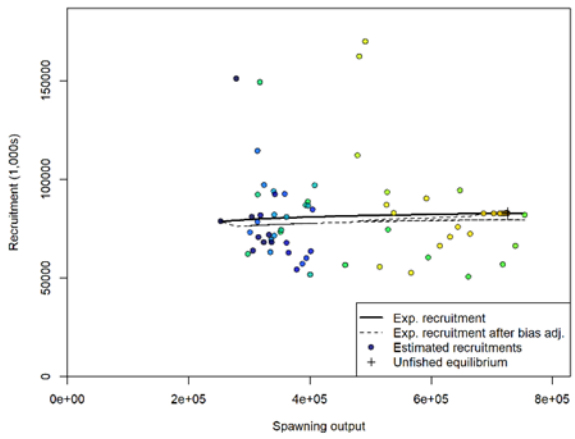
Run 1



Run 2



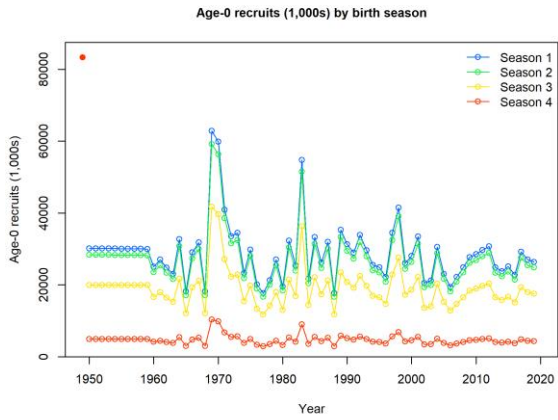
Run 3



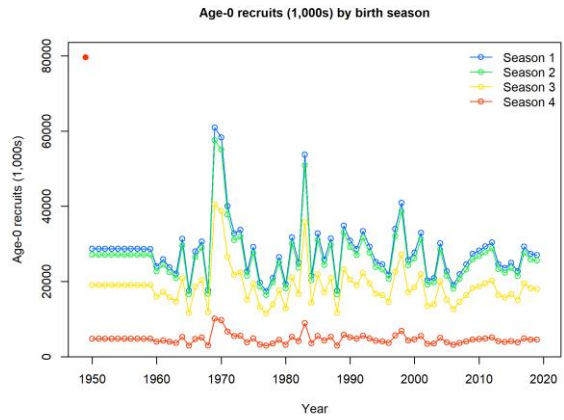
Run 4

Figure 46. The estimated stock recruitment relationships showed little evidence of a relationship between SSB and recruits for the Stock Synthesis runs.

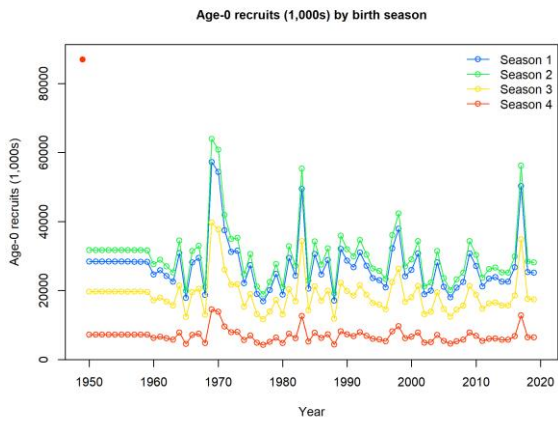
Run 1



Run 2



Run 3



Run 4

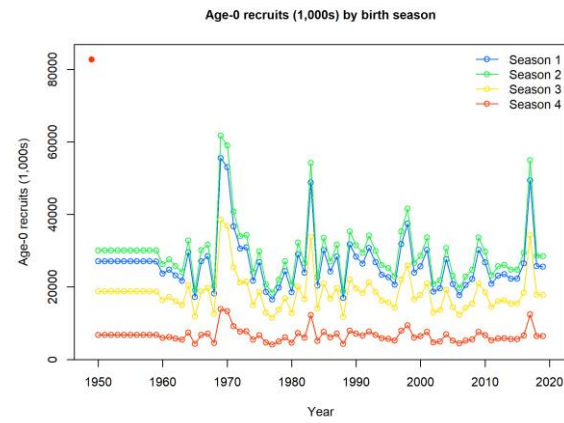
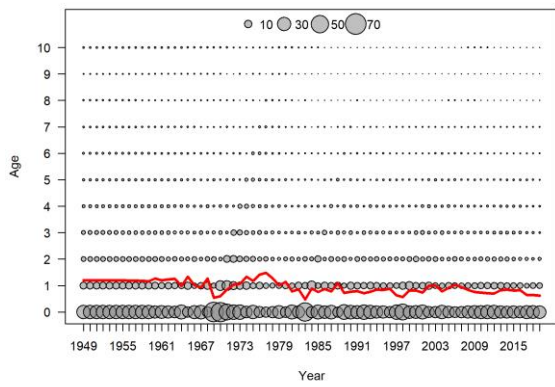
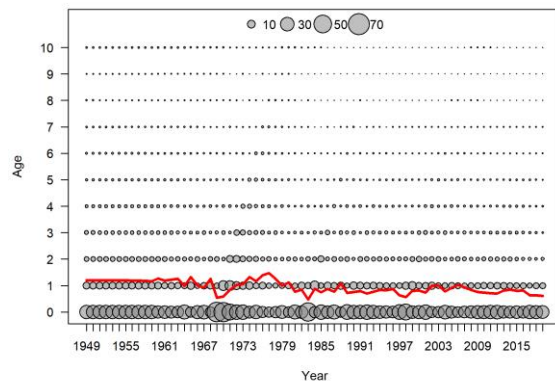


Figure 47. Recruitment by season for the Stock Synthesis runs indicates that the highest fraction of recruits was estimated to be born in seasons 1 and 2 (Jan-June) and the lowest in season 4 (Oct-Dec).

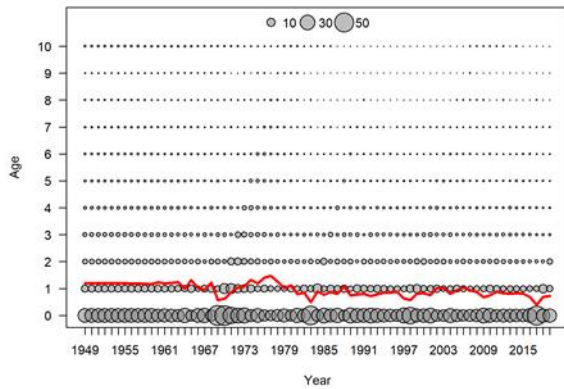
Run 1



Run 2



Run 3



Run 4

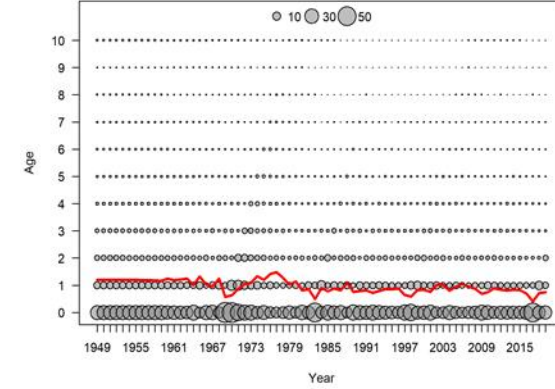


Figure 48. Time series of the numbers at age from Stock Synthesis runs shows little evidence of strong cohort structure and a decline in the mean age in the population over time.

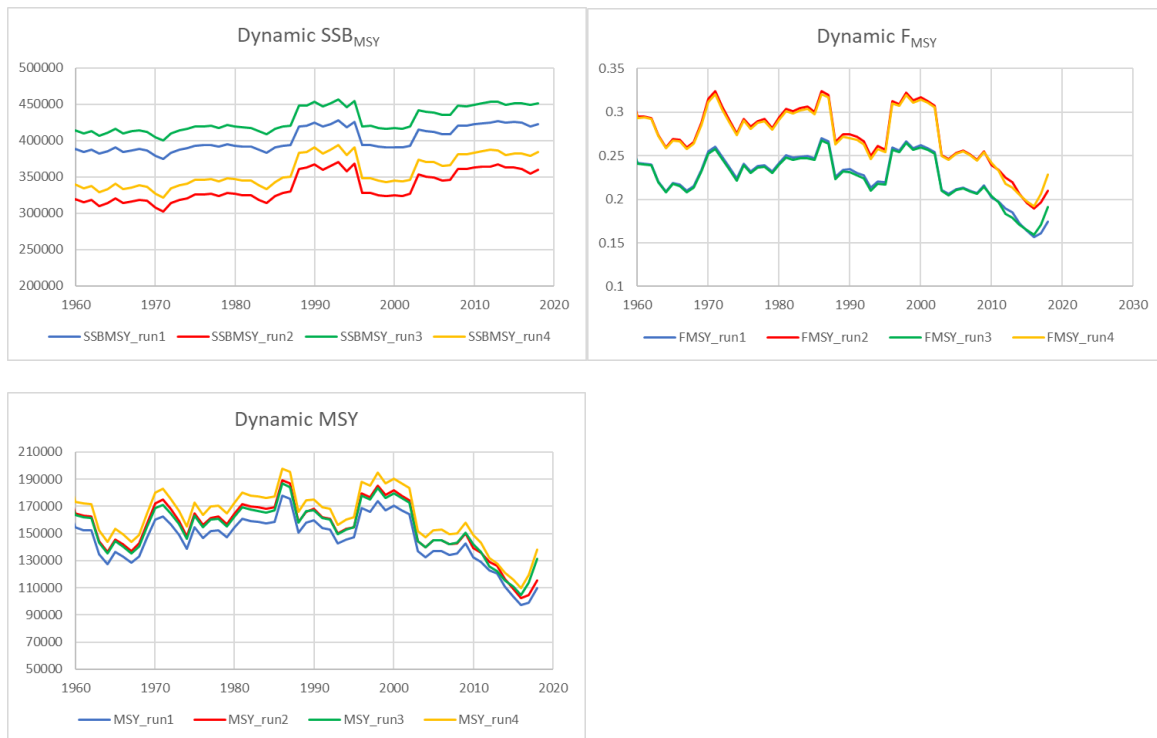


Figure 49. Dynamic SSB_{MSY} , F_{MSY} and MSY for the Stock Synthesis runs.

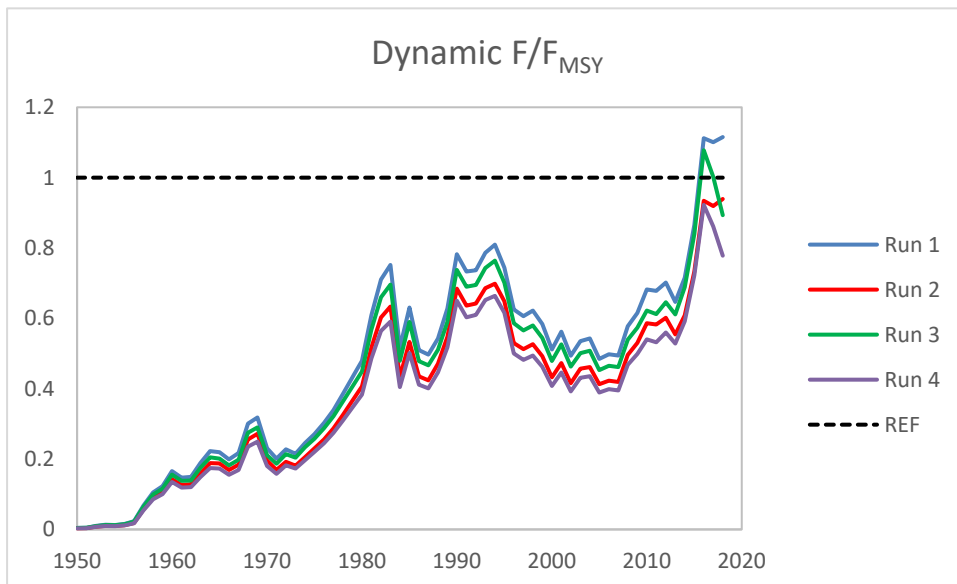
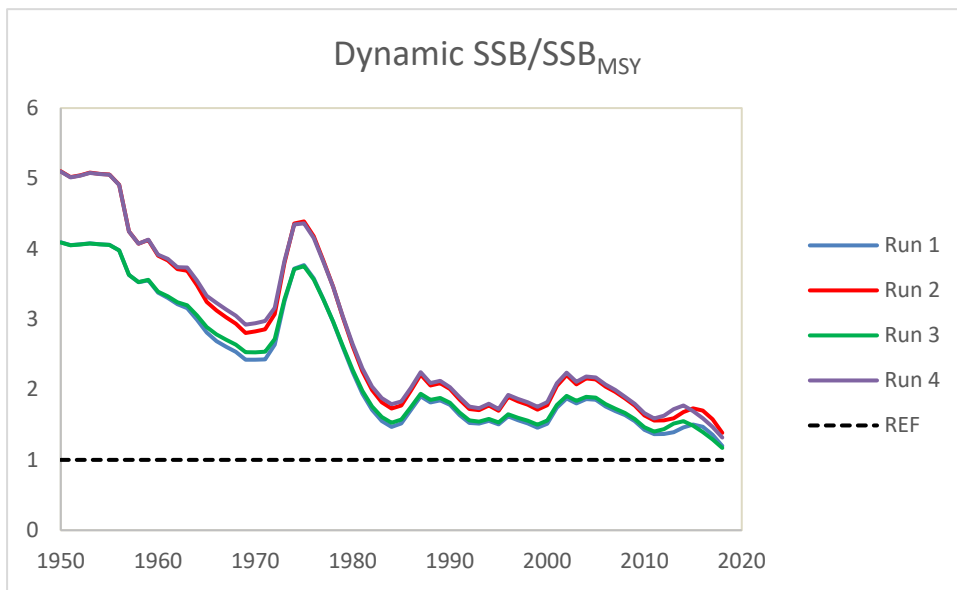


Figure 50. The dynamic SSB/SSB_{MSY} and F/F_{MSY} for the Stock Synthesis runs.

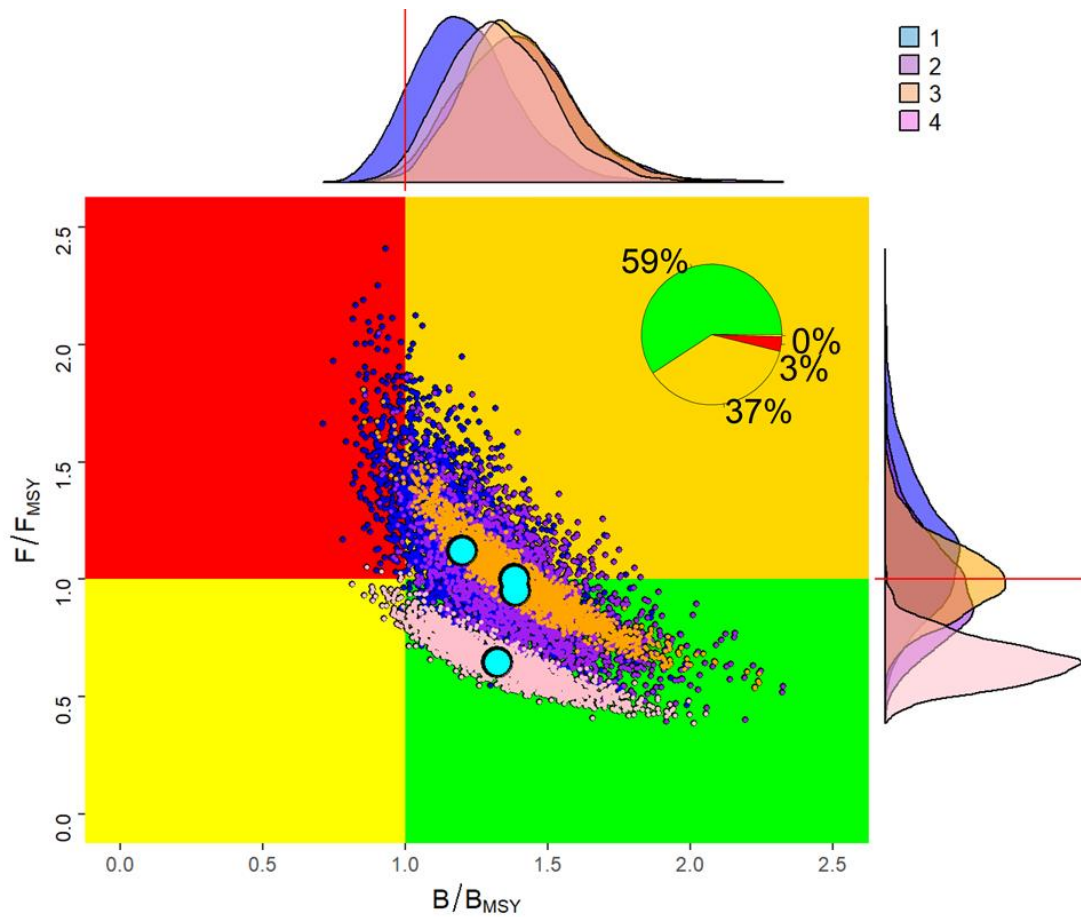


Figure 51. Estimates for 2018 biomass and fishing mortality relative to B_{MSY} and F_{MSY} using 2500 MVN iterations from the Stock Synthesis runs for Atlantic yellowfin stock.

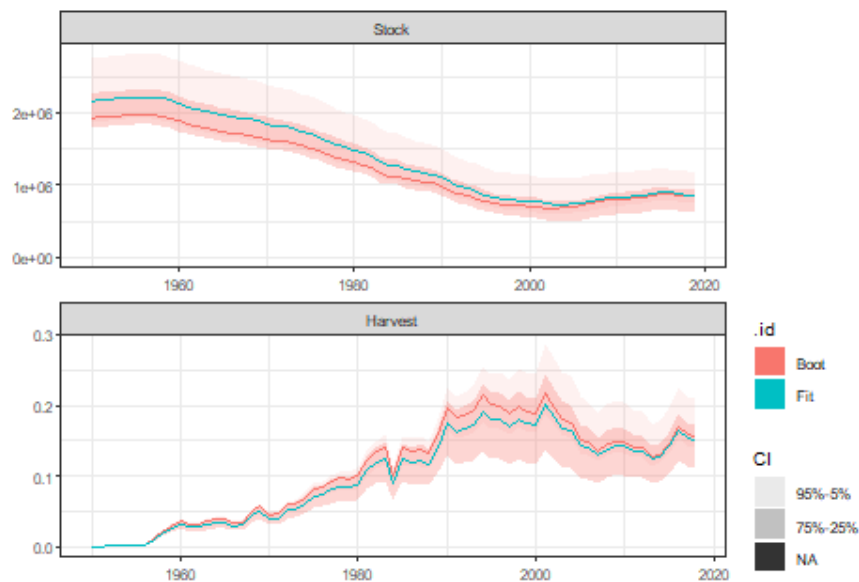


Figure 52. Trajectories of biomass (t) and F for the Atlantic yellowfin tuna Reference Case from MPB. Green and red lines show the model fit and the median of 500 bootstrapped iterations, respectively. The shade areas represent the 95% confidence interval.

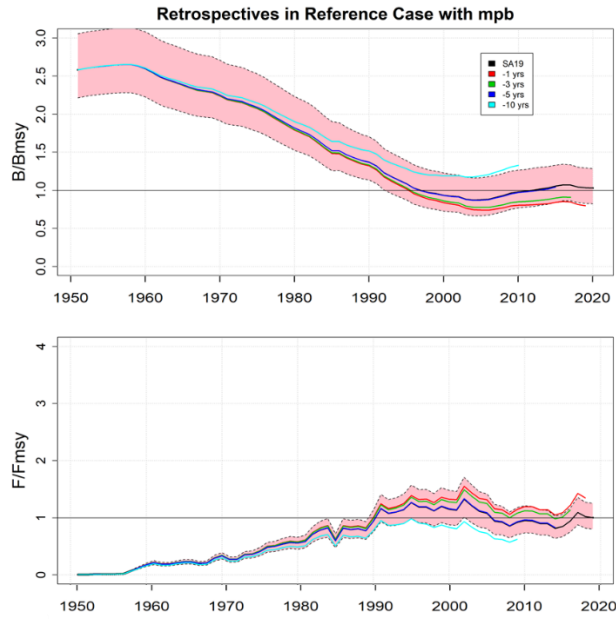


Figure 53. Retrospective analysis. Trajectories of B/B_{MSY} and F/F_{MSY} from the Atlantic yellowfin tuna for the Reference Case and retrospective analysis. Black, red, green, blue, and skyblue lines show the Reference Case, retrospective -1, -3, -5, and -10 years, respectively. The shade areas represent the 95% confidence interval.

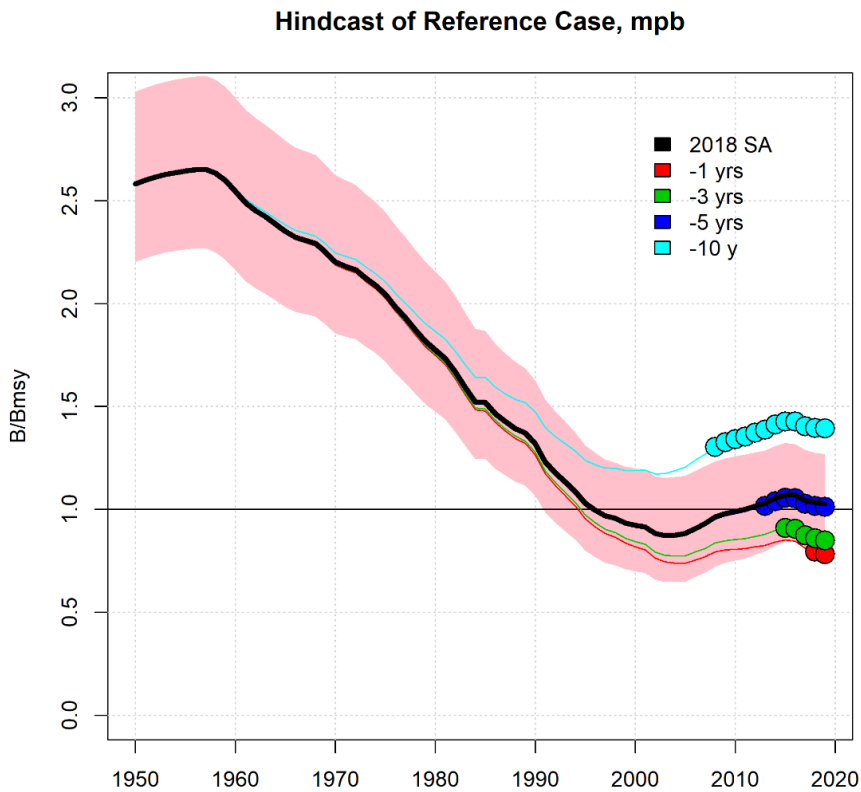


Figure 54. Forward projection of relative biomass from the retrospective runs for the MPB model compare to the reference case (2018 SA, terminal year of stock assessment) including the 80% confidence bounds (shade area).

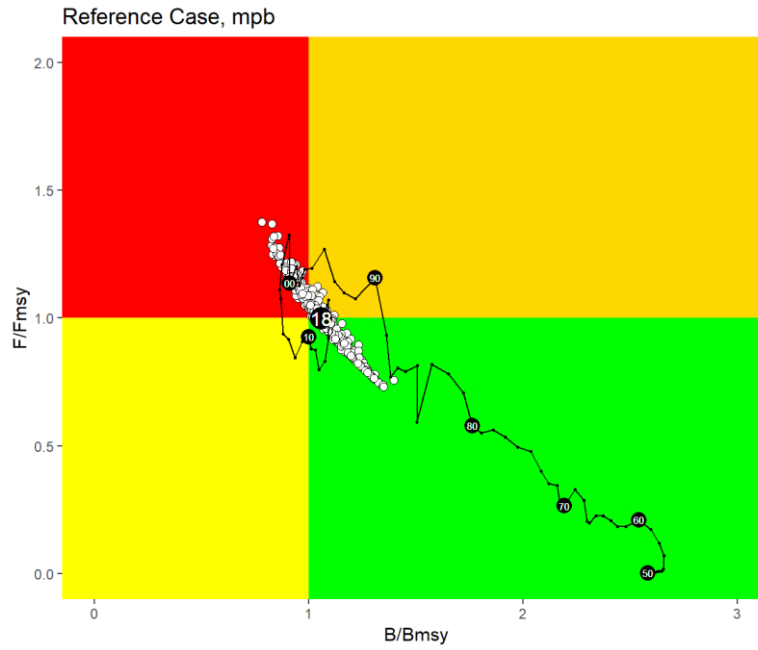


Figure 55. Estimated median historical trend of Atlantic yellowfin stock using the MPB-Reference Case (black line). 500 bootstraps for 2018 of biomass and fishing mortality relative to B_{MSY} and F_{MSY} . Top-right panel: Estimated probabilities of the stock in 2018 being in each of the Kobe plot quadrants estimated from the 500 bootstrapped iterations.

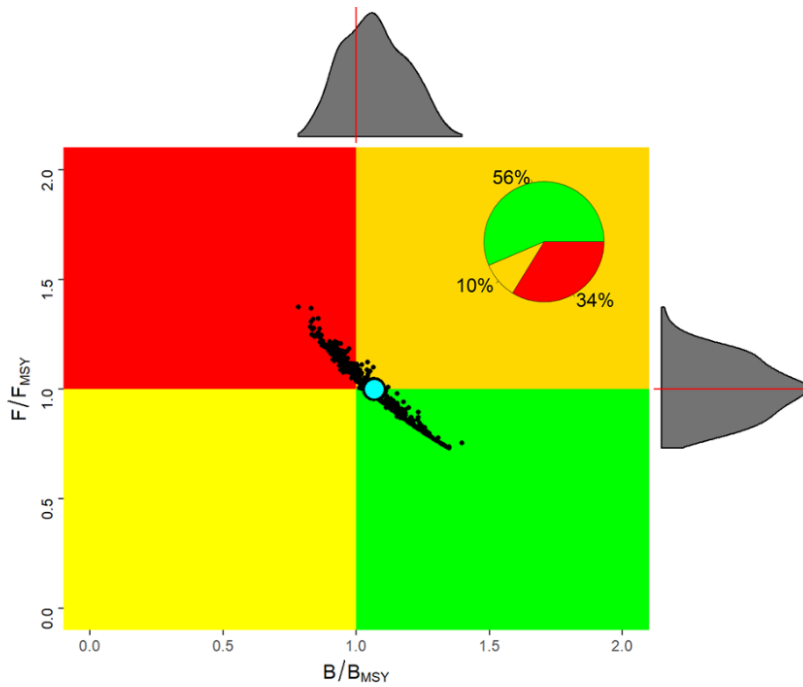


Figure 56. Estimated for 2018 biomass and fishing mortality relative to B_{MSY} and F_{MSY} using 500 bootstrapped iterations from MPB for Atlantic yellowfin stock showing the marginal density of the estimates.

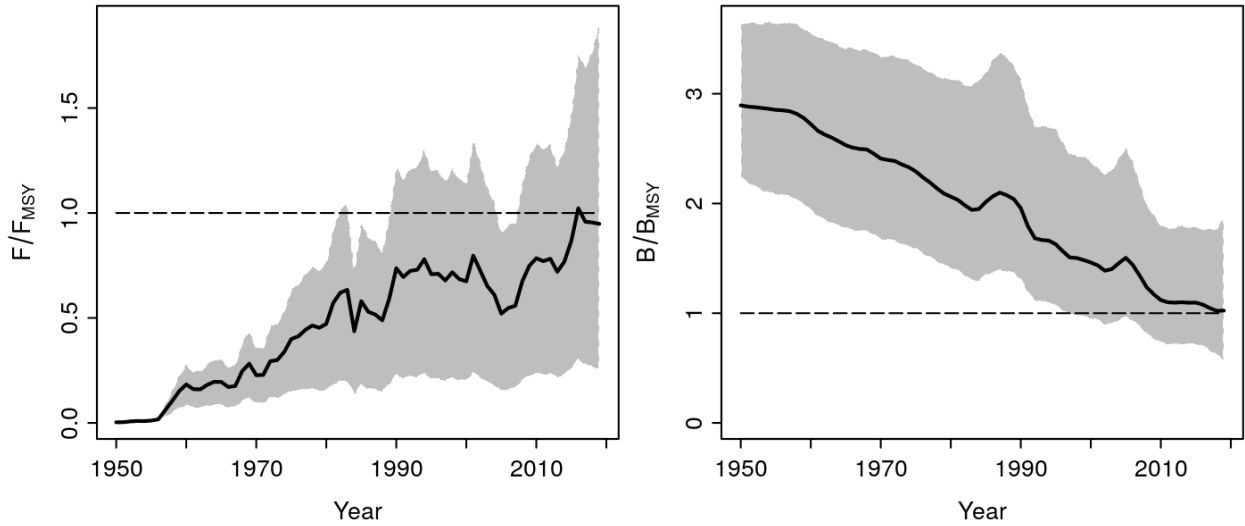


Figure 57. Trajectories of B/B_{MSY} and F/F_{MSY} predicted from posteriors from the JABBA Reference Base Case for Atlantic yellowfin stock. Grey shade areas represent the 95% credibility interval.

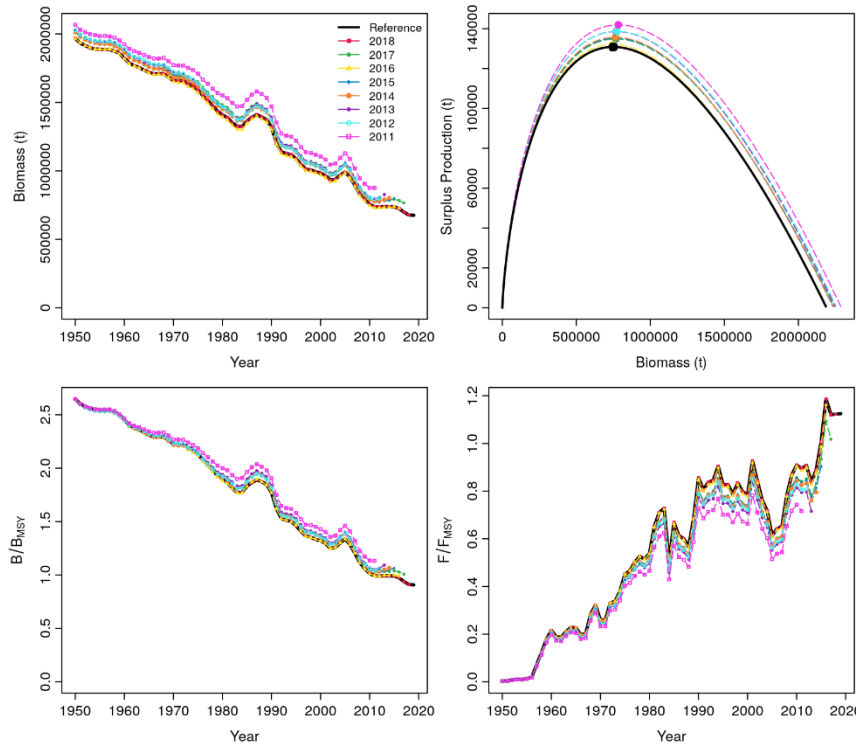


Figure 58. Retrospective analysis for stock biomass (t), surplus production function (maximum = MSY), B/B_{MSY} and F/F_{MSY} shown for the JABBA Reference Base Case. The label “Reference” indicates the model fits and associated 95% CIs. The numeric year label indicates the retrospective results, sequentially excluding CPUE data back to 2011.

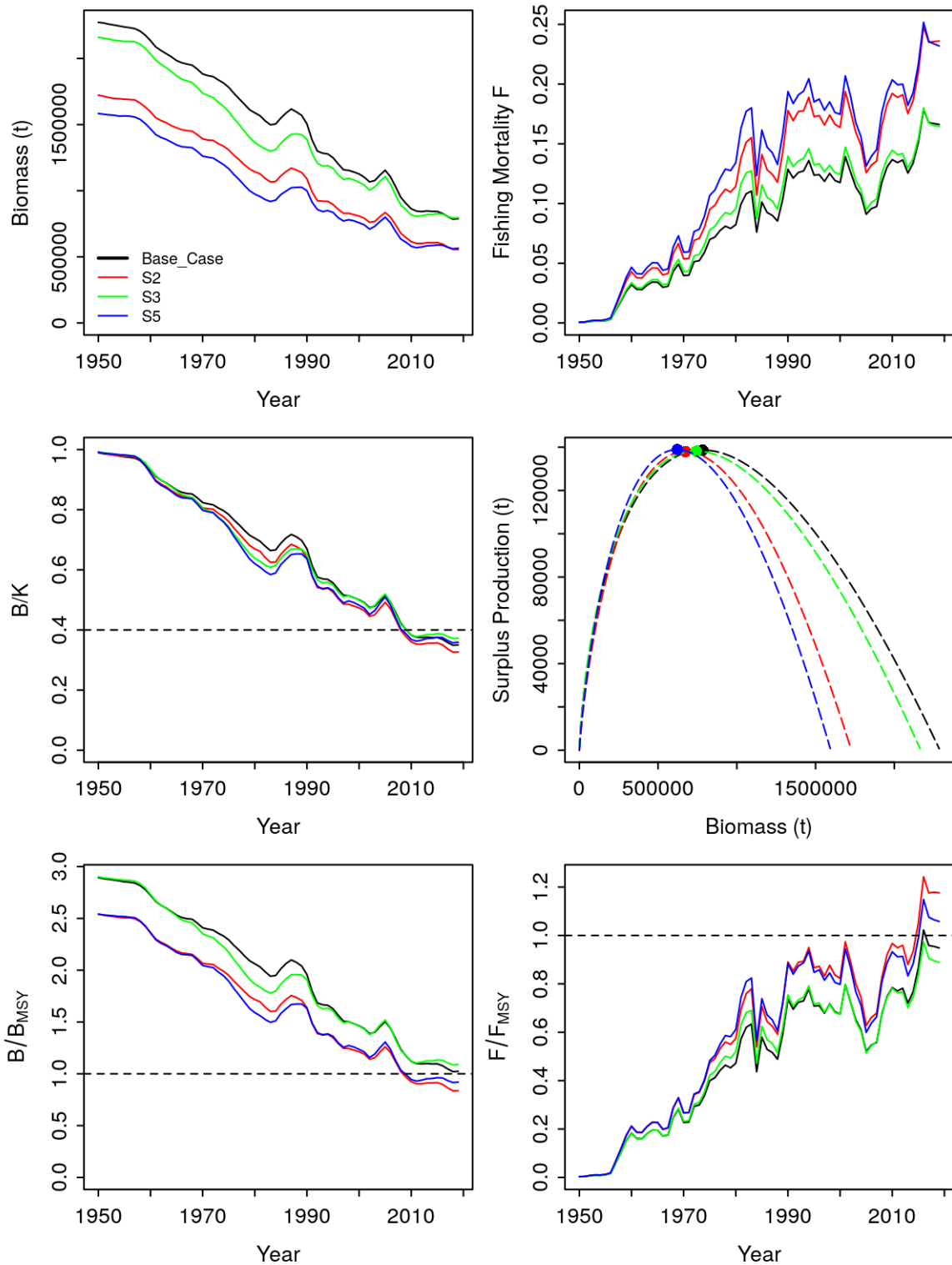


Figure 59. Trends in biomass and fishing mortality (upper panels), biomass relative to K (B/K) and surplus production curve (middle panels) and biomass relative to B_{MSY} (B/B_{MSY}) and fishing mortality relative to F_{MSY} (F/F_{MSY}) (bottom panels) for each scenario from the JABBA Reference Base Case (black), S2 (red), S3 (green), and S5 (blue) for Atlantic yellowfin tuna.

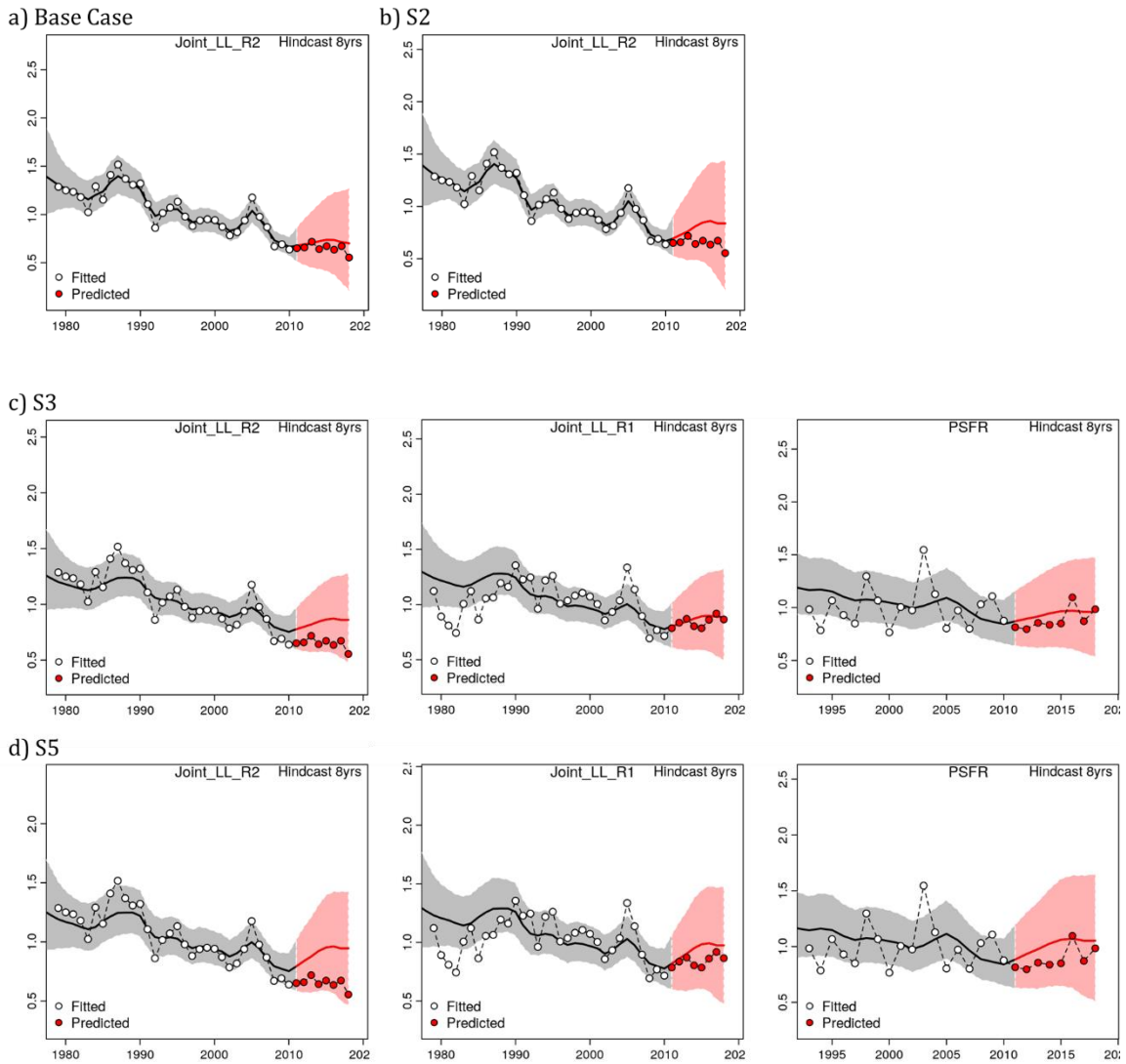


Figure 60. The predicted abundance indices for (none fitted) hindcasting periods of 8 years fitted for the four JABBA Reference Cases (a: Base Case, b: S2, c: S3, and d: S5) for Atlantic yellowfin stock. Predicted mean CPUE and 95% CIs are denoted by black lines with grey shaded area and red lines with red shaded areas for the fitted and hindcasting years, respectively.

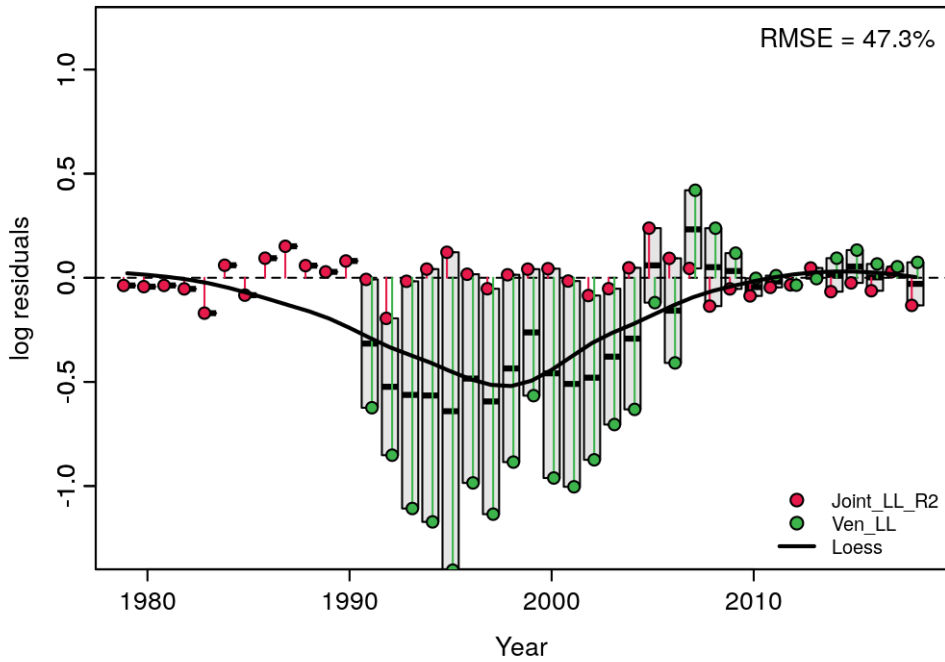


Figure 61. JABBA residual diagnostic plots for sensitivity analysis of Venezuelan longline index examined for each scenario for Atlantic yellowfin tuna. Boxplots indicate the median and quantiles of all residuals available for any given year, and solid black lines indicate a loess smoother through all residuals.

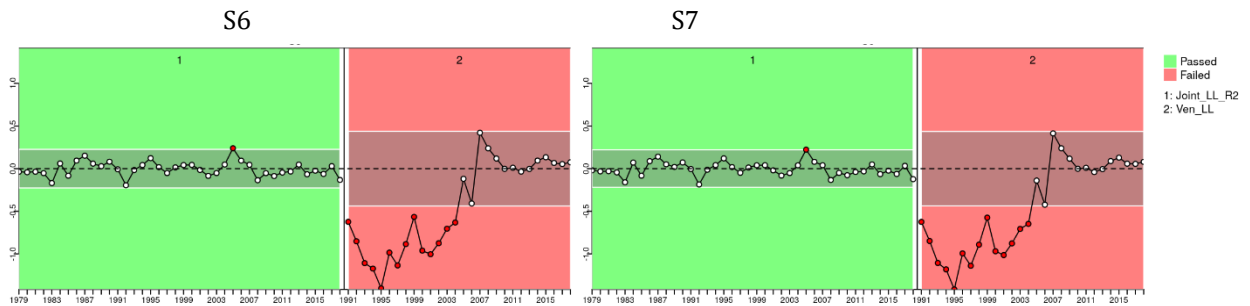


Figure 62. Runs tests to quantitatively evaluate the diagnostic test of randomness for the time series of CPUE residuals by fleet for each scenario. Red panels indicate the lack of randomness for the time-series residuals ($p < 0.05$) while green panels indicate the opposite. The inner shaded area shows three standard errors from the overall mean and red circles identify a specific year with residuals greater than this threshold value (3x sigma rule).

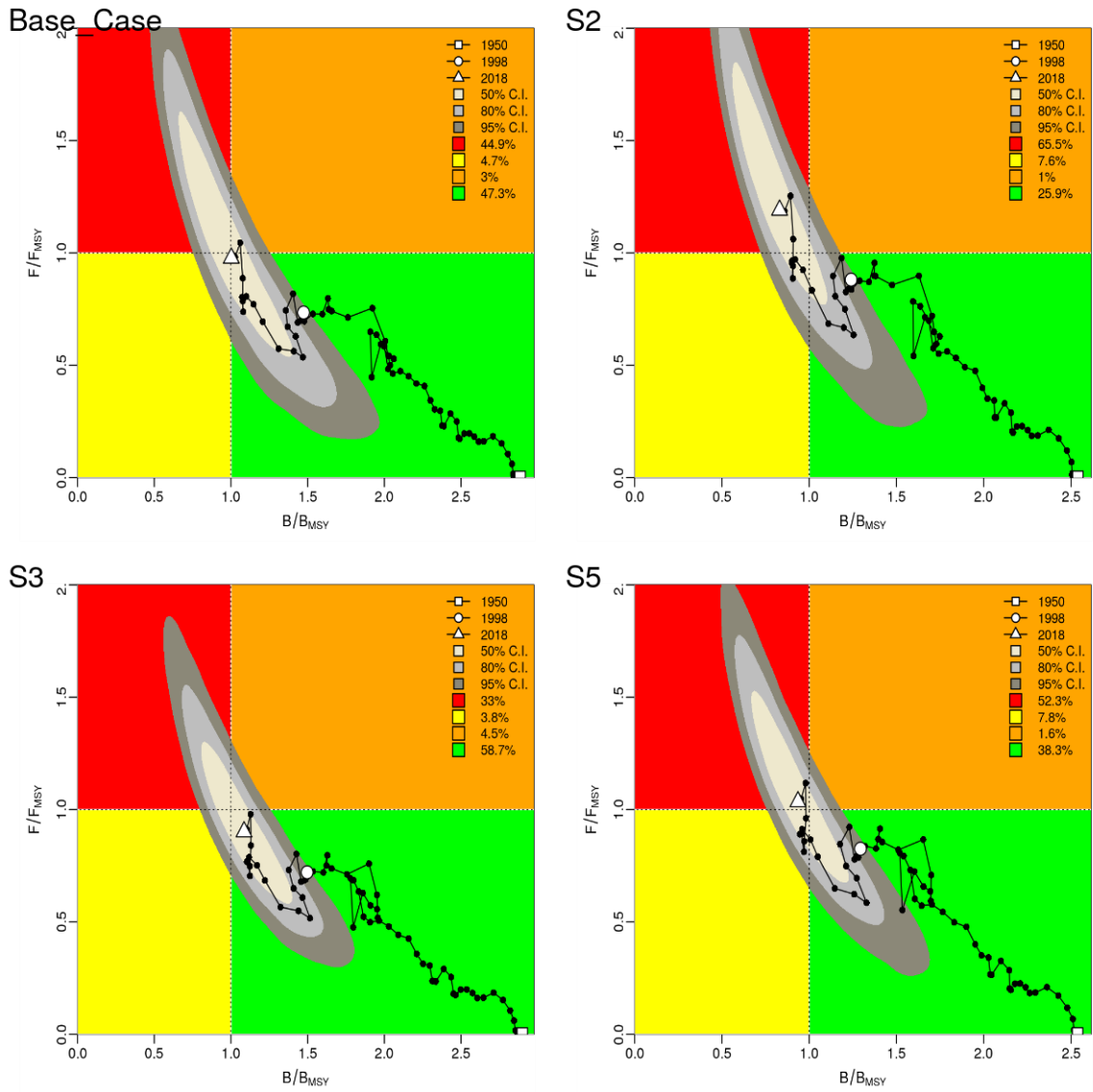


Figure 63. Kobe phase plot of B/B_{MSY} and F/F_{MSY} for the terminal assessment year 2018 for Atlantic yellowfin stock from each JABBA Reference Case (Base Case, S2, S3, and S5) showing the marginal density of the estimates from 10000 MCMC iterations. The probability of the terminal year points falling within each quadrant is indicated in the figure legend.

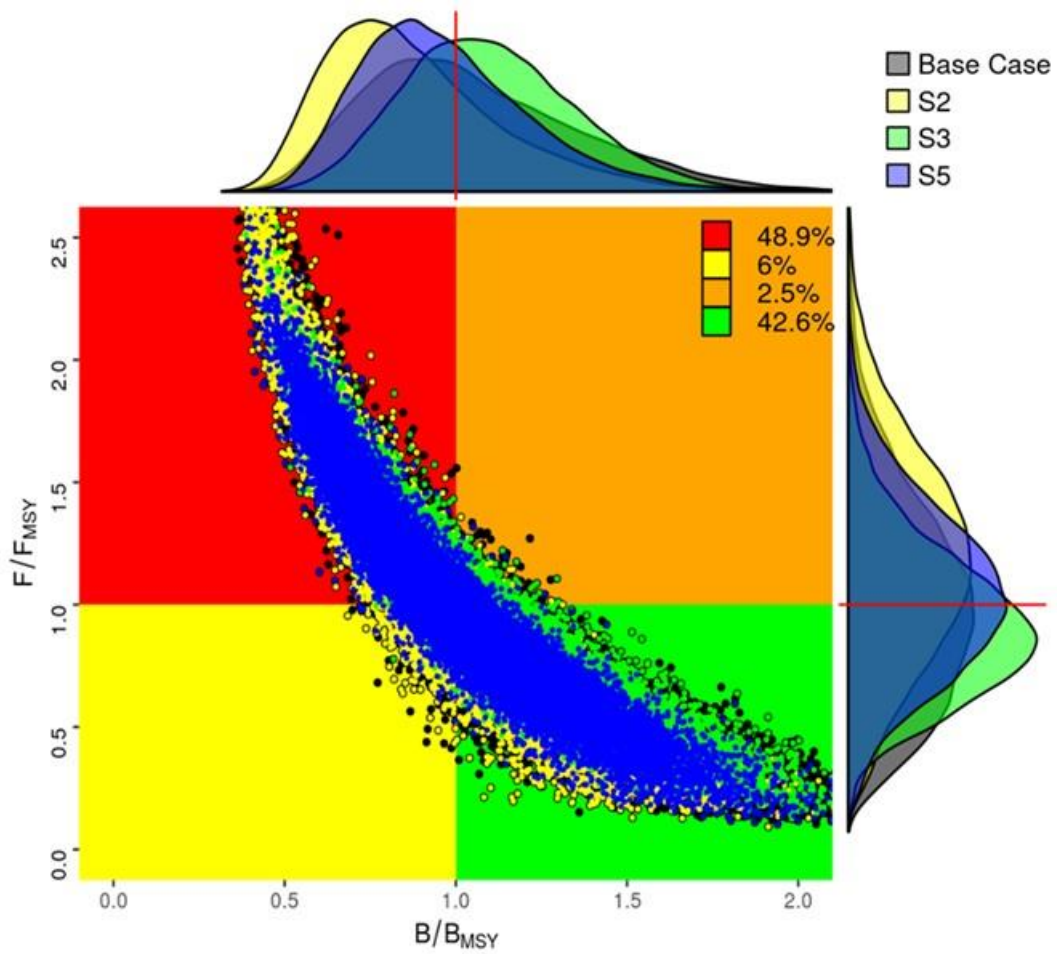


Figure 64. Combined Kobe phase plot of B/B_{MSY} and F/F_{MSY} for the terminal assessment year 2018 for Atlantic yellowfin stock from the JABBA all Reference Cases (gray: Base Case, yellow: S2, green: S3, and blue: S5) showing the marginal density of the estimates from 10000 MCMC iterations in each model. The probability of the terminal year points falling within each quadrant is indicated in the figure legend.

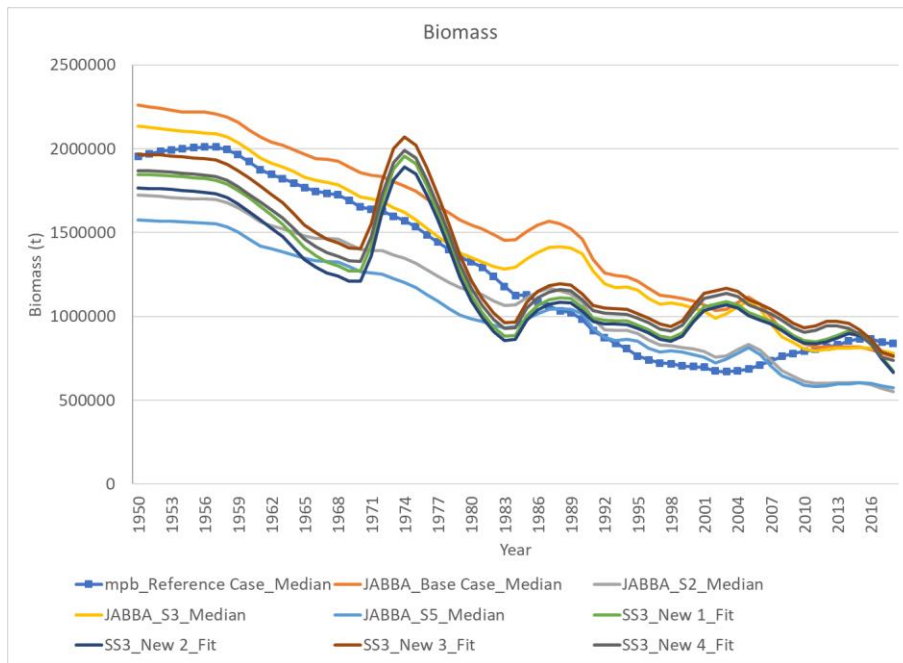


Figure 65: Estimates of total biomass obtained for all model runs used to develop the management advice.

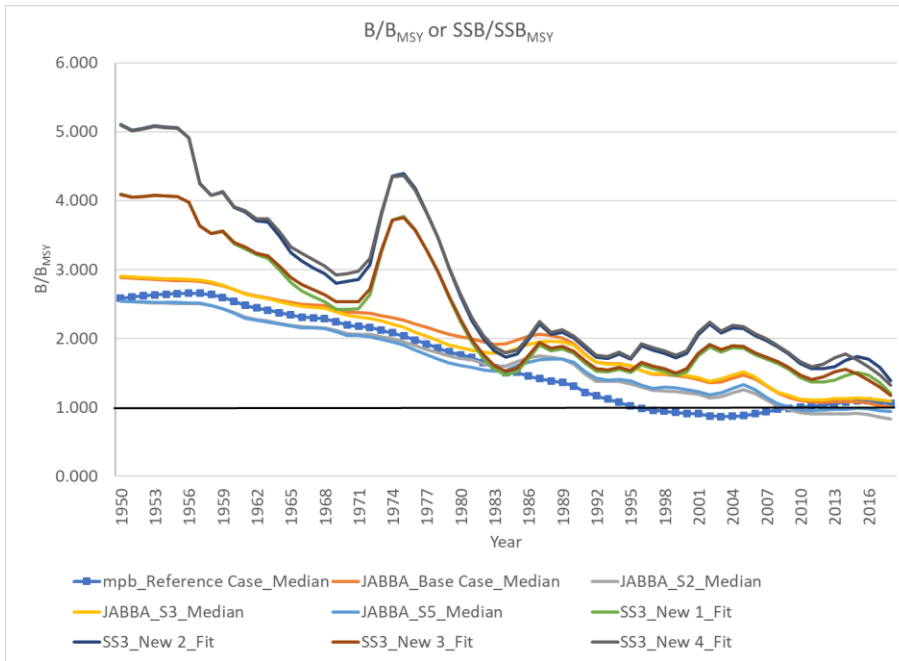


Figure 66. Estimates of relative Biomass B/B_{MSY} obtained for all model runs used to develop the management advice.

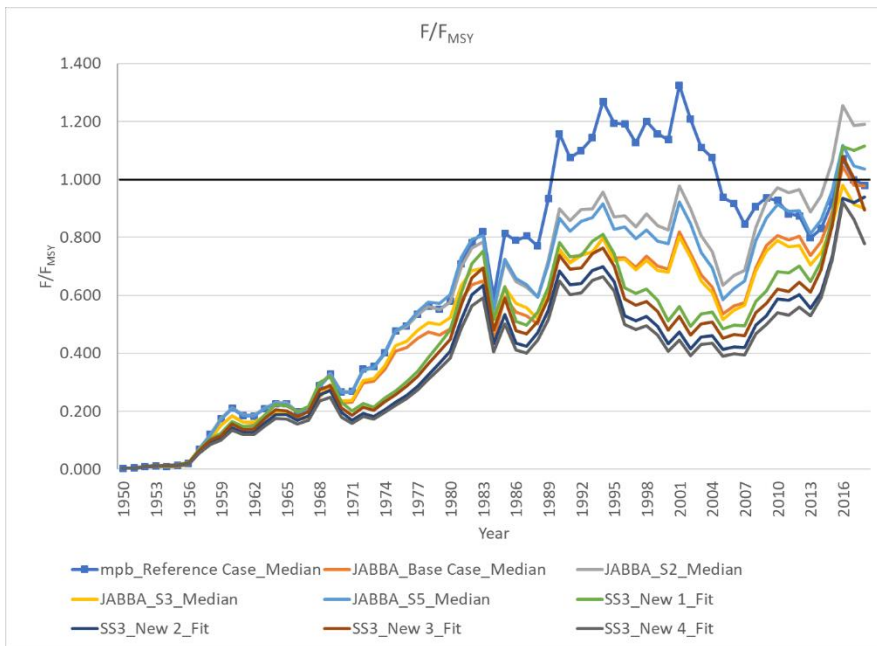


Figure 67. Estimates of relative fishing mortality F/F_{MSY} obtained for all model runs used to develop the management advice.

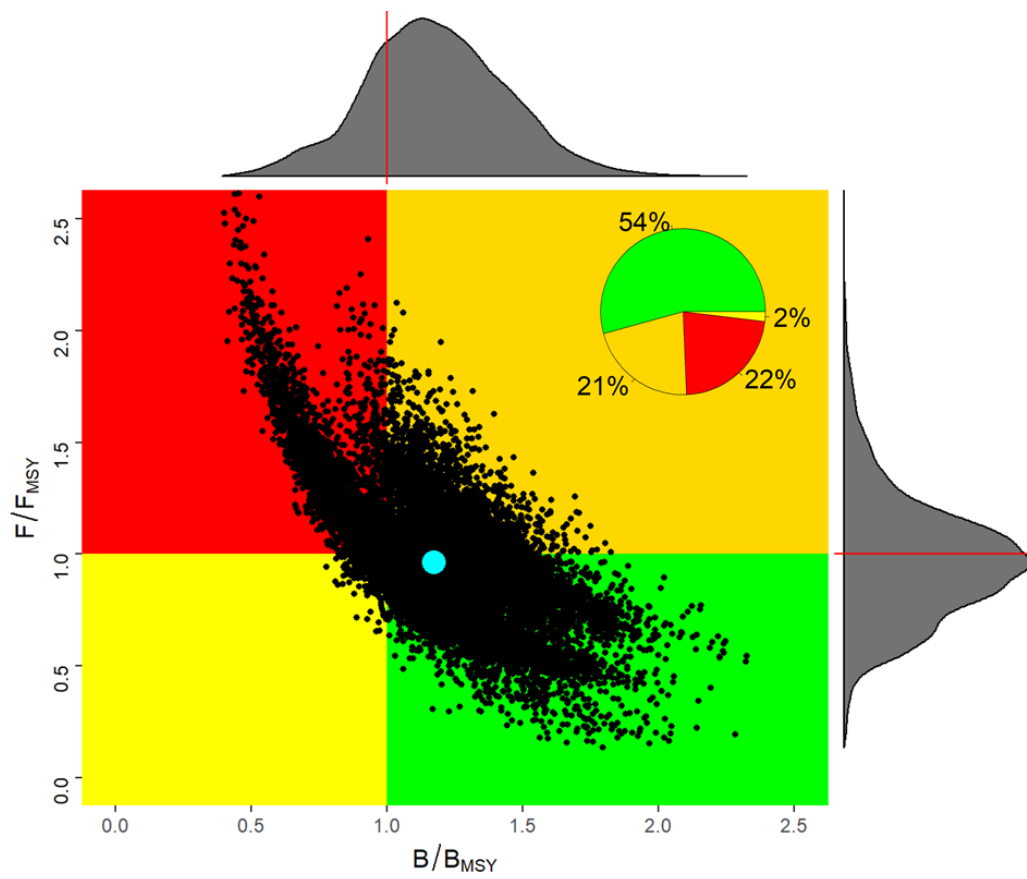


Figure 68. Kobe plot estimated from the combination of stock synthesis, JABBA and MPB model runs chosen to develop the management advice.

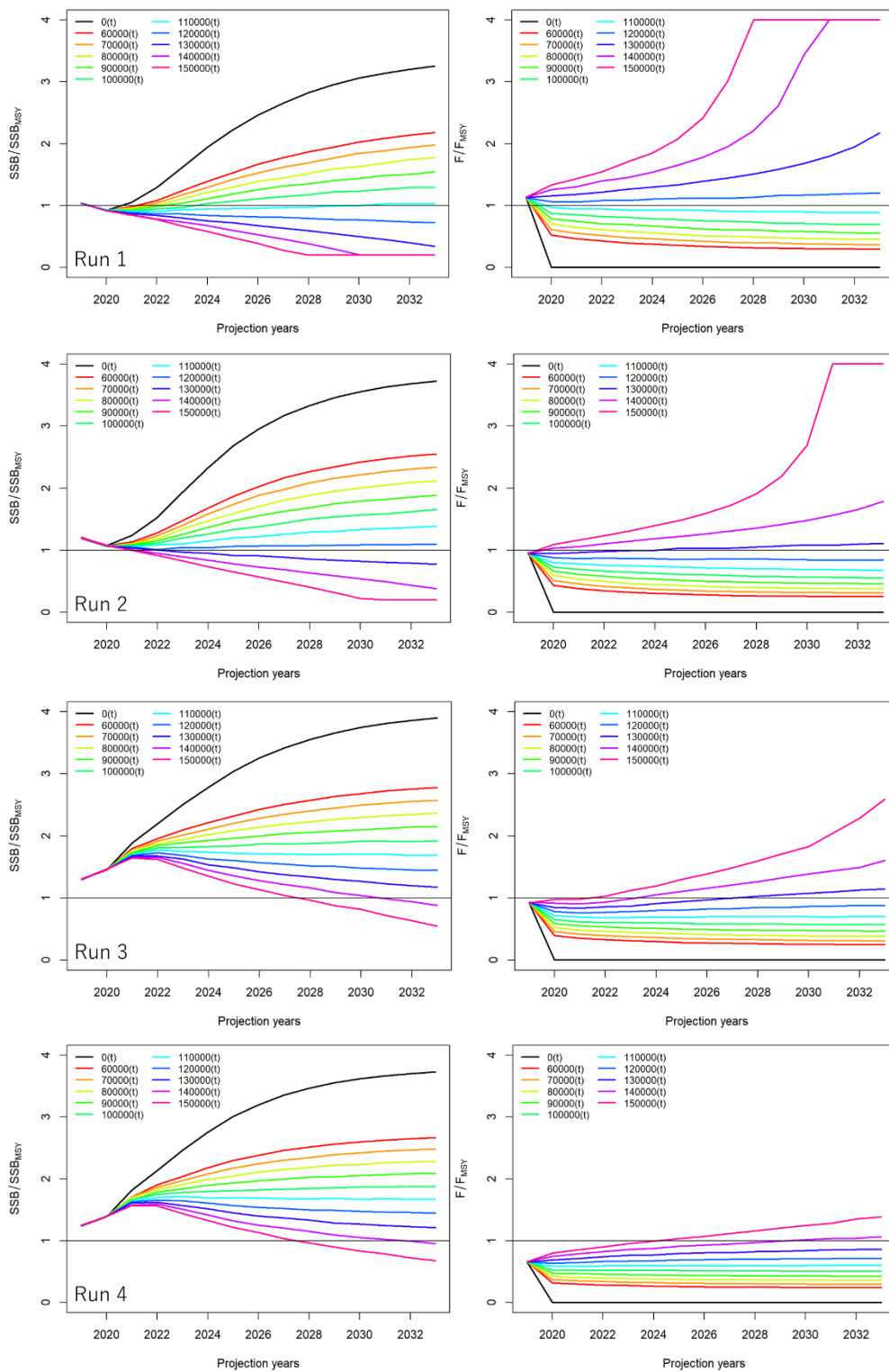


Figure 69. Trends of projected relative biomass (left panel, B/B_{MSY}) and fishing mortality (right panel, F/F_{MSY}) of Atlantic yellowfin stock under different TAC scenarios (0, 60000 – 150000 t) from SS3 uncertainty grid runs (Run 1, Run 2, Run 3, and Run 4). Each line represents the median of 10000 MVN iterations by projection year.

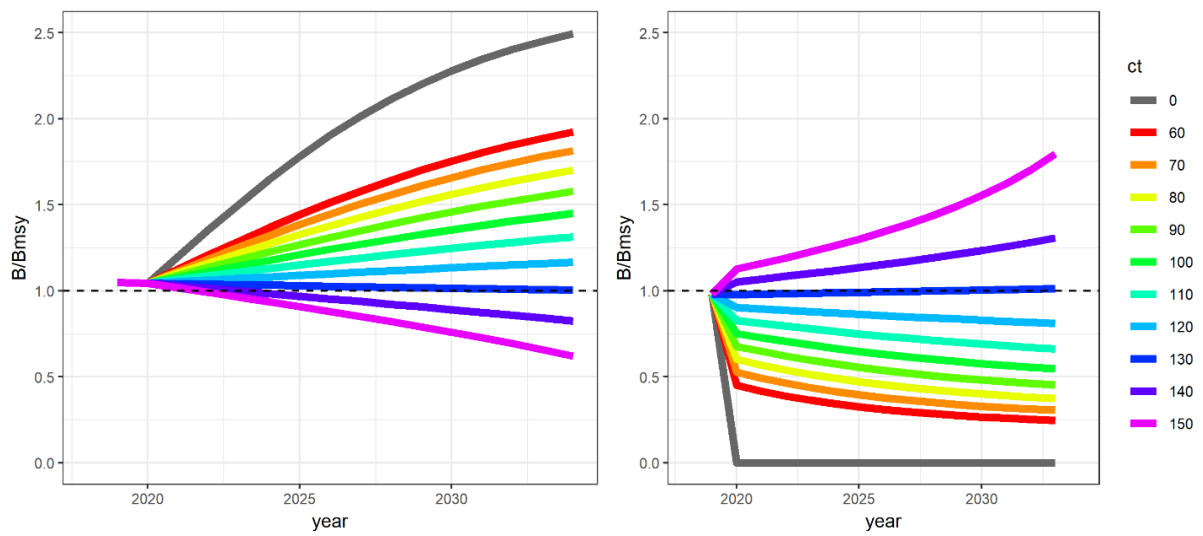


Figure 70. Trends of projected relative biomass (left panel, B/B_{MSY}) and fishing mortality (right panel, F/F_{MSY}) of Atlantic yellowfin stock under different TAC scenarios (0, 60,000 – 150,000 t) from MPB Reference Case. Each line represents the median of 500 bootstrap iterations by projected year.

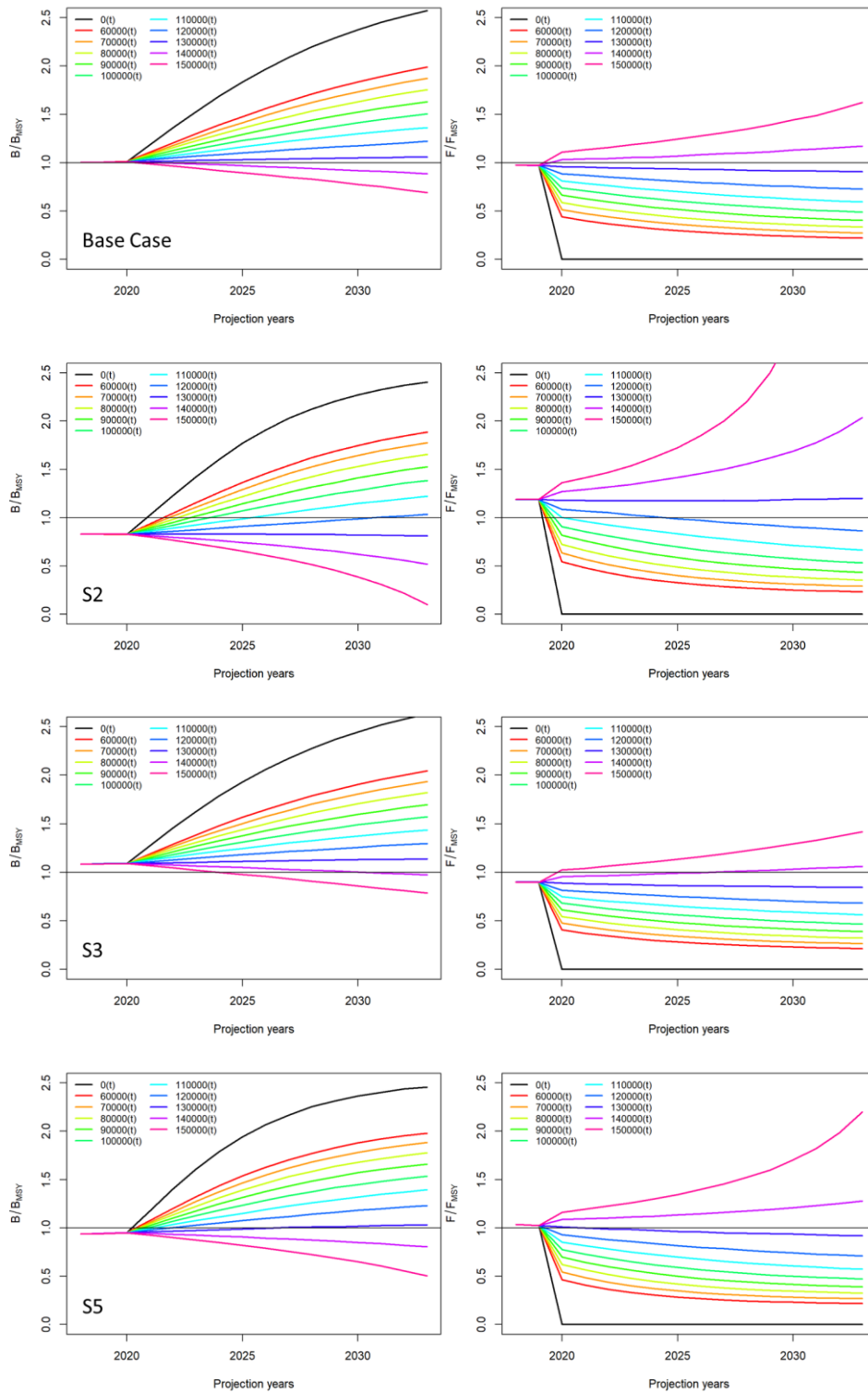


Figure 71. Trends of projected relative biomass (left panel, B/B_{MSY}) and fishing mortality (right panel, F/F_{MSY}) of Atlantic yellowfin stock under different TAC scenarios (0, 60,000 – 150,000 t) from JABBA Reference Cases (Base Case, S2, S3, and S5). Each line represents the median of 36000 MCMC iterations by projected year.

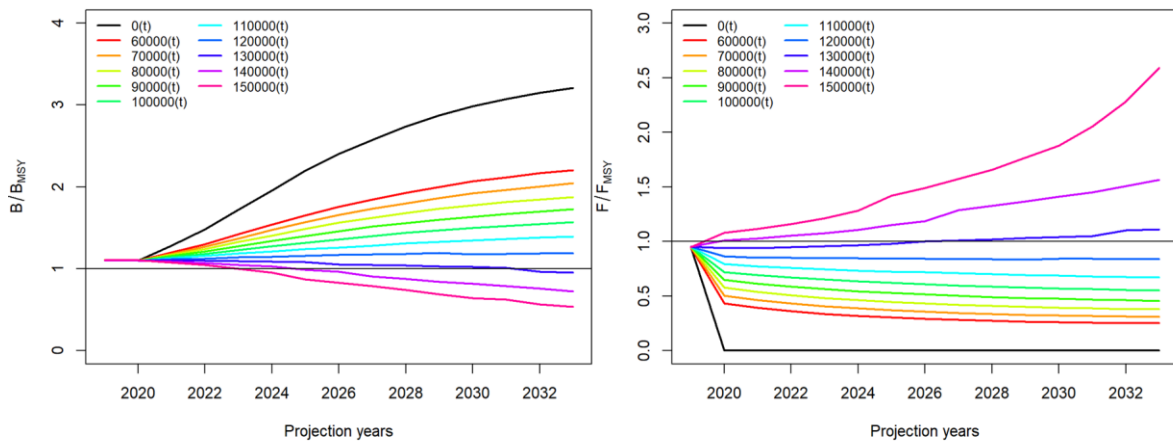


Figure 72. Trends of projected relative biomass (left panel, B/B_{MSY}) and fishing mortality (right panel, F/F_{MSY}) of Atlantic yellowfin stock under different TAC scenarios (0, 60000 – 150000 t) from JABBA, MPB, and SS3 using 9 runs (JABBA (Base Case, S2, S3, and S5), MPB, Stock Synthesis (runs 1-4)). Each line represents the median of 20000 iterations by projected year. This result was used to develop the management advice of Atlantic YFT stock.

| PHASE and TASK | | 2018 | | | | | | 2020 | | | | | | 2021 | | | | | | | | | | | | | | | | |
|------------------------------|--|------|------|----|---|----|-----|------|----|-----|----|---|----|------|------|----|---|----|-----|---|----|-----|----|---|----|-----|------|----|---|----|
| | | VII | VIII | IX | X | XI | XII | I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XII | I | II | III | IV | V | VI | VII | VIII | IX | X | XI |
| Phase 1 | 1.1) Develop detailed workplan | █ | █ | █ | █ | █ | █ | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.2) Intiate MSE framework | █ | █ | █ | █ | █ | █ | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.3) Participate in workshops | █ | █ | █ | █ | █ | █ | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.4) Ensure technical integration with stock assessments | █ | █ | █ | █ | █ | █ | | | | | | | | | | | | | | | | | | | | | | | |
| | 1.5) Ensure quality in inputs | █ | █ | █ | █ | █ | █ | | | | | | | | | | | | | | | | | | | | | | | |
| Phase 2 | 2.1) Condition OM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2.1.1) Develop ss3 for SKJ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2.1.2) Condition OM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2.2) Analisis OEM | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2.3) Identify MP | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 2.3.1) Assessment model | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.3.2) Management advice | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.4) Preliminary simulations | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Phase 3 | 3.1) Evaluation of MPs. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3.2) Summary and presentation of results | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3.3) Dissemination of the main findings | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3.4) Peer review publication | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Figure 73. Calendar and list of activities proposed for phase two and three for the research project in support of the MSE for tropical tunas

Agenda

1. Opening, adoption of Agenda and meeting arrangements
2. Summary of available data for assessment
 - 2.1 Biology
 - 2.2 Catch, effort, size and CAS estimates
 - 2.3 Relative Abundance estimates
3. Stocks Assessment Methods and other data relevant to the assessment
 - 3.1 Stock Synthesis
 - 3.2 Surplus production model MPB
 - 3.3 Bayesian Surplus Production Models
4. Stock status results
 - 4.1 Stock Synthesis
 - 4.2 Surplus production model MPB
 - 4.3 Bayesian Surplus Production Models
 - 4.4 Synthesis of assessment results
5. Projections
 - 5.1 Projections JABBA
 - 5.2 Projections MPB
 - 5.3 Projections Stock Synthesis
 - 5.4 Kobe matrix for yellowfin tuna [to be adopted by correspondence Sep 2, 2019]
6. Recommendations
 - 6.1 Research and statistics
 - 6.2 Management
7. Other matters
8. Adoption of the report and closure

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List of Papers and Presentations

| Reference | Title | Authors |
|---------------|---|---|
| SCRS/2019/011 | Report of the Yellowfin tuna stock assessment session | Anon. |
| SCRS/2019/100 | Datos estadísticos de la pesquería de túnidos de las Islas Canarias durante el periodo 1975 a 2018 | Delgado R. |
| SCRS/2019/107 | Using effort control measures to implement catch capacity limits in ICCAT PS fisheries: an update | Sharma R., and Herrera M. |
| SCRS/2019/115 | Stock assessment for Atlantic yellowfin using a biomass production model | Merino G., Murua H., Urtizberea A., Santiago J., Andonegi E., and Winker H. |
| SCRS/2019/120 | Regional abundance indices of yellowfin tuna (<i>Thunnus albacares</i>) inferred from data based on the Taiwanese distant-water longline fishery in the Atlantic Ocean | Sung YF., Lin WR., Su NJ., and Lu YS. |
| SCRS/2019/121 | Stock synthesis model for Atlantic yellowfin tuna | Walter J., Urtizberea A., Hiroki Y., Satoh K., Ortiz M., Kimoto K, and Matsumoto T. |
| SCRS/2019/122 | Standardization of yellowfin tuna CPUE in the Atlantic Ocean by the Japanese longline fishery which includes cluster analysis | Matsumoto T., Yokoi H., and Hoyle S. |
| SCRS/2019/123 | Standardized catch rates for yellowfin tuna (<i>Thunnus albacares</i>) from the Venezuelan pelagic longline fishery in the Caribbean Sea and adjacent waters of the western central Atlantic for the period of 1991-2018. | Narvaez M., Alarcon J., Evaristo E., Gutierrez X., and Arocha F. |
| SCRS/2019/124 | Estimation of Ghana tasks I and II purse seine and baitboat catch 2012 – 2018: data input 2019 yellowfin stock assessment | Ortiz M., Palma C., Ayivi S., and Bannerman P. |
| SCRS/2019/125 | Atlantic Yellowfin tuna stock assessment: an implementation of Bayesian state-space surplus production model using JABBA | Sant'Ana R., Mourato B., Kimoto A., Walter J., and Winker H. |

| Reference | Title Presentation | Authors |
|-----------------|---|---|
| SCRS/P/2019/037 | Age Estimates of Yellowfin Tuna Caught near Ascension Island | Downes K., Pacicco A., and Ailloud L. |
| SCRS/P/2019/039 | Catch, effort, size and weight of yellowfin tuna (<i>Thunnus albacares</i>) from the Venezuelan purse seine and baitboat fleets operating in the Caribbean Sea and the western central Atlantic | Narv ez M., Alarc n J., Evaristo, E., Marcano J., and Arocha F. |
| SCRS/P/2019/043 | Diagnostics for stock synthesis model SS3 | Yokoi H., Satoh K., Walter J., and Matsumoto T. |

SCRS Document and Presentations Abstracts as provided by the authors

SCRS/2019/100. - This document presents a summary of the development and current composition of the Canary Islands baitboat fleet and the catches made between 1975 and 2018. This paper also presents size histograms of the different species caught in 2018 and the average between 2013 and 2017. An estimate of fishing effort was made, differentiating between vessels lesser than and greater than 50 GRT, taking into account that the former (vessels less than 50 GRT) carry out daily trips, with an average of 9 hours at sea, whereas the latter carry out trips lasting more than a day.

SCRS/2019/107 - Total Allowable Catches (TAC's) have been implemented for numerous stocks by ICCAT. However, catch controls, while ensuring that overall fishing mortalities are not exceeded, are not implemented properly because some ICCAT CPCs exceed targets on a regular basis or are not covered by the measures. This is an issue in multi-species fisheries where monitoring of catch in near-real time is complex, especially for industrial tuna purse seine and pole-and-line fisheries, that very often catch juvenile yellowfin tuna and bigeye tuna when targeting skipjack tuna, as those species tend to aggregate forming mixed schools. Also, discards of tropical tunas are usually not reported to the ICCAT and may be important in industrial purse seine and longline fisheries. In other multi-species fisheries, the adoption of measures on one stock may prompt changes of target to other stocks, with a potential to undermine the status of those, -e.g. longline fisheries changing gear configuration, purse seine fisheries shifting from free-school to associated sets, or the contrary, and multi-gear fisheries moving from a gear targeting a stock (pole-and-line targeting skipjack tuna) to another (handline targeting yellowfin tuna).

We examined the historic data series of catch and effort for the Purse seine fleet on tropical tuna in the Atlantic Ocean. Based on the information numerous models were developed to predict how much would be caught at a particular effort target. While these catch targets may vary by time and area, the implementation of time-area closures by the ICCAT has not been successful, mostly due to effort redistribution and catches in areas outside the closure making up for the catch reduction expected from it or an unwanted increase in the catches of other stocks (ICCAT 2016). The purpose of this study is to explore how full seasonal closures (monthly measures), where vessels remain in port, may better assist surface fisheries in achieving the targets set by the ICCAT. We developed a model based on parameter estimates of individual models to estimate catches by time as a function of available biomass for BET, effort by strata (month), and month-effort interactions to estimate BET catch targets (and associated YFT and SKJ as a result). While these models are subject to some uncertainty, they provide managers with the ability to predict catches over a time-period, thereby facilitating monitoring and the use of a more precautionary adaptive approach in attaining conservation targets with a desired precision level. In addition, the implementation of seasonal fishery closures has proved successful at the IATTC, which has been using a control rule based on this principle for over fifteen years with stocks maintained by the target reference level throughout that period. Management systems based on seasonal fishery closures have also proved to be more efficient than those based on TACs, due to the latter leading to underreporting unless extensive monitoring is in place. Some examples of how the control rule may be implemented are provided. A decision support tool is developed based on the data and proposed season closures to implement an overall target catch on Bigeye tuna, one of the stocks managed to a TAC by ICCAT.

SCRS/2019/115. - In this paper we present a stock assessment for Atlantic Ocean yellowfin using a biomass dynamic model. Overall, using the Joint Longline CPUE index presented to the data preparatory meeting and the catch series made available by ICCAT Secretariat, we estimate that the stock is not overfished and not undergoing overexploitation with a 43.4% of probability. However, the initial set of diagnostics calculated with the best fit to the available data suggest that these results need further analysis. This could be refining the space of parameters to facilitate model estimates and to try alternative CPUE indices. These results are a start point for the stock assessment of yellowfin and will be further explored during the stock assessment session in July 2019.

SCRS/2019/116 - Standardization of yellowfin tuna CPUE by Japanese longline in the Atlantic Ocean was conducted using generalized linear models (GLM). The models incorporated fishing power based on vessel ID where available, and used cluster analysis to account for targeting. The variables year-quarter, vessel ID, latlong5 (five-degree latitude-longitude block), cluster, number of hooks per basket and number of hooks per set were used in the standardization. The numbers of clusters selected were 4 for all the regions.

Dominant species differed among clusters. The effects of each covariate varied by region and period. The CPUE trends differed among regions, and were similar to those estimated using the 'traditional method' (without vessel ID and cluster analysis), though with some differences probably due to the inclusion of vessel effects and cluster variables.

SCRS/2019/117 - Standardized index of relative abundance for yellowfin tuna (*Thunnus albacares*) was estimated using Generalized Linear Models approach assuming a delta lognormal model distribution. For this, a combination of data sources (the Venezuelan Pelagic Longline Observer Program 1991-2011 and the National Observer Program 2012-2018) was used, considering as categorical variables year, season/quarter, condition and type of bait, vessel type, depth of fishing, and area. As indicators of overall model fitting, diagnostic plots were evaluated. The standardized yellowfin tuna catch rate index show relatively stable values through 2004 subsequently catch rates increased to a maximum in 2007. Thereafter, standardized catch rates showed a declining trend that appears to be stabilized during the last four years (2015-2018).

SCRS/2019/118 - Information from the AVDTH Ghana fisheries and other sources was used to estimate the task I and II for the Ghanaian tuna baitboat and purse seine fisheries during 2012 – 2018. Catch and landing data collected and managed by the Marine Fisheries Research Division (MRFD) of Ghana included both landings and logbook information from 2005 up to 2017. The estimation of total Ghana catches, catch composition and quarterly-spatial (1°x1°) distribution followed the recommendations from the SCRS Tropicals working group agreed during the yellowfin data preparatory meeting. Sampling for species composition and size distribution were reviewed to determine appropriate sampling for the different components of the Ghana fleets by major gear type. In summary, estimates of total yellowfin catch from the AVDTH database were lower compared to prior reports.

SCRS/2019/119 - Tropical tunas, including bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacares*), are major target species for the Taiwanese distant-water tuna longline fishery, with the main fishing ground occurring in tropical waters of the Atlantic Ocean. Regional abundance indices of yellowfin tuna were developed by period using generalized linear models (GLMs). A whole period (from 1967-2018) and three separate periods from 1967-1989, 1990-2005, and 2006-2018 with the information on operation type (i.e., the number of hooks per basket, HPB) available for this late period were considered in the standardization models of yellowfin tuna CPUE (catch per unit effort). Standardized CPUE of yellowfin tuna showed almost identical trends between whole and separate periods. However, the trends differed among regions especially in recent years from 2010, with an increase for the western tropical Atlantic Ocean but slightly decrease in the eastern tropical waters.

SCRS/2019/121 - This paper represents a stock assessment of Atlantic yellowfin tuna using the age and length structured integrated assessment model Stock Synthesis version 3.30.09 (SS). The model configuration is largely similar to that of the 2016 assessment and benefits from a joint longline index rather than several separate longline indices with conflicting trends. Additionally, the model benefits from substantially revised length composition input which has reduced conflicting length data and homogenized the fleet structure. Initially we constructed a reference model and tested its performance across a suite of standard model diagnostic tests which indicated decent model performance. Then we produced a series of sensitivity models that evaluated different model formulations. After evaluation of the sensitivity runs, a structured uncertainty grid across multiple model assumptions and structures may be developed. This uncertainty grid is designed to capture much of the key uncertainties in model inputs and parameter assumptions and represents the basis for quantification of Kobe management advice.

Summary of active Commission requests and previous SCRS responses for tropical tunas

Ghana's comprehensive and detailed capacity management plan on the level of catches. Rec. 16- 01, paragraph 12c:

Background: (Rec. 16-01), paragraph 12c. *Ghana shall be allowed to change the number of its vessels by gear type within its capacity limits communicated to ICCAT in 2005, on the basis of two baitboats for one purse seine vessel. Such change must be approved by the Commission. To that end, Ghana shall notify a comprehensive and detailed capacity management plan to the Commission at least 90 days before the Annual Meeting. The approval is notably subject to the assessment by the SCRS of the potential impact of such a plan on the level of catches.*

The SCRS has not yet provide a response to this request because it has not received the information required to evaluate the impact of changes in the Ghana capacity management plan.

Evaluate the efficacy of the area/time closure referred to in paragraph 13 for the reduction of catches of tropical tuna juveniles. Rec. 16-01, paragraph 15

Background: (Rec. 16-01), paragraph 15. *As soon as possible and at the latest by 2018, the SCRS shall evaluate the efficacy of the area/time closure referred to in paragraph 13 for the reduction of catches of juvenile bigeye and yellowfin tunas. In addition the SCRS shall advise the Commission on a possible alternative area/time-closure of fishing activities on FADs to reduce the catch of small bigeye and yellowfin tuna at various levels.*

In 2017 the SCRS was not able to respond to this request, however, in 2018 it did provide a response building on a number of moratorium analyses that were conducted by the SCRS in previous years. Although the SCRS conducted a preliminary analysis, it reiterated that additional years of data (beyond 2017) would be required to adequately assess the result of the new closure, and those data will not be available until after the deadline provided by the Commission.

The Committee noted that preliminary results indicate that further increases in the number of purse seiners and relocation of effort to areas outside the moratorium has undermined the effectiveness of the moratorium in achieving the objective set by the Commission.

The Committee noted that while more time is needed to be able to answer the request from the Commission to evaluate de current moratorium, preliminary results show that FAD effort relocation to areas outside the moratorium and/or future increases of the effort (number of purse seiners, number of FADs sets, etc.) may render this measure ineffective unless additional measures are adopted to address these impacts.

The Committee considered that a larger area, possibly combined with a longer closure, may address the issue of redistribution of effort. Along with a thorough analysis of the AOTTP data and of the interplay between fishing capacity, fishing effort and fishing mortality, these considerations will allow the further exploration of the effectiveness of any time/area closures within a much broader management context.

Recommendations made by the FAD Working Group (Annex 8) and develop a work plan. Rec. 16-01, paragraph 49 (a)

Background: [Rec. 16-01] paragraph 49(a). *At its 2017 meeting the SCRS shall address to the extent possible the Recommendations made by the FAD Working Group in 2016 (Annex 8) and for the remaining ones develop a work plan to be presented to the Commission at its 2017 Annual meeting.*

In 2017 the SCRS started incorporating some of the actions recommended by the FAD working group in 2016 as part of the group's workplan. During 2018 the SCRS made progress on some of these actions including definitions of FAD related terms, which were presented to the tRFMO FAD working group in early 2019, reporting requirements and data submission forms (i.e. ST08). Other recommended actions are still to be considered by the tropical working group and have to be developed as part of the Tropical tuna working group working plan and the plans of other SCRS working groups related to FAD fishing.

Provide performance indicators for skipjack, bigeye and yellowfin tuna, with the perspective to develop management strategy evaluations for tropical tunas. Rec. 16-01, paragraph 49 (b)

Background: [Rec. 16-01] paragraph 49(b). *At its 2017 meeting the SCRS shall provide performance indicators for skipjack, bigeye and yellowfin tuna as specified in Annex 9, with the perspective to develop management strategy evaluations for tropical tunas.*

In 2017 the SCRS recommended and performance indicators developed for North albacore (see Report of the Second Intersessional meeting of Panel 2, Anon. 2017b) can be used as an initial list to be used for MSE simulations. The SCRS conducted phase one of a project on tropical tuna MSE ((Merino et al 2018)).

Develop a table that quantifies the expected impact on MSY, BMSY, and relative stock status for both bigeye and yellowfin resulting from reductions of the individual proportional contributions of major fisheries to the total catch. Rec. 16-01, paragraph 49 (c)

Background: [Rec. 16-01] paragraph 49(c). *At its 2017 meeting the SCRS shall develop a table for consideration by the Commission that quantifies the expected impact on MSY, BMSY, and relative stock status for both bigeye and yellowfin resulting from reductions of the individual proportional contributions of longline, FAD purse seine, free school purse seine, and baitboat fisheries to the total catch.*

In 2017 and 2018 the SCRS provided extensive responses to this request which were considered but the Commission in the respective annual meetings.

Evaluate the contribution of by-catches and discards to the overall catches in ICCAT tropical tuna fisheries, on a fishery by fishery basis. Rec. 16-01, paragraph 53

Background: [Rec. 16-01] paragraph 53. The SCRS shall evaluate the contribution of by-catches and discards to the overall catches in ICCAT tropical tuna fisheries, on a fishery by fishery basis.

The SCRS provided a response to the Commission on this matter in 2017.

Advise the Commission on possible measures allowing to reduce discards and to mitigate onboard post-harvest losses and by-catch in ICCAT tropical tuna fisheries. Rec. 16-01, paragraph 53

Background: [Rec. 16-01] paragraph 53. *The SCRS shall advise the Commission on possible measures allowing to reduce discards and to mitigate onboard post-harvest losses and by-catch in ICCAT tropical tuna fisheries.* The SCRS provided a response to the Commission on this matter in 2017.