REPORT OF THE 2015 ICCAT BIGEYE TUNA STOCK ASSESSMENT SESSION

(Madrid, Spain - July 13 to 17, 2015)

1. Opening, adoption of agenda and meeting arrangements

The meeting was held at the ICCAT Secretariat in Madrid from July 13 to 17, 2015. The Executive Secretary opened the meeting and welcomed participants ("the Group"). Mr. Driss Meski informed the Group that a contract has been recently signed between the European Union and ICCAT regarding the Atlantic Ocean Tropical tuna Tagging Programme (AOTTP) and that a first payment has been received. He also informed that the Secretariat has already announced three fixed-term positions at the Secretariat (Programme Coordinator, Administrative and Financial Officer, and Accountant), and the results are expected to be announced by the next SCRS meeting.

Dr Hilario Murua (EU-Spain), meeting Chairperson, welcomed meeting participants and thanked the Secretariat for hosting the meeting and providing all the logistical arrangements. Dr Murua proceeded to review the Agenda which was adopted with some minor 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 following participants served as rapporteurs:

Section	*Rapporteur*
Item 1.	Miguel Neves dos Santos
Item 2.1	Rodrigo Forsello
Item 2.2	Mauricio Ortiz
Item 2.3	Mauricio Ortiz and Craig Brown
Item 2.4	Daniel Gaertner
Item 3.1	Paul de Bruyn and Gorka Merino
Item 3.2	Paul de Bruyn, Gorka Merino and Michael Schirripa
Item 3.3	Paul de Bruyn, Gorka Merino and John Walter
Item 3.4	Paul de Bruyn and Gorka Merino
Item 4.1	Laurence Kell and Gorka Merino
Item 4.2	Laurence Kell, Gorka Merino and Michael Schirripa
Item 4.3	Laurence Kell, Gorka Merino and John Walter
Item 4.4	Laurence Kell and Gorka Merino
Item 4.5	Laurence Kell, Paul de Bruyn and Hilario Murua
Item 5.	Laurence Kell, David Die and Hilario Murua
Item 6.	Miguel Neves dos Santos, David Die and Hilario Murua
Item 7.1	David Die
Items 7.2 and 8	Hilario Murua

2. Summary of available data for assessment

2.1 Biology

Document SCRS/2015/138 presented length-weight relationships for bigeye tuna in the Northeast Atlantic. The study is based on the Fork Length (FL in cm) and Round Weight (RW in kg) of 1,501 individuals landed between 2007 and 2014. The range of sizes (61 – 194 cm) studied represents the most frequently observed sizes in bigeye tuna catches. Linear and non-linear fits were tested for the relationship $RW=a*FL^\wedge b$ and were compared between them.

Linear fit equation: $RW = 5.29919\text{E}^{-05} * FL^{\,2.8211264}$

Non-linear fit equation: $RW = 6.0568\text{E}^{-05} * FL^{\,2.79379}$

The fit of the non-linear equation to the data was slightly better than the fit of the linear equation, especially in the case of the large size specimens that are poorly represented in the sample and that are less frequent in the catch. However, the differences between results obtained with each equation are minor, with a 0.2% increase in the mean weight when using the non-linear fit. Both equations were compared with the relationship published by Parks *et al.* (1982) currently used by ICCAT, resulting in slight differences between the three equations.

The document presents an extensive revision of length-weight relationships for bigeye tuna in the Atlantic, Pacific and Indian Oceans. However, no comparisons between the relationships were presented as many were made using different morphometrics. Also, the new relationships presented for the Northeast Atlantic are not comparable with the new information for the Southwest Atlantic presented in SCRS/2015/096 during the 2015 Bigeye Tuna Data Preparatory Meeting, as different weight types (i.e. round weight vs gutted weight) are used.

During the presentation and discussion of the document, it was recommended to use the non-linear fit rather the linear, as this type of regressions have a better performance with such types of data.

A compilation of historical and new information on biology and conversion factors to be used for the assessment are available in Tables 1 and 2 of the Report of the 2015 ICCAT Bigeye Tuna Data Preparatory Meeting (SCRS/2015/011).

2.2 Catch, effort, size and CAS/CAA estimates

2.2.1 Catch estimates

An update of the bigeye Task I nominal catch series (T1NC) for the period 1950 to 2014 was presented by the Secretariat. The changes made since the Bigeye Tuna Data Preparatory Meeting (new and/or revised figures reported by the CPCs before July 2, 2015) were included. An update from the Ghana BET fisheries statistics was expected following the recommendations and guidelines from the Bigeye Tuna Data Preparatory Meeting. Those estimations were provided at the start of the meeting (SCRS/2015/139). Reports of 2014 BET catch were also received from Brazil and Venezuela just before the meeting. Catch reported from Brazil for 2014 was 3,475 t, while catches from Venezuela were unusually high (29,000 t) and well above historical values. The Group discussed that Brazil T1NC estimates were the highest in the Brazil catch time series and most of the catch was from handline gear, which is rather unusual for BET catches. The Group recommended continuing with the T1NC carry over estimates for Brazil and Venezuela from the data preparatory meeting for stock assessment purposes. It was requested by the Group that the Secretariat confirm with the statistical correspondents of Brazil and Venezuela the validity of the data submitted.

Document SCRS/2015/139 presents the details of the estimation of Ghana PS and BB catch statistics for 2006 - 2013. Following the recommendations from the data preparatory meeting, the Ghana BET catch estimates (T1NC) were prepared for two fleet components. The EU-PS species composition sampling data was used for estimating the catch composition by species (CAS) for Fleet P component. The Ghana sampling data was used to obtain the catch composition for Fleet A component. The Group concluded that the estimates presented for Task I were more robust and recommended to be included for the assessment. However, Task II catch and effort and catch at size data were not accepted as they required further analysis and work. During the discussions, the following was noted: a) there is still limited number of logbooks for the Fleet P, as well as limited size/composition sampling for the catches from this fleet; b) there is also concern regarding the spatial distribution of fishing effort for the Fleet P. The Group noted the importance of continuing the collaboration between Ghanaian and EU scientists to ensure the implementation of established sample and estimation protocols, and highlighted the long term goal of improving the Ghanaian capacity to carry out this work.

In summary, the Group recommended to update the T1NC including the Ghana BET catch presented in SCRS/2015/139 assuming that these estimates represent both the PS and BB catches. For Ghanaian catches in 2014, the Group decided to carry over the 2013 catch estimate. Therefore T1NC was updated for all assessment models. In the case of the VPA, as CAS was not available for the new Ghana estimates, the Group recommended updating the CAA assuming the same age distribution of the early CAA version presented by the Secretariat, and adjusting the yield at age using the mean weights at age such that the total catch match the update Task I.

The final input of T1NC estimates (both reported and estimated by the Group) are presented in **Table 1. Figure 1** shows the cumulative Task I catch series (1950 to 2014). Best estimates of total removals of BET for 2014 were 68,390 t. The catch in 2013 and 2014 continue the decreasing trend when compared to the 2011 catches which were over 80,000 t. Total catches of BET have been below the TAC since 2005 with the exception of 2011. **Figure 2** shows the spatial distribution of the catch by the areas defined for the stock synthesis model (SS3).

2.2.2 Size data

Document SCRS/2015/121 presented an analysis of the size frequency data and proposed size frequency data input for the Stock Synthesis Model. Overall, there is sufficient number of size samples for BET, in particular since 2004, in part due to the large number of size measurements from the Chinese-Taipei longline fleets that covers practically 100% of their catch. Proportions of size sampling by major gears (PS, LL and BB) compared to the proportion of the catch by gear, indicated that size sampling for the PS fleet can be improved. It was also noted during the discussion that the size data available and used in the SS3 analysis was limited for the EU and associated PS and BB fleets. Only 25% of the original samples were available for the 1980-2014 period. The size frequency data were aggregated by year, quarter, and fishery ID (15 fisheries described in **Table 2**) as defined in the data preparatory meeting for the SS3 models. Statistical indicators suggest that the minimum number of size samples to use should be about 200, however due to low sampling in early years the minimum number of samples was set at 50. Size frequency observations for Fishery ID 2 and 7 are very limited and it was recommended to link the size frequencies of these fisheries ID to the size frequencies of other similar fleet/gears.

Trends of mean size by Fishery ID show an increase in the latest years particularly for some of the longline fleets (**Figure 3**). Mean size estimated from the CAS of Chinese-Taipei match the mean size trends from the reported Task II size data of Chinese-Taipei, which is consistent with the CAS data having been estimated using the same size data as reported in Task II. However, the abrupt change in the size composition of bigeye tuna between years prior to 2005 and years after 2006, which may be the same case for YFT from the Chinese Taipei fleet, warrants further exploration.

The Secretariat presented an overview of the CAS and CAA for BET 1975-2014 (**Figures 4** and **5**). Overall, CAS was updated following the recommendations from the data preparatory meeting without including the recent estimates of Ghana catch statistics, as they were not available when the work was conducted (see above). The CAS was converted to CAA with the same algorithms used in the last assessment (Anon., 2011a). Briefly, the CAA was estimated by “slicing” the size data by inversion of the current von Bertalanffy growth model for Atlantic BET (Hallier *et al*., 2005), by year–quarter strata. During the meeting, the CAA matrix was updated to reflect the revised Ghana statistics adopted by the Group. Comparisons with the 2010 CAA matrix showed some differences in age distribution. These differences were in part due to changes in the CAS submitted by some CPCs since the last assessment. The resulting CAA matrix is shown in **Figure 5** and **Table 3**. The proportion of the Age 0 and 1 fish in the total catch began to increase over time and in 2014 represented 86% of the catch in numbers and 26% in weight.

2.3 Relative abundance estimates

During the 2015 Bigeye Tuna Data Preparatory Meeting, a number of alternative relative abundance indices were presented. At that meeting, the Group reviewed those estimates for suitability as indices of relative abundance to use in different stock assessment models. In some cases, the Group recommended that some modifications or additional analyses be conducted prior to the Bigeye Tuna Stock Assessment Session. The Group requested the development of indices of abundance utilizing the purse seine catch and effort data for potential use in sensitivity runs.

Document SCRS/2015/105 presents those CPUE indices derived using the EU purse seine detailed daily logbook data from 1991 to 2014, applying generalized linear fixed and mixed models. Results were presented on seasonal (Year-Quarter) standardized catch rate. The explanatory variables used in the analysis included: year, zone, quarter, harvest capacity, country, and starting date of the vessel. No annual abundance indices were developed, which would have been required for consideration in the VPA model. The Group was unable to thoroughly evaluate the indices presented as it considered that the description of the methodologies applied and the diagnostic shown were at times unclear or incomplete. The Group recommended the author to address those concerns in a subsequent revision to SCRS/2015/105, which could potentially be reviewed at the 2015 Tropical Tunas Working Group annual meeting. The Group did not adopt the indices in SCRS/2015/105 for use in any analyses conducted during the assessment meeting. The Group considers that advancing this work to achieve the long term objective of the development of abundance indices for juvenile bigeye tuna is of much greater importance.

2.4 Fishery indicators

In the Atlantic Ocean, bigeye tuna has been exploited by three major gears: longline, baitboat and purse seine. Many countries contribute to the total catch and ICCAT has detailed data on the fishery for this stock since the 1950s. While bigeye tuna is now a primary target species for some of the longline and baitboat fisheries, this species has always been of secondary importance for the other surface fisheries. Landings in weight for the 2010-2014 periods represent 48%, 15% and 37% for longliners, baitboats and purse seiners, respectively.

The total annual Task I catch (**Table 1**) increased up to the mid-1970s reaching 60,000 t and fluctuated over the next 15 years. In 1991, catch surpassed 97,000 t and continued to increase, reaching a historic high of about 135,000 t in 1994. Reported and estimated catch has been declining since then and fell below 100,000 t in 2001. This gradual decline in catch has continued, although with some fluctuations from year to year (**Figure 1**). The preliminary estimate for 2014 is 68,390 t. These reductions in catch are related to declines in fishing fleet size (longline) as well as decline in CPUE (longline and baitboat). Catch series from fisheries located at the limits of the spatial distribution of bigeye or in very local areas may be indicators to detect changes in abundance. Bigeye tuna catch series for the peripheral fishery of small baitboats in Azores shows large interannual variations but without any specific trend; except for the very low catch registered in the 2000s (**Figure 6**). The bigeye tuna catch in Madeira and Canary Islands are stable but at lower levels than in the 1990s or even decreasing as depicted for baitboat operating from Dakar (**Figure 6**). The number of active purse seiners declined by more than half from 1994 until 2006, but then increased since 2007 as some vessels returned from the Indian Ocean to the Atlantic. The number of European and associated purse seiners operating in 2009-2013 was similar to the number operating in 2003-2004, but the carrying capacity increased by 20%.

During the meeting, two documents describing the Spanish tuna tropical fisheries were discussed. SCRS/2015/131 depicts the tropical tuna purse seine and baitboat fisheries for the 1991-2014 period. Off the Mauritanian coast the dFAD fishery developed since 2009 and continued to be very active in 2014, but exclusively targeting skipjack. On average, the yearly number of 1° squares fished by purse seiners has increased in the last five years. In contrast to skipjack, bigeye tuna catch from Spanish purse seiners decreased since 2011. The same decreasing trend has been observed for the fishing effort in terms of number of vessels and in carrying capacity. The mean weight of bigeye tuna caught by fishing mode showed a slow increase since 2008 for the FAD component (reaching 3.5 kg) and a more pronounced increase for the free school component (from 5 kg in the 2005 to 20-25 kg in the last two years). With respect to the baitboats operating off Senegal, catch of bigeye tuna and fishing effort remained stable. Document SCRS/2015/136 showed large fluctuations over time in the average weight (between 10 and 20 kg) of bigeye tuna caught by the Canary Islands baitboat fishery, but without any apparent trend. Bigeye catch from this fishery was also relatively stable in the last 3 years.

Mean average weight of bigeye tuna decreased from 1975 to 1998, but has remained relatively stable at around 10 kg during the last decade (**Figure 7**). This mean weight, however, is quite different for the different fishing gears, around 62 kg for longliners, 7 kg for baitboats, and 4 kg for purse seiners. In the last ten years, several longline fleets have shown increases in the mean weight of bigeye tuna caught, with the average longline-caught fish increasing from 40 kg to 60 kg between 1999 and 2010. During the same period, purse seine-caught bigeye tuna had average weights between 3 kg and 4 kg. Average weight of bigeye tuna caught in free schools is more than twice the average weight of those caught around FADs. This difference in average weight between these two fishing modes is even more pronounced since 2006 (**Figure 8**). Similarly, baitboat-caught bigeye tuna had an average weight between 6 and 10 kg over the same period, showing a higher inter-annual variability of the average weight compared to longline or purse seine caught fish.

Juveniles of bigeye tuna exhibit a strong association with natural or artificial floating object and as a consequence the development of a fishing mode using drifting fish aggregating devices (dFADs) may increase the vulnerability of these smaller fish to surface fishing gears. The proportion of bigeye tuna catch under dFADs by the main purse seiner fleets shows some differences between fleets, being 100% FAD-fishing for Ghana (SCRS/2015/139), about 84% for Spain (2010-2014, SCRS/2015/131) and close to 53% for France (2008-2012, Floch *et al*., 2014).

Within the framework of the EU CECOFAD research project (SCRS/2015/104), an indirect method has been proposed to reconstruct a time series of the number of FADS and GPS buoys deployed (SCRS/2014/133). From this study, the estimated total numbers of FADs released yearly has dramatically increased from less than 7000 FADs before 2008, to 17300 FADs in 2013(**Figure 9**). It should be stressed that there is a large variability in the number of dFADs deployed by vessel, as showed for the Spanish purse seine fleet. For instance, the number of active dFAD followed by quarter by Spanish vessel varies between 100 and 1100 (Delgado de Molina *et al*., 2015).

The change in buoy technology, expressed as the number of buoys by category (i.e., HF, satellite only, satellite and echo-sounder buoys) purchased every year, has been provided for the French purse seiner fleet for the 2004-2014 period (SCRS/2015/014). Buoys equipped with echo-sounder, have progressively substituted the two other types and are now predominant with a potential impact on the increase in fishing efficiency for purse seiners fishing on FADs (**Figure 10**). Such improvement in FAD-fishing technology over time has been also documented for the Spanish purse seine fleet (**Figure 11**) and these new technologies can increase the catchability of juvenile bigeye tuna in the recent years.

Fishery indicators based on the number of 5°x5° fished where bigeye tuna were caught may detect potential changes in abundance or in fishing strategies over time (SCRS/2014/080). The number of 5° squares explored with bigeye catch (>1 ton per year) by the longline fleets fluctuated, but without any discernible trend between the 1970s and the 2000s. However, since the early 2000s the number of 5°x5° with bigeye tuna catches by several fleets of longliners has substantially decreased (**Figure 12**). The situation is opposite for the EU purse seiners whose fishing grounds have expanded since 2007, likely due to a combination of the increasing use of dFADs/buoys and the access to new or historic areas that resulted from the renewal of fishing agreements (**Figure 13**).

Document SCRS/2015/140 presented an analysis of the length frequency data (CAS) for Atlantic bigeye tuna using two methods. Powell-Wetherall plots explored changes in Z based on length data and catch curve analysis using the CAA to evaluate changes in selection patterns. The document provides estimates of total mortality Z for fully selective ages and estimates of selectivity by age. The Group noted the usefulness of using simple methods for both exploration and verification of input data, as well as good indicator of trends, and initial estimates for parameters of more complex models. For example, the F ratio for the age plus group in the VPA, or terminal F values, and potential identification of changes in selectivity patterns inferred from catch curve analysis by major gear and time period.

Mean length, and its confidence intervals over years are superposed to length-reference points (i.e., length at infinity, the length at which the population achieves its maximum biomass and the length at which 50% of the population reach maturity) with the aim to identify for each fishing gear the lengths for which the respective catch can be assessed. Estimates of Z derived from the Powell-Wetherall plots (**Figure 14**) showed a significant decrease from 1990 (Z=0.55) to 1995 (Z=0.35) then a slow continuous increase until 2014 (Z=0.45).

3. Methods and other data relevant to the assessment

3.1 Production models

Document SCRS/2015/073 presented a generic strategy for conducting stock assessment which was proposed at the Atlantic bigeye (*Thunnus obesus*) data preparatory meeting, i.e. i) agree in advance on the hypotheses to test; ii) check for convergence; ii) identify violation of assumptions by plotting residuals; iii) use methods such as the jack knife or bootstrap to identify problems with the data and model specifications; and iv) conduct hindcasts to evaluate predictive ability and, hence, robustness of advice. Although the diagnostics presented were for a biomass dynamic model, they are generic and applicable to models that use different datasets and a variety of structures. As the complexity of models increase, diagnostics become more important to understand the robustness of estimates and how they are incorporated into the management advice. Diagnostics also make the stock assessment process more transparent and help identify where more knowledge and better data are required. The diagnostics were presented and alternative possibilities for the shape of the production function and abundance indexes to be used were discussed by the Group. The aim of this presentation was to agree on a strategy to perform the stock assessment of Atlantic bigeye rather than to getting into the technical details of this analysis. The Group noted the usefulness of the approach and attempted to apply it to production models.

An ASPIC surplus production model was applied to the Atlantic bigeye tuna fishery during the meeting to assess the current status of the stock. Life history studies have been used to show that the logistic (Schaefer) production model is probably not appropriate for tunas (Maunder, 2003) and that $B_{MSY}<0.5B_0$ is probably more realistic. However, there is seldom sufficient information in stock assessment datasets to estimate the shape of the production function parameter. Therefore, the Fox production function was used. The Group agreed to run an initial model using the CPUE series included in table 10 of the Report of the 2015 ICCAT Bigeye Tuna Data Preparatory Meeting (SCRS/2015/011) (**Figure 15**). Subsequent runs included the use of different individual CPUE indices as well as a combined index which represented a continuity run from 2010. Details of the different model scenarios are outlined in **Table 4**. The generic diagnostic procedure proposed at the data-preparatory meeting (SCRS/2015/073) was used to select the scenarios to carry through to advice.

3.2 Statistical catch-at-age models: Stock Synthesis

An initial assessment of the Atlantic bigeye tuna stock was conducted in advance of the 2015 Bigeye Tuna Stock Assessment Session. The full assumptions and data inputs to this model are described in SCRS/2015/126. The inputs were discussed and suggested at the 2015 Bigeye Tuna Data Preparatory Meeting (SCRS/2015/011). The key assumptions and configurations of the initial “model” are as follows:

- 15 fleets as specified in Bigeye Tuna Data Preparatory Meeting (**Table 2**).
- Three regions (north of 25ºN, between 25ºN and 15ºS, and south of 15ºS) separating out tropical and temperate waters.
- Growth was modeled by fitting a growth curve within the model framework (**Figure 16**). The plus group was specified as 10+.
- Length size frequency samples were provided by the ICCAT Secretariat, no Catch-at-size data was used.
- The between-area movement of bigeye tuna was modelled to reflect the assumption that spawning takes place in the winter (season 1; Jan, Feb, Mar), and mostly in Area 2. An annual migration of at least part of the spawning stock begins in the spring (season 2; April, May, June) from the spawning area, northward to feeding areas (Area 1). In season 4 (Oct, Nov, Dec) fish moved back to Area 2.
- The time frame for the model was 1950-2014.
- Wt = (2.396E-05)*TL2.9774 (**Figure 16**).
- The maturity schedule used was adopted from previous assessments: 0% for ages 0-2, 50% for age 3, and 100% for ages 4-10+ (**Figure 16**).
- Age-specific M was derived using a Lorenzen (2005) function with the reference M = 0.2794 over the "fully selected" age classes (1-15). The reference M was approximated using a maximum age of 15. The M vector was developed using the Hallier *et al.* (2005) growth curve (**Figure 16**).
- Beverton Holt Stock-Recruitment Relationship. Steepness was estimated, sigma-r was fixed at 0.60 and recruitment was assessed to be equal across all seasons and regions. Recruitment by each of the three areas was estimated such that Area 1 and Area 3 received equal amounts of recruits and the percentage going to Area 2 was estimated within the model, informed by the landings, CPUE, and length information. Recruit distribute by season and area remained constant each year. Deviations in annual recruitment were estimated from 1974 to 2013.
- Length-based selectivity was estimated for each of the fifteen fleets.
- Asymptotic selectivity for the longline fleets in Areas 1 and 3 (fleets 10, 12, 13, and 15) and for longline fleets in Area 2 (fleets 11 and 14) the selectivity was allowed to be to be dome-shaped.

Tagging data were not included because it was felt that they would not accurately reflect the migration between regions, in particular between regions 1 and 2. The list of CPUE series included in the model is presented in **Table 5**. The Group discussed the initial model presented by the author and a number of additional model runs were discussed, proposed, and conducted. It was noted that there are conflicts in the information provided by the CPUE series and the length frequency data and, thus, additional model runs with variations in the weighting of these series were also conducted. It was also discussed whether steepness should be estimated as often the information available is not sufficient to estimate this parameter and it was concluded to use different values of steepness as 0.7, 0.8 and 0.9. It was also agreed to use different growth curves from Hallier *et al.* (2005) using either Von Bertalanffy growth curve fitted to both otoliths and tagging data (the one used in previous assessment – see table 2 of 2015 Bigeye data preparatory meeting) or Richards growth curve fitted to otolith data. Finally, likelihood profiling was conducted to fully explore the model configurations and decide on possible base cases.

The details of these runs are provided in **Table 6**.

3.3 VPA

An initial VPA model was presented to the Group based on the 2010 VPA model (Anon., 2011a), but incorporating updated data and several new formulations. The full specifications of the model are provided in **Appendix 4**. The model was run using VPA-2BOX software, and used the updated catch-at-age data specified in Section 2 and used the CPUE indices specified in **Table 7** as agreed in the data preparatory meeting. The biological assumptions used for the model run were as follows:

A Lorenzen M vector was included, with the reference M = 0.2794 over the "fully selected" age classes (1-15), (**Figure 17**). The reference M was approximated using a maximum age of 15 and the Hallier *et al.* (2005) growth curve. For additional runs,

- All Terminal Fs were estimated.
- The CVs on the indices were increased to 0.4.
- The F ratio was estimated as four time blocks.
- Increased plus group age to 10+ and 13+.

After reviewing the outputs of the initial model, the Group recommended several modifications to be conducted. These additional model run assumptions are described in **Table 8**.

4. Stock status results

4.1 Production models

The procedure for rejecting scenarios[1] was based on the diagnostics recommended by the data preparatory group. Three scenarios were chosen to represent stock status and historical trends, i.e.

- **Run 1:** United States Longline index (US)
- **Run 2:** Japanese Longline index (Japan)
- **Run 3:** Chinese Taipei Longline late period (Chinese-Taipei Late)

The Group also requested a sensitivity analysis for some runs that included multiple indices which were chosen based on their correlation (**Figure 18**) and cross-correlation (**Figure 19**):

- **Mult 1:** Chinese Taipei Longline early and late period indices
- **Mult 2:** Chinese Taipei late and Uruguay late period Longline indices
- **Mult 3:** Japan, Uruguay early and US Longline

Other assessment scenario using a composite index created from the standardized CPUEs (Table 10, Report of the 2015 ICCAT Bigeye Tuna Data Preparatory Meeting) using the same procedure as in the last assessment for the continuity run was also considered.

Figure 20 shows the composite index used in 2010 and the one generated in 2015, using the same procedure as in 2010, with the CPUE indexes agreed to be used in ASPIC and described in table 10 of the Report of the 2015 ICCAT Bigeye Tuna Data Preparatory Meeting. The results of the ASPIC fits to both indices are compared in **Figure 21** and estimates of stock biomass and harvest rates relative to MSY benchmarks are shown in **Figure 22**, where the 2010 assessment is projected through 2010 to 2014 using the reported catches.

Profiles of the residual sums of squares were plotted to check that a minimum had actually been found. **Figure 23** shows the profiles for MSY.

4.1.1 Residual analysis

In general, patterns in the residuals of the fits of the CPUE with stock abundance may indicate a violation of model assumptions, which in turn may result in biased estimates of parameters, reference points and stock trends. **Figure 24** plots the observed CPUE against the fitted values for the different assessment scenarios (the blue line is a linear regression fitted to points and the black line is the y=x line). If the index is a good proxy for stock abundance the two lines should coincide. The residuals are then plotted against year along with a lowess smoother (**Figure 25**) to indicate systematic patterns that may indicate that the index is a poor proxy for stock abundance. Moreover, variance estimates obtained via bootstrapping assume that residuals are Independent and Identically Distributed (IID). **Figure 26** shows a Quantile-quantile plot to compare residual distribution with the normal distribution. In **Figure 27** the residuals are plotted against the fitted value, to check variance relationship. It is assumed that the residuals are not autocorrelated, since significant autocorrelations could be due to an increase in catchability with time; which may result in a more optimistic estimate of current stock status as any decline in the stock is masked by an increase in catchability. **Figure 28** plots the residuals against each other with a lag of 1 to identify autocorrelation. Using multiple indices results in a violation of all the above assumptions.

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[1] A possible, plausible, internally consistent, but not necessarily probable, development (Field, 2012).

Figures 29 and **30** plot predicted stock trend by index for the multiple runs, i.e. scaling the observations by catchability. This also contributes to identify indices that do not track the stock properly.

4.1.2 Current status

Based on the diagnostics described above, three ASPIC runs using separate CPUE indices were selected to provide advice on stock status, biomass levels, and harvest rate (**Figure 31**). The ASPIC results show that the stock biomass has declined since the beginning of the time series in the 1950s with a sharp decrease, which corresponds with a sharp increase in fishing mortality and catch in the 1990s and a peak in fishing mortality by the end of the 1990s. From the late 1990s, the biomass and fishing mortality trajectories of the 3 runs are different. While biomass increased and fishing mortality decreased in run 3, biomass continued decreasing at a lower rate in runs 1 and 2 and fishing mortality showed a general increasing trend in run 2 (except the last 3 years when decreased) and was somewhat stable in run 1.

Figure 32 shows the estimated bootstrapped trajectories of runs 1, 2 and 3 biomass and harvest rate relative to MSY references. The three show similar trajectories of increasing fishing mortality and decreasing biomass towards the red area of the Kobe plot ($F>F_{MSY}$ and $B<B_{MSY}$) until the end of the 1990s, but run 1 and run 2 estimate that on average the stock still remains the red area since 2000 while run 3 estimates a recovery towards the green area since mid-2000s. **Figure 33** shows the Kobe phase plots by run. The results based on the three cases suggest that the stocks status in recent years varied between cases (B_{2014}/B_{MSY} ratio is from 0.554 to 1.225 and F_{2014}/F_{MSY} ratio is from 0.576 to 1.436, **Table 9**). The combined phase plots of three cases are shown in **Figure 34**. MSY is estimated to be from 66,030 t to 86,830 t (**Table 9**) which is lower (run 1) and larger (runs 2 and 3) than the 2014 catch (68,390 t).

4.2 Stock Synthesis

The Group chose 12 model configurations to formulate the stock status and management advice (**Table 10**).

Model results indicated that spawning stock biomass and recruitment have been steadily declining (**Figure 35**). The CPUE data used to fit the model tend to indicate a less productive stock while the information within the length and size-at-age data indicate a higher productivity.

Figure 36 shows the estimated relative biomass and fishing mortality since 1950 for all runs. These results show that fishing mortality increased steadily since the beginning of the time series and rapidly increased by the end of the 1990s surpassing the level corresponding to F_{MSY} in half of the scenarios. In the 2000s, F fluctuated and decreased slightly being above or below F_{MSY} depending on the scenario investigated. The F increased sharply at the end of the 2000s when $F>F_{MSY}$ in 2011 for all the scenarios (peaked as much as twice F_{MSY} according to run 51h7) and decreased in the latest three years in all scenarios. In 7 out of 12 scenarios the fishing mortality is kept at levels higher than F_{MSY} in 2014. With regards to biomass, it decreased constantly since the beginning of the time series and fell below B_{MSY} levels by the end of the 1990s or 2000s depending on the scenario. Since 2010, the biomass has been estimated to be lower than the level of B_{MSY} in all the scenarios. **Figure 37** and **38** show the Kobe phase plots by run and including all runs in one plot, respectively.

The estimated MSY and MSY related benchmark for all of the models are presented in **Table 11**.

4.3 VPA

Run 21 shows trends comparable with the runs produced using SS3 and the Surplus Production Model with regards to stock and harvest against MSY benchmarks. However, the Group decided not to use this model to provide stock status because of the concerns expressed with regards to age slicing, convergence of the model and other problematic model diagnostics.

Run 21 indicates that the VPA estimated fishing mortality has gradually increased since 1975, peaking in 2004 (**Figure 39**). Fishing mortality is highest in ages 0 and 1 with a second peak at age five with fishing mortality declining at older ages. The F-ratio is estimated to be well below 1 indicating that the model is estimating dome-shaped vulnerability.

The model also indicates a spawning stock biomass decline since the mid-1970s, which has not recovered despite the recent catch reductions (**Figure 40**). Average recruitment over the entire time series was assumed to calculate benchmark quantities ($F_{0.1}$ and $SSB_{F0.1}$ were used for MSY proxies) to evaluate relative stock status for the VPA (**Figure 40**). Bootstrap estimates of stock status indicate that the stock is overfished (**Figure 40**) and that stock is not currently undergoing overfishing (bootstrap median=0.896 versus the MLE =0.925, **Table 12**). It should be noted that the stock status of not overfishing is due to the replacement of the last three years of recruitment with the long-term average. If the raw VPA estimates of recruitment were used instead, then fishing mortality rates would be estimated to be above $F_{0.1}$. More complete documentation of the model is available in **Appendix 4**.

4.4 Synthesis of assessment results

In order to evaluate the robustness of the procedure used to give advice in 2010, a new composite index was generated using the same methodology and an ASPIC run was conducted with a similar set up as that used in 2010 (which is referred as a continuity case) using the latest catch data up to 2014. To compare both assessments, the 2010 assessment was projected (i.e. hindcast) using the catch data from 2010 to 2014. This allows comparing changes in the perception of the stock solely resulting from the addition or update of the datasets used to fit the production model used to provide the main advice about stock status in 2010. This new run only differs from the one in 2010 in that the catch estimates contain additional years of data (2010-2015), and that the combined index of abundance has been estimated with indices that were presented/agreed during the 2015 preparatory meeting. There were big differences between the 2015 continuity run and the 2010 assessment and projection, which were due to the large difference in the 2010 and 2015 composite indexes. In addition, it was difficult to recreate the CPUE combined series when the CPC’s CPUEs were updated in a different manner from last assessment. Using combined indices, when individual indices show conflicting trends, will result in average/intermediate biomass/harvest estimates that differ from those estimated when fitting to individual indices. Therefore, indices should be evaluated separately or jointly within the stock assessment using appropriate diagnostics.

In 2015, to maintain continuity with the approach used to develop the previous advice for Atlantic bigeye tuna, results from non-equilibrium production models were used to provide the status of the resource; these included runs 1, 2, and 3, which used different individual CPUE indices. Those results were complemented with the results of an integrated statistical stock assessment model (SS3), which can account for changes in selectivity. Although VPA models also account for changes in selectivity, given that VPA results were uncertain in regards to absolute size of the stock and showed convergence problems, the VPA model results were not used to develop the management advice.

The stock biomass estimated from the three production model runs show a decline since the beginning of the time series in the 1950s (**Figure 31**). Corresponding with a sharp increase of fishing mortality and catch in the 1990s and a peak of fishing mortality by the end of the 1990s, biomass showed a sharp decrease during the same time period. From the late 1990s, the biomass and fishing mortality trajectories of the 3 runs are different. While biomass increased and fishing mortality decreased in run 3; biomass continued to decrease at a lower rate in runs 1 and 2 and fishing mortality showed a general increasing trend in run 2 (except the last 3 years when it decreased) and was somewhat stable in run 1. The three runs show similar trajectories of increasing F and decreasing B towards the red area of the Kobe plot ($F>F_{MSY}$ and $B<B_{MSY}$) until the end of the 1990s, but run 1 and run 2 estimate that on average the stock still remains in the red area since 2000; while run 3 estimates a recovery towards the green area since mid-2000s (**Figure 32**). The current MSY estimated using the three production model runs ranges from 66,030 t to 86,830 t.

The integrated model, SS3, was run with twelve different configurations to characterize uncertainty in model parameters. SS3 Model results indicate that fishing mortality increased steadily since the beginning of the fishery, rapidly increased by the end of the 1990s, fluctuating around the level corresponding to F_{MSY} in the 2000s, then increased sharply at the end of the 2000s where $F>F_{MSY}$ in 2011, and decreased in the latest three years despite being kept at levels higher than F_{MSY} in 7 out of the 12 scenarios. With regards to biomass, it decreased constantly since the beginning of the time series and fell below and remained below B_{MSY} levels since 2010. The current MSY estimated using the 12 SS runs ranges from 80,889 t to 102,268 t.

Most of the SS runs give a similar view compared to the ASPIC runs regarding the historical evolution of the relative trends in biomass and fishing mortality. Both assessment models (ASPIC and SS3) suggest that biomass decreased in the period investigated, with the exception of run 3 of ASPIC where a recovery is observed since 2005. For fishing mortality, both assessment models show that F increased sharply by the late 1990s, then fluctuated to reach a similar level of the late 1990s in 2004/2005 and increased again in 2011 to decrease the last three years. The range of MSY values estimated by SS3, however, is larger than those estimated by ASPIC.

5. Projections

Resolution [13-10] adopted by the Commission, provides detailed guidance regarding the information that should be included in the Kobe strategy matrix. In 2010, the Working Group on Assessment Methods (Anon., 2011b) provided additional recommendations to facilitate the construction and interpretation of the Kobe II Strategy Matrix (e.g. guidelines for the application, specifications regarding projection methods and recommendations for development of Kobe matrices). Therefore, the Group based the following outlook for the Atlantic Bigeye tuna on the projections and the Kobe strategy matrix.

The outlook for bigeye tuna, considering the quantified uncertainty in the 2015 assessment, is presented in **Tables 13** and **14** and **Figures 41** and **42**, which provide a characterization of the prospects of the stock achieving or being maintained in the green quadrant of the Kobe plot for different levels of future constant catch and fishing mortality. The tables and figures are based on the 500 bootstrap simulations conducted for each of the three ASPIC assessment scenarios; which were all given equal weight. The F projections were performed for multipliers on the final year Fs.

ASPIC

The bootstrapped (500 simulations) ASPIC stock estimates were projected for 15 years (see Section 4.1) for the three runs. The catch in 2015 was set as the reported catch in 2014 (68,390 t) and thereafter (2016-2035) the stock was projected with TACs of 0 and from 40,000 t to 100,000 t in 10,000 intervals. Projections based on constant F scenarios were also conducted, i.e. for a multiplier on the final year Fs from 0 to 1.5 in 0.15 intervals. The results of the constant catch projections in stock biomass and harvest rate are shown in **Figures 43** and **44** and relative to MSY benchmarks in **Figures 45** and **46** for biomass and harvest rate, respectively. Median estimates of the projections showed that the stock should recover within the projected time period if future constant catch of run 1 and 2 (using US LL and Japanese LL CPUE indices, respectively) are less than 65,000 t (a similar level of the lower range of estimated MSY 66,000 t by ASPIC), and if constant F (relative to recent F) of each case is around 75% (**Figure 47**). For run 3, projections show that the stock will be maintained in the green quadrant of the Kobe plot (B>Bmsy and F<Fmsy) with catches of 90,000 t and F at current levels.

Projections at the current catch levels (~65,000 t) indicate that the stock has a 47 % probability of rebuilding by the end of the projection period (2028). The probability of recovery of the stock with current TAC (85,000 t) level by the end of the projected period would be around 32 %. Higher probabilities of rebuilding require longer timeframes and/or larger reduction of current catches. For instance, 75% probability of rebuilding would be achieved by 2028 with a constant catch of 50,000 t (**Table 13**).

SS3

No projections were done due to a lack of time. However, projections inputs and specifications were discussed and the Group agreed to run stochastic projections using 12 scenarios agreed during the meeting encompassing the structural uncertainty of the current SS3 assessment.

6. Recommendations

6.1 Research and statistics

- The raw size information of the European PS sampling from 1980 to 2014, as requested by the SCRS, has been partly provided to ICCAT since all French Task II size samples (all species) from 1980 onwards were submitted. Thus, the Group recommends that the raw size information of other PS sampling programs is provided to ICCAT.
- The Group recommends that estimates of variance of the estimated weight at size be provided for the relationship presented during the meeting, for considering updating the current weight-size used by ICCAT.
- Noting that juvenile FAD purse seine CPUE, once standardised, can be used as an indicator of the recruitment index in the stock assessment models, the Group recommends that the standardised CPUE index for juvenile yellowfin tuna and bigeye tuna caught by the EU purse seiner fleets be estimated and submitted to the next meeting of the tropical tunas species group (e.g. yellowfin data preparatory meeting) before the next round of stock assessments of tropical tunas.

- The Group noted that the change in the size composition of Chinese-Taipei LL fleet catches around 2005, showing larger fish from that period onwards, could be related to changes in fishing strategy due to the introduction of control and surveillance in domestic regulations. The Group recommends that the length frequencies of Chinese Taipei be reviewed relative to potential changes in the sampling strategies due to domestic regulations.

- The Group reviewed and compared the updated bigeye tuna catch-at-size provided by Japan and the current available dataset at the Secretariat. Differences were found in the size frequency distributions by years and total estimated numbers of fish caught by year. When estimated landings were compared to reported Task I significant differences were also found for some years. The Group is requesting Japan to review these differences and report to the Group the reasons for such differences, indicating what will be the best scientific estimates of total catch.

- Natural mortality at age has been identified as one of the most important parameters in tuna stock assessments. While the logistic shape of the Lorenzen vector of M used in the assessment models was considered by the Group as realistic, future work should be conducted to estimate alternative vectors of natural mortality at age. These alternative estimates of natural mortality should for instance cover: (i) comparison to values of M used in other tuna RFMOs, (ii) M estimated by other methods, (iii) insights from tagging data of IOTC and the Atlantic through AOTTP. As such, the Group recommends analyzing different M vectors as sensitivity analysis in future bigeye tuna stock assessments.

- Statistical analysis of the logbook and sampling data of the EU purse seiners (and of the fleet of associated flags) should be conducted by EU scientists to review current methodology to estimate catches and sizes by species of the PS fleet. This study should be focused in order of priority: (1) the revision and identification of best time and area strata that should be used in the data processing, and (2) the revision of basic criteria to be used in an improved data processing system (e.g. concerning the minimum levels of samples used, sampling rate and number of fish measured and, when needed, the rules used in strata substitution).

- The Group recommends continuing with the recovery of fisheries statistics from Angola, in particular for tropical tuna species. The Group supports the efforts of the Secretariat and the JCAP program to continue working with Angola scientists and the CPCs involved with tropical tunas catch within the Angola EEZ (foreign fleets) to confirm the level of catches and if these have been or not already reported to ICCAT. The Group request a report made available for review for the next species group.

- The Group inquired about the quality of the fisheries statistics (Task I and II) submitted by the different CPCs to the Secretariat. A form has been designed to be circulated to the main catching CPCs, asking for details of their sampling and data collection programs, as well as the protocols for fisheries statistics estimation in other ICCAT species groups. It was recommended that a similar form be proposed for the tropical tuna fisheries, in order to provide to the Group some information which can be used for evaluation of quality of the fisheries data submitted.

- Within the overall plan of improving Ghana statistics, in 2014, the SCRS recommended develop and apply software necessary for the treatment of Ghana statistics. At its 2014 annual meeting, the Commission considered that this activity could be funded by other sources (e.g. JCAP) and did not include it in the list of activities eventually approved by the Commission. The JCAP estimated budget for 2015 will not be able to cover the total cost of this project. Thus, the Group recommends that the Secretariat seeks alternative funds to complete this activity.

- Due to the lack of data regarding the reproductive biology of bigeye tuna and the importance of these data in all stock assessment models, the Group recommended, as a matter of priority, that reproductive biology (maturity, fecundity, etc.) studies be conducted as soon as possible.

- The Group recommends the systematic collection of direct size at age observations be obtained for use in integrated models and for estimating growth. This could be direct otolith readings or other direct ageing methods in conjunction with growth information from tagging.

- The Group recommends CPCs to contribute funding in order to reach the 20 % needed for co-funding the AOTTP.

7. Other matters

7.1 Revision of the first steps of the AOTTP

The Secretariat informed the Group of the progress made in the Atlantic Ocean Tropical Tagging Program (AOTTP). The contract between the European Union and ICCAT was recently signed after ICCAT agreed to commit (capital) funds, as required by the rules of funding established by the EU. The contract signed has a duration of five year with a possibility of an 18 month extension for data analysis.

The Secretariat has developed the requirements for the recruitment of the most urgent members of the AOTTP team. The announcement for the hiring of the first three fixed-term positions at the ICCAT Secretariat (Programme Coordinator, Administrative and Financial Officer, and Accountant), was posted on June 30 with an application deadline of September 4, 2015. The Group was informed that according to the contract, four additional fixed-term positions may be hired during the implementation period of the Programme (Assistant Coordinator, Publicity and Tag Recovery Coordinator, and two Data Entry Assistants). The plan is to have the three initial positions filled by the time of the 2015 annual meeting of the SCRS. Before the end of 2015, the process to hire the other members of the team will be initiated. The current project plan is to start tagging fish in the first half of 2016.

The Group was informed that Chinese-Taipei and the U.S.A. had already committed to co-funding €25,000 and US$30,000, respectively. Furthermore, there have been recent expressions of interest of additional co-funding from Brazil (€30,000). During the recent meeting of the Working Group on Convention Amendment, the ICCAT and STACFAD Chairs agreed that the Secretariat could make use of the Working Capital Fund for co-funding the Programme, however this decision will be further discussed at the forthcoming Commission meeting in November 2015. The SCRS Chair urged participants to work with their delegations to seek such necessary funds and highlighted the importance of this project to the work of the tropical tunas species group.

The Group briefly discussed the possible composition of the AOTTP Steering Committee (SC), highlighting the need for balanced expertise, geographical representativeness and effectiveness within the SC. The Group also stressed the importance that the external member be somebody with no current or recent relationship with ICCAT. The participation of the external member can provide an independent view to support decisions, and bring expertise gained in non-tuna fisheries. The Group recognized that to maintain the effectiveness of the SC, clear rules of procedure will have to be established to define the responsibilities of each member of the Committee and the AOTTP Programme Coordinator.

Finally, the Group discussed the exceptional opportunities that the AOTTP offers to researchers that are interested in tropical tunas, being a unique chance for carrying out other projects that could complement and benefit from the AOTTP as a platform to enhance data and sample collection, aimed at filling current gaps in aspects related to the biology and fisheries of tropical tuna species. However, the Group stressed that such efforts need to be coordinated so as to ensure that they do not compromise the objectives of the AOTTP.

7.2 Defining the procedure to update the analysis of the effects of the current moratoria on FADs

ICCAT [Rec. 14-01] paragraph 26 requests the SCRS to analyse in 2015 the efficacy of the area/time closure, referred to in paragraph 24, to reduce catches of juvenile bigeye, yellowfin, and skipjack tunas. The Group discussed the possible approach to update previous analysis of the effects of the Moratoria on FADs to answer this request from the Commission. The Group noted that the stock assessment models carried out during the bigeye tuna assessment do not allow to fully answer this question because the Moratoria were implemented in 2013 and any effect will be difficult to characterize through stock assessment models without additional years of data. However, it was agreed that the possible changes in exploitation patterns as well as trends in catches of juveniles of bigeye tuna and yellowfin tuna before and after the implementation of the Moratoria could be examined to answer this question. The Group also pointed out that it would be difficult to associate any changes to the Moratoria since there were only implemented in 2013. The Group recommended that a small *ad hoc* group of participants work intersessionally to update and further explore the analysis that was developed and presented to the SCRS in 2014.

8. Adoption of the report and closure

Due to the limited time, only items 1 to 3, and partly items 4 and 5 were reviewed and adopted by the Group during the meeting. The rest of the report was adopted by correspondence. Dr Murua thanked the participants and the Secretariat for their hard work. The meeting was adjourned.

Literature cited

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Table 1. Estimated catches (t) of bigeye tuna (*Thunnus obesus*) by area, gear and flag adopted by the Group as best estimates of total removals (July 15, 2015).

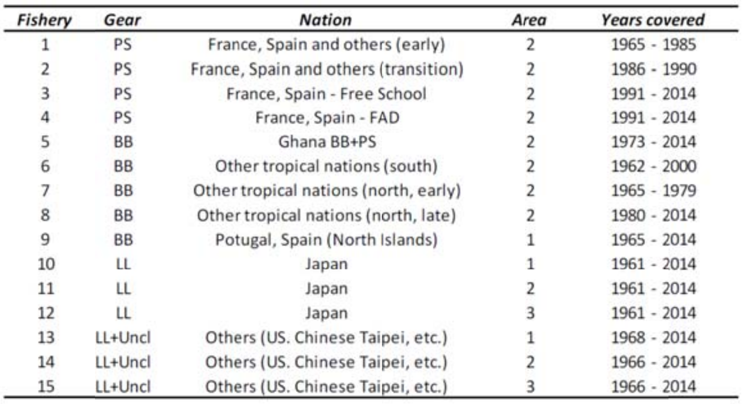
		1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
TOTA A+M		808	1651	2018	2951	2932	4808	2779	8720	4290	7732	9113	17060	23132	26039	23631	39394	25386	25252	23911	36889	42433	55866	47287	56991	64093	61301	45302	54880	52693	45975	63597	67869	73682	59586	71129	78262
Landin A+M	Bait boat	808	1651	2018	2951	2932	4808	2769	8266	3837	6254	6127	5805	7112	10927	5698	9822	5320	11434	3792	9770	10518	11846	9304	13620	17922	14636	9939	12758	14629	9591	12350	10124	6950	9853	11439	17651
	Longline	0	0	0	0	0	0	10	454	453	1478	2986	11255	16020	15112	17928	29572	20046	13726	19683	24149	28526	39904	33293	38453	39535	41347	27847	29531	28796	27560	41677	41608	51805	33757	43303	52595
	Other surf.	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	449	716	174	481	366	365	290	163	247	415
	Purse seine	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	20	92	436	2970	3389	4116	4690	4918	6636	5318	7067	11875	9094	8343	9204	15772	14476	15654	16063	7554
Landin A+M	Purse seine	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	0	0	0	161	158	77	46
Discarc A+M	Longline	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	0	0	0	0	0	0	0
Landin A+M	Angola	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	0	0	0	0	0	0	0
	Argentina	0	0	0	0	0	0	0	0	0	0	56	163	213	235	187	400	200	75	347	200	100	44	0	25	18	95	176	84	23	0	0	0	0	0	0	100
	Barbados	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	0	0	0	0	0	0	0
	Belize	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	0	0	0	0	0	0	0
	Benin	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	0	0	40	45	0	0	0
	Brazil	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	28	70	197	181	678	1183	812	782	698	505	776	521	656	419
	Cambodia	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	0	0	0	0	0	0	0
	Canada	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	23	0	0	0	0	0	0	0	0	0
	Cape Verde	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	111	95	146	142	131	115	50	47	464	45	27	72	200	293	167	112
	China PR	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	0	0	0	0	0	0	0
	Chinese Taipei	0	0	0	0	0	0	0	0	0	0	0	0	20	47	54	0	672	2521	6039	8456	8538	6191	5639	4314	3499	4464	3701	3364	2970	2486	2561	1887	2147	1623	925	1220
	Congo	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	0	5	0	0	0	0	8
	Cuba	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	89	300	217	886	1027	4100	3200	2000	2600	2400	1900	1300	1800	2300	2300	1385	711	521	421	447	239
	Curaçao	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	0	0	0	0	0	0	0
	Côte D'Ivoire	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	0	0	0	0	0	0	0
	Dominica	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	0	0	0	0	0	0	0
	EU.España	0	0	0	0	0	0	0	0	0	0	0	0	98	491	144	1017	1145	1272	1399	1810	4072	7418	4015	5681	4515	8882	7436	9736	6849	5419	8430	10010	9332	8794	13617	10340
	EU.France	0	0	0	0	0	0	0	0	0	0	0	0	400	2400	840	10	60	1740	155	3645	3885	3972	3954	4442	5201	4901	6485	8970	8985	7308	6283	8020	7074	8124	4254	4615
	EU.Ireland	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	0	0	0	0	0	0	0
	EU.Poland	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	0	0	0	4	0	0	0
	EU.Portugal	808	1651	2018	2951	2932	4808	2769	8266	3837	6254	6127	5805	6588	8021	4684	8670	4133	8051	1597	5620	5133	2892	3962	5855	10945	6813	2929	4522	5350	3483	3706	3086	1861	4075	4354	6457
	EU.United Kingdom	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	0	0	0	0	0	0	0
	FR.St Pierre et Miquelon	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	0	0	0	0	0	0	0
	Faroe Islands	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	0	0	0	0	0	0	0
	Gabon	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	0	1	0	0	0	0	0
	Ghana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	73	84	170	237	124	238	332	780	791	491	2162	1887
	Grenada	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	0	0	0	0	0	0	0
	Guatemala	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	0	0	0	0	0	0	0
	Guinea Ecuatorial	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	0	0	0	0	0	0	0
	Guinée Rep.	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	0	0	0	0	0	0	0
	Honduras	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	0	0	0	0	0	0	0
	Iceland	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	0	0	0	0	0	0	0
	Japan	0	0	0	0	0	0	10	454	453	1478	2904	11044	15746	14505	17366	28663	17578	9012	11345	11783	9504	21299	19665	22014	22946	17548	8170	10144	9863	12150	20922	22091	33513	15212	24870	32103
	Korea Rep.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	289	320	263	1857	4079	7353	5730	6018	7831	10493	6923	8090	9716	8022	10235	12274	10809	9383	8989	10704
	Liberia	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	0	0	0	0	0	0	0
	Libya	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	0	0	0	0	0	0	0
	Maroc	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	15	170	324	394	414	387	622	625	552	120	30
	Mexico	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	0	0	0	0	0	0	0
	Mixed flags (FR+ES)	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	0	0	116	0	0	0	0
	NEI (ETRO)	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	0	0	0	338	1141	157	0
	NEI (Flag related)	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	0	0	0	0	46	369	354
	Namibia	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	0	0	0	0	0	0	0
	Nigeria	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	0	0	0	0	0	0	0
	Norway	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	0	0	0	0	0	0	0
	Panama	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	182	2710	2081	2091	2135	1493	2127	513	4518	2500	2844	2789	3165	4461
	Philippines	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	0	0	0	0	0	0	0
	Russian Federation	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	0	0	0	0	0	0	0
	S. Tomé e Príncipe	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	0	0	0	0	0	0	0
	Senegal	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	0	0	0	0	0	0	0
	Seychelles	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	0	0	0	0	0	0	0
	Sierra Leone	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	0	0	0	0	0	0	0
	South Africa	0	0	0	0	0	0	0	0	0	0	0	0	0	286	214	0	0	0	0	0	0	0	0	1	0	0	0	0	0	19	422	381	137	187	60	102
	St. Vincent and Grenadines	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	0	0	0	0	0	0	0
	Sta. Lucia	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	0	0	0	0	0	0	0
	Togo	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	0	0	0	0	14	52	18
	Trinidad and Tobago	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	0	0	0	0	191	41	22
	U.S.A.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	18	148	195	544	212	113	865	67	28	331	248	212	202	158	422	315	539	639
	U.S.S.R.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	385	680	1820	1677	2200	2580	2729	1637	2961	3367	3652	4907	4086	2202	2229	2813	2832	635	352	1233	870
	UK.Bermuda	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	0	0	0	0	0	0	0
	UK.Sta Helena	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	5	22	8	9	14	23	14	19	0
	UK.Turks and Caicos	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	0	0	0	0	0	0	0
	Uruguay	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	0	0	86	397	605	714	597
	Vanuatu	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	0	0	0	0	0	0	0
	Venezuela	0	0	0	0	0	0	0	0	0	0	26	48	67	54	137	160	329	224	185	143	136	92	117	15	24	0	21	464	244	347	661	1684	1027	4284	4142	2918
Landin A+M	Belize	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	0	0	0	0	0	0	0
	Cape Verde	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	0	0	0	0	0	0	0
	Curaçao	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	0	0	0	0	0	0	0
	Côte D'Ivoire	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	0	0	0	0	0	0	0
	EU.España	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	0	0	0	0	7	41	24
	EU.France	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	0	0	0	96	93	14	3
	Guatemala	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	0	0	0	0	0	0	0
	Guinée Rep.	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	0	0	0	0	0	0	0
	Mixed flags (EU tropical)	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	0	0	0	65	58	23	20
	Panama	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	0	0	0	0	0	0	0
	St. Vincent and Grenadines	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	0	0	0	0	0	0	0
Discarc A+M	Chinese Taipei	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	0	0	0	0	0	0	0
	South Africa	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	0	0	0	0	0	0	0

Table 1 (continued). Estimated catches (t) of bigeye tuna (*Thunnus obesus*) by area, gear and flag adopted by the Group as best estimates of total removals (July 15, 2015).

		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
TOTA A+M		65445	57416	66410	78720	85264	97207	100117	113862	134936	128018	120751	110261	107804	121643	103680	91201	75726	87702	90534	67964	64263	72874	66094	82864	81988	85856	73386	67986	68390
Landin A+M	Bait boat	15618	13458	9710	12672	18280	17750	16248	16467	20361	25576	18300	21276	18999	22301	12365	14540	8523	11450	20812	13058	13686	12703	9064	14509	10000	15294	12099	9225	8885
	Longline	39942	35570	47766	58389	56537	61556	62403	62871	78898	74852	74930	68310	71856	76527	71193	55265	46438	54466	48396	38035	34182	46232	41063	43985	42925	38211	35005	32062	33395
	Other surf.	550	626	474	644	293	437	607	652	980	567	357	536	434	1377	1226	1628	1138	1340	1301	717	552	448	220	257	461	977	678	838	540
	Purse seine	9286	7148	7859	6371	9407	15524	19223	31582	32665	25355	26624	19147	15525	20254	17533	19511	19414	19578	19005	15128	15301	12799	14976	23032	27608	30098	24762	25205	24942
Landin A+M	Purse seine	48	613	600	644	747	1941	1636	2290	2032	1667	540	993	989	1184	1363	257	214	867	1019	1026	542	692	772	1082	994	1277	823	632	609
Discarc A+M	Longline	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	19	24	18
Landin A+M	Angola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	476	75	0	0	0	452	410	320	394	375	363
	Argentina	41	72	50	17	78	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Barbados	0	0	0	0	0	0	0	0	0	0	0	24	17	18	18	6	11	16	19	27	18	14	14	7	12	7	15	11	11
	Belize	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	60	70	234	249	1218	1242	1336	1502
	Benin	15	6	7	8	10	10	7	8	9	9	9	30	13	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Brazil	873	756	946	512	591	350	790	1256	601	1935	1707	1237	644	2024	2768	2659	2582	2455	1496	1081	1479	1593	958	1189	1151	1799	1400	1159	1451
	Cambodia	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Canada	11	144	95	31	10	26	67	124	111	148	144	166	120	263	327	241	279	182	143	187	196	144	130	111	103	137	166	197	218
	Cape Verde	86	60	117	100	52	151	105	85	209	66	116	10	1	1	2	0	1	1	1	1077	1406	1247	444	545	554	1037	713	1333	2204
	China PR	0	0	0	0	0	0	0	70	428	476	520	427	1503	7347	6564	7210	5840	7890	6555	6200	7200	7399	5686	4973	5489	3720	3231	2371	2232
	Chinese Taipei	1125	1488	1469	940	5755	13850	11546	13426	19680	18023	21850	19242	16314	16837	16795	16429	18483	21563	17717	11984	2965	12116	10418	13252	13189	13732	10805	10316	13272
	Congo	19	10	10	14	15	12	12	14	9	9	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Cuba	171	190	151	87	62	34	56	36	7	7	5	0	0	0	0	0	16	16	0	0	0	0	0	0	0	0	0	0	
	Curaçao	0	0	0	0	0	0	0	0	0	0	1893	2890	2919	3428	2359	2803	1879	2758	3343	0	416	252	1721	2348	2688	3441	2890	1964	1585
	Côte D'Ivoire	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	790	576	47	507	635	323
	Dominica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	
	EU.España	10884	9702	8475	8263	10355	14705	14656	16782	22096	17849	15393	12513	7110	13739	11250	10133	10572	11120	8365	7618	7454	6675	7494	11966	11272	13100	10914	10082	10736
	EU.France	4266	3905	4161	3261	5023	5581	6888	12719	12263	8363	9171	5980	5624	5529	5949	4948	4293	3940	2926	2816	2984	1629	1130	2313	3329	3507	3756	3222	3549
	EU.Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	33	0	0	0	0	0	0	0	0	
	EU.Poland	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	
	EU.Portugal	7428	5036	2818	5295	6233	5718	5796	5616	3099	9662	5810	5437	6334	3314	1498	1605	2590	1655	3204	4146	5071	5505	3422	5605	3682	6920	6128	5345	3922
	EU.United Kingdom	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	32	0	0	0	0	
	FR.St Pierre et Miquelon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	28	6	0	2	3	0	2	0	0	0	
	Faroe Islands	0	0	0	0	0	0	0	0	0	0	0	0	0	11	8	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Gabon	0	0	0	0	0	0	0	1	87	10	0	0	0	184	150	121	0	0	0	0	0	0	0	0	0	0	0	0	
	Ghana	1720	1178	1214	2158	5031	4090	2866	3577	4738	5517	4751	10165	10155	10416	5269	9214	5611	8646	17744	8860	7429	5923	6102	10603	11922	11764	7027	6130	6130
	Grenada	0	0	0	0	0	65	25	20	10	10	0	1	0	0	0	0	0	0	0	0	0	10	31	0	0	0	0	0	
	Guatemala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	998	949	836	998	913	1011	282	262	163	993
	Guinea Ecuatorial	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	50	0	58	0	0	10
	Guinée Rep.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	328	322	1516	1429	902
	Honduras	0	0	0	0	0	0	44	0	0	61	28	59	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Iceland	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Japan	23081	18961	32064	39540	35231	30356	34722	35053	38503	35477	33171	26490	24330	21833	24605	18087	15306	19572	18509	14026	15735	17993	16684	16395	15205	12306	15390	13397	10855
	Korea Rep.	6084	4438	4919	7896	2690	802	866	377	386	423	1250	796	163	124	43	1	87	143	629	770	2067	2136	2599	2134	2646	2762	1908	1151	1123
	Liberia	0	0	0	206	16	13	42	65	53	57	57	57	57	57	57	57	57	57	0	0	0	0	0	0	0	0	0	0	
	Libya	0	0	0	0	0	0	508	1085	500	400	400	400	400	400	400	31	593	593	0	0	4	0	0	0	0	0	0	0	
	Maroc	0	8	0	0	0	0	0	0	0	0	0	0	0	700	770	857	913	889	929	519	887	700	802	795	276	300	300	308	300
	Mexico	0	0	0	0	0	0	0	1	4	0	2	6	8	6	2	2	7	4	5	4	3	3	1	1	3	1	1	2	
	Mixed flags (FR+ES)	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	
	NEI (ETRO)	0	85	20	93	959	1221	2138	4594	5034	5137	5839	2746	1685	4011	2285	3027	2248	2504	1387	294	42	0	0	0	0	0	0	0	
	NEI (Flag related)	758	1406	2155	4650	5856	8982	6151	4378	8964	10697	11862	16569	24896	24060	15092	8470	531	0	0	0	0	0	0	0	0	0	0	0	
	Namibia	0	0	0	0	0	0	0	0	715	29	7	46	16	423	589	640	274	215	177	307	283	41	146	108	181	289	376	135	232
	Nigeria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	
	Norway	0	0	60	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	
	Panama	5173	5616	3847	3157	5258	7446	9991	10138	13234	9927	4777	2098	1252	580	952	89	63	0	1521	2310	2415	2922	2263	2405	3047	3462	1694	2774	2315
	Philippines	0	0	0	0	0	0	0	0	0	0	0	0	1154	2113	975	377	837	855	1854	1743	1816	2368	1874	1880	1399	1267	532	1323	1964
	Russian Federation	0	0	0	0	0	0	0	0	0	0	13	38	4	8	91	0	0	0	0	1	1	26	73	43	0	0	0	0	
	S. Tomé e Príncipe	0	0	5	8	6	3	4	4	3	6	4	5	6	5	4	4	4	4	11	6	4	0	92	94	97	0	0	0	
	Senegal	0	0	0	0	0	15	5	9	126	237	138	258	730	1473	1131	1308	565	474	561	721	1267	805	926	1042	858	239	230	646	371
	Seychelles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58	0	162	0	0	0	0	0	0	0	0	0	0	0	
	Sierra Leone	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	0	0	0	1088	0	0	
	South Africa	168	200	561	367	296	72	43	88	79	27	7	10	53	55	249	239	341	113	270	221	84	171	226	159	145	153	47	435	212
	St. Vincent and Grenadines	0	0	0	0	0	0	1	3	0	0	4	2	2	1	1216	506	15	103	18	0	114	567	171	292	396	38	25	16	26
	Sta. Lucia	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	2	2	0	2	0	0	0	0	0	0	0	0	
	Togo	24	22	7	12	12	6	2	86	23	6	33	33	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Trinidad and Tobago	0	0	1	19	57	263	0	3	29	27	37	36	24	19	5	11	30	6	5	9	12	27	69	56	40	33	33	37	58
	U.S.A.	1085	1074	1127	847	623	975	813	1090	1402	1209	882	1138	929	1263	574	1085	601	482	416	484	991	527	508	515	571	722	867	881	711
	U.S.S.R.	1071	1887	1077	424	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	UK.Bermuda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
	UK.Sta Helena	0	5	1	1	3	3	10	6	6	10	10	12	17	6	8	5	5	0	0	0	25	18	28	17	11	190	51	19	17
	UK.Turks and Caicos	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	4	2
	Uruguay	177	204	120	55	38	20	56	48	37	80	124	69	59	28	25	51	67	59	40	62	83	22	27	201	23	15	2	30	
	Vanuatu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	104	109	52	132	91	34	42	39	23	9	23
	Venezuela	1136	349	332	115	161	476	270	809	457	457	189	274	222	140	221	708	629	516	1060	243	261	318	122	229	85	264	98	94	152
Landin A+M	Belize	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	46	42	16	41	23
	Cape Verde	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	28	37	38	61	102	40	22	45	97
	Curaçao	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	25	20	13	117	59	46	60	34	42
	Côte D'Ivoire	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	2	95	45	
	EU.España	34	355	204	192	242	625	571	764	605	371	58	255	328	487	474	0	0	223	244	143	88	49	190	250	211	216	98	80	143
	EU.France	8	154	233	281	352	653	686	1032	970	713	314	437	467	553	607	229	205	446	397	222	79	26	51	150	122	394	192	56	54
	Guatemala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	56	28	15	26	9	18	6	11	5	15
	Guinée Rep.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72	0	60	20	22	74	203	288	245	209
	Mixed flags (EU tropical)	7	103	164	172	153	663	379	494	457	582	169	301	193	143	281	28	8	198	378	294	189	348	337	375	324	257	0	0	
	Panama	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	151	106	135	97	85	38	70	41	80	27
	St. Vincent and Grenadines	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	
Discarc A+M	Chinese Taipei	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	19	24	18
	South Africa	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	

* Highlighted cells represents the estimates of Ghana Catch adopted by the WG and not the official Task I NC submitted by the CPC

Table 2. Fleets used in the SS3 model.



Fishery	*Gear*	*Nation*	*Area*	*Years covered*
1	PS	France, Spain and others (early)	2	1965 - 1985
2	PS	France, Spain and others (transition)	2	1986 - 1990
3	PS	France, Spain - Free School	2	1991 - 2014
4	PS	France, Spain - FAD	2	1991 - 2014
5	BB	Ghana BB+PS	2	1973 - 2014
6	BB	Other tropical nations (south)	2	1962 - 2000
7	BB	Other tropical nations (north, early)	2	1965 - 1979
8	BB	Other tropical nations (north, late)	2	1980 - 2014
9	BB	Potugal, Spain (North Islands)	1	1965 - 2014
10	LL	Japan	1	1961 - 2014
11	LL	Japan	2	1961 - 2014
12	LL	Japan	3	1961 - 2014
13	LL+Uncl	Others (US. Chinese Taipei, etc.)	1	1968 - 2014
14	LL+Uncl	Others (US. Chinese Taipei, etc.)	2	1966 - 2014
15	LL+Uncl	Others (US. Chinese Taipei, etc.)	3	1966 - 2014

Table 3. Catch at age (CAA) matrix for bigeye tuna for the period 1975-2014. Catch-at-age includes the best estimates of Ghana catch between 2006 and 2014.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7+
1975	590075	291789	372592	258167	254018	157497	83912	105435
1976	1568826	601669	201109	171394	155971	112648	66651	60989
1977	1479079	590746	317721	238859	201174	140874	73092	59302
1978	947152	871165	332446	221270	174857	108437	63047	73504
1979	814374	542328	376506	186082	151089	91644	55298	65795
1980	1370218	955366	289129	432937	244508	133817	69306	59926
1981	3047619	1174755	354703	332136	302176	138635	60823	49412
1982	2097903	1086598	299974	421715	329823	181392	83466	60089
1983	2294423	1180720	343594	268688	244941	124605	53758	51692
1984	1937725	1646424	469171	381278	288181	155747	60263	47893
1985	1768553	1062078	461241	379402	347228	215251	91490	55338
1986	2080697	1317193	354279	323711	265748	150489	68903	44690
1987	1849186	732323	266094	303614	250508	179158	67564	34219
1988	2011477	506694	403589	407226	351507	148042	59835	39122
1989	2636991	897327	270255	433633	399452	211395	90827	56998
1990	4004450	1029203	477229	488985	405051	202419	78594	31273
1991	5600646	1427356	561387	461798	525554	271552	64107	33799
1992	5180806	1697912	628291	664351	440454	196942	77944	51724
1993	6936087	2188778	841610	523644	412427	236529	100475	73510
1994	7649321	2195316	935250	658743	382449	282039	130169	117178
1995	6777020	2381295	748278	697812	363646	233205	129533	138240
1996	6582217	2029731	651702	518019	386930	266754	144010	149413
1997	7297045	1999117	509503	516604	537755	201426	98552	89987
1998	6667761	1797699	622049	514958	461393	215030	89584	84163
1999	6737608	3220737	888845	699172	371738	212791	104222	81892
2000	5485092	2228592	816848	642028	373290	152182	72387	91214
2001	5655238	1793603	476369	500421	355325	169969	61319	60367
2002	4542497	1802508	295013	301322	297631	201733	75989	71304
2003	5602475	2177706	292608	276869	306919	277908	104088	90433
2004	9610329	2331945	317635	274298	301715	182988	90581	68968
2005	5447739	1431567	310637	248463	229238	152558	72026	61887
2006	3657108	1260035	386827	374662	187736	121138	74416	62123
2007	4188249	1074763	305733	255093	209527	149490	100032	132310
2008	5841640	918920	231990	196512	182404	148298	86882	103390
2009	5642110	1928420	416466	257002	245933	168605	94081	101050
2010	7675604	1518290	364848	265456	213462	155808	92441	105678
2011	6753468	2101693	460669	357171	227104	144848	89047	89715
2012	5196244	1498779	525875	305510	215684	127493	73043	76649
2013	5063351	1261877	467224	266668	159329	112140	72484	89440
2014	5442268	1040631	267407	246111	215142	140197	76368	95735

Table 4. Details of the ASPIC model runs.

Run	**Specification**	**Nº indices**
Run1	CPUE included – US_W	Single
Run2	CPUE included – JN_LL_CORE_W	Single
Run3	CPUE included – Late CH_TAI_CORE_W_LOG	Single
Mult 1	Chinese Taipei Longline early and late period indices	Multiple
Mult 2	Chinese Taipei late and Uruguay late period Longline indices	Multiple
Mult 3	Japan, Uruguay early and US Longline	Multiple
Combined	Combined index of US Longline Weight, early Chinese-Taipei, Late Chinese-Taipei core are in weight, Japan Longline core area in weight, Uruguay early in weight, and Uruguay late in weight	Combined index

Table 5. CPUE indices used in the SS3 model.

Index	Description	document	SS	SS area
US_N	US PLL index in number 1986-2014	SCRS-2015-082	Yes	1
CH_TAI_ALL_N_T2	CH_TAI LL index in number, task 2 data (1968-1992), whole Atlantic Ocean	SCRS-2015-091	Yes	2
CH_TAI_CORE_N_LOG	CH_TAI LL index in number, logbook data, BET fleet, core area, 1993-2014	"	Yes	2
JN_LL_CORE_N	JNLL index in N, core area (2, mainly, 1961-2014)	SCRS-2015-071	Yes*	1,2,3
URU_W_1 index	URU LL index time period 1 (1982-1991) in w	SCRS/2015/098	Yes	3
URU_W_2	URU LL index time period 2 (1992-2010) in w	"	Yes	3
AZ_BB	Azores baitboat index	SCRS/2015/62	Yes	1

Table 6. Details of the various SS3 model runs.

Run	**Specifications**
11h	Base model described in section 3.2
11	Same as 11h but steepness fixed at 0.7
12	All longline fleets are spline, h fixed at 0.70
12h	Same as 12 but h estimated
30	Same as 11, but fix the growth at Hallier values. No PS index
30h	Same as 30 but h estimated
31	Model 30 with fixed full selectivity on age 0 for all fleets
31h	Same as 30 with estimated steepness
32	Same as 31 with estimated sigma-r
33	Same as 32 but seasonal recruitment estimated
34	Seasonal recruitment estimated and steepness fixed at 0.70
34h	Same as 34 with estimated steepness
50h	Same as 34h with varying q on Japan LL CPUE in Area 2
51h	Same as 34h with varying q on Japan LL CPUE in areas 1,2 and 3, Lambda = 1
51h07	Same as 51h with steepness fixed at 0.7
51h08	Same as 51h with steepness fixed at 0.8
51h09	Same as 51h with steepness fixed at 0.9
51h07R	Same as 51h07 with Richards growth curve from Hallier et al. (2005)
51h08R	Same as 51h08 with Richards growth curve from Hallier et al. (2005)
51h09R	Same as 51h09 with Richards growth curve from Hallier et al. (2005)
51h07L05	Same as 51h07 with Lambda 0.5
51h08 L05	Same as 51h08 with Lambda 0.5
51h09 L05	Same as 51h09 with Lambda 0.5
51h07RL05	Same as 51h07R with Lambda 0.5
51h08R RL05	Same as 51h08R with Lambda 0.5
51h09R RL05	Same as 51h09R with Lambda 0.5
51h8mL	Same as 51h with lower M level
51h8mL	Same as 51h with higher M level

Table 7. CPUE indices used in the VPA model.

1	US PLL	US PLL index in number (1986-2014)
2	JAP_LL_ALL	JLL N, core area (2, mainly) 1975-2014
3	URU_LL_EARLY	URU LL (1982-1991) in weight
4	URU_LL_LATE	URU LL (1992-2010) in weight
5	CHIN_TAI_LL_EARLY	TAI LL N task 2 data (1968-1992)
6	CHIN_TAI_LL_LATE	TAI LL N, logbook data, core area (1993-2014)

Table 8. Details of the various VPA model runs.

Run	name
Run0	2010 VPA
Run1	Mimic 2010 VPA
Run2	use SS natural mortality, same specs
Run3	New specs, all term F parms estimated, increase sigma on cpue to 0.4
Run4	same as 3, 4 time blocks
Run5	age 10+
Run6	age 13+
Run7	NoJLL, like 3
Run8	NoUSLL, like 3
Run9	NoUru, like 3
Run10	NoChTai, like 3
Run11	Like 4, split ChiTai
Run12	Like 5, split ChiTai
Run13	Like 11, split URU
Run14	Like 11, but new CAA
Run15	Like 11 but input CV wt URU
Run16	Like 11 but double CV on URU
Run17	use old TAI LL PCAA back in time
Run18	Like 14, remove URU LL
Run19	Like 14, but age links on F
Run20	Like18 est var scaling
Run21	**Like14 est var scaling***
Run22	Like14 fix scaling
Run23	Like 21 but remove vuln penalty

**preferred model configuration

Table 9. ASPIC: Results from the three runs with the biomass dynamic model.

	ASPIC RUN1_USLL			ASPIC RUN2_JLL			ASPIC RUN3 CHTAI		
	MLE	80%LCL	80%UCL	MLE	80%UCL	80%UCL	MLE	80%UCL	80%UCL
K (B virgin)	1,944,000	1,372,000	3,419,000	1,253,000	1,021,000	1,587,000	1,003,000	825,500	1,278,000
MSY(mt)	66030	37060	75920	75900	68130	81100	86830	82280	89060
SSBmsy	715200	504600	1258000	461100	375500	583800	368900	303700	470300
Fmsy (exploitatic	0.092	0.031	0.150	0.165	0.116	0.216	0.235	0.178	0.290
SSB/SSBmsy	0.749	0.593	0.925	0.554	0.474	0.634	1.225	1.050	1.380
F/Fmsy	1.209	0.896	1.947	1.436	1.210	1.766	0.576	0.493	0.689

Table 10. SS3: Agreed 12 scenarios based on run 51.

Common specifications for all Run 51

- Growth is fixed to the Hallier et al. (2005) growth function
- Allow fishing mortality on age_0 for all fleets
- Remove the purse seine index
- Sigma-r is estimated
- Varying catchability in areas 1, 2, and 3for Japanese longline.
-

Modifications to common specifications to build 12 scenarios

- 3 different Steepness values of 0.7, 0.8 and 0.9: name scenarios as **Run 51h7**, **Run 51h8** and **Run 51h9**.
- 2 values of Lambda of 1 (as above **Run 51h7**, **Run 51h8** and **Run 51h9)** and 0.5 (**Run 51h7L05**, **Run 51h8 L05** and **Run 51h9 L05)**.
- Different growth curve using Richards growth model from Hallier et al. (2005) (with Lambda 1 **51h07R**, **51h08R** and **51h09R**; and with Lambda 0.5 **51h07RL05**, **51h08R RL05**, and **51h09R RL05**.

Table 11. MSY and MSY related reference points for all the 12 scenarios investigated.

Run Number	1	2	3	4	5	6	7	8	9	10	11	12
Natural Mortality	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid	Mid
Length Lambda	1	1	1	1	1	1	0.5	0.5	0.5	0.5	0.5	0.5
Growth	VB	VB	VB	Richards	Richards	Richards	VB	VB	VB	Richards	Richards	Richards
Steepness	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9	0.7	0.8	0.9
Model_name	Model_51h7	Model_51h8	Model_51h9	Model_51h7R	M_51h8R	M_51h9R	Model_51h7L05	Model_51h8L05	Model_51h9L05	Model_51h7RL05	Model_51h8RL05	Model_51h9RL05
Unfished SSB	2,342,600	2,144,940	2,046,290	2,159,580	2,023,140	1,968,130	2,429,430	2,246,250	2,180,170	2,274,000	2,161,800	2,138,580
Unfished Total Biomass	2,559,740	2,343,760	2,235,970	2,393,960	2,242,620	2,181,610	2,654,510	2,454,250	2,382,080	2,520,760	2,396,390	2,370,650
Unfished Rec. (R0)	28,082	25,712	24,530	31,082	29,117	28,325	29,122	26,925	26,133	32,728	31,114	30,779
SSB at 40% B0	937,039	857,977	818,517	863,832	809,256	787,250	971,773	898,501	872,066	909,602	864,722	855,433
F at 40 % B0	0.1279	0.1370	0.1459	0.1383	0.1498	0.1598	0.1247	0.1342	0.1436	0.1344	0.1456	0.1560
Total Yield at 40% B0	78,614	80,341	82,318	78,419	81,003	84,697	83,418	85,662	88,679	84,879	88,909	94,007
SSB at 40 % SPR	768,372	772,179	783,438	708,342	728,330	753,511	796,854	808,651	834,692	745,874	778,249	818,772
F at 40 % SPR	0.1552	0.1532	0.1533	0.1685	0.1679	0.1680	0.1511	0.1500	0.1508	0.1637	0.1632	0.1640
Yield at 40 % SPR	80,810	82,550	83,617	80,530	83,225	86,025	85,835	88,065	90,104	87,233	91,373	95,495
SSB at MSY	732,249	601,354	491,550	678,732	566,461	472,195	754,760	624,921	516,162	711,430	603,263	510,670
SPR at MSY	0.3862	0.3253	0.2613	0.3878	0.3250	0.2610	0.3845	0.3233	0.2580	0.3865	0.3241	0.2599
F at MSY	0.1618	0.1916	0.2325	0.1750	0.2113	0.2579	0.1582	0.1885	0.2304	0.1706	0.2056	0.2521
MSY	80,889	84,519	89,464	80,592	85,214	92,009	85,941	90,282	96,719	87,314	93,614	102,268

Table 12. VPA: Summary of VPA results.

VPA	**Median**	**MLE**	**80%LCL**	**80%UCL**
K (B virgin)*	2506500	2446000	2033900	3458000
MSY(mt)+	103550	102300	89490	135530
$SSB_{F0.1}$	630400	615673	532680	854510
Fmsy ($F_{0.1}$)	0.287	0.278	0.231	0.341
$SSB/SSB_{F0.1}$	0.717	0.680	0.448	1.030
$F/F_{0.1}*^{\$}$	0.896	0.925	0.517	1.586
*obtained by projecting model 100 yrs with constant recruitment at arithmetic mean				
"+ obtained by projecting at F0.1"				
"$ geometric mean of 2012-2014"				

Table 13. ASPIC Kobe2 Strategy Matrix for the constant catch projections using equal weighting of the three assessment runs.

Constant catch projections														
Probability of Underfishing (F<Fmsy)														
tac (000 t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	39	100	100	100	100	100	100	100	100	100	100	100	100	100
40	39	82	87	90	91	92	93	93	94	94	94	95	95	95
45	39	70	76	81	84	86	87	88	90	91	91	91	92	92
50	39	58	64	70	74	78	80	82	83	84	85	86	87	87
55	39	49	53	57	62	65	69	71	73	76	77	79	80	81
60	39	44	46	48	50	53	56	59	61	63	65	66	68	69
65	39	41	42	42	44	45	46	47	49	51	51	53	54	55
70	39	37	38	38	39	39	40	41	41	42	43	43	44	44
75	39	35	35	35	35	36	36	36	36	37	37	37	38	38
80	39	33	33	32	32	32	32	32	32	32	32	32	32	32
85	39	33	33	32	32	32	32	32	32	32	32	32	32	32
90	39	31	31	30	30	29	28	28	28	27	26	26	25	24
95	39	29	28	26	25	23	21	19	17	15	14	12	10	9
100	39	25	23	19	16	13	10	7	6	4	3	2	2	2
Probability of being underfished (B>Bmsy)														
tac (000 t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	34	35	41	53	73	85	92	94	96	97	97	98	98	99
40	34	35	37	40	45	50	58	66	72	77	81	83	85	87
45	34	35	36	39	43	47	52	59	65	70	74	78	81	83
50	34	35	36	38	41	44	47	52	57	62	67	70	73	76
55	34	35	36	37	39	42	44	47	50	53	57	61	64	67
60	34	35	35	36	38	39	41	43	45	47	49	52	54	56
65	34	35	35	36	36	38	39	40	41	42	44	45	46	47
70	34	35	35	35	35	36	37	37	38	39	39	40	40	41
75	34	35	35	35	35	35	35	35	35	36	36	36	36	36
80	34	35	34	34	34	33	33	33	33	33	33	32	32	32
85	34	35	34	34	34	33	33	33	33	33	33	32	32	32
90	34	35	34	33	33	32	32	31	31	30	29	29	28	28
95	34	35	34	33	31	31	29	28	26	24	22	20	19	16
100	34	35	33	31	30	28	25	22	18	15	12	9	7	5
Probability of being in the green zone (B>Bmsy and F<Fmsy)														
tac (000 t)	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	34	35	41	53	73	85	92	94	96	97	97	98	98	99
40	34	35	37	40	45	50	58	66	72	77	81	83	85	87
45	34	35	36	39	43	47	52	59	65	70	74	78	81	83
50	34	35	36	38	41	44	47	52	57	62	67	70	73	76
55	34	35	36	37	39	42	44	47	50	53	57	61	64	67
60	34	35	35	36	38	39	41	43	45	47	49	52	54	56
65	34	34	35	35	36	37	39	40	41	42	44	45	46	47
70	34	34	35	35	35	36	36	37	38	39	39	40	40	41
75	34	34	34	35	35	35	35	35	35	35	35	36	36	36
80	34	33	33	33	33	33	32	32	32	32	32	32	32	32
85	34	33	33	33	33	33	32	32	32	32	32	32	32	32
90	34	31	31	30	30	29	28	28	28	27	26	26	25	24
95	34	29	28	26	25	23	21	19	17	15	14	12	10	9
100	34	25	23	19	16	13	10	8	6	4	3	2	2	2

Table 14. ASPIC Kobe2 Strategy Matrix for the constant F projections using equal weighting of the three assessment runs.

Constant F projections

Probability of Underfishing (F<Fmsy)

Fmult	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	39	100	100	100	100	100	100	100	100	100	100	100	100	100
0.075	39	100	100	100	100	100	100	100	100	100	100	100	100	100
0.15	39	99	99	99	99	99	99	99	99	99	99	99	99	99
0.225	39	99	99	99	99	99	99	99	99	99	99	99	99	99
0.3	39	99	99	99	99	99	99	99	99	99	99	99	99	99
0.375	39	99	99	99	99	99	99	99	99	99	99	99	99	99
0.45	39	98	98	98	98	98	98	98	98	98	98	98	98	98
0.525	39	95	95	95	95	95	95	95	95	95	95	95	95	95
0.6	39	90	90	90	90	90	90	90	90	90	90	90	90	90
0.675	39	78	78	78	78	78	78	78	78	78	78	78	78	78
0.75	39	63	63	63	63	63	63	63	63	63	63	63	63	63
0.825	39	54	54	54	54	54	54	54	54	54	54	54	54	54
0.9	39	47	47	47	47	47	47	47	47	47	47	47	47	47
0.975	39	43	43	43	43	43	43	43	43	43	43	43	43	43
1.05	39	40	40	40	40	40	40	40	40	40	40	40	40	40
1.125	39	37	37	37	37	37	37	37	37	37	37	37	37	37
1.2	39	35	35	35	35	35	35	35	35	35	35	35	35	35
1.275	39	34	34	34	34	34	34	34	34	34	34	34	34	34
1.35	39	33	33	33	33	33	33	33	33	33	33	33	33	33
1.425	39	31	31	31	31	31	31	31	31	31	31	31	31	31
1.5	39	29	29	29	29	29	29	29	29	29	29	29	29	29

Probability of Underfished (B>Bmsy)

Fmult	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	34	35	41	53	73	85	92	94	96	97	97	98	98	99
0.075	34	35	40	50	68	82	89	93	94	96	96	97	97	98
0.15	34	35	39	48	63	77	86	90	93	94	96	96	97	97
0.225	34	35	39	46	58	72	81	87	91	93	94	95	96	96
0.3	34	35	38	45	53	66	76	83	87	90	93	93	94	95
0.375	34	35	38	44	50	60	70	77	83	86	89	91	92	93
0.45	34	35	37	43	47	54	63	70	76	80	84	86	88	90
0.525	34	35	37	41	45	50	56	62	68	72	76	79	82	84
0.6	34	35	37	40	44	47	51	55	60	63	67	70	72	75
0.675	34	35	36	39	42	44	47	50	52	55	58	60	62	64
0.75	34	35	36	38	40	43	44	46	48	49	51	52	53	54
0.825	34	35	36	37	39	41	42	43	44	45	46	47	47	48
0.9	34	35	35	37	38	39	40	41	42	43	43	44	44	44
0.975	34	35	35	36	37	38	38	39	40	40	40	41	41	42
1.05	34	35	35	35	36	36	37	37	38	38	38	38	38	39
1.125	34	35	35	35	35	35	36	36	36	36	36	36	36	36
1.2	34	35	35	35	35	35	35	35	35	35	35	35	35	35
1.275	34	35	34	34	35	34	34	34	34	34	34	34	34	34
1.35	34	35	34	34	34	34	33	33	33	33	33	33	33	33
1.425	34	35	34	33	33	33	32	32	32	32	32	32	31	31
1.5	34	35	34	33	32	31	31	31	31	30	30	30	30	30

Probability of being in the green zone (B>Bmsy and F<Fmsy)

Fmult	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
0	34	35	41	53	73	85	92	94	96	97	97	98	98	99
0.075	34	35	40	50	68	82	89	93	94	96	96	97	97	98
0.15	34	35	39	48	63	77	86	90	93	94	96	96	97	97
0.225	34	35	39	46	58	72	81	87	91	93	94	95	96	96
0.3	34	35	38	45	53	66	76	83	87	90	93	93	94	95
0.375	34	35	38	44	50	60	70	77	83	86	89	91	92	93
0.45	34	35	37	43	47	54	63	70	76	80	84	86	88	90
0.525	34	35	37	41	45	50	56	62	68	72	76	79	82	84
0.6	34	35	37	40	44	47	51	55	60	63	67	70	72	75
0.675	34	35	36	39	42	44	47	50	52	55	58	60	62	64
0.75	34	35	36	38	40	43	44	46	48	49	51	52	53	54
0.825	34	35	36	37	39	41	42	43	44	45	46	47	47	48
0.9	34	35	35	37	38	39	40	41	42	43	43	44	44	44
0.975	34	35	35	36	37	38	38	39	40	40	40	41	41	42
1.05	34	35	35	35	36	36	37	37	37	38	38	38	38	38
1.125	34	34	35	35	35	35	35	36	36	36	36	36	36	36
1.2	34	34	34	35	35	35	35	35	35	35	35	35	35	35
1.275	34	34	34	34	34	34	34	34	34	34	34	34	34	34
1.35	34	33	33	33	33	33	33	33	33	33	33	33	33	33
1.425	34	31	31	31	31	31	31	31	31	31	31	31	31	31
1.5	34	29	29	29	29	29	29	29	29	29	29	29	29	29

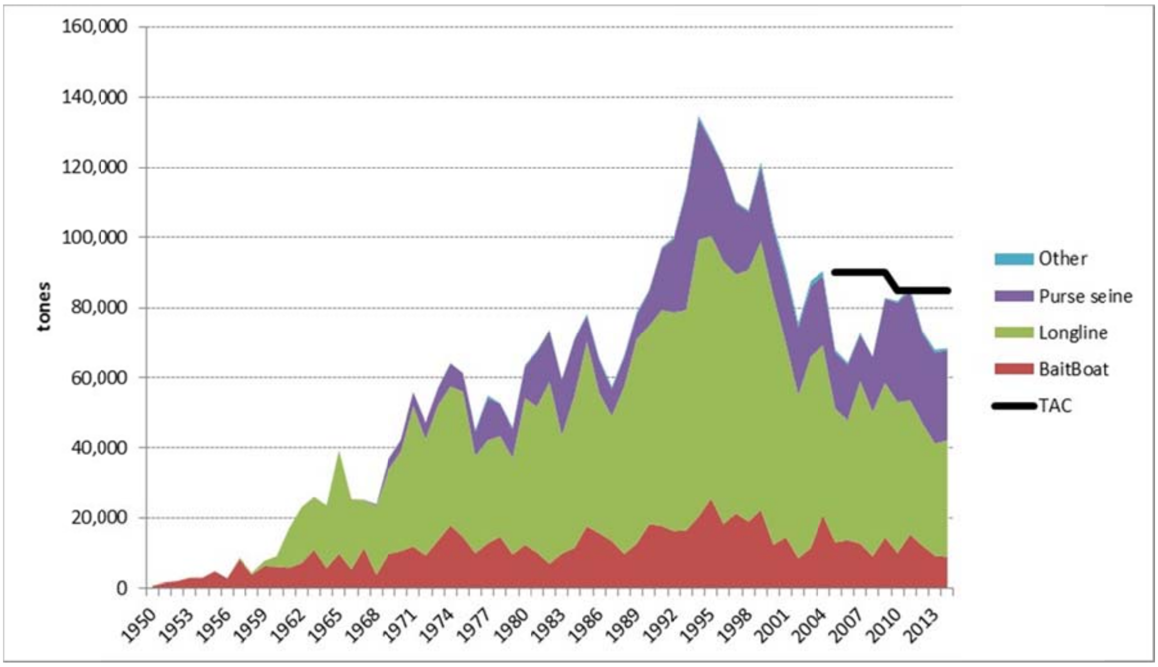


Figure 1. Best estimates, by main fishing gear, of bigeye tuna annual catch for the period 1950-2014, as adopted by the Group for the assessment.

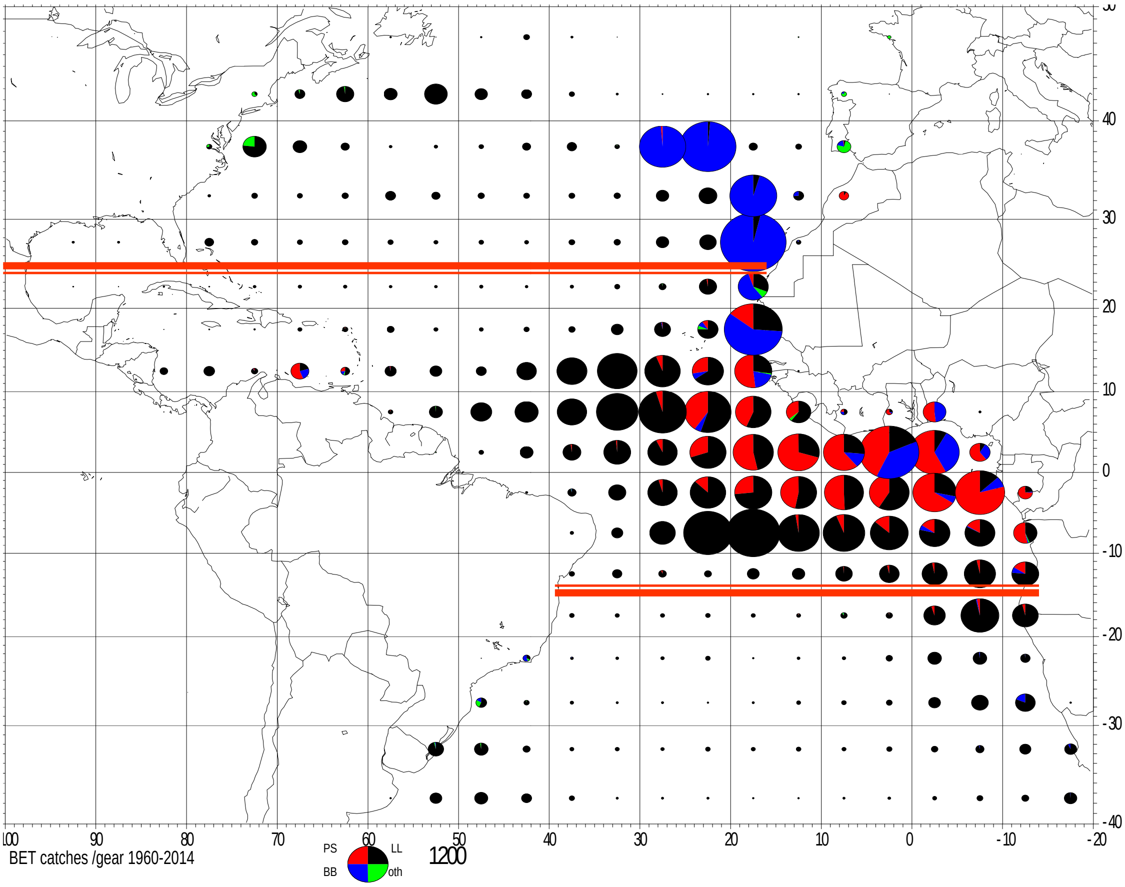


Figure 2. Spatial distribution of BET catch by gear. The red lines indicate SS3 model areas. This figure was provided by a CPC scientist but will be updated and redrafted by the Secretariat based on the revised agreed information prior to inclusion in the Executive Summary.

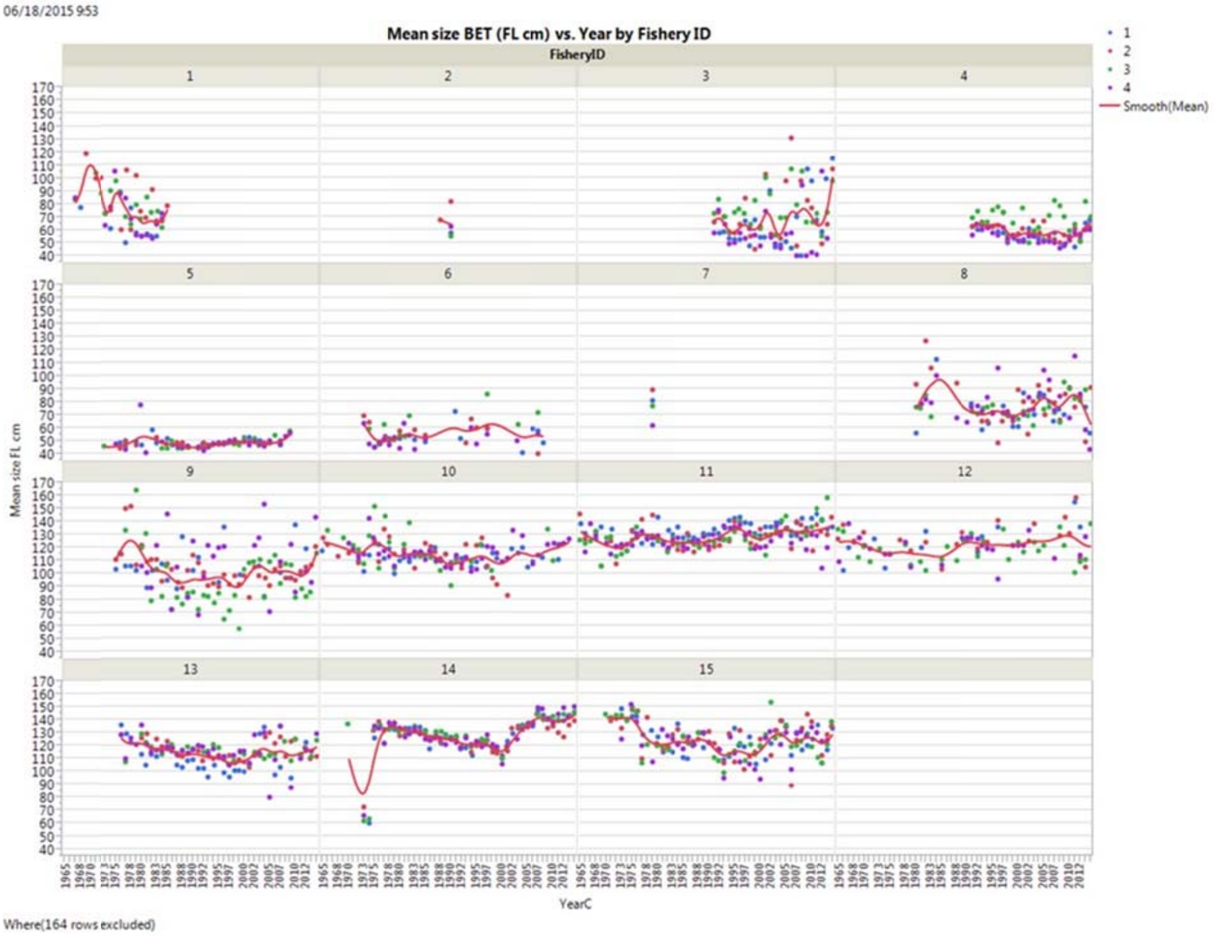


Figure 3. Trends of mean size of bigeye tuna, calculated from the size frequency distribution by year, quarter and fishery strata, as defined for the Stock Synthesis model. Line represents the smooth trend of the data.

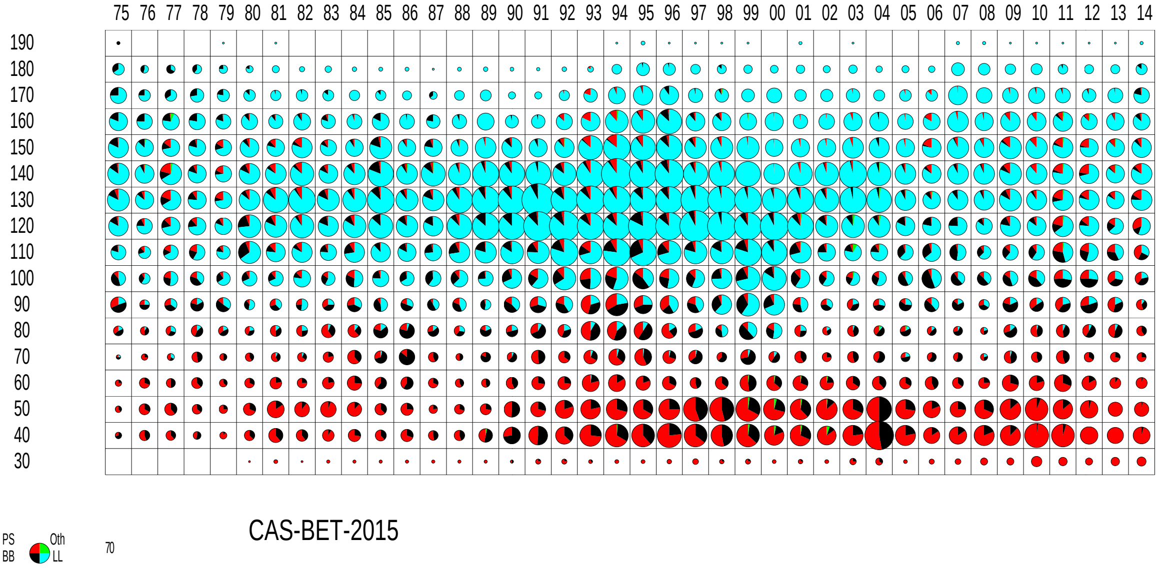


Figure 4. Catch-at-size for bigeye tuna by year (x axis) size class (y-axis) per major gear. This figure was provided by a CPC scientist but will be updated and redrafted by the Secretariat based on the revised agreed information prior to inclusion in the Executive Summary.

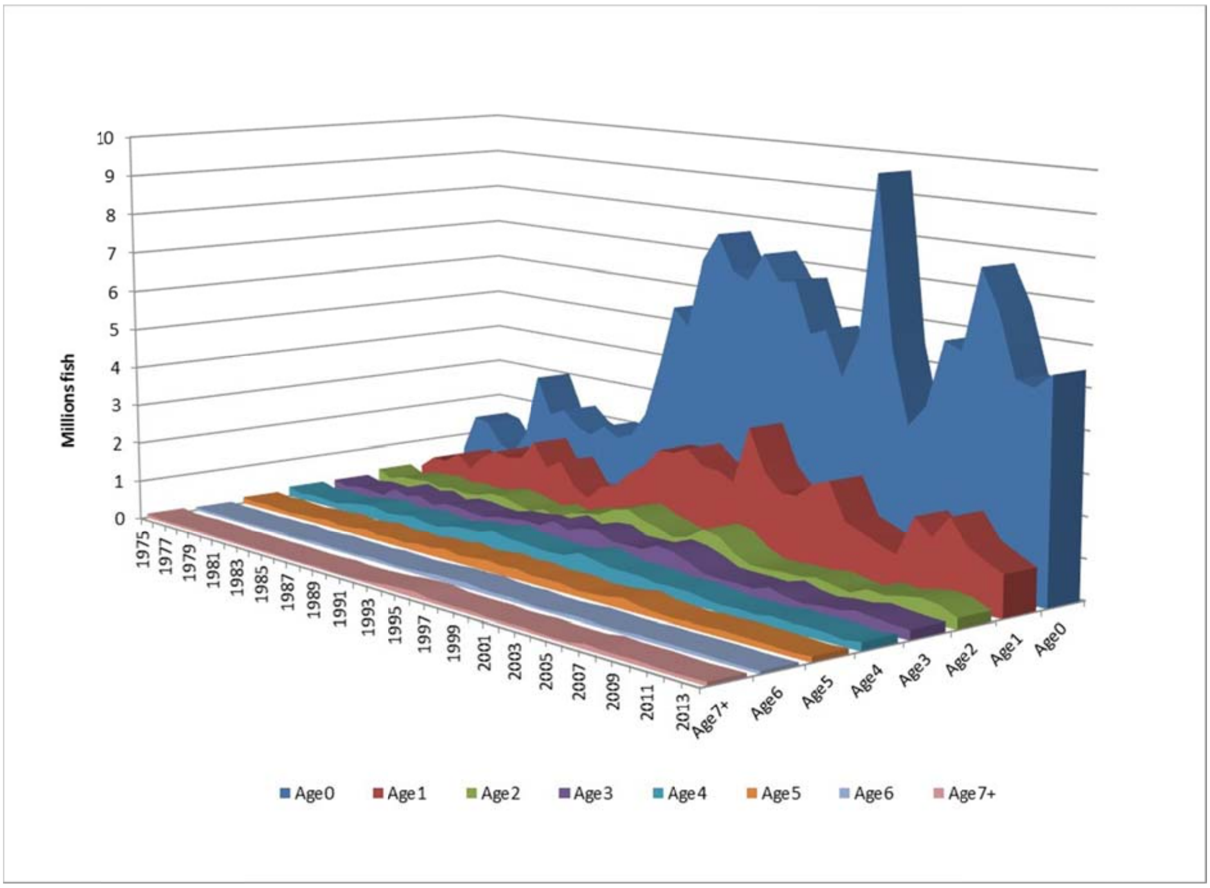


Figure 5. Annual bigeye tuna catch-at-age (CAA) distributions for the period 1975-2014.

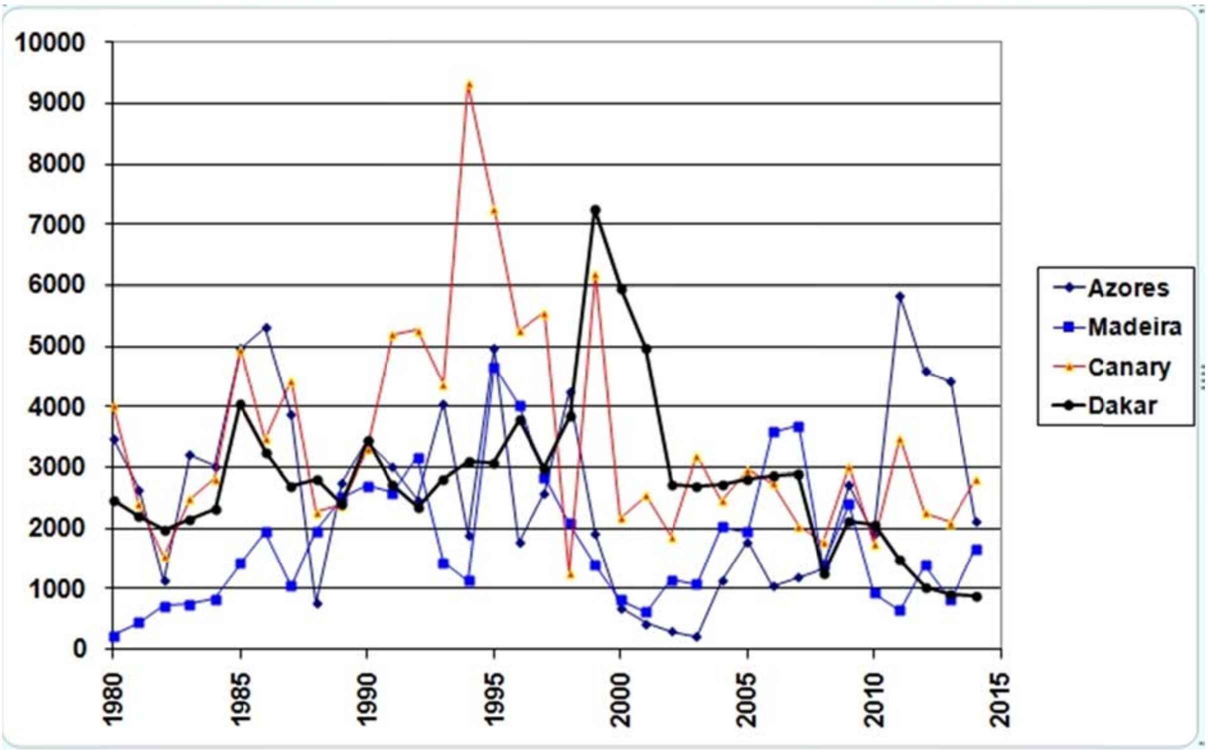


Figure 6. Bigeye catch for the local baitboat fisheries of Azores, Madeira, Canary Islands and Senegal.

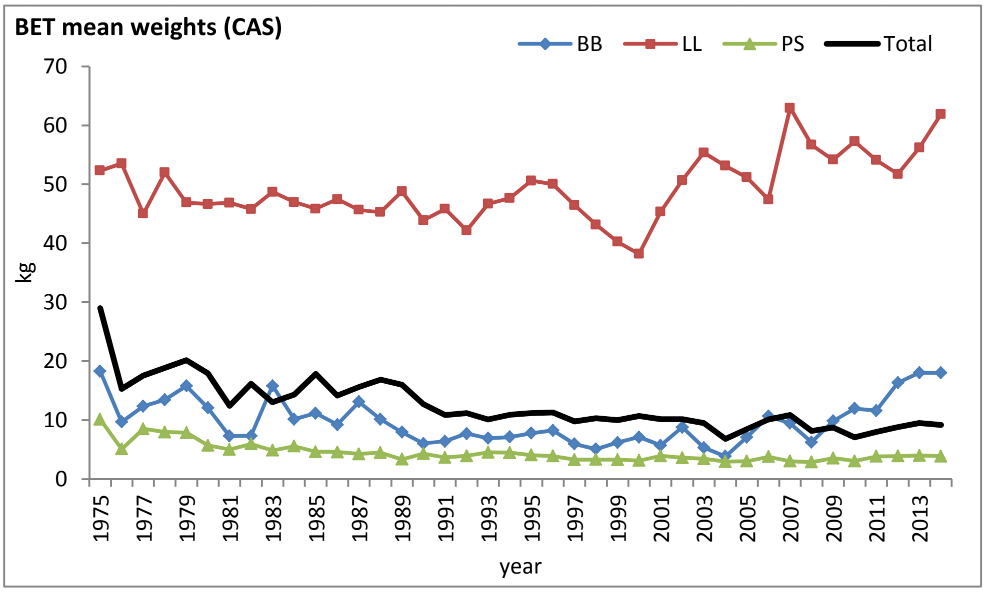


Figure 7. Trend of mean weight for bigeye tuna based on the catch-at-size data by major fisheries (BB=Baitboats, LL=Longlines, PS=Purse seine) for 1975-2014.

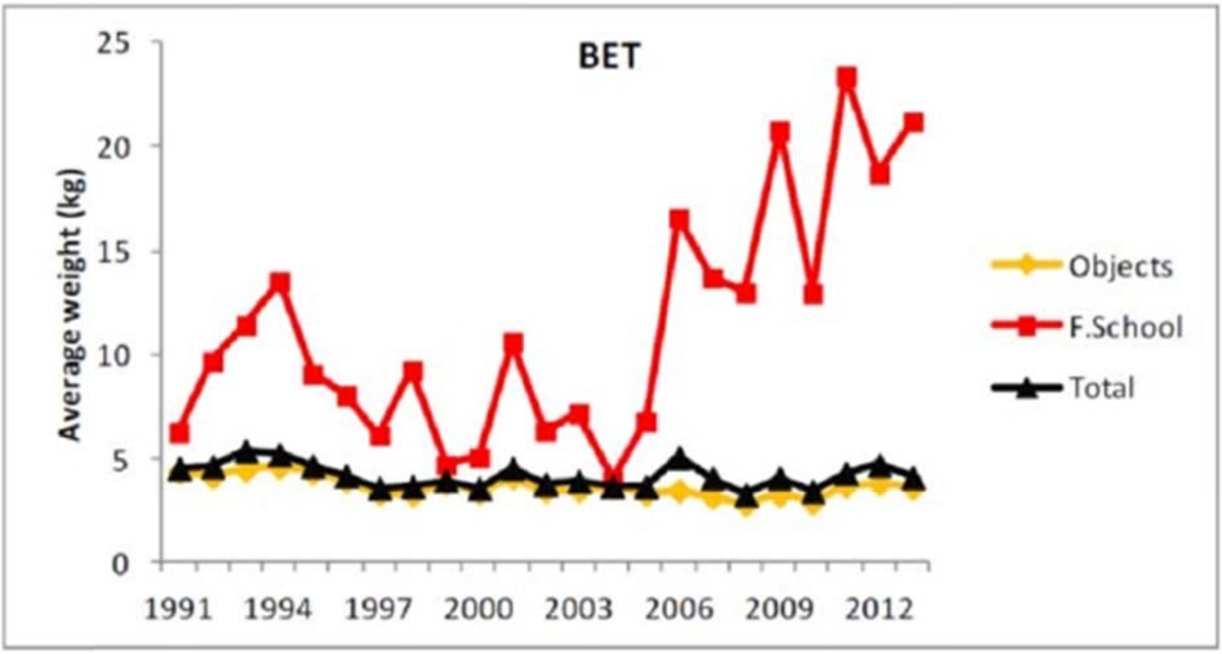


Figure 8. Trend of mean weight for bigeye tuna for European purse seiners and separated between free schools (F School) and FAD associated schools (Objects).

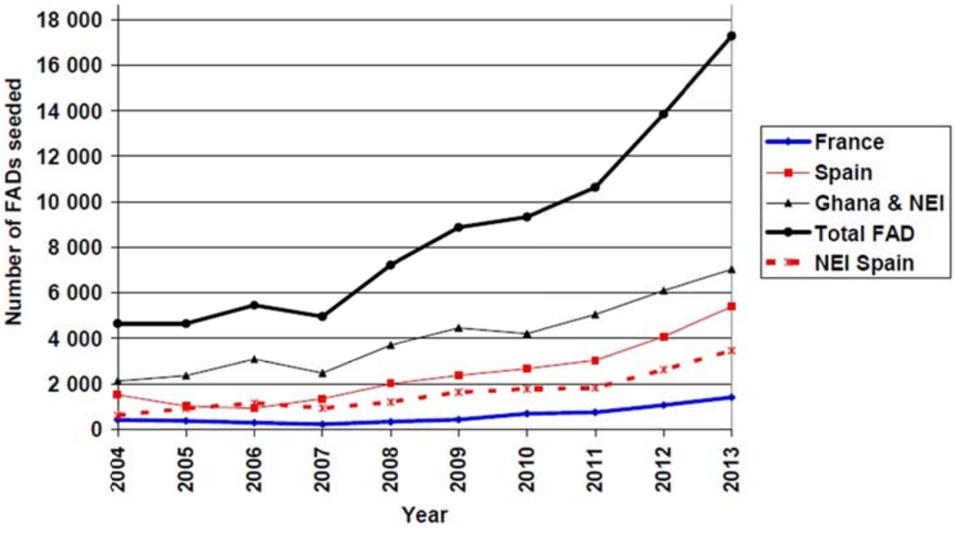


Figure 9. Estimated yearly numbers of FADs seeded, by flags and total in the Atlantic Ocean (from SCRS/2014/133).

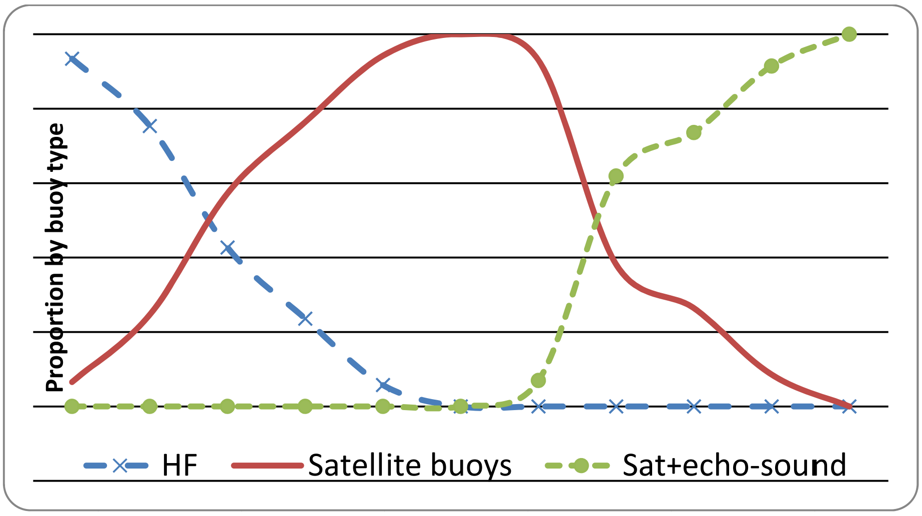


Figure 10. Change over time of the type of buoys equipping drifting FADs in the French purse seine fleet (drawn from SCRS/2014/187).

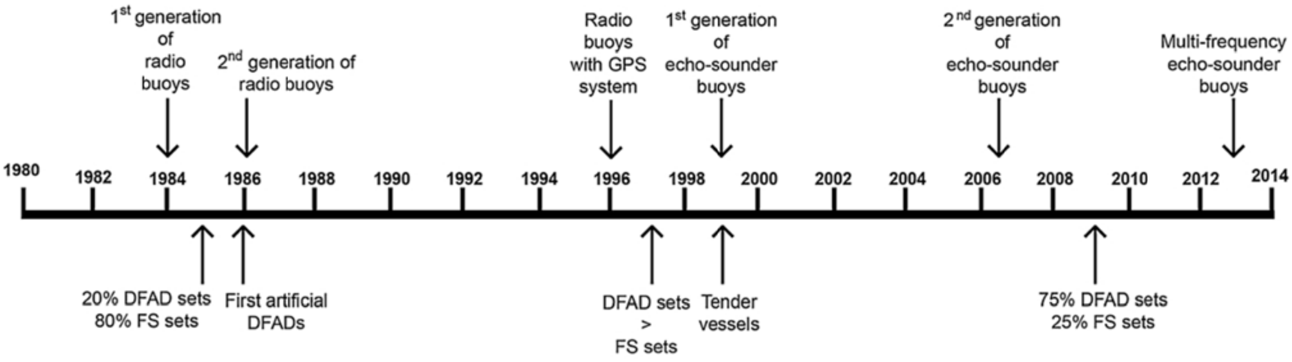


Figure 11. Evolution over time of the equipment associated with FAD-fishing in the Spanish purse seiners (Lopez *et al.*, 2014).

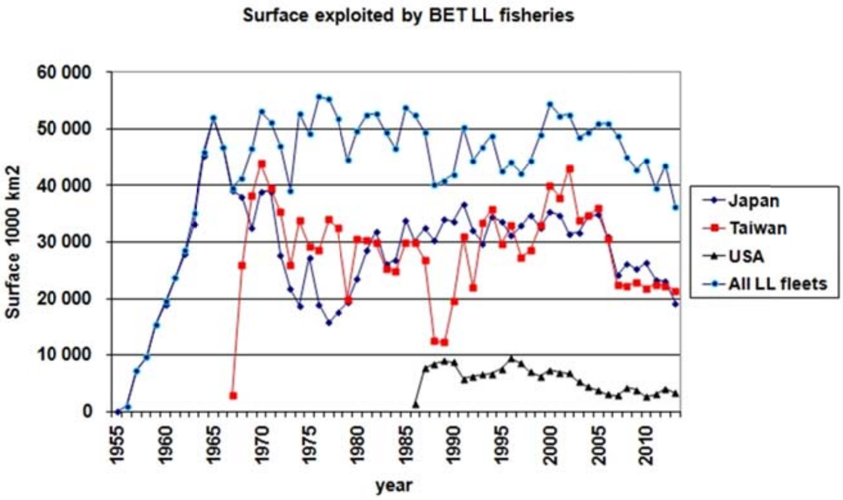


Figure 12. Surface successfully explored (nº of 5ºx5º squares with BET catch >1 t) by several longline fleets.

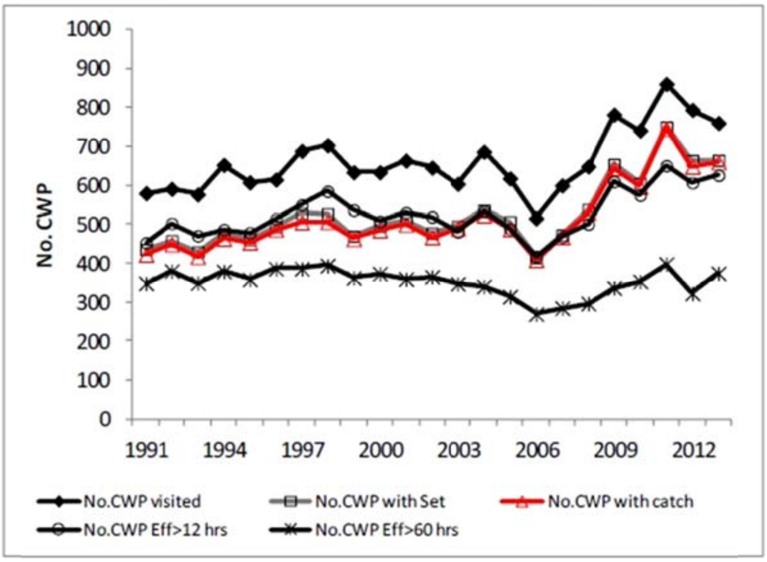


Figure 13. Numbers of 1° squares explored according to various levels of effort for the European Union purse seiners (from SCRS/2014/080).

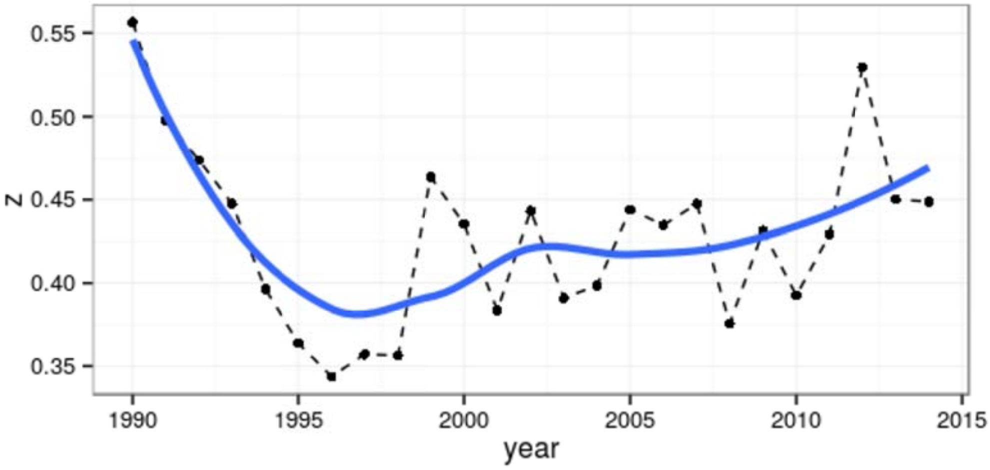


Figure 14. Estimates of Z derived from the Powell-Wetherall plots; showing the estimates from each year (points with hatched line) and a smoother (blue continuous line).

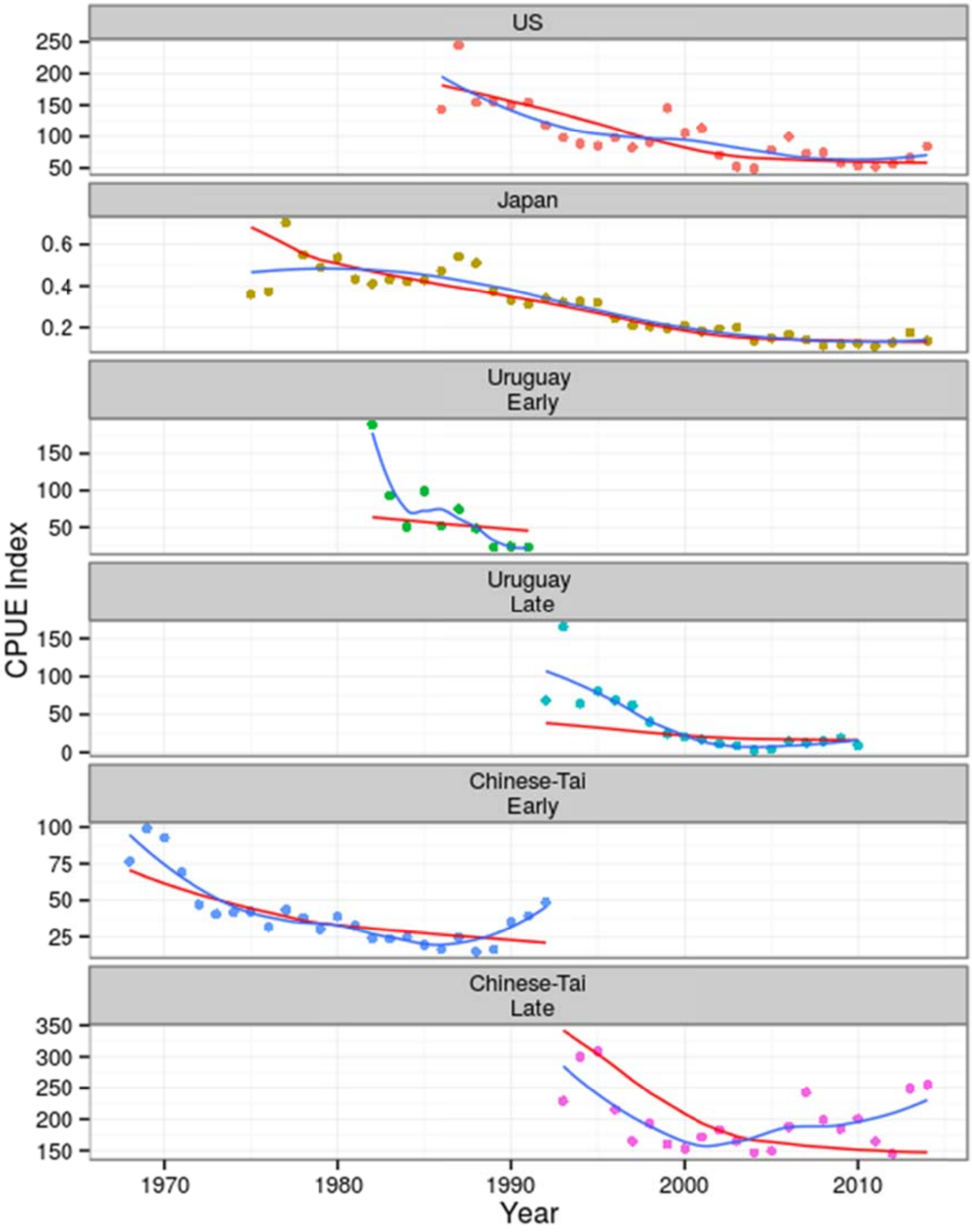


Figure 15. CPUE series agreed at the data preparatory meeting as potential proxies for stock abundance; points are the standardised values, lines the prediction from a GAM fitted to all the indices with year as a smooth term and index as a factor (red) and by index individually (blue).

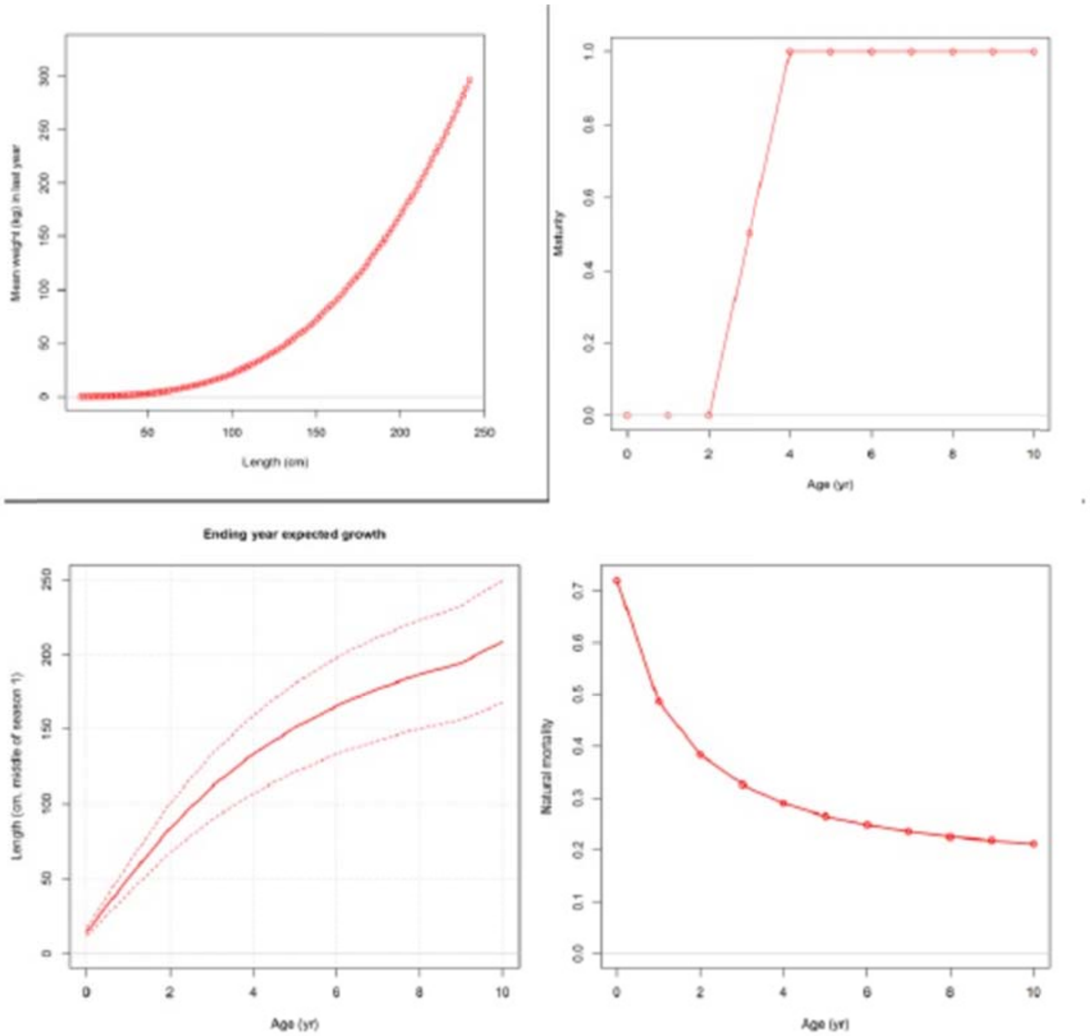


Figure 16. Life history functions used in the initial run of SS3 to assess BET: (top left) weight-length, (top right) maturity at age, (bottom left) growth, and (bottom right) natural mortality.

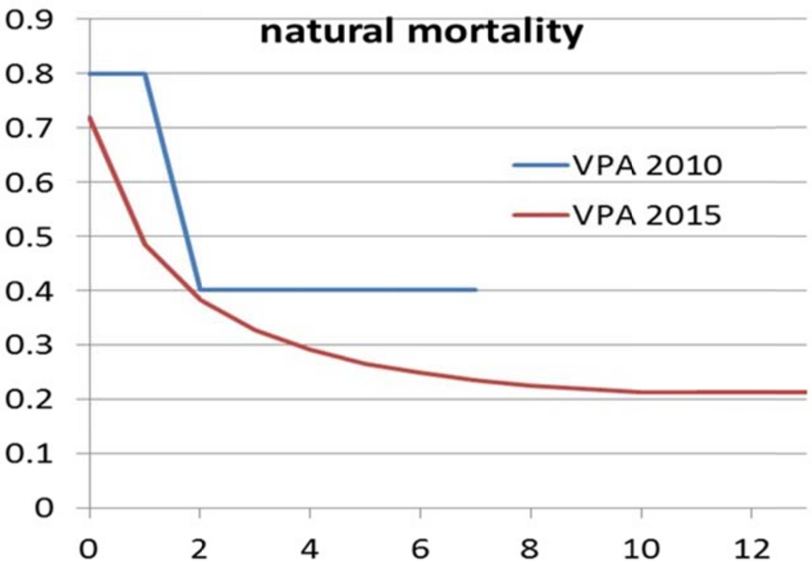


Figure 17. Lorenzen natural mortality vector used in the VPA model of 2015 and vector used in 2010.

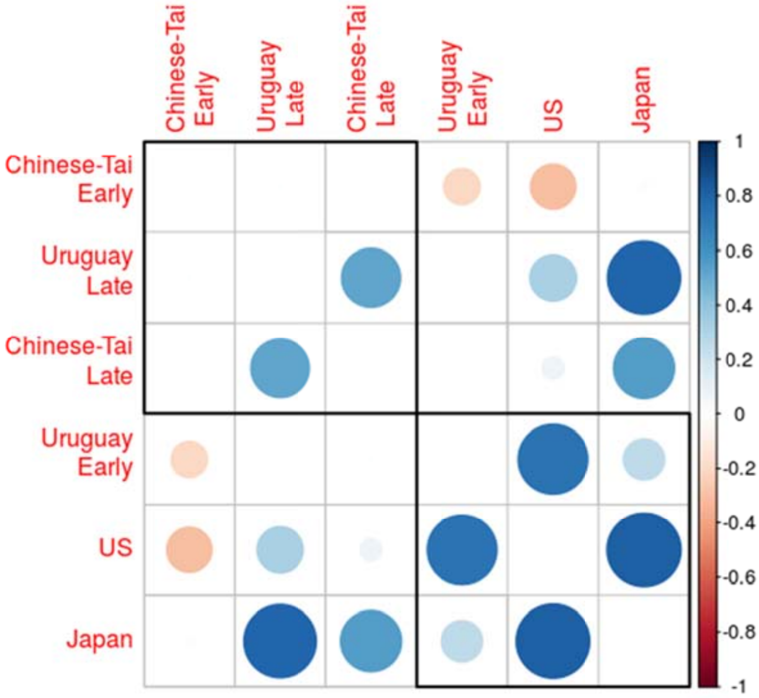


Figure 18. ASPIC: Correlation matrix for the agreed indices; blue indicates positive and red negative correlations, the order of the indices and the rectangular boxes are chosen based on a hierarchical cluster analysis using a set of dissimilarities.

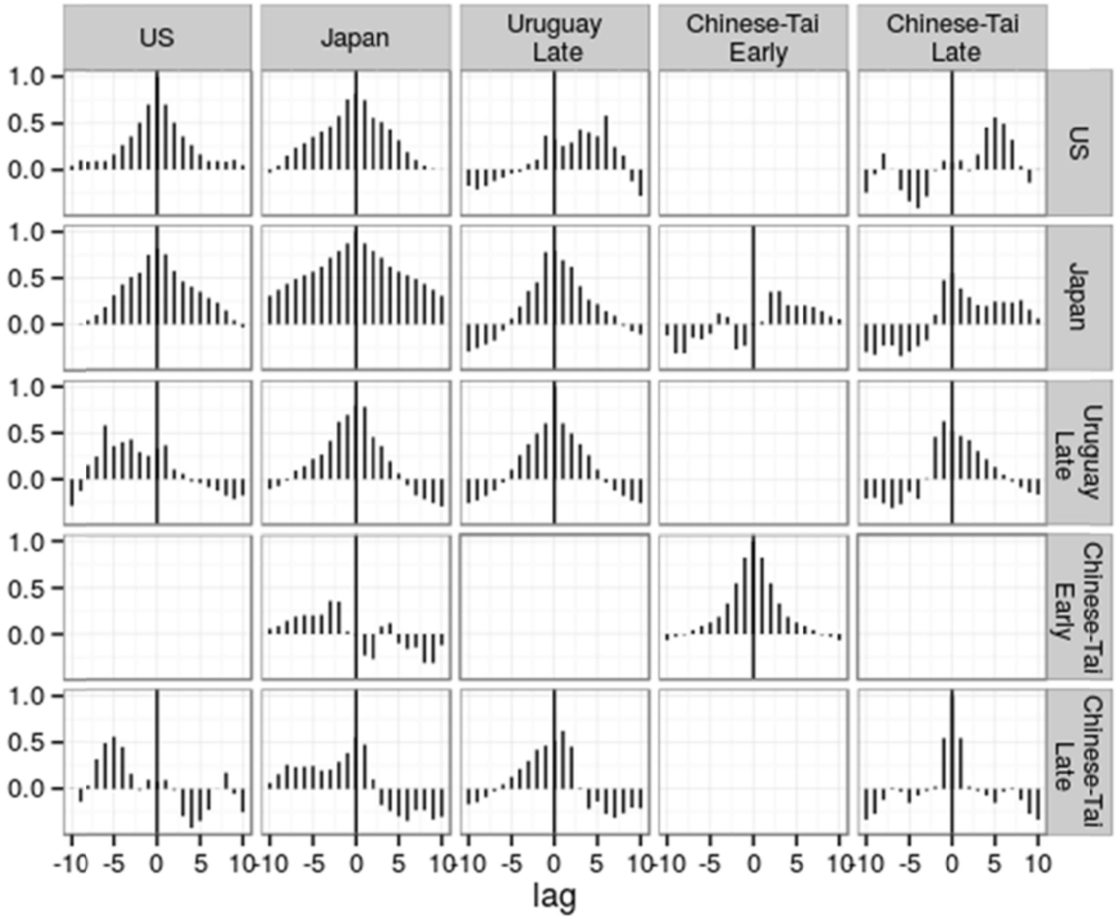


Figure 19. ASPIC: Cross correlations between indices, to identify potential lags due to year-class effects.

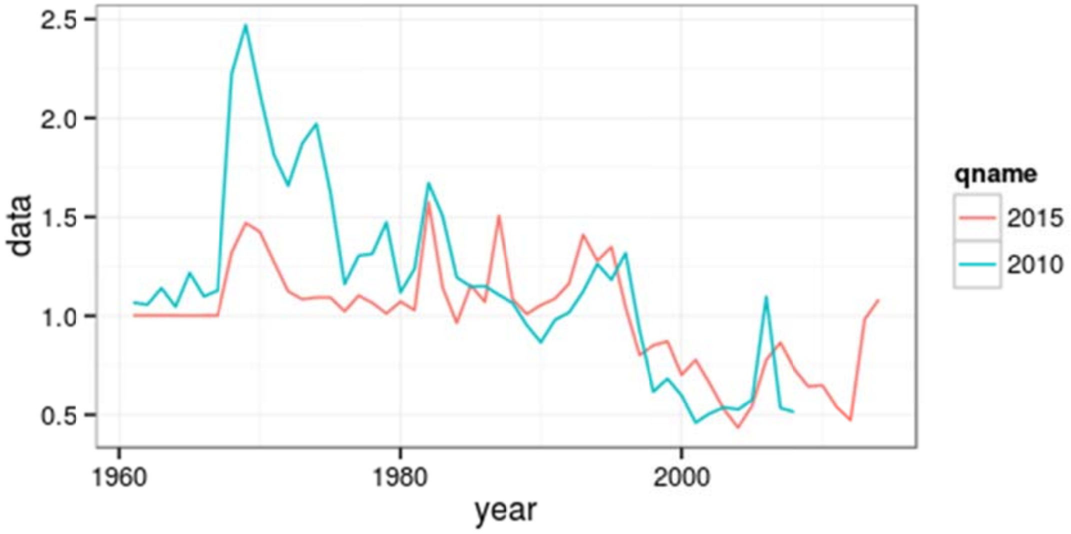


Figure 20. ASPIC: Composite index as estimated in 2015 using the same methodology as in 2010 compared to that estimated in 2010. Note that indices used in 2015 are not the same as those used in 2010.

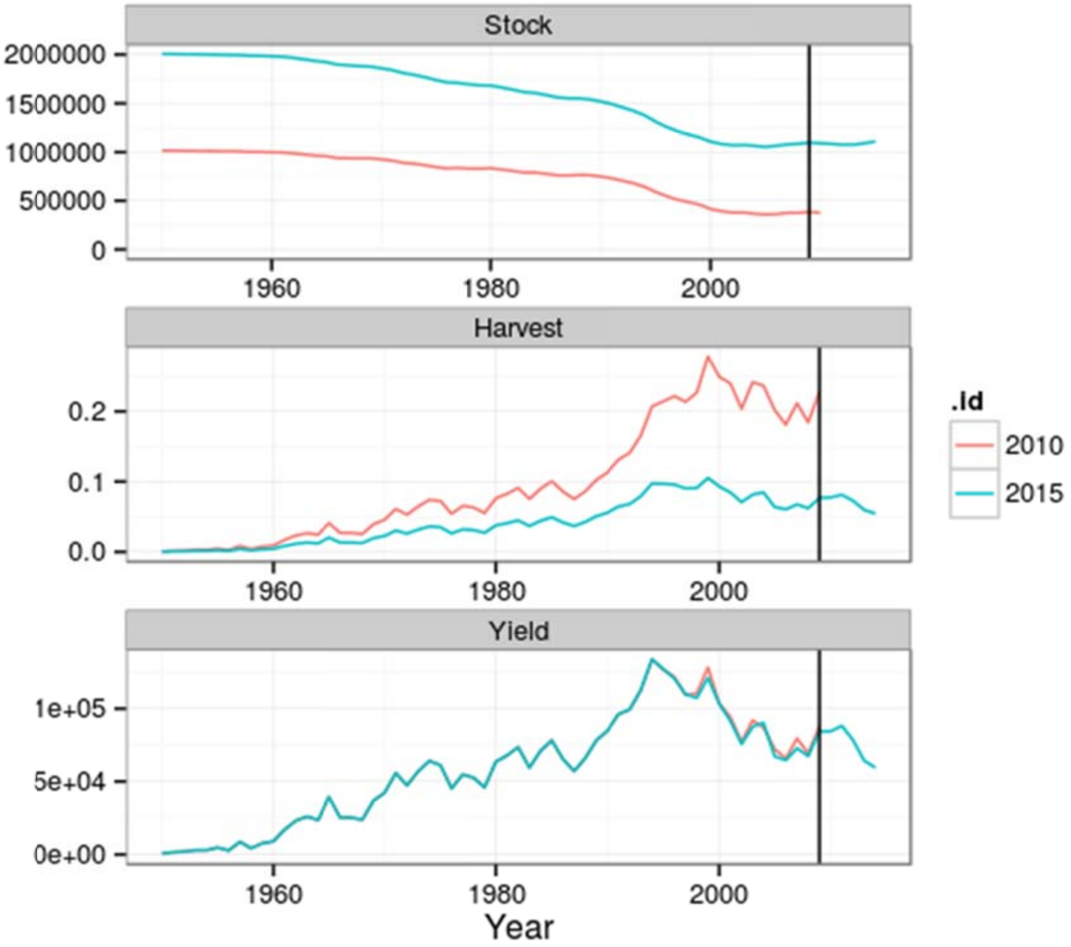


Figure 21. ASPIC: Model fits to 2010 and 2015 composite indices. Biomass trajectory (upper panel), fishing mortality (middle panel), and yield used as input (lower panel).

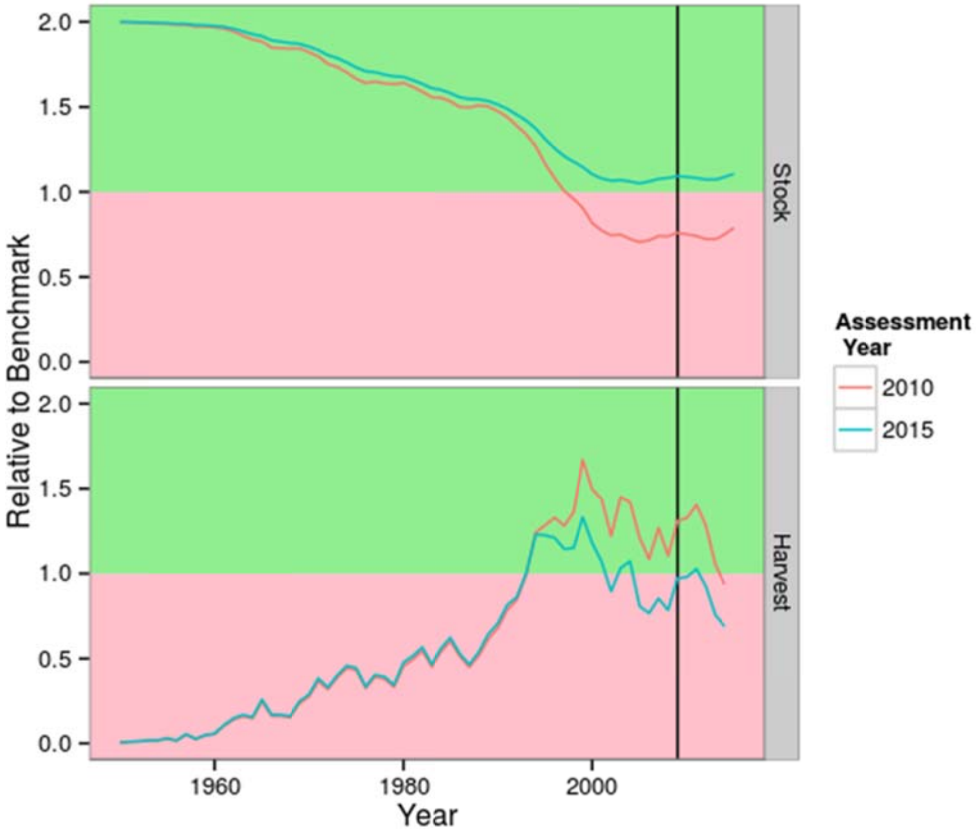


Figure 22. ASPIC: ASPIC fits to composite indices relative to benchmarks; 2010 fit is projected using the reported catches to 2014. All values relative to MSY benchmarks.

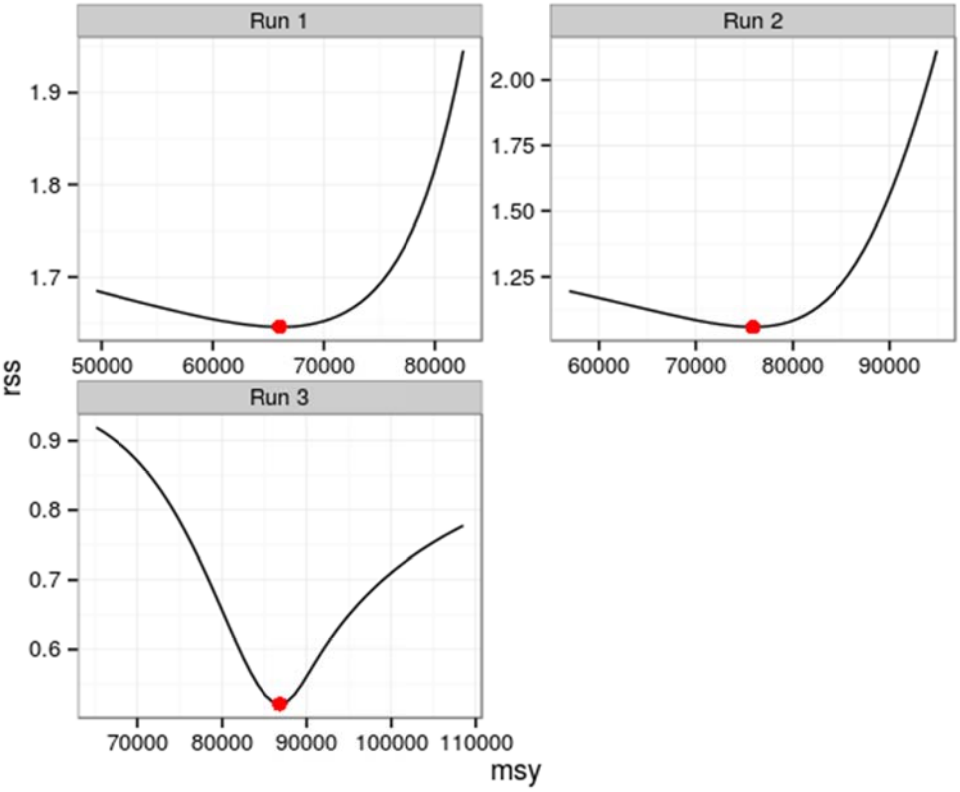


Figure 23. ASPIC: Residual sum of squares profiles, as a function of MSY, for selected ASPIC runs.

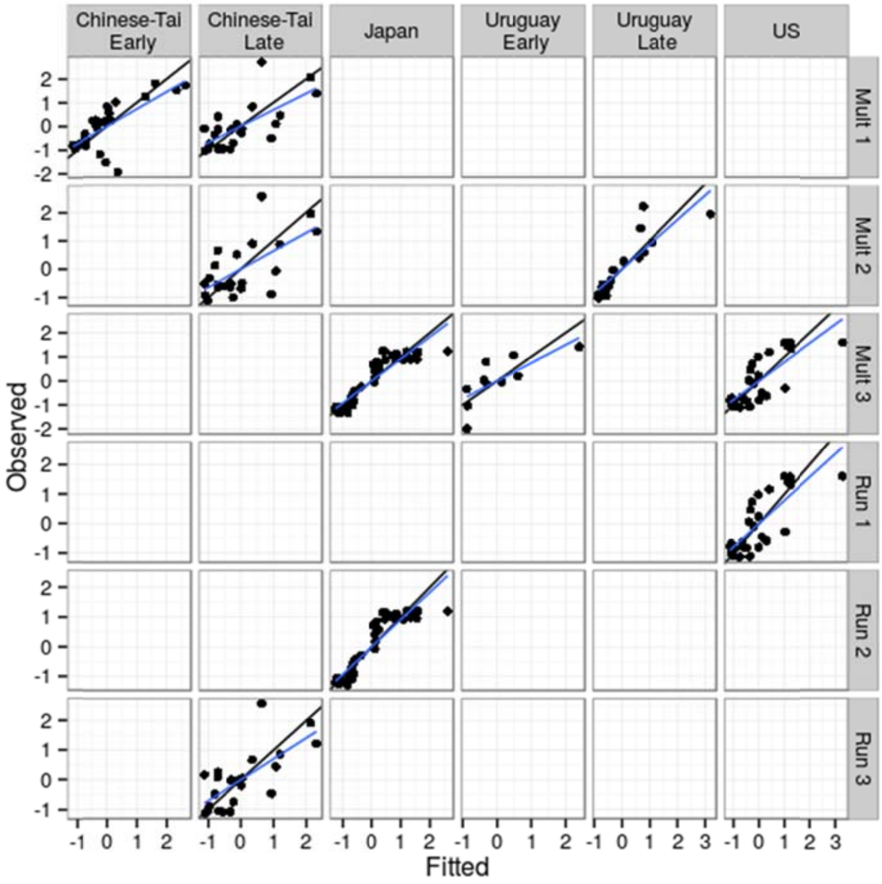


Figure 24. ASPIC: Observed CPUE verses fitted, blue line is a linear regression fitted to points, black line the y=x line. The assessment scenarios are shown in rows and indices in columns, which allows comparing diagnostics for a single index across runs by reading down a column.

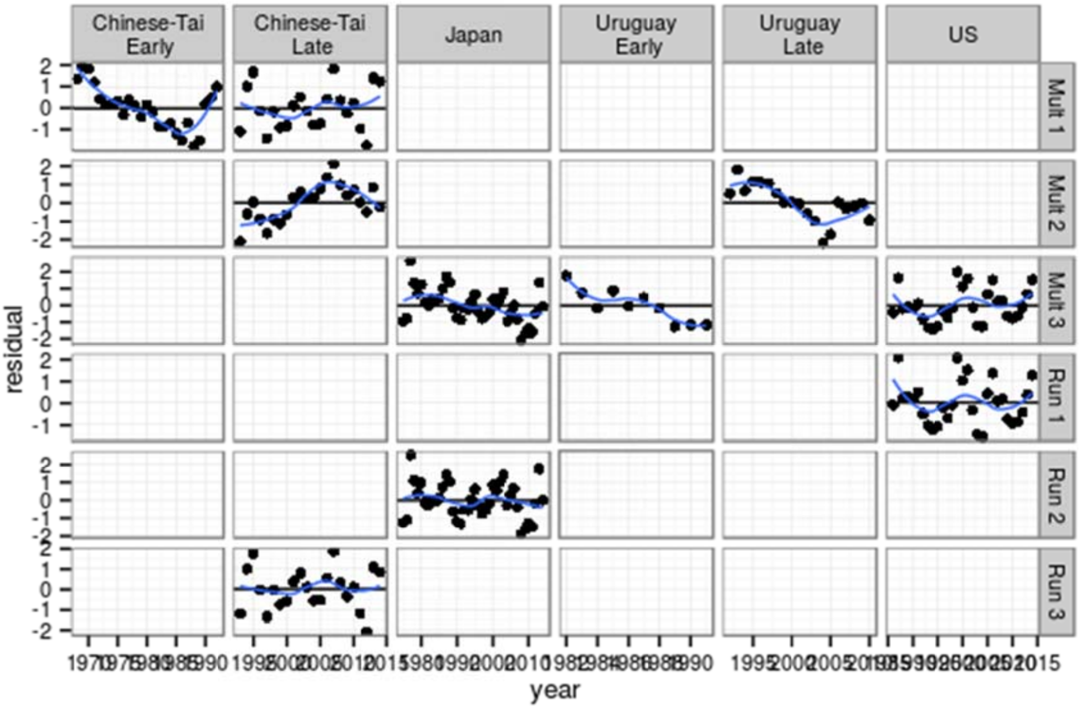


Figure 25. ASPIC: Residuals by year, with loess smoother and SEs. The assessment scenarios are shown in rows and indices in columns, which allows comparing diagnostics for a single index across runs by reading down a column.

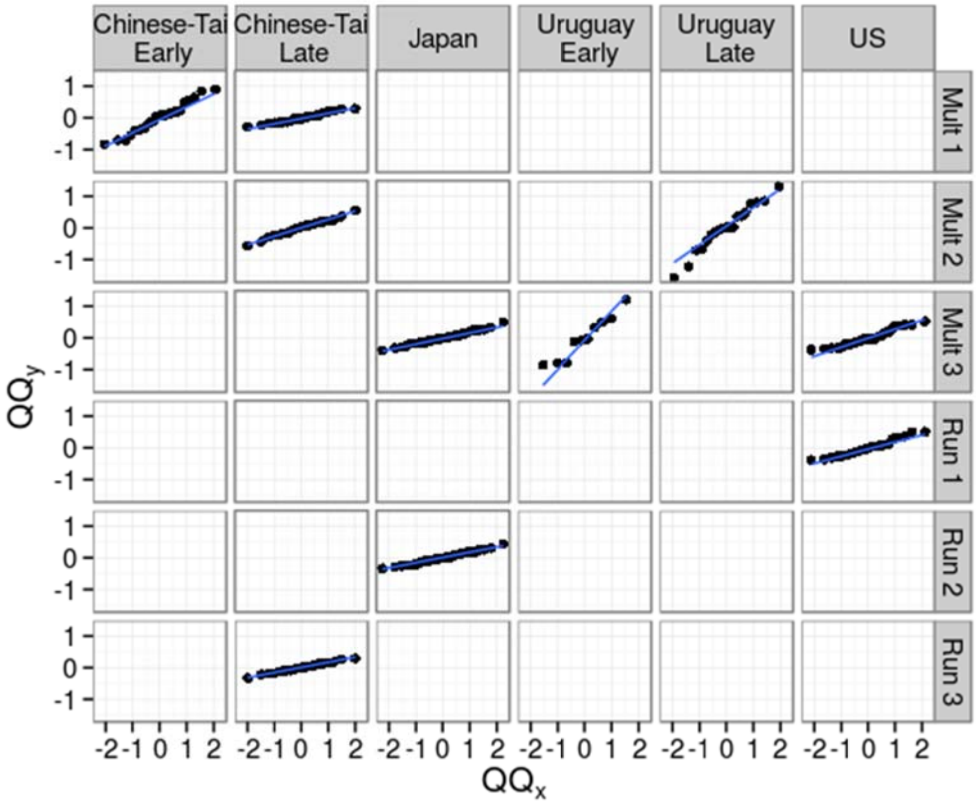


Figure 26. ASPIC: Quantile-quantile plot to compare residual distribution with the normal distribution. The assessment scenarios are shown in rows and indices in columns, which allows comparing diagnostics for a single index across runs by reading down a column.

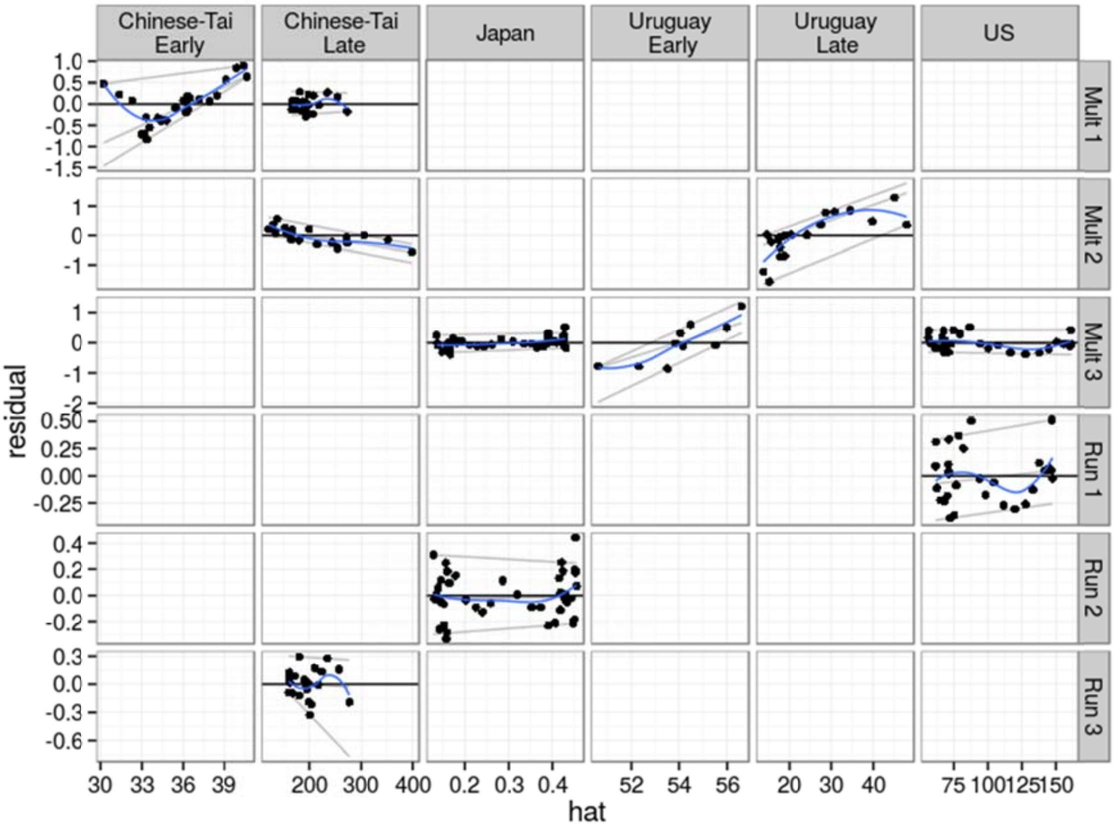


Figure 27. ASPIC: Plot of residuals against fitted value with 5th & 95th percentiles to check variance relationship. The assessment scenarios are shown in rows and indices appear in columns, which allows comparing diagnostics for a single index across runs by reading down a column.

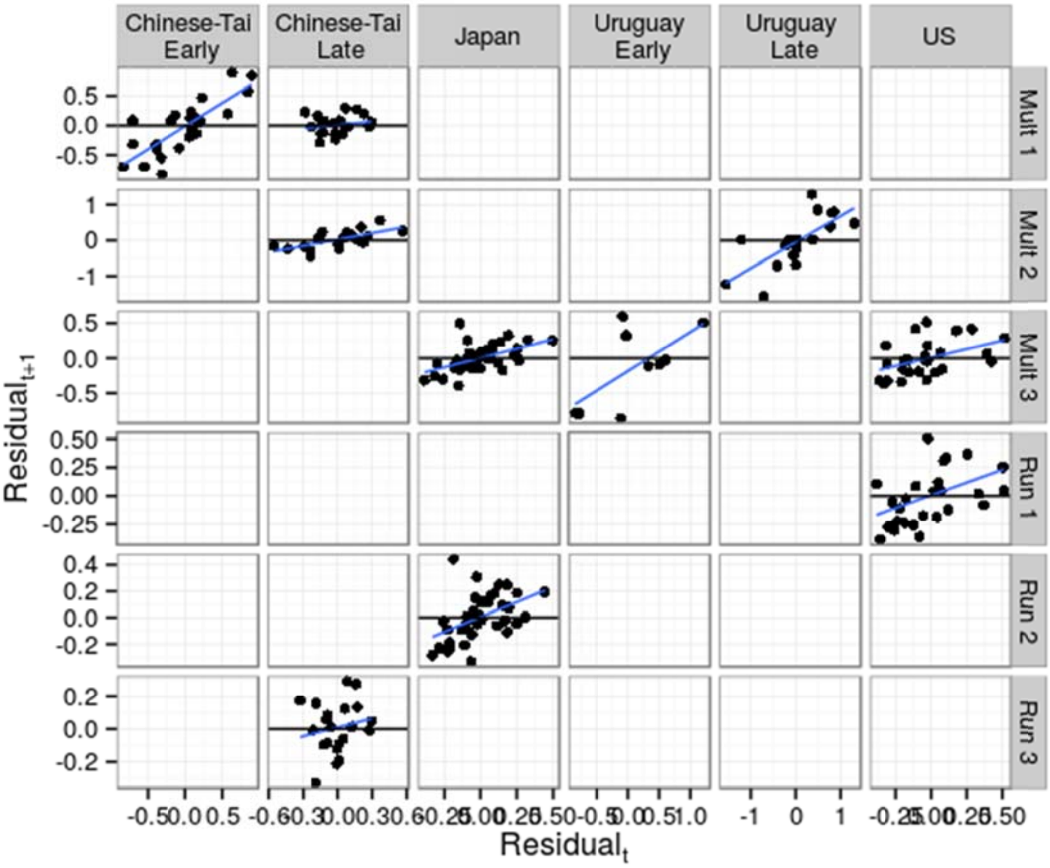


Figure 28. ASPIC: Plot of autocorrelation, i.e. $residual_{t+1}$ verses $residual_t$. The assessment scenarios are shown in rows and indices in columns, which allows comparing diagnostics for a single index across runs by reading down a column.

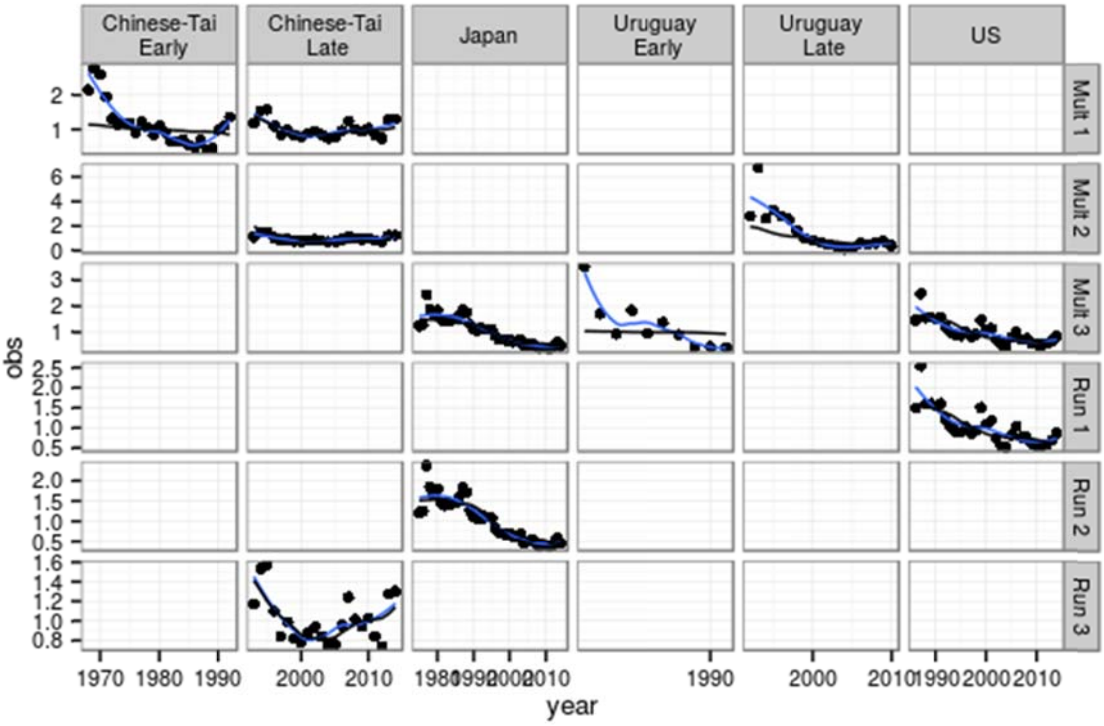


Figure 29. ASPIC: Predicted stock trend by index (points), with biomass estimates (blue) and a local regression (black). The assessment scenarios are shown in rows and indices in columns, which allows comparing diagnostics for a single index across runs by reading down a column.

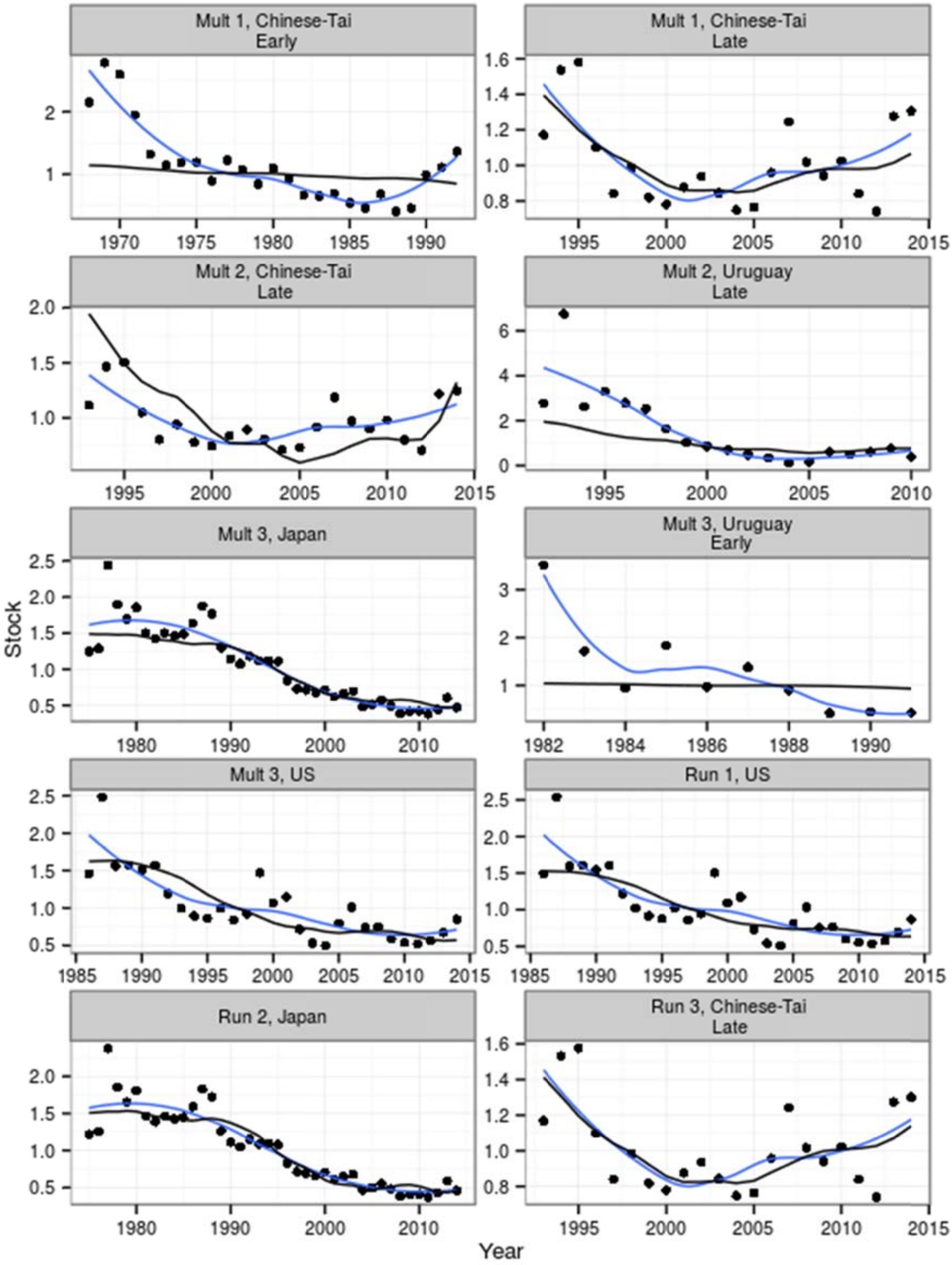


Figure 30. ASPIC: Predicted stock trend by index (points), with biomass estimates (blue) and a local regression (black).

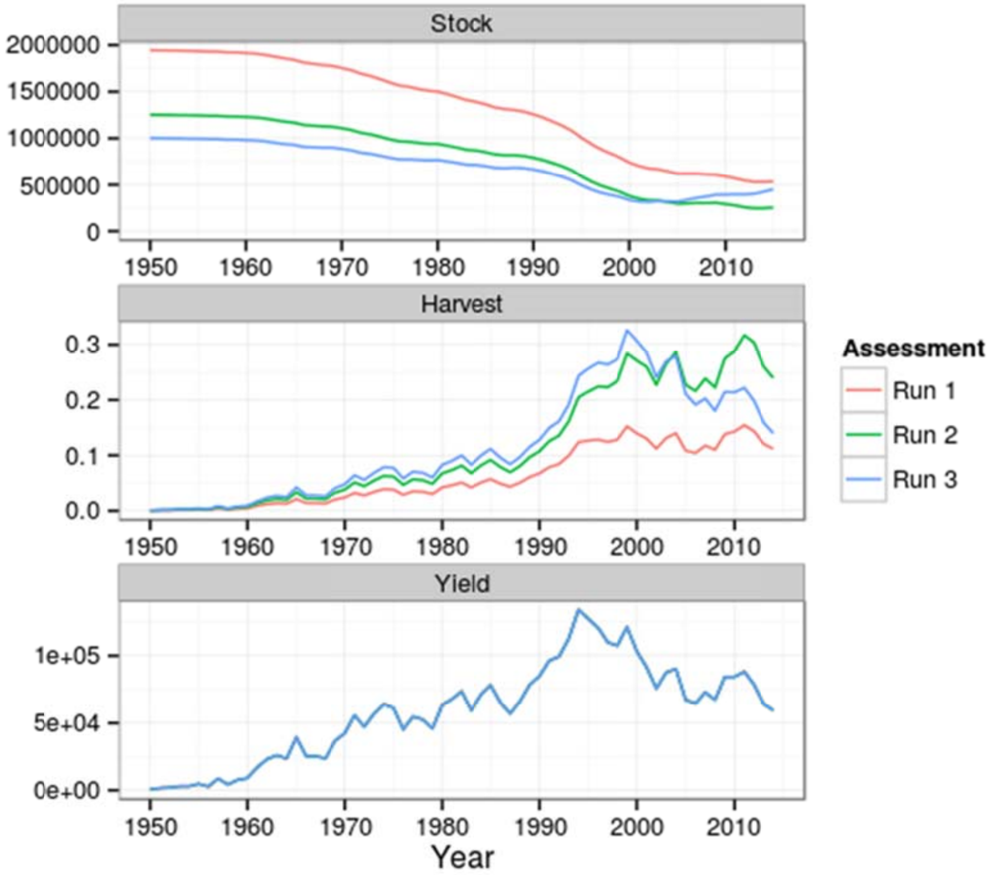


Figure 31. ASPIC: Time series of stock biomass, harvest rate and catch by assessment scenario.

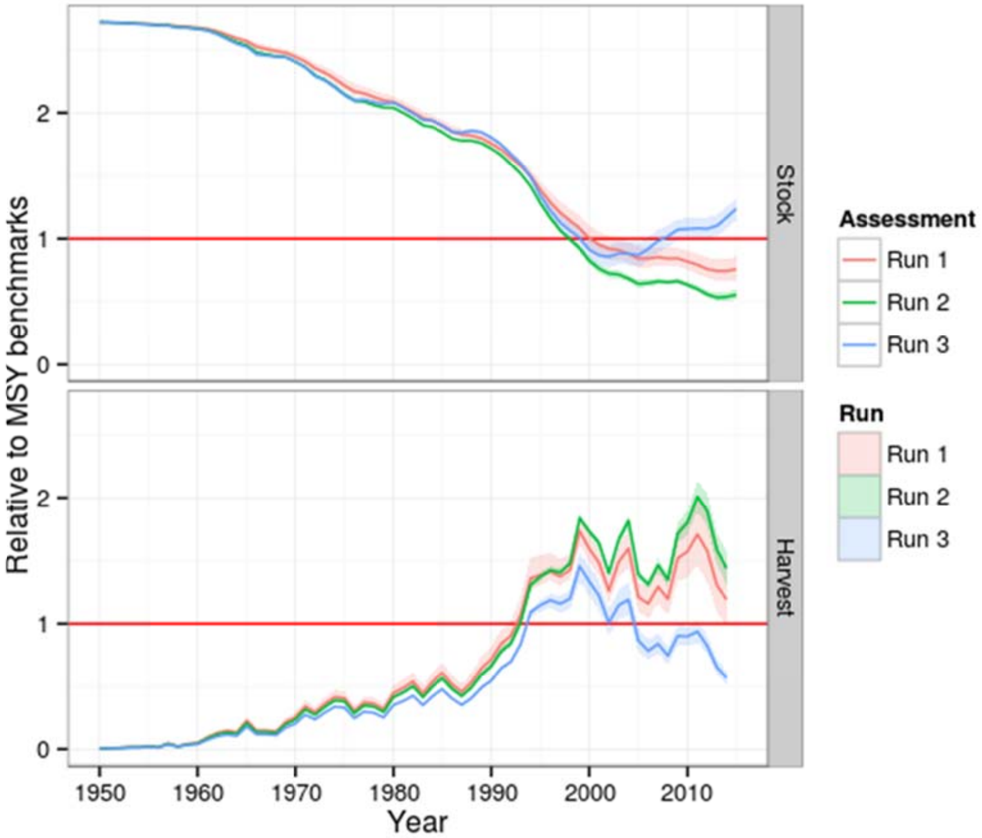


Figure 32. ASPIC: Time series of stock biomass and harvest rate relative to MSY benchmarks; lines are medians and ribbons inter-quartiles.

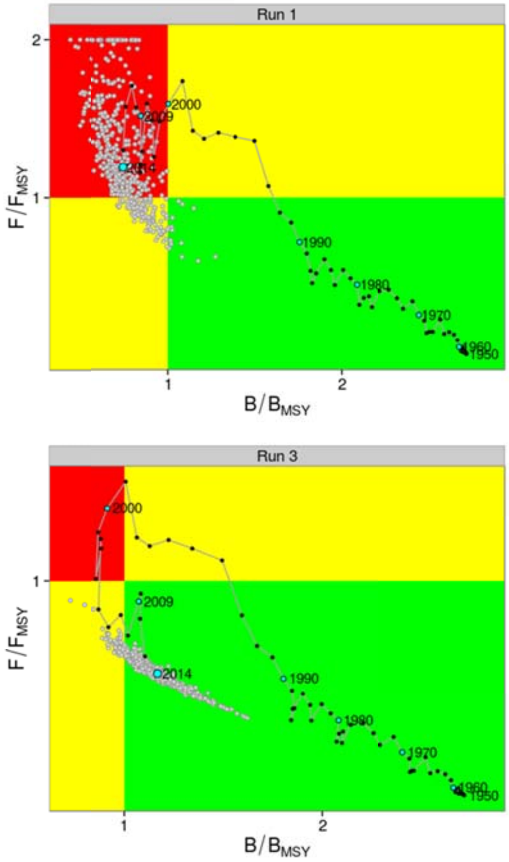


Figure 33. ASPIC: Kobe Phase Plot, by run with tracks showing medians.

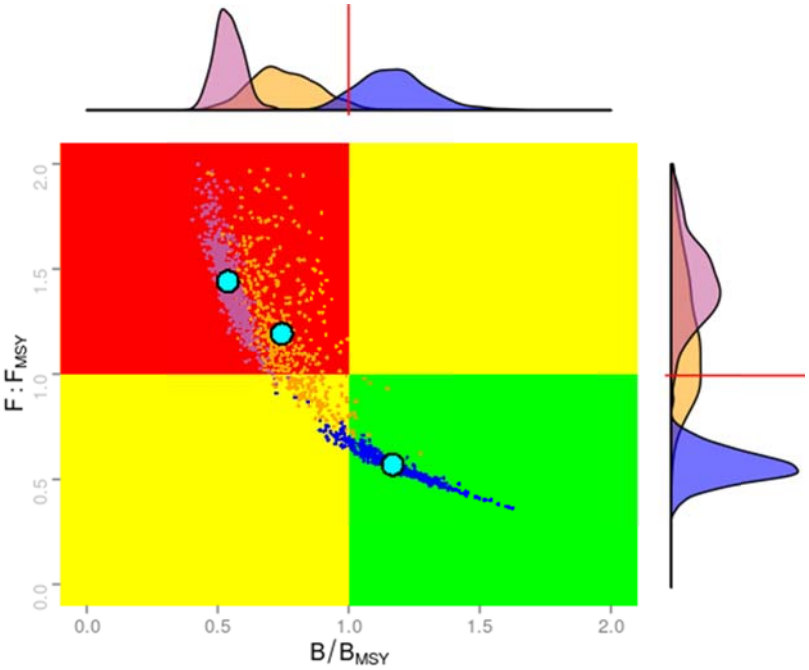


Figure 34. ASPIC: Current status (2014) of bigeye tuna based on ASPIC. Graph combines results for the 3 runs considered. The clouds of points depict the bootstrap estimates of uncertainty for the most recent year (purple = Japan LL run, brown = US LL run, blue= Chinese-Taipei LL run). The median point estimate for each models results are shown in open (cyan) circles. The marginal density plots shown above and to the right of the main graph reflect the frequency distribution of the bootstrap estimates of each model with respect to relative biomass (top) and relative fishing mortality (right). The red lines represent the benchmark levels (ratios equal to 1.0).

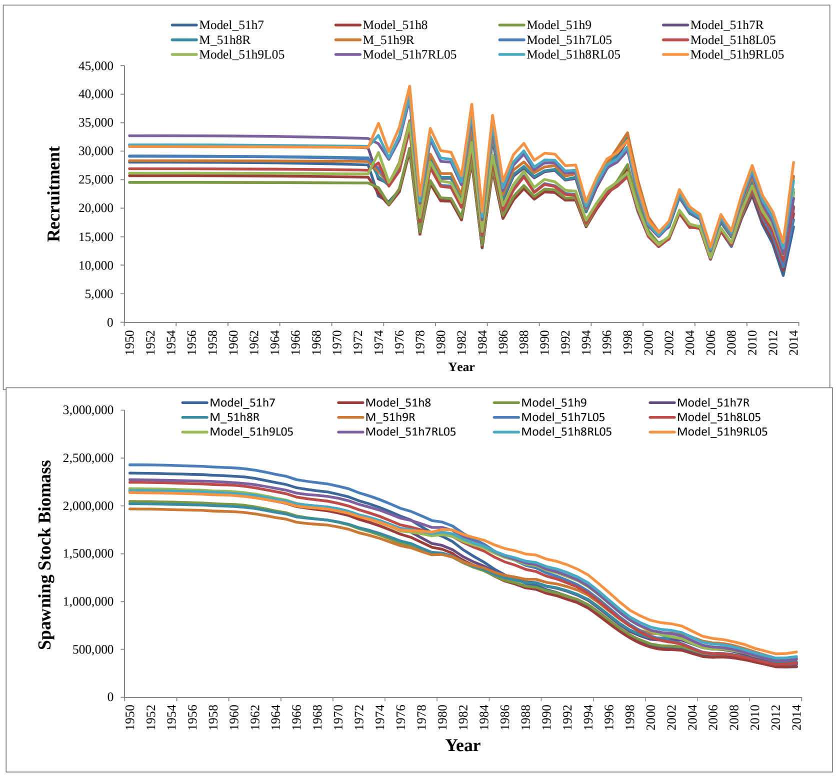


Figure 35. SS3 estimated Spawning Stock Biomass (absolute) and recruitment for the 12 selected runs.

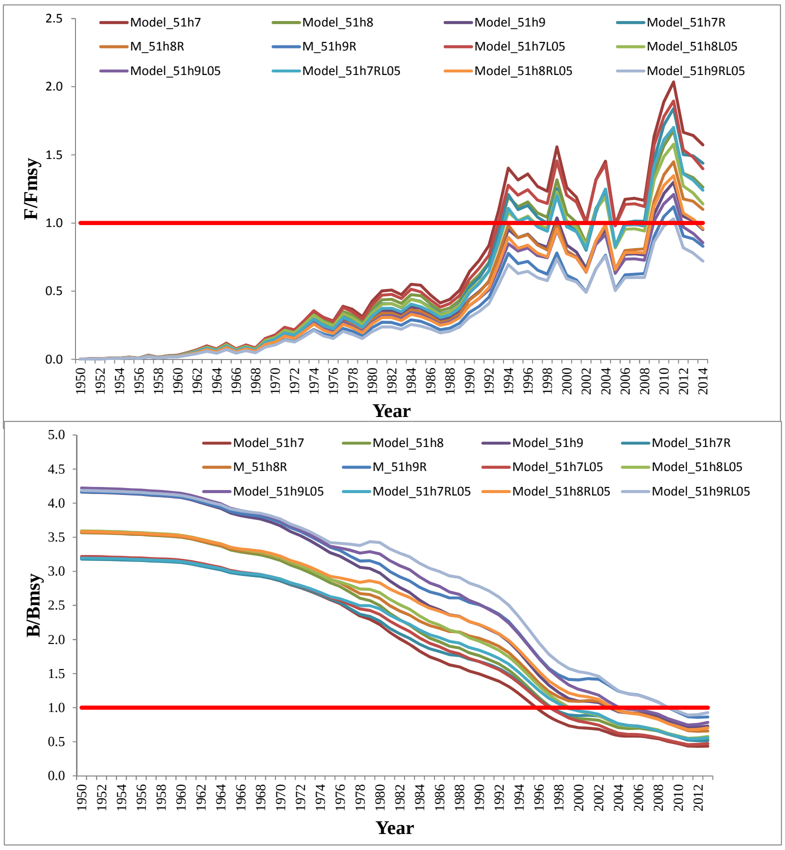


Figure 36. SS3 estimated Spawning Stock Biomass relative to MSY benchmark (B/B_{MSY}) and fishing mortality (F/F_{MSY}) for the selected runs.

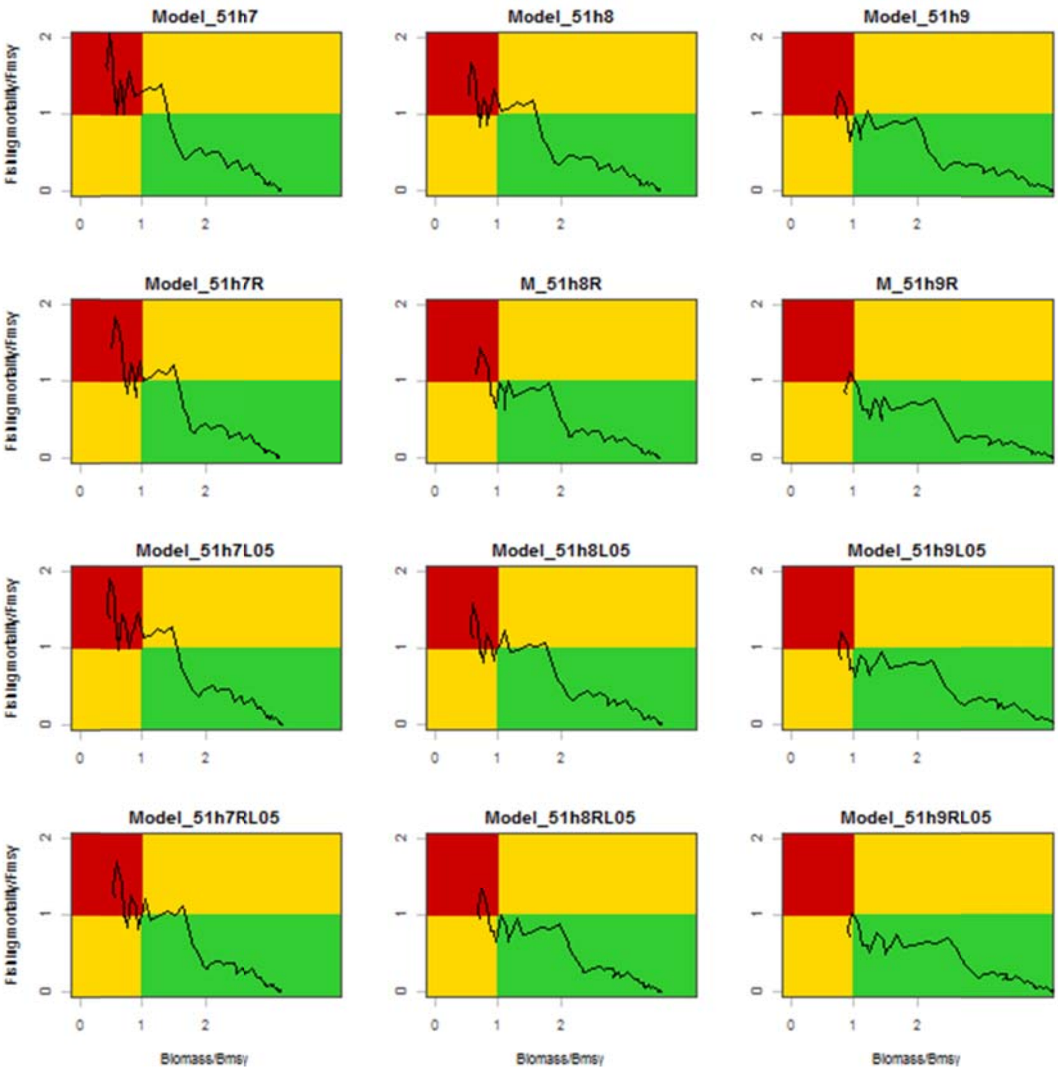


Figure 37. SS3: Kobe Phase Plot by each scenario.

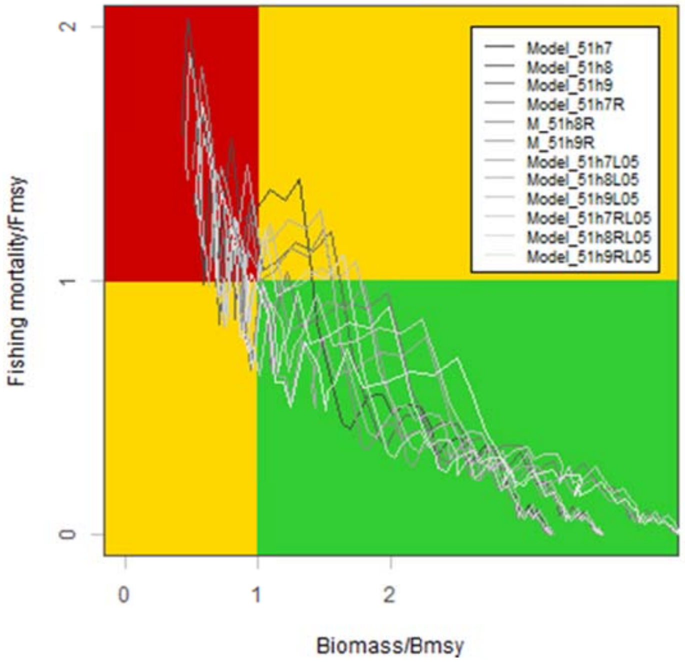


Figure 38. SS3: Kobe Phase Plot all scenarios.

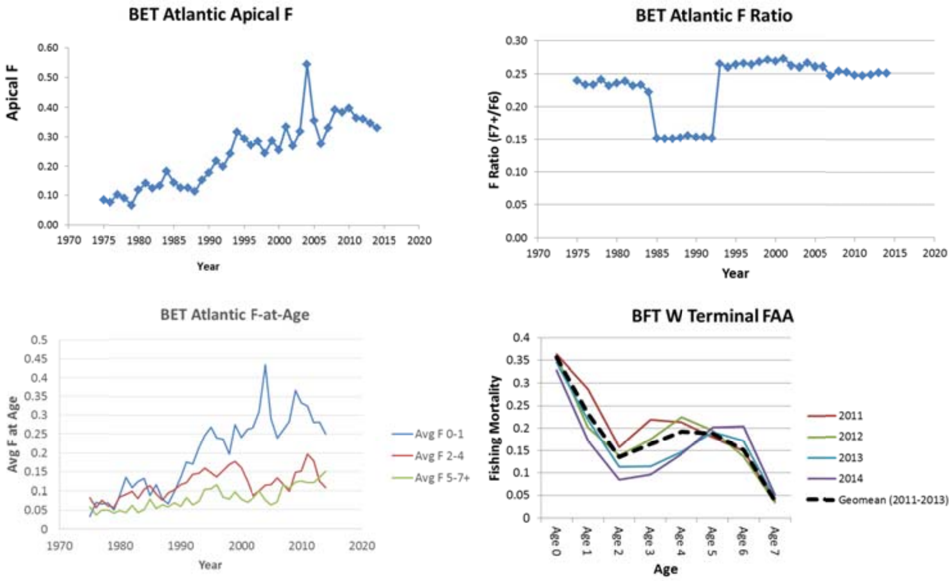


Figure 39. VPA: Trajectories of apical F, F-ratio (ratio of F7+/F6), F at several ages and terminal year F from the VPA.

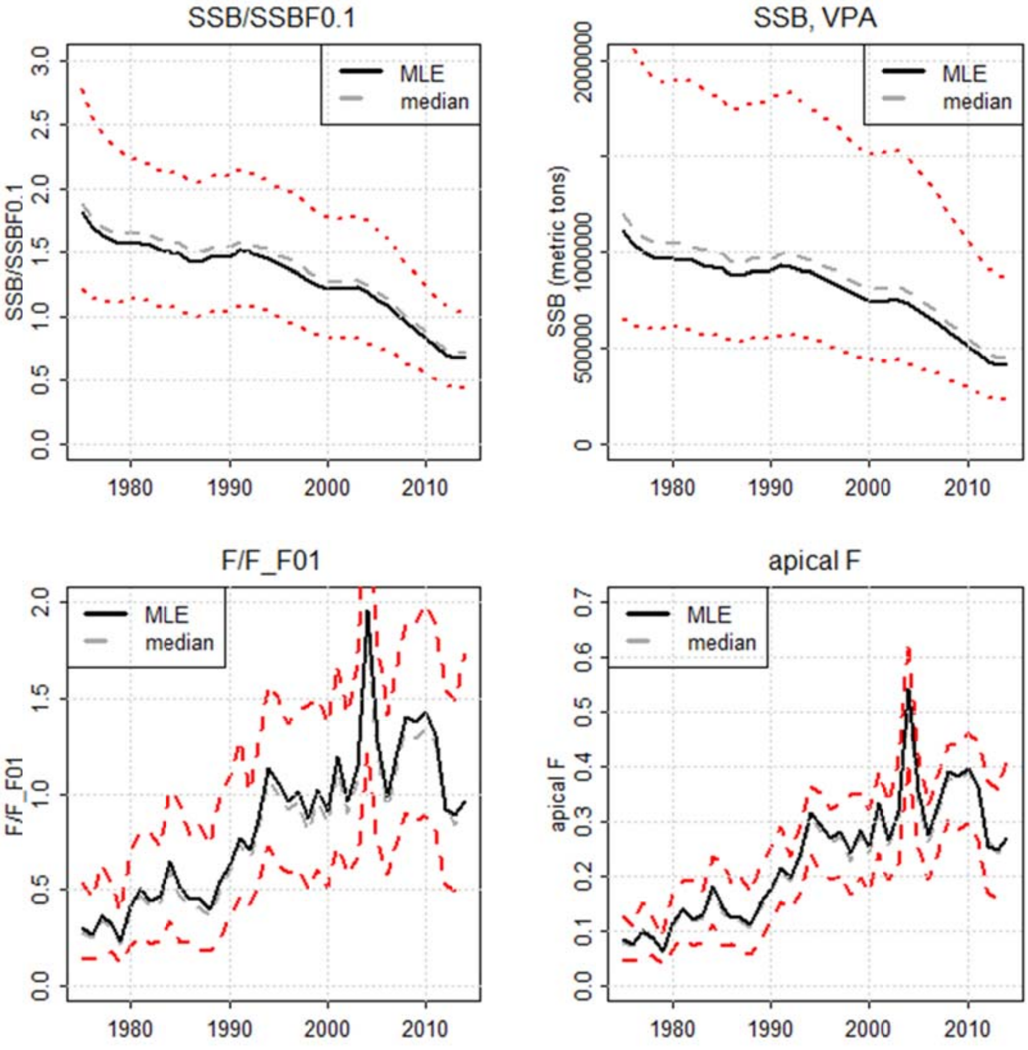


Figure 40. VPA: Trajectories of SSB/SSB$_0$, SSB, F/F$_{0.1}$ and apical F for the VPA. Note that the final three years of F estimates are reduced due to the replacement of the terminal three years of recruits.

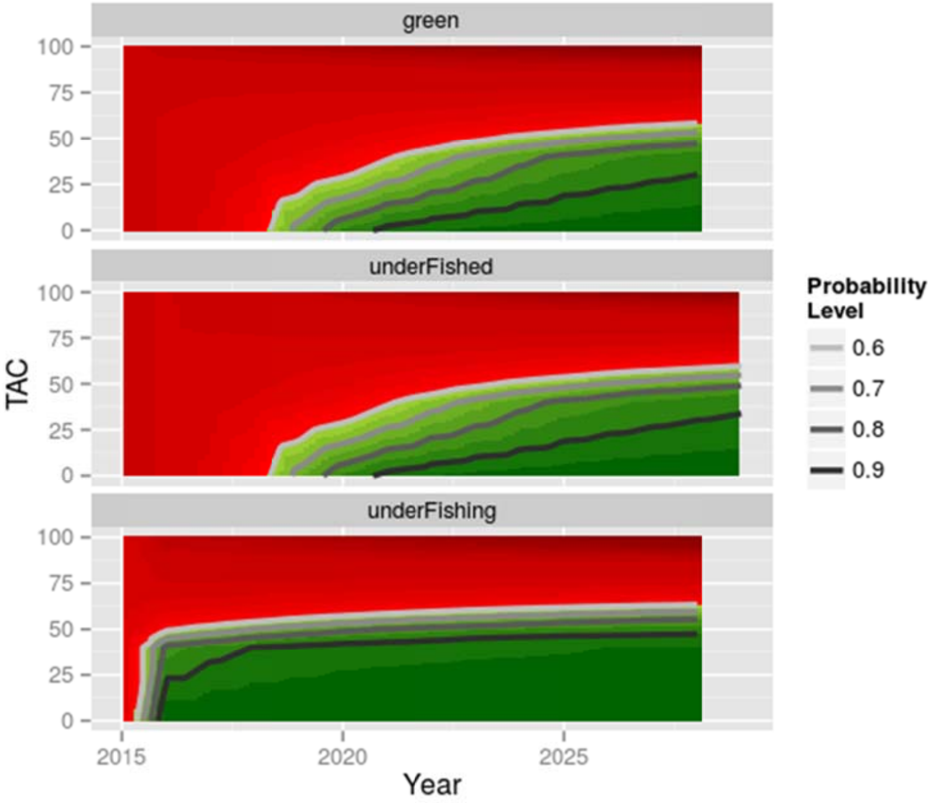


Figure 41. ASPIC: Plots of probability of being in the green zone, under fished and under fishing for catch projections for the 3 runs combined.

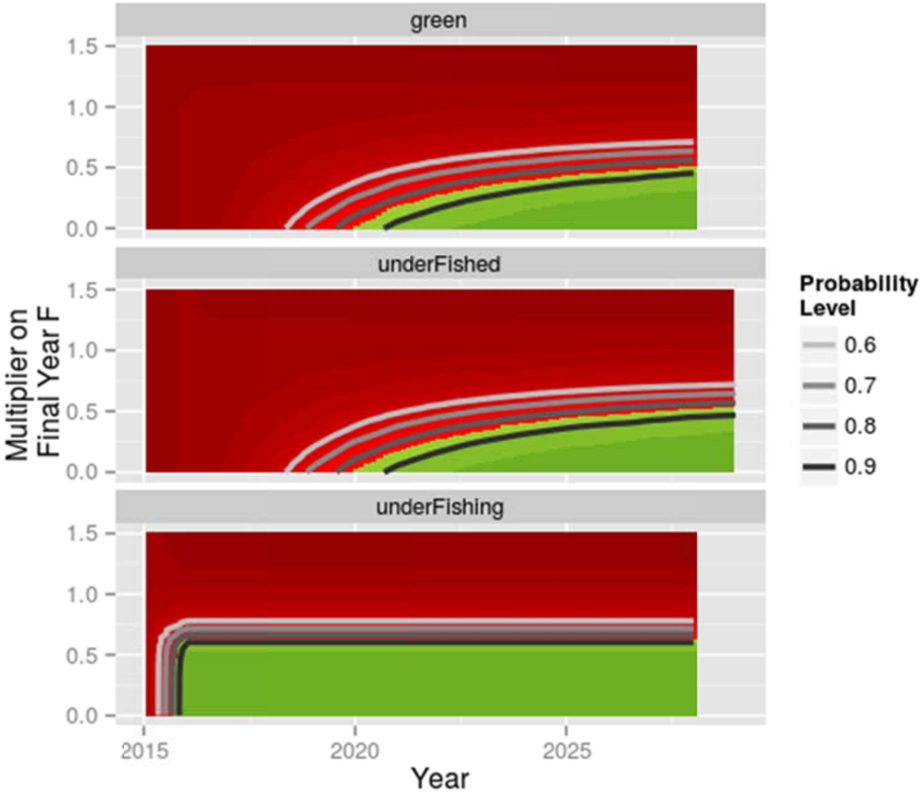


Figure 42. ASPIC: Plots of probability of being in the green zone, under fished and under fishing for F strategies projections for the 3 runs combined.

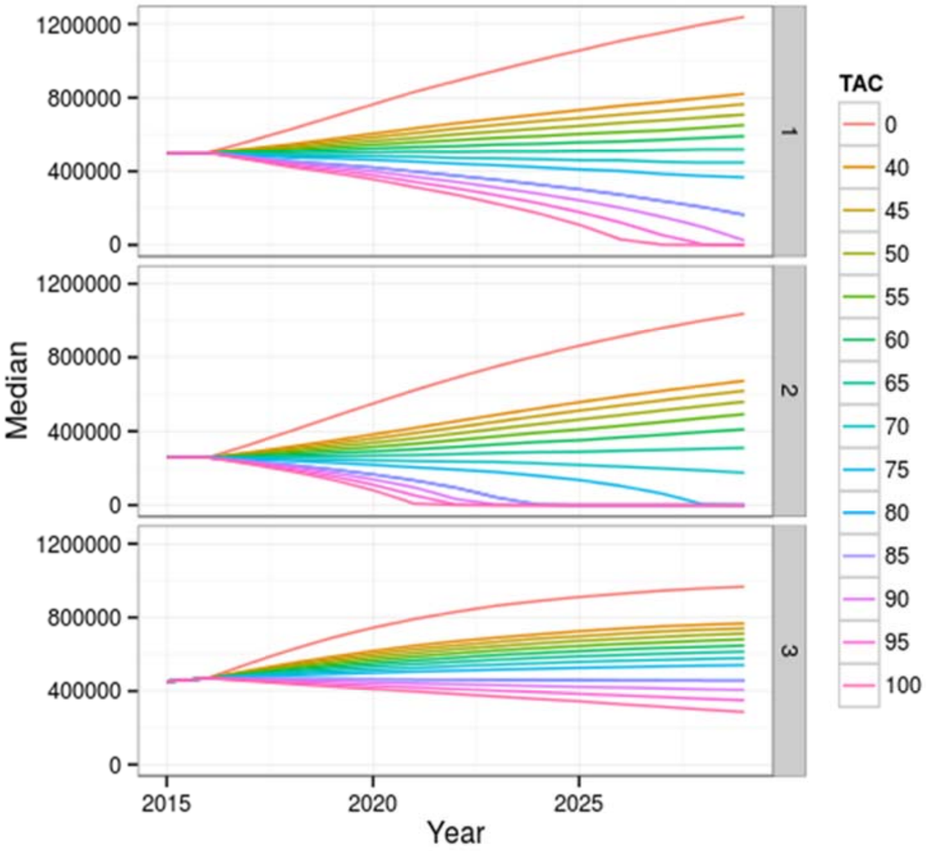


Figure 43. ASPIC: Projected stock biomass for constant catch strategies by each assessment run.

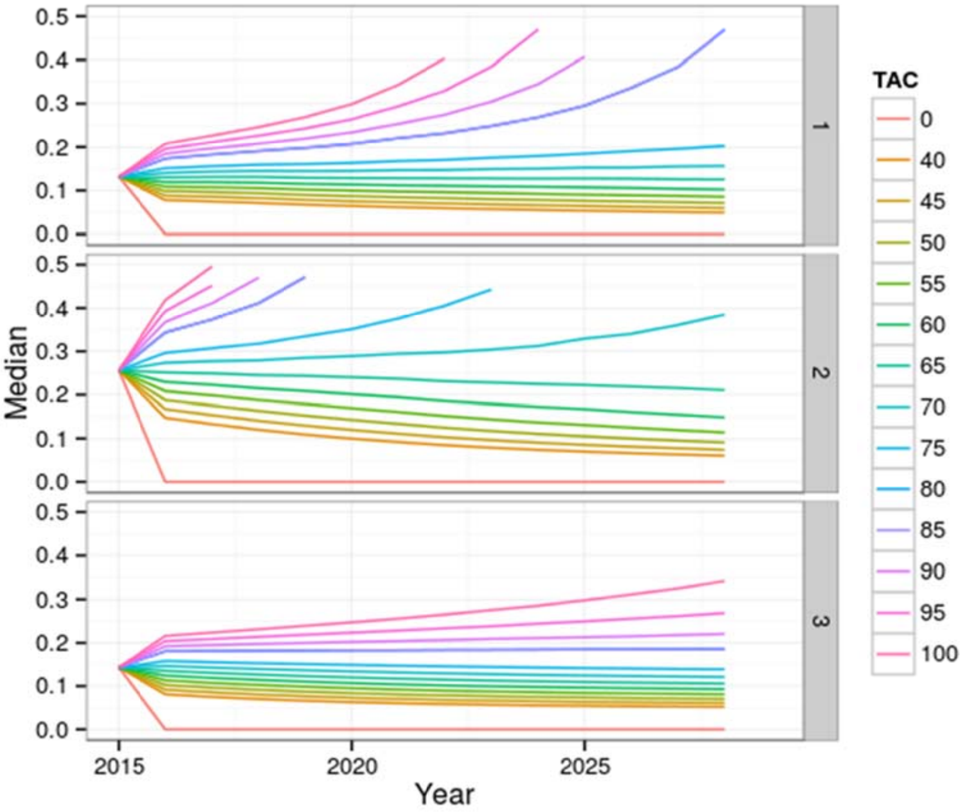


Figure 44. ASPIC: Projected harvest rate for constant catch strategies by each assessment run.

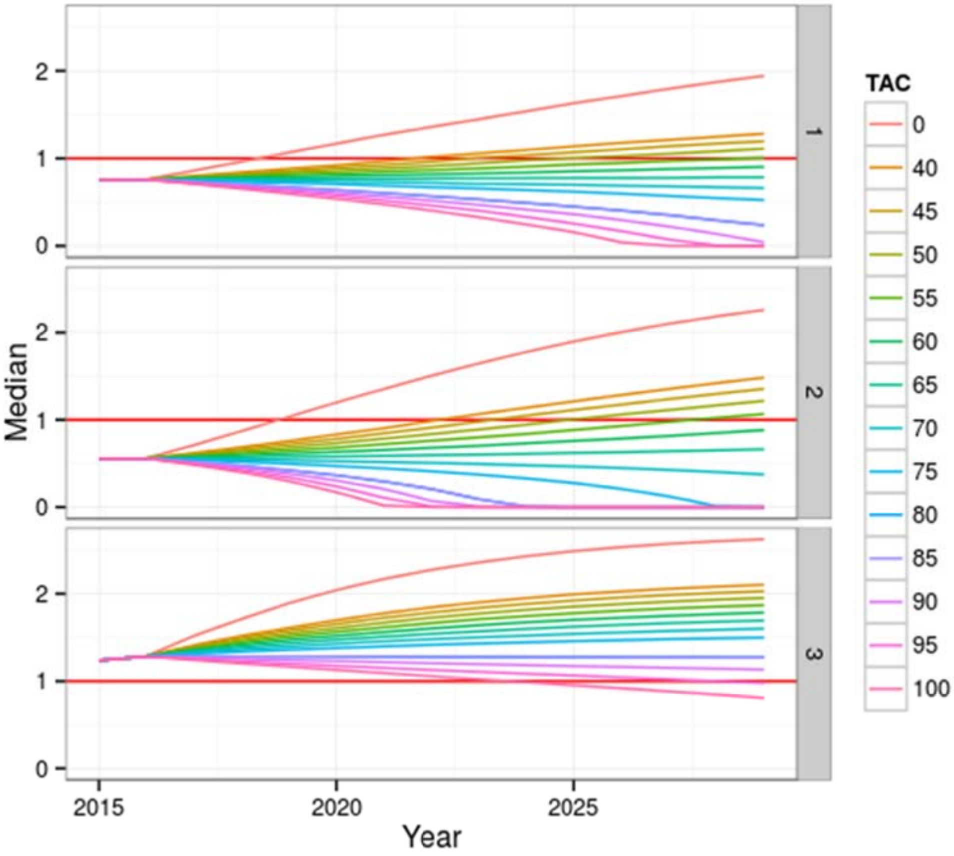


Figure 45. ASPIC: Projected stock biomass relative to B_{MSY} for constant catch strategies by each assessment run.

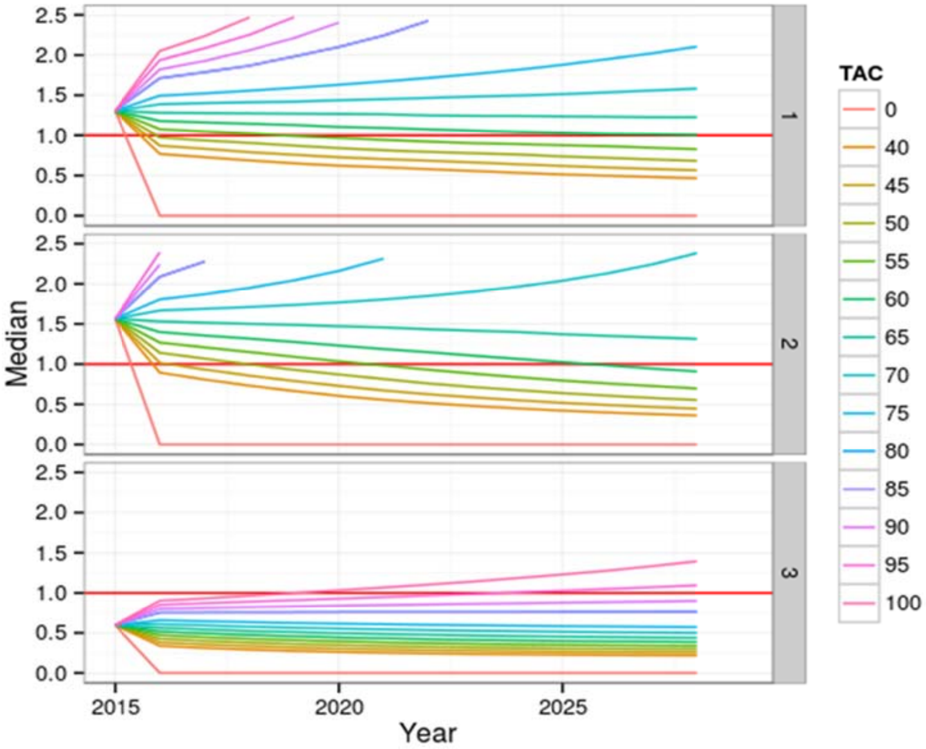


Figure 46. ASPIC: Projections of harvest rate relative to F_{MSY} for constant catch strategies by each assessment run.

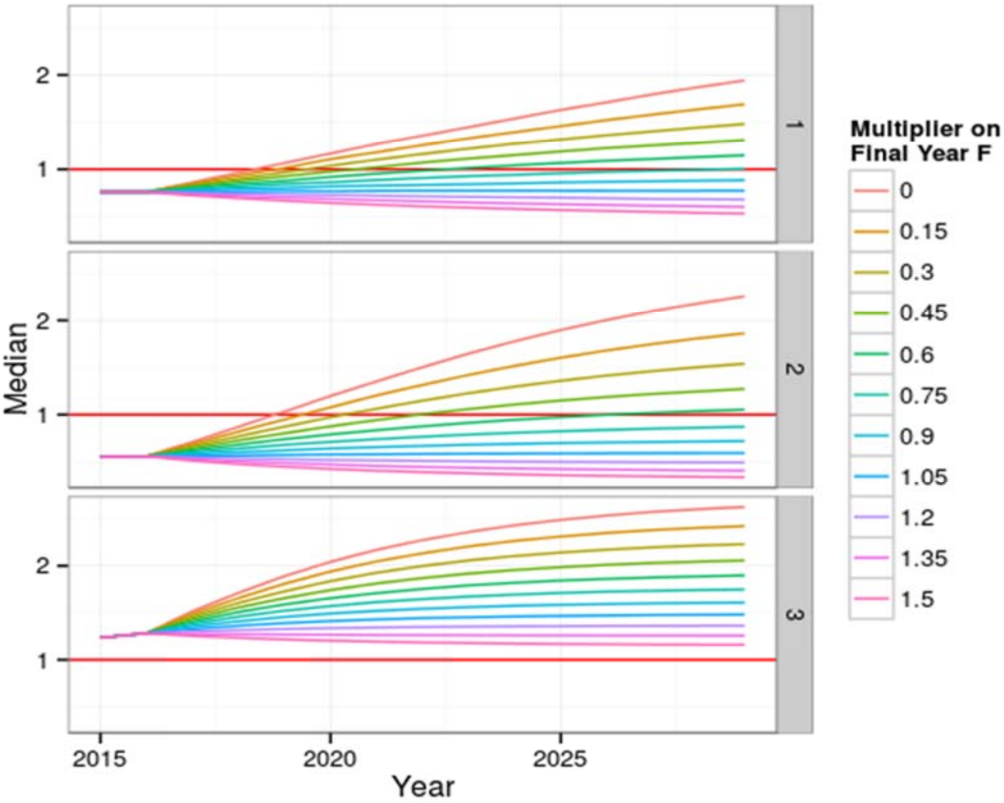


Figure 47. ASPIC: Projected stock biomass relative to B_{MSY} for constant harvest rate strategies by assessment run.

Appendix 1

AGENDA

1. Opening, adoption of Agenda and meeting arrangements
2. Summary of available data for assessment
   - 2.1 Biology
   - 2.2 Catch estimates
   - 2.3 Relative Abundance estimates
   - 2.4 Fisheries indicators
3. Methods and other data relevant to the assessment
   - 3.1 Production models
   - 3.2 Catch statistical models: Stock Synthesis and/or MULTIFAN-CL
   - 3.3 VPA
   - 3.4 Other methods
4. Stock status results
   - 4.1 Production models
   - 4.2 Stock Synthesis or MULTIFAN-CL
   - 4.3 VPA
   - 4.4 Other methods
   - 4.5 Synthesis of assessment results
5. Projections
   - 5.1 Kobe matrix for bigeye
6. Recommendations
   - 6.1 Research and statistics
   - 6.2 Management
7. Other matters
   - 7.1 Revision of the first steps of the AOTTP
   - 7.2 Defining the procedure to update the analysis of the effects of the current moratoria on FADs
8. Adoption of the report and closure

Appendix 2

LIST OF PARTICIPANTS

CONTRACTING PARTIES

CÔTE D'IVOIRE

Amandè, Monin Justin
Chercheur Halieute, Centre de Recherches Océanologiques de Côte d'Ivoire, Département Ressources Aquatiques Vivantes – DRAV, 29 Rue des Pêcheurs, BP V 18, Abidjan 01, Côte d'Ivoire
Tel: +225 05 927 927, Fax: +225 21 351 155, E-Mail: monin.amande@yahoo.fr; monin.amande@cro-ci.org

EUROPEAN UNION

Carmona, Itsaso
AZTI - Tecnalia /Itsas Ikerketa Saila, Txatxarramendi irla z/g, 48395 Sukarrieta (- Bizkaia), País Vasco, Spain
Tel: +34 94 6574000, E-Mail: icarmona@azti.es

Daniel, Patrick
Commission européenne - DG Affaires maritimes et Pêche, J-99 02/49, 1000 Brussels, Belgium
Tel: +322 229 554 58, E-Mail: patrick.daniel@ec.europa.eu

Fonteneau, Alain
9, Bd Porée, 35400 Saint Malo, France
Tel: +33 4 99 57 3200, Fax: +33 4 99 57 32 95, E-Mail: alain.fonteneau@ird.fr

Gaertner, Daniel
I.R.D. UR nº 109 Centre de Recherche Halieutique Méditerranéenne et Tropicale, Avenue Jean Monnet - B.P. 171, 34203 Sète Cédex, France
Tel: +33 4 99 57 32 31, Fax: +33 4 99 57 32 95, E-Mail: daniel.gaertner@ird.fr

Herrera Armas, Miguel Angel
OPAGAC, C/ Ayala 54, 28001 Madrid, Spain
Tel: 91 431 48 57, Fax: 91 576 12 22, E-Mail: miguel.herrera@opagac.org

Lopez, Jon
IEO - Instituto Español de Oceanografía, C/ Corazón de María, 8, 28002 Madrid, Spain
Tel: +34 91 510 75 18, E-Mail: jon.lopez@md.ieo.es

Merino, Gorka
AZTI - Tecnalia /Itsas Ikerketa Saila, Herrera Kaia Portualde z/g, 20110 Pasaia (Gipuzkoa), País Vasco, Spain
Tel: +34 94 657 4000, Fax: +34 94 300 4801, E-Mail: gmerino@azti.es

Murua, Hilario
AZTI - Tecnalia /Itsas Ikerketa Saila, Herrera Kaia Portualde z/g, 20110 Pasaia (Gipuzkoa), País Vasco, Spain
Tel: +34 667 174 433, Fax: +34 943 004801, E-Mail: hmurua@azti.es

Pascual Alayón, Pedro José
Ministerio de Economía y Competitividad, Instituto Español de Oceanografía, C.O. de Canarias, Vía Espaldón, Dársena Pesquera, PCL 8, 38180 Santa Cruz de Tenerife Islas Canarias, Spain
Tel: +34 922 549 400, Fax: +34 922 549 554, E-Mail: pedro.pascual@ca.ieo.es

Pereira, João Gil
Universidade dos Açores, Departamento de Oceanografia e PescasRua Professor Dr. Frederico Machado, 9901-862 Horta Azores, Portugal
Tel: +351 292 200 406, Fax: +351 292 200 411, E-Mail: pereira@uac.pt

Rodríguez-Sahagún González, Juan Pablo
Gerente Adjunto, ANABAC, c/Txibitxiaga, 24, entreplanta apartado 49, 48370 Bermeo Bizkaia, Spain
Tel: +34 94 688 2806; 627454864, Fax: +34 94 688 5017, E-Mail: anabac@anabac.org

Santiago Burrutxaga, Josu
Head of Tuna Research Area, AZTI-Tecnalia, Txatxarramendi z/g, 48395 Sukarrieta (Bizkaia) País Vasco, Spain
Tel: +34 94 6574000 (Ext. 497); 664303631, Fax: +34 94 6572555, E-Mail: jsantiago@azti.es; flarrauri@azti.es

Soto Ruiz, María
Ministerio de Economía y Competitividad, Instituto Español de Oceanografía, c/Corazón de María, 8, 28002 Madrid, Spain
Tel: +34 91 347 3620, Fax: +34 91 413 5597, E-Mail: maria.soto@md.ieo.es

GHANA

Bannerman, Paul
Ministry of Fisheries, Marine Fisheries Research Division P.O. Box BT 62, Tema, Ghana
Tel: +233 244 794859, Fax: +233 302 208048, E-Mail: paulbann@hotmail.com

Iriarte, Federico
TTV-LTDA, Fishing HarbourP.O.Box CE 11254, Tema , Ghana
Tel: +233 33 205 403, Fax: +233 33 206 218, E-Mail: federico.iriarte@mwbrands.com

JAPAN

Ashida, Hiroshi
5-7-1 Orido, Shimizu-ku, Shizuoka-shi, Shizuokaken 424 8633, Japan
Tel: +81 54 336 6000, Fax: +81 1154 335 9642, E-Mail: hashida@affrc.go.jp

Matsumoto, Takayuki
Senior Researcher, Tuna and Skipjack Resources Division, National Research Institute of Far Seas Fisheries, Fisheries Research Agency 5-7-1 Orido, Shizuoka Shimizu 424-8633, Japan
Tel: +81 54 336 6000, Fax: +81 54 335 9642, E-Mail: matumot@affrc.go.jp

Uozumi, Yuji
Visiting Scientist, National Research Institute of Far Seas Fisheries, Fisheries Research Agency5-7-1 Orido, Shizuoka Shimizu 424-8633, Japan
Tel: +81 54 336 6000, E-Mail: uozumi@affrc.go.jp

MAURITANIA

Habibe, Beyahe Meissa
Institut Mauritanien de Recherches Océanographiques et des Pêches - IMROP, B.P. 22, Nouadhibou, Mauritania
Tel: +222 2242 1047, Fax: +222 574 5081, E-Mail: bmouldhabib@gmail.com

UNITED STATES

Brown, Craig A.
Chief, Highly Migratory Species Branch, Sustainable Fisheries Division, NOAA Fisheries Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami Florida 33149, United States
Tel: +1 305 361 4590, Fax: +1 305 361 4562, E-Mail: craig.brown@noaa.gov

Díaz, Guillermo
NOAA-Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami Florida 33021, United States
Tel: +1 305 898 4035, E-Mail: guillermo.diaz@noaa.gov

Schirripa, Michael
NOAA Fisheries, Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami Florida 33149, United States
Tel: +1 305 361 4568, Fax: +1 305 361 4562, E-Mail: michael.schirripa@noaa.gov

Sculley, Michelle
University of Miami, Rosenstell School of Marine and Atmospheric Science, 4600 Richenbacker Causeway, Miami FL 33149, United States
Tel: +1 305 421 4831, Fax: 4600 Richen, E-Mail: mjohnston@rsmas.miami.edu

Walter, John
NOAA Fisheries, Southeast Fisheries Center, Sustainable Fisheries Division75 Virginia Beach Drive, Miami Florida 33149, United States
Tel: +305 365 4114, Fax: +1 305 361 4562, E-Mail: john.f.walter@noaa.gov

URUGUAY

Forselledo Cladera, Rodrigo
Dirección Nacional de Recursos Acuáticos - DINARA, Sección de Recursos Pelágicos de Altura, Constituyente 1497, 11200 Montevideo , Uruguay
Tel: +598 2400 46 89, Fax: +598 241 32 16, E-Mail: rforselledo@gmail.com

OBSERVERS

CHINESE TAIPEI

Huang, Julia Hsiang-Wen
Director and Associate Professor, Institute of Marine Affaires and Resource Management, National Taiwan Ocean University, No. 2 Pei-Ning Road, 20224 Keelung, Chinese Taipei
Tel: +886 2 2462 2192 Ext. 5608, Fax: +886 2 2463 3986, E-Mail: julia@ntou.edu.tw

INTERNATIONAL SEAFOOD SUSTAINABILITY FOUNDATION – ISSF

Justel, Ana
ISSF-Spain, C/ Francisco Giralte, 2, 28002 Madrid, Spain
Tel: +34 91 745 3075, E-Mail: ajustel@iss-foundation.org

SCRS Chairman

Die, David
Cooperative Institute of Marine and Atmospheric Studies, University of Miami, 4600 Rickenbacker Causeway, Miami Florida 33149, United States
Tel: +1 305 421 4607, Fax: +1 305 421 4221, E-Mail: ddie@rsmas.miami.edu

EXTERNAL EXPERT

Sharma, Rishi
IOTC Secretariat, Le Chantier Mall (2nd floor), PO Box 1011, Victoria Mahé – Seychelles
Tel: +248 4225494, Fax: +248 4224364, E-Mail: Rishi.Sharma@iotc.org

****

ICCAT Secretariat
C/ Corazón de María, 8 – 6th floor, 28002 Madrid, Spain
Tel: + 34 91 416 5600; Fax: +34 91 415 2612: E-Mail: info@iccat.int

de Bruyn, Paul
Ortiz, Mauricio
Kell, Laurence
Neves dos Santos, Miguel

Appendix 3

LIST OF DOCUMENTS

SCRS/2015/073	Diagnostics for a biomass dynamic stock assessment of Atlantic bigeye tuna (*Thunnus obesus*)	Merino G. and Kell L.
SCRS/2015/105	Standardized CPUE for juveniles of bigeye caught by the European and associated Purse Seine fishery on FADs in the Atlantic Ocean during 1991 to 2014	Soto M., Fernandez F., Pascual P. and Gaertner D.
SCRS/2015/121	Review and preliminary analyses of size frequency samples of Atlantic Bigeye tuna (*Thunnus obesus*)	Ortiz M. and Palma C.
SCRS/2015/126	An assessment of Atlantic bigeye tuna for 2015	Schirripa M.J.
SCRS/2015/131	Estadísticas españolas de la pesquería atunera tropical, en el Océano Atlántico, hasta 2014	Delgado de Molina A., Delgado de Molina R., Santana J.C. and Ariz J.
SCRS/2015/136	Datos estadísticos de la pesquería de túnidos de las Islas Canarias durante el periodo 1975 a 2014	Delgado de Molina A., Delgado de Molina R., Santana J.C. and Ariz J.
SCRS/2015/138	Size-weight relationship of the bigeye tuna (*Thunnus obesus*) from North Atlantic areas using linear and non-linear fits	Carroceda A., and Colmenero C.
SCRS/2015/139	Estimating Ghanaian purse seine and baitboat catch during 2006-2013: input data for 2015 bigeye stock assessment	Chassot E., Ayivi S., Floch L., Damiano A. and Dewals P.
SCRS/2015/140	Catch-at-size and age analyses for Atlantic bigeye	Kell L., Palma C. and Merino G.
SCRS/P/2015/028	Bigeye tuna VPA: initial model and results	Walter J.
SCRS/P/2015/029	BET Catch at size, L infinity & growth curve in the Atlantic & Indian Ocean	Fonteneau A.

Appendix 4

VPA SPECIFICATIONS

The VPA specifications generally followed the design from the 2010 assessment. All model runs were run using VPA-2BOX software (Version 3.01[1]) (**Table A.1**). Initial runs (1-13) used the CAA prior to incorporating the revised 2006-2013 and 2014 carry-over estimates for Ghana. All subsequent model runs use the most recent CAA. Overall differences from the 2010 VPA include a new natural mortality vector derived using a Lorenzen (2005) function with the reference M = 0.279 over the fully selected age classes (1-15). The reference M was approximated using a maximum age of 15. The M vector was developed using the Hallier *et al*. (2005) growth curve. This differs from the assumed M used in 2010 (Ages 0-1 = 0.8, Ages 2-7+ = 0.4).

The remaining biological parameters used for the VPA are the same as those used during the 2010 bigeye tuna assessment. The von Bertalanffy growth parameters of Hallier *et al.* (2005): k=0.180 yr-1, $L\infty$ = 217.3 cm and t_0 = -0.709 year, and the weight-length equation of Parks *et al.* (1982): Weight (kg) = 2.396 E^{-5} * $FL(cm)^{2.9774}$ were used to estimate the age of the plus-group.

Fecundity was estimated using a proxy, %Maturity * Weight-at-Age of the stock (calculated from the growth curve on January 1). For the fecundity of the plus group, the population was assumed to be composed of 50% Age-7 and 50% Age-8 individuals.

Other specifications unchanged from the 2010 VPA include a penalty (Std Dev = 0.4) was applied to deviations in vulnerability at ages 0-7 during the last three years to prevent large fluctuations in the estimated recruitment estimates. Initially the parameters and their estimation specifications remained unchanged from 2010, but the biological parameters used in 2015 for the VPA were as follows:

	Age 0	*Age 1*	*Age 2*	*Age 3*	*Age 4*	*Age 5*	*Age 6*	*Age 7+*
% mature	0	0	0	0.5	1	1	1	1
Weight (kg)	0.393	4.16	12.78	25.56	41.15	58.21	75.60	100.50
M	0.72	0.49	0.38	0.33	0.29	0.27	0.25	0.24

The F-ratios (age7+ relative to age 6) were modeled by estimating the ratio in 1975, then allowing a random walk (SD = 0.2). This option allows some flexibility to the model to better fit the data but does not require the estimation of all F-ratios as independent values, which would likely result in over-parameterization. Terminal-F parameters were estimated for ages 1, 4, 5 and 6. The age 0 terminal-F was fixed at 1.08 times the age 1 estimate. The age 2 and age 3 terminal-Fs were fixed at 0.57 and 0.73 times the age-4 estimate, respectively. These values were determined using the results of a separable VPA conducted in 2010. For 2015 a catch curve analysis was run which suggested four potential time-blocks for estimated the F-ratios. No separable VPA was conducted in 2015 and all terminal F parameters were freely estimated in the 2015 VPA models.

In 2010 an index from the Brazilian longline and the Azores baitboat were used but these were either not updated for 2015 (BRLL) or deemed unrepresentative of the stock as a whole (AZBB) by the data workshop. Indices were initially equally weighted with a CV of 0.2. Indices were input in the native units (numbers) of measurement, except for the URU LL index which was measured in weight (**Table A.2**). To construct the partial weight at ages for this index when mean weights at age were missing, the average over all years was input for that age. This was necessary for the URU-LL as mean weights were often missing from some age classes in certain years. These indices are provided below.

1	US PLL	US PPL index in number (1986-2014)
2	JAP_LL_ALL	JLL N, core area (2, mainly) 1975-2014
3	URU_LL_EARLY	URU LL (1982-1991) in weight
4	URU_LL_LATE	URU LL (1992-2010) in weight
5	CHIN_TAI_LL_EARLY	TAI LL N task 2 data (1968-1992)
6	CHIN_TAI_LL_LATE	TAI LL N, logbook data, core area (1993-2014)

---

[1] Version 3.01, Porch, ICCAT software catalog.

The starting time 1975 was chosen similar to the 2010 VPA. While the indices and the landings go back further than 1975 and it might be desirable to do so to capture the initiation of the fishery, the CAA could not be calculated for the meeting and there was some concern noted regarding the misidentification of small BET as YFT prior to 1975. Some concern was noted regarding the odd pattern in the CAA in 1975, relative to 1976 and later years. However they likely reflect real changes in the fishery as they correspond to an increasing percentage of purse seine removals relative to total removals from ~10% in 1975 to ~20% in 1976.

The overall catch at age (CAA) was obtained by age-slicing (**Table 3** of this report). For each of the indices partial catches at age were developed from the total catch at age to reflect the fleet-specific selectivity (**Table A3**). For the Uruguay index that was in weight, the average weight was obtained from the catch at size to convert the index in weight into number (**Table A4**).

VPA diagnostics

All initial model diagnostics were performed on run 4- with the new model specifications and a four-year time block on the F-ratio. The first model diagnostic was to vary the starting seed to determine whether a global minima had been reached. Thirty different starting seeds were explored with no difference in the objective function, indicating stable model performance. The second model diagnostic was to evaluate estimability of the parameters by conducting a likelihood profile on key parameters. Another diagnostic is the first derivative test that evaluates the estimability of the parameters, and provides similar information on the shape of the likelihood surface around the maximum likelihood estimate. The next diagnostic evaluated was the chi-squared discrepancy statistic which measures the fit to the indices. This tests the hypothesis of what is the probability that the chi-sq test statistic is greater than what would be expected under the distribution with the given degrees of freedom. Chi-square p-values that are extremely high (~1) are indicative of an over-parameterized model while very low values (<0.01) indicate a model that is inconsistent with the data, or very conflicting indices.

Retrospective analyses going back 10 years were also conducted to evaluate retrospective patterns.

We employed two statistics to describe a) the degree of retrospective bias (ρ) and (b) the degree of retrospective error ($|\rho|$). The statistic ρ, is similar to that proposed by Mohn (1999) except we calculate it for 10 years going back for five retrospective peels. The statistic is calculated as the sum of the differences between the retrospective estimates for a given year and the estimates obtained from the entire time series, divided by the full time series estimates. As this statistic is signed, it measures consistent retrospective bias above or below the values estimated for the full time series.

A second statistic, $|\rho|$, measures the absolute deviation between retrospective values and the values estimated for the full time series and is the same equation as (3) but with the absolute value of the quantity in the numerator. Both statistics are useful measures of performance as ρ measures the degree of retrospective bias (consistent under or overestimation of terminal year values with successive removals of a year of data) and $|\rho|$ measures absolute variability. High values for either statistic indicate poor VPA performance.

A leave-one out analysis was also performed for the models to evaluate the sensitivity of the model to removing a single index. The goal here is to determine where there are conflicting indices and to then identify whether there are discrepancies between indices that can be resolved with VPA model changes.

The last diagnostic was to run bootstraps and to check for bad bootstraps, extraordinary run time or highly divergent bootstrap estimates.

Results

As data inputs (notably the CAA) changed and as parameter specifications were altered, multiple model runs were conducted (**Table A5**). Based upon poor diagnostics including high retrospective bias, bimodality in retrospectives and poor fit diagnostics as measured by the chi-square test multiple model configurations were necessary to achieve a relatively stable model configuration (run 21). These changes included an additional split in the Chinese Taipei index in 2005 to address an apparent change in selectivity, increasing and then estimating the variance on all indices and modeling the F-ratio with four time blocks. Additionally model runs with a 10+ and 13+ group were run but due to concerns regarding the validity of the age-slicing beyond age 7, these runs were not preferred configurations.

Ultimately, run 21 was chosen as the best model to use as a comparison with ASPIC and SS3 but not for management advice. This model showed the best performance diagnostics and appeared to be the most stable configuration. Given the high number of model runs, only results for the final, best model run are shown. This model allowed for all index variances to be freely estimated allowing the model to reconcile the conflicting CPUE indices. Bootstraps were conducted for this model and showed no bad bootstraps and a reduction in bootstrap bias and error over other models for which bootstrapping was evaluated.

Fits to indices and index residuals indicate a very poor fit to the URU LL 1 and 2 indices and the Chinese-Taipei 1 index. Overall there is substantial conflict between the indices, notably between the Chinese-Taipei indices and the Japanese longline index. Over different model configurations that weighted indices differently (e.g. jack-knifing indices, fixing index variances) the tension between the JLL and the Chinese Taipei indices appeared to suggest very different model states. This is reconciled by the model fitting the JLL index better when the variances are estimates but, in the future, it may be most logical to follow the approach for the ASPIC modeling where individual indices are run as states of nature.

Nonetheless the ‘best’ model still shows high retrospective bias (**Figure A1**) making it unreliable for projection advice. In addition, the substantial variability of model estimates due to slight changes in parameter specifications diminished confidence in the results such that the Group did not recommend projecting the model.

The final, most stable, run configuration indicates that the stock biomass has seen a long slow decline with a slight uptick in the early 1990s. Fishing mortality has slowly increased and, despite one peak in 2005, is estimated to be at the highest levels over the modelled time period. This increase in F is largely due to declines in estimated recruitment in the most recent 10 years (**Figure A2**). Fishing mortality rates indicate highest vulnerability at ages 0 and 5 with dome-shaped vulnerability and F-ratio estimates well below 1 (**Figure 39** of this report). To provide benchmark estimates, average recruitment over the entire time series was used and an F0.1 and SSB/SSBF0.1 proxies were used for the MSY-benchmarks (**Figure 40** of this report).

Table A1. Parameter settings for VPA model runs. See the VPA manual (available at www.iccat.int) for detailed description of the format of this file.

```
#------------------------------------------------------------------------------
# PARAMETER FILE FOR PROGRAM VPA_2BOX, Version 3.0
#      The specifications are entered in the order indicated
#      by the existing comments. Additional comments must be preceded by a # symbol
#      in the first column, otherwise the line is perceived as free format input.
#
#      Each parameter in the model must have its own specification line unless a $
#      symbol is placed in the first column followed by an integer value (n), which
#      tells the program that the next n parameters abide by the same specifications.
#
#      The format of each specification line is as follows
#
#      column 1
#      |  number of parameters to which these specifications apply
#      |  |  lower bound
#      |  |  |      best estimate (prior expectation)
#      |  |  |      |      upper bound
#      |  |  |      |      |      method of estimation
#      |  |  |      |      |      |     standard deviation of prior
#      $  5  0      1.2    2.0    1     0.1
#
# The methods of estimation include:
# 0   set equal to the value given for the best estimate (a fixed constant)
# 1 estimate in the usual frequentist (non-Bayesian) sense
# 2(0.1)  estimate as a random deviation from the previous parameter
# 3(0.2)  estimate as a random deviation from the previous constant or type 1 parameter
# 4(0.3)  estimate as random deviation from the best estimate.
# -0.1    set equal to the value of the closest previous estimated parameter
# -n    set equal to the value of the nth parameter in the list (estimated or not)
#------------------------------------------------------------------------------
#==============================================================================
# TERMINAL F PARAMETERS: (lower bound, best estimate, upper bound, indicator, reference age)
#     Note 1: the method indicator for the terminal F parameters is unique in that if it is
#     zero but the best estimate is set to a value < 9, then the 'best estimate'
#     is taken to be the vulnerability relative to the reference age in the last
#     (fifth) column.  Otherwise these parameters are treated the same as the
#     others below and the fifth column is the standard deviation of the prior.
#   Note 2: the last age is represented by an F-ratio parameter (below), so the number
#      of entries here should be 1 fewer than the number of ages
#------------------------------------------------------------------------------
0.1    0.6 3.0  1    0.4  Age 0
0.05 0.4    3.0 1    0.4  Age 1
0.05 0.2   3.0  1    0.4  Age 2
0.05 0.2   3.0  1    0.4  Age 3
0.05 0.3   3.0  1    0.4  Age 4
0.05 0.4   3.0  1    0.4  Age 5
0.05 0.5   3.0  1    0.4  Age 6
#==============================================================================
# F-RATIO PARAMETERS F{oldest}/F{oldest-1} one parameter (set of specifications) for each year
#------------------------------------------------------------------------------
$     1     1.0000D-01   0.7000D+00   0.5000D+01   1      0.0200D+01
$     9     1.0000D-01   0.7000D+00   0.5000D+01   -0.1 1
$     1     1.0000D-01   0.7000D+00   0.5000D+01   1     0.0200D+01
$     7     1.0000D-01   0.7000D+00   0.5000D+01   -0.1 11
$     1     1.0000D-01   0.7000D+00   0.5000D+01   1     0.0200D+01
$     13    1.0000D-01   0.7000D+00   0.5000D+01   -0.1 19
$     1     1.0000D-01   0.7000D+00   0.5000D+01   1     0.0200D+01
$     7     1.0000D-01   0.7000D+00   0.5000D+01   -0.1 32
#==============================================================================
# NATURAL MORTALITY PARAMETERS: one parameter (set of specifications) for each age
#------------------------------------------------------------------------------
0    0.72 1    0     0.1
0    0.486     1    0    0.1
0    0.383     1    0    0.1
0    0.326     1    0    0.1
```

```
0      0.29 1      0      0.1
0      0.265      1      0      0.1
0      0.248      1      0      0.1
0      0.235      1      0      0.1
#==============================================================================
# MIXING PARAMETERS: one parameter (set of specifications) for each age
#------------------------------------------------------------------------------
$ 8 0  0.0  1.0  0  .1
#==============================================================================
# STOCK-RECRUITMENT PARAMETERS: five parameters so 5 sets of specifications
#------------------------------------------------------------------------------
 0  220982.5   1.D20  0  0.4        maximum recruitment
 0  16441.44   1.D20  0  0.0        spawning biomass scaling parameter
 0  0.000      0.9    0  0.0        extra parameter (not used yet)
 0  0.5        1      0  0        autocorrelation parameter
 0  10         1000   0  0   (0.3464)     variance of random component (discounting the autocorrelation)
#==============================================================================
# VARIANCE SCALING PARAMETER (lower bound, best estimate, upper bound, indicator, std. dev.)
#   this parameter scales the input variance up or down as desired
#   In principal, if you estimate this you should obtain more accurate estimates of the
#   magnitude of the parameter variances-- all other things being equal.
#------------------------------------------------------------------------------
  0.0000D+00   1   3     1   0.4000D+00      #est
  0.0000D+00   1   3     1   0.4000D+00      #est
  0.0000D+00   1   3     1   0.4000D+00      #est
  0.0000D+00   1   3     1   0.4000D+00     #est
  0.0000D+00   1   3     0   0.4000D+00
  0.0000D+00   1   3     1   0.4000D+00     #est
  0.0000D+00   1   3     1   0.4000D+00     #est
  0.0000D+00   1   3     0   0.4000D+00
  0.0000D+00   1   3     0   0.4000D+00
  0.0000D+00   1   3     0   0.4000D+00
  0.0000D+00   1   3     1   0.4000D+00   #noest
  0.0000D+00   1   3     0   0.4000D+00
@ END PARAMETER INPUT
```

Table A2. Indices of abundance for VPA assessment. Note that index CVs were initially input as 0.2 for all indices but subsequently were estimated in the model.

	US_N		TAI_ALL_N		TAI_CORE_N		JLL_CORE_N		URU_W_1		URU_W_2	
UNITS	number		number		number		number		weight		weight	
MODEL	VPA		VPA		VPA		VPA		VPA		VPA	
AREA	1		1,2,3		2		2		3		3	
	index	cv	index	cv	index	cv	index	cv	index	cv	index	cv
1961							9.448	0.005				
1962							9.210	0.005				
1963							10.782	0.004				
1964							9.025	0.005				
1965							9.017	0.004				
1966							9.308	0.005				
1967							9.283	0.005				
1968			1.774	0.062			11.342	0.004				
1969			2.204	0.047			10.788	0.005				
1970			1.834	0.042			10.043	0.005				
1971			1.388	0.046			9.250	0.005				
1972			1.085	0.052			9.984	0.005				
1973			1.061	0.061			11.674	0.004				
1974			1.126	0.048			12.912	0.004				
1975			1.105	0.053			7.663	0.006				
1976			1.035	0.048			7.870	0.007				
1977			1.143	0.045			13.520	0.004				
1978			1.037	0.046			10.933	0.004				
1979			0.899	0.055			10.238	0.005				
1980			1.058	0.048			11.247	0.003				
1981			0.796	0.046			9.233	0.004				
1982			0.579	0.044			8.813	0.003	190.161	0.338		
1983			0.572	0.051			10.093	0.004	92.788	0.360		
1984			0.609	0.050			9.327	0.003	50.948	0.362		
1985			0.485	0.045			9.411	0.003	99.417	0.327		
1986	2.891	0.197	0.437	0.042			10.371	0.003	52.525	0.387		
1987	5.079	0.122	0.702	0.048			11.939	0.003	74.816	0.386		
1988	3.215	0.128	0.384	0.080			11.266	0.003	48.411	0.403		
1989	3.234	0.125	0.425	0.054			8.357	0.003	22.819	0.459		
1990	3.129	0.125	0.896	0.062			7.317	0.004	23.917	0.427		
1991	3.224	0.128	1.029	0.049			6.904	0.004	23.083	0.443		
1992	2.436	0.131	1.239	0.064			6.775	0.004			68.484	0.654
1993	2.494	0.131			5.331	0.032	6.857	0.004			165.957	0.639
1994	2.142	0.133			7.630	0.016	5.858	0.004			64.496	0.785
1995	2.174	0.130			7.353	0.011	5.609	0.004			80.926	0.783
1996	2.556	0.125			4.896	0.007	4.727	0.005			68.707	0.782
1997	2.240	0.127			3.621	0.008	4.387	0.006			62.060	0.636
1998	2.498	0.124			4.588	0.009	4.235	0.006			40.128	0.629
1999	3.516	0.123			3.553	0.006	4.421	0.006			24.923	0.736
2000	2.624	0.128			3.297	0.007	4.550	0.006			20.915	0.767
2001	2.660	0.126			3.956	0.010	3.985	0.007			17.096	0.757
2002	2.229	0.127			4.112	0.008	4.035	0.008			11.701	0.725
2003	1.457	0.137			3.568	0.008	3.960	0.007			8.775	0.586
2004	1.270	0.149			3.113	0.008	2.804	0.010			3.175	0.576
2005	2.020	0.140			3.183	0.006	2.955	0.010			4.053	0.596
2006	2.657	0.134			3.888	0.014	3.409	0.008			15.057	0.622
2007	1.612	0.141			4.586	0.007	2.633	0.011			12.609	0.615
2008	1.737	0.139			3.798	0.008	2.117	0.013			15.093	0.618
2009	1.503	0.140			3.534	0.006	2.254	0.012			18.909	0.619
2010	1.458	0.138			3.955	0.006	2.381	0.012			9.592	0.745
2011	1.478	0.144			3.378	0.005	2.198	0.013				
2012	1.451	0.138			2.923	0.006	2.715	0.011				
2013	1.913	0.135			4.979	0.007	3.585	0.009				
2014	2.400	0.130			4.399	0.006	2.843	0.026				

Table A3. Partial catches at age for VPA assessment.

#Index_ID	Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	
1	1986	4	301	4319	7770	3833	1490	510	249	'US PLL'
1	1987	90	1090	3477	8094	4698	1457	572	248	'US PLL'
1	1988	32	1303	5888	6765	4345	1126	231	127	'US PLL'
1	1989	21	919	4353	6064	3563	1236	284	95	'US PLL'
1	1990	22	685	5567	4383	3037	992	266	99	'US PLL'
1	1991	9	902	4884	10227	4379	1353	368	132	'US PLL'
1	1992	101	1160	6002	4408	2910	968	344	181	'US PLL'
1	1993	16	700	10634	9505	2995	789	192	82	'US PLL'
1	1994	52	1296	8155	11230	4044	921	351	257	'US PLL'
1	1995	51	1185	11161	8398	4669	1510	579	383	'US PLL'
1	1996	58	1408	7017	10739	2511	527	101	36	'US PLL'
1	1997	72	4200	10872	8110	3812	450	73	26	'US PLL'
1	1998	42	1263	9407	7546	2857	697	81	42	'US PLL'
1	1999	27	1156	6560	13953	4017	843	146	27	'US PLL'
1	2000	11	958	4990	5869	3021	657	153	61	'US PLL'
1	2001	9	540	5189	8940	3167	836	187	78	'US PLL'
1	2002	14	542	4573	4761	3904	716	128	50	'US PLL'
1	2003	3	497	2285	2656	1303	653	167	102	'US PLL'
1	2004	1	533	3225	2178	1708	560	132	44	'US PLL'
1	2005	2	430	2166	3893	1441	441	121	52	'US PLL'
1	2006	0	286	2758	4313	4631	545	131	69	'US PLL'
1	2007	6	822	1660	2815	2710	999	167	123	'US PLL'
1	2008	5	986	2412	4918	2185	864	116	33	'US PLL'
1	2009	28	970	3214	2691	3136	912	272	82	'US PLL'
1	2010	12	2281	3109	3899	2484	777	242	124	'US PLL'
1	2011	14	896	5825	6338	3178	814	197	76	'US PLL'
1	2012	11	2418	2607	4875	4670	807	266	144	'US PLL'
1	2013	16	2567	6470	3965	2176	1008	212	98	'US PLL'
1	2014	3	2248	4774	5418	4018	725	188	47	'US PLL'
2	1975	1135	12793	33476	76662	80000	48246	29015	41230	'JAP_LL_ALL'
2	1976	46	3578	27429	40543	33441	23682	12902	8671	'JAP_LL_ALL'
2	1977	76	4811	32492	51285	38744	26877	16874	10236	'JAP_LL_ALL'
2	1978	223	10472	37795	60850	45655	26778	12547	6919	'JAP_LL_ALL'
2	1979	174	27864	119996	77393	47986	24386	12297	8260	'JAP_LL_ALL'
2	1980	165	27538	95667	179541	89583	42307	22596	20452	'JAP_LL_ALL'
2	1981	294	23983	101532	142332	143832	45848	19530	13197	'JAP_LL_ALL'
2	1982	5727	50063	112466	228869	153823	92101	47429	45157	'JAP_LL_ALL'
2	1983	539	10309	55969	87871	66624	41813	23812	25087	'JAP_LL_ALL'
2	1984	234	25044	108147	157259	116940	64176	31566	30988	'JAP_LL_ALL'
2	1985	333	27684	157261	216645	160659	91830	42147	30028	'JAP_LL_ALL'
2	1986	601	19002	71145	148931	121278	67233	35812	29145	'JAP_LL_ALL'
2	1987	91	15819	84303	145002	110747	48201	21119	14228	'JAP_LL_ALL'
2	1988	109	25509	151887	220445	172348	81734	40900	27695	'JAP_LL_ALL'
2	1989	63	22487	99180	242488	215948	126719	62263	43618	'JAP_LL_ALL'
2	1990	93	40342	149760	224307	191314	121474	52251	23149	'JAP_LL_ALL'
2	1991	7	9282	101271	186276	167671	94321	42909	26257	'JAP_LL_ALL'
2	1992	177	23564	120906	177405	172461	119243	55006	39168	'JAP_LL_ALL'
2	1993	12196	39772	73138	139194	182671	133730	66388	47199	'JAP_LL_ALL'
2	1994	361	17685	56398	147848	152246	127828	73188	85445	'JAP_LL_ALL'
2	1995	245	20356	35658	68080	106553	120749	77767	107727	'JAP_LL_ALL'
2	1996	3	6093	41536	101407	116906	100104	68604	93871	'JAP_LL_ALL'
2	1997	0	2009	31702	141292	129545	67737	45621	57321	'JAP_LL_ALL'
2	1998	141	11050	78824	110872	109828	67503	39637	49405	'JAP_LL_ALL'
2	1999	14	8686	55827	147992	108953	62689	29011	36103	'JAP_LL_ALL'
2	2000	49	4499	66596	151686	144898	77170	30323	36345	'JAP_LL_ALL'
2	2001	93	4946	54073	106697	93923	66134	29837	22701	'JAP_LL_ALL'
2	2002	84	5556	35855	69333	69756	61999	24582	23861	'JAP_LL_ALL'
2	2003	13	4493	24330	65120	81500	68036	37945	46716	'JAP_LL_ALL'
2	2004	37	3960	33283	68172	82259	57826	37002	41839	'JAP_LL_ALL'
2	2005	0	1634	32946	59375	46295	42205	27347	35218	'JAP_LL_ALL'
2	2006	3	8948	37950	90605	65610	47807	31353	26291	'JAP_LL_ALL'
2	2007	16	2659	30401	70283	78947	56253	37660	39027	'JAP_LL_ALL'
2	2008	42	11720	21931	44587	64250	58100	37948	39837	'JAP_LL_ALL'
2	2009	4	8057	27386	57947	69285	51144	36288	36758	'JAP_LL_ALL'
2	2010	12	7963	39115	44473	63558	46738	28834	37549	'JAP_LL_ALL'
2	2011	232	16888	39262	42501	45710	33151	26639	28902	'JAP_LL_ALL'
2	2012	141	25873	67865	80447	71203	40103	27209	21511	'JAP_LL_ALL'
2	2013	97	18249	41345	41997	37814	35454	28865	38354	'JAP_LL_ALL'
2	2014	42	11720	21931	44587	64250	58100	37948	39837	'JAP_LL_ALL'
3	1982	11	605	1844	2946	3305	1051	293	86	'URU_LL_EARLY'
3	1983	0	0	1122	561	2244	810	810	3054	'URU_LL_EARLY'
3	1984	0	622	622	3763	2364	3017	1213	1213	'URU_LL_EARLY'

3	1985	0	1644	4985	1542	4162	976	565	719	'URU_LL_EARLY'
3	1986	0	0	600	3599	0	600	0	0	'URU_LL_EARLY'
3	1987	0	170	306	527	1376	646	476	238	'URU_LL_EARLY'
3	1988	39	322	745	447	479	424	212	157	'URU_LL_EARLY'
3	1989	0	6	47	258	539	178	55	19	'URU_LL_EARLY'
3	1990	0	1	36	155	396	138	23	8	'URU_LL_EARLY'
3	1991	0	45	980	9	0	27	0	0	'URU_LL_EARLY'
4	1992	0	16	959	401	278	99	0	0	'URU_LL_LATE'
4	1993	10	78	656	597	272	33	18	2	'URU_LL_LATE'
4	1994	129	206	528	389	132	49	37	5	'URU_LL_LATE'
4	1995	0	196	738	856	226	120	92	26	'URU_LL_LATE'
4	1996	904	1658	733	326	1134	381	8	0	'URU_LL_LATE'
4	1997	0	36	687	1171	355	6	0	0	'URU_LL_LATE'
4	1998	0	0	209	995	245	80	8	0	'URU_LL_LATE'
4	1999	0	46	14	463	248	12	6	0	'URU_LL_LATE'
4	2000	0	34	254	399	77	9	6	2	'URU_LL_LATE'
4	2001	0	4258	198	0	0	0	0	0	'URU_LL_LATE'
4	2002	0	22	115	1438	603	13	4	0	'URU_LL_LATE'
4	2003	0	0	0	97	520	474	0	0	'URU_LL_LATE'
4	2004	0	0	0	66	353	322	0	0	'URU_LL_LATE'
4	2005	0	0	0	0	0	904	0	0	'URU_LL_LATE'
4	2006	10	197	361	308	265	231	72	217	'URU_LL_LATE'
4	2007	0	17	129	82	69	81	26	46	'URU_LL_LATE'
4	2008	0	14	24	254	113	74	34	36	'URU_LL_LATE'
4	2009	1	33	69	74	723	993	413	517	'URU_LL_LATE'
4	2010	0	5	44	58	27	61	80	68	'URU_LL_LATE'
6	1975	0	3923	14666	18616	27489	16151	5280	5683	'CHIN_TAI_LL_EARLY'
6	1976	237	6146	12342	17061	23631	13443	3898	1506	'CHIN_TAI_LL_EARLY'
6	1977	918	15730	21409	19152	18395	12184	3614	850	'CHIN_TAI_LL_EARLY'
6	1978	146	10051	10415	15732	20248	10779	3569	1602	'CHIN_TAI_LL_EARLY'
6	1979	0	2538	11888	15386	9411	3901	2012	6687	'CHIN_TAI_LL_EARLY'
6	1980	963	6464	9104	17562	14866	7591	2517	2077	'CHIN_TAI_LL_EARLY'
6	1981	128	2471	4713	11463	12484	5786	2079	1641	'CHIN_TAI_LL_EARLY'
6	1982	396	2780	9669	17041	14430	5455	1881	884	'CHIN_TAI_LL_EARLY'
6	1983	12	1558	3899	9371	13669	5049	1608	1057	'CHIN_TAI_LL_EARLY'
6	1984	146	926	2488	4972	5946	3696	1031	554	'CHIN_TAI_LL_EARLY'
6	1985	16	1265	4650	6957	8714	4930	861	619	'CHIN_TAI_LL_EARLY'
6	1986	115	526	3695	12638	8112	2540	273	120	'CHIN_TAI_LL_EARLY'
6	1987	31	4495	7638	10099	11145	4464	627	229	'CHIN_TAI_LL_EARLY'
6	1988	0	383	1465	6351	16563	4763	506	110	'CHIN_TAI_LL_EARLY'
6	1989	100	471	966	5637	9005	2450	618	209	'CHIN_TAI_LL_EARLY'
6	1990	15	2243	21925	45909	43163	13770	3326	572	'CHIN_TAI_LL_EARLY'
6	1991	0	4028	19694	61712	137634	74132	6378	1567	'CHIN_TAI_LL_EARLY'
6	1992	0	4208	58054	142255	88077	18824	3670	2041	'CHIN_TAI_LL_EARLY'
7	1993	6187	17204	55451	100971	85280	37530	7040	5043	'CHIN_TAI_LL_LATE'
7	1994	2906	24063	114407	167400	93376	58227	16938	8719	'CHIN_TAI_LL_LATE'
7	1995	3569	17719	65894	185369	94321	40155	16179	6109	'CHIN_TAI_LL_LATE'
7	1996	2640	21093	97497	139871	120741	72446	29667	18048	'CHIN_TAI_LL_LATE'
7	1997	0	7798	67275	116310	176357	53270	18713	11452	'CHIN_TAI_LL_LATE'
7	1998	23	17995	100626	108458	115840	46583	14011	6625	'CHIN_TAI_LL_LATE'
7	1999	34	24451	141895	128537	72919	45086	22735	13388	'CHIN_TAI_LL_LATE'
7	2000	3562	38331	178154	151130	72098	23843	14437	19462	'CHIN_TAI_LL_LATE'
7	2001	8450	30748	56966	111285	110256	48082	11042	12827	'CHIN_TAI_LL_LATE'
7	2002	22	767	30686	82304	113718	85644	29250	28139	'CHIN_TAI_LL_LATE'
7	2003	4	230	10196	61721	120280	147828	38550	19137	'CHIN_TAI_LL_LATE'
7	2004	0	239	8243	48653	117579	84856	35752	18725	'CHIN_TAI_LL_LATE'
7	2005	4	450	6237	35389	82261	53084	19607	12756	'CHIN_TAI_LL_LATE'
11	2006	19	274	2249	9734	11100	9070	6388	8065	'CHIN_TAI_LL_LATE'
11	2007	3	348	5640	20810	36171	34051	25141	42025	'CHIN_TAI_LL_LATE'
11	2008	36	350	3047	16383	31325	32771	21828	35813	'CHIN_TAI_LL_LATE'
11	2009	0	346	5878	26352	47706	40320	27337	42087	'CHIN_TAI_LL_LATE'
11	2010	23	630	8869	27483	43803	39944	29383	40448	'CHIN_TAI_LL_LATE'
11	2011	150	2809	15044	48159	48100	37058	28101	38858	'CHIN_TAI_LL_LATE'
11	2012	7	1089	11510	31349	44770	28365	18574	33427	'CHIN_TAI_LL_LATE'
11	2013	7	927	9048	30792	35620	29793	19592	31196	'CHIN_TAI_LL_LATE'
11	2014	31	283	5713	26241	43742	37443	27658	45014	'CHIN_TAI_LL_LATE'

Table A4. Fleet specific weights at age for VPA assessment. Used to convert indices expressed in biomass to numbers.

INDEX	YEAR	AGE0	AGE1	AGE2	AGE3	AGE4	AGE5	AGE6	AGE7	
3	1981	2.1	8.8	17.5	35.0	50.1	63.0	80.9	113.8	'URU_LL_EARLY'
3	1982	3.5	10.5	20.2	33.6	48.9	64.8	81.3	103.4	'URU_LL_EARLY'
3	1983	3.8	10.4	18.6	39.1	46.0	64.2	82.2	108.3	'URU_LL_EARLY'
3	1984	3.8	9.6	23.0	35.8	50.0	70.7	84.1	109.7	'URU_LL_EARLY'
3	1985	3.8	13.4	20.0	37.6	53.8	70.9	90.1	103.7	'URU_LL_EARLY'
3	1986	3.8	10.4	23.2	32.2	48.4	70.1	82.9	109.8	'URU_LL_EARLY'
3	1987	3.8	7.3	16.0	34.2	52.2	64.0	81.3	102.6	'URU_LL_EARLY'
3	1988	6.3	12.2	20.6	28.9	52.1	67.2	81.7	111.5	'URU_LL_EARLY'
3	1989	3.4	8.5	19.0	37.1	49.3	61.7	87.0	98.4	'URU_LL_EARLY'
3	1990	3.8	9.7	19.6	35.6	49.6	66.0	81.7	105.1	'URU_LL_EARLY'
3	1991	3.8	13.7	17.3	24.6	48.4	62.0	82.9	109.8	'URU_LL_EARLY'
4	1992	3.8	12.2	19.9	36.1	48.4	68.3	82.9	109.8	'URU_LL_LATE'
4	1993	3.2	10.8	20.3	31.0	46.8	63.1	80.1	95.0	'URU_LL_LATE'
4	1994	3.5	8.3	19.9	30.0	48.9	67.3	85.4	98.6	'URU_LL_LATE'
4	1995	3.8	11.3	20.8	30.6	48.1	69.4	84.3	98.1	'URU_LL_LATE'
4	1996	4.5	7.3	21.5	28.9	52.0	60.2	82.0	109.8	'URU_LL_LATE'
4	1997	3.8	11.3	22.4	33.2	43.7	65.9	82.9	109.8	'URU_LL_LATE'
4	1998	3.8	10.4	24.3	35.0	47.2	58.4	76.2	109.8	'URU_LL_LATE'
4	1999	3.8	10.4	25.2	33.4	45.0	74.4	81.9	109.8	'URU_LL_LATE'
4	2000	3.8	11.1	18.1	32.2	44.8	69.7	87.0	131.7	'URU_LL_LATE'
4	2001	3.8	11.1	13.1	33.1	48.4	65.8	82.9	109.8	'URU_LL_LATE'
4	2002	3.8	7.0	15.9	27.4	42.7	59.8	73.5	109.8	'URU_LL_LATE'
4	2003	3.8	10.4	20.1	29.4	42.5	62.0	82.9	109.8	'URU_LL_LATE'
4	2004	3.8	10.4	20.1	29.4	42.5	62.0	82.9	109.8	'URU_LL_LATE'
4	2005	3.8	10.4	20.1	33.1	48.4	67.9	82.9	109.8	'URU_LL_LATE'
4	2006	4.8	9.8	20.3	37.2	50.7	66.1	84.8	113.6	'URU_LL_LATE'
4	2007	3.8	11.4	20.6	36.5	48.6	69.8	86.8	116.2	'URU_LL_LATE'
4	2008	3.8	10.8	24.2	34.4	54.1	66.2	82.4	113.0	'URU_LL_LATE'
4	2009	3.1	9.8	18.7	32.2	52.8	65.8	82.6	116.2	'URU_LL_LATE'
4	2010	3.8	13.1	21.3	33.4	52.2	68.7	84.5	112.2	'URU_LL_LATE'

Table A5. 2015 BET VPA runs and model diagnostic results.

Run	name	CAA	obj	n parms	n data	AIC	Chi-square	chi-sq pval*	Mohn bias[$]	Mohn abs[#]
Run0	2010 VPA	2010	583	48	204	1637	3545.42	0.000	28.03	28.70
Run1	Mimic 2010 VPA	Old	-22.5	50	138	308.6	760.6	0.000	18.04	18.04
Run2	use SS natural mortality, same specs	Old	-24.6	50	138	304.4	743.5	0.000	-2.08	11.50
Run3	New specs, all term F parms estimated, increase sigma on cpue to 0.4	Old	-132	53	138	95.6	184.8	0.000	-1.61	1.82
Run4	same as 3, 4 time blocks	Old	-72	17	138	143.7	178.6	0.001	-1.28	1.35
Run5	age 10+	Old	-34.9	13	138	210	337.76	0.000	-3.77	3.78
Run6	age 13+	Old	-28.8	17	138	230.1	343.2	0.000	-3.90	4.18
Run7	NoJLL, like 3	Old	-94.4	52	98	95.4	224.5	0.000	-1.10	1.38
Run8	NoUSLL, like 3	Old	-109	52	109	85.7	174.0	0.000	-2.40	2.40
Run9	NoUru, like 3	Old	-169	51	109	-36.0	34.4	0.994	-1.21	4.69
Run10	NoChTai, like 3	Old	-107	51	98	67.9	147.6	0.000	-1.02	1.69
Run11	Like 4, split ChiTai	Old	-75.5	18	138	139	162.74	0.006	-0.69	0.79
Run12	Like 5, split ChiTai	Old	-35.2	14	138	215	337.32	0.000	-4.10	4.10
Run13	Like 11, split URU	Old	-71.3	19	138	149	173.17	0.001	-0.56	1.66
Run14	Like 11, but new CAA	New	-75.2	18	138	139	162.75	0.006	-0.65	0.81
Run15	Like 11 but input CV wt URU	New	-85.4	18	138	119	107.77	0.781	-1.10	1.48
Run16	Like 11 but double CV on URU	New	-91.1	18	138	107	66.01	1.000	-0.26	2.10
Run17	use old TAI LL PCAA back in time	New	-67.6	17	138	152	203.05	0.000	-2.61	2.62
Run18	Like 14, remove URU LL	New	-98.7	16	109	35	33.12	1.000	-20.79	20.79
Run19	Like 14, but age links on F	New	-97.3	13	109	31.7	33.65	1.000	-13.51	13.51
Run20	Like18 est var scaling	New	-134	21	109	-25.6	107.21	0.080	-24.44	24.44
Run21	Like14 est var scaling	New	-125	25	138	53.7	112.52	0.495	-14.29	14.29
Run22	Like14 fix scaling	New	-115	18	138	58.7	169.92	0.002	142.17	143.39
Run23	Like 21 but remove vuln penalty	New	-113	25	138	77.6	128.68	0.149	-7.75	13.17

* Measure of index fit, ideal is non-significant
$ measure of retrospective error, prefer values near zero
# measure of retrospective error, prefer low values

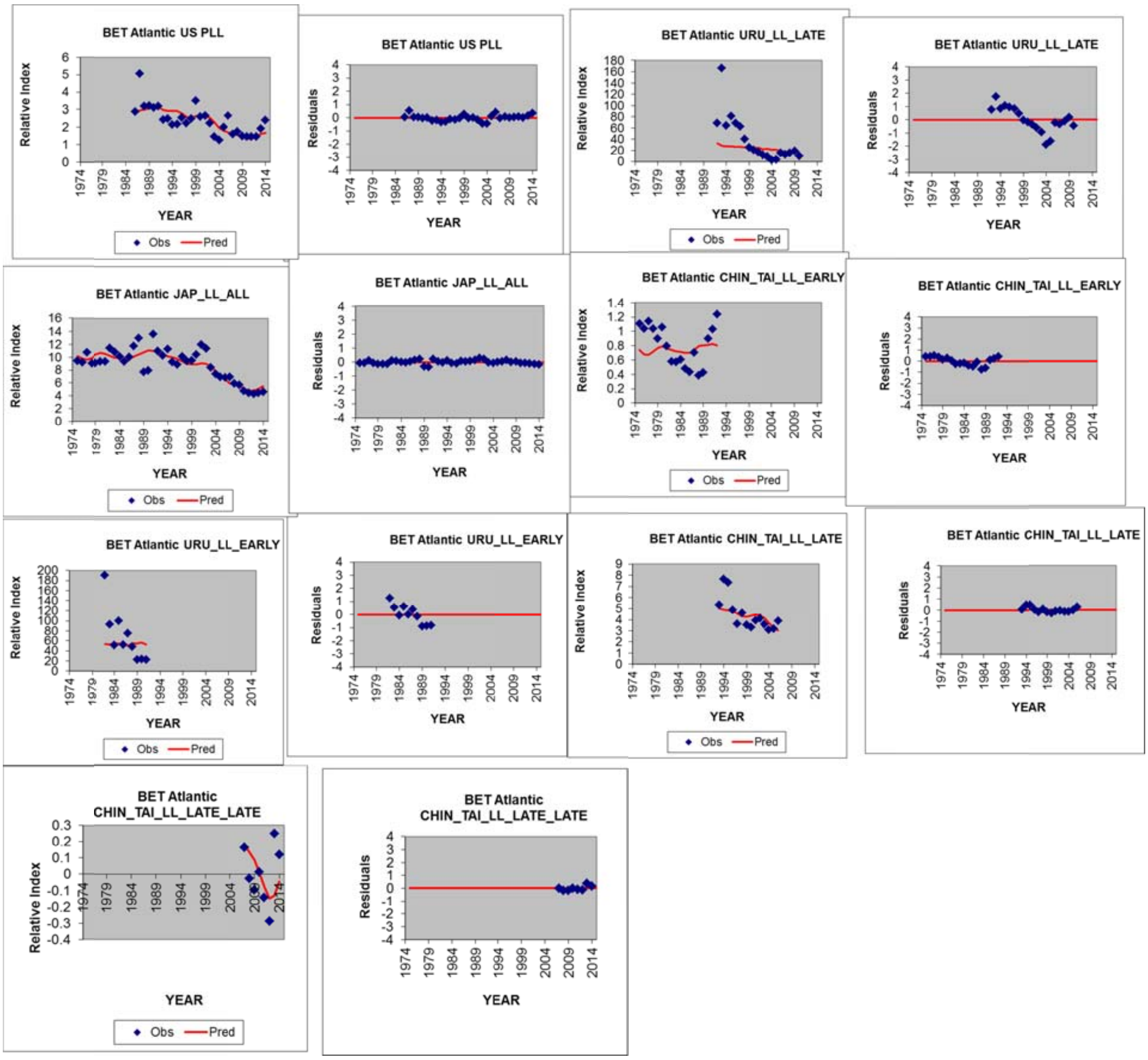


Figure A1. Fits to CPUEs and residuals for indices used for VPA.

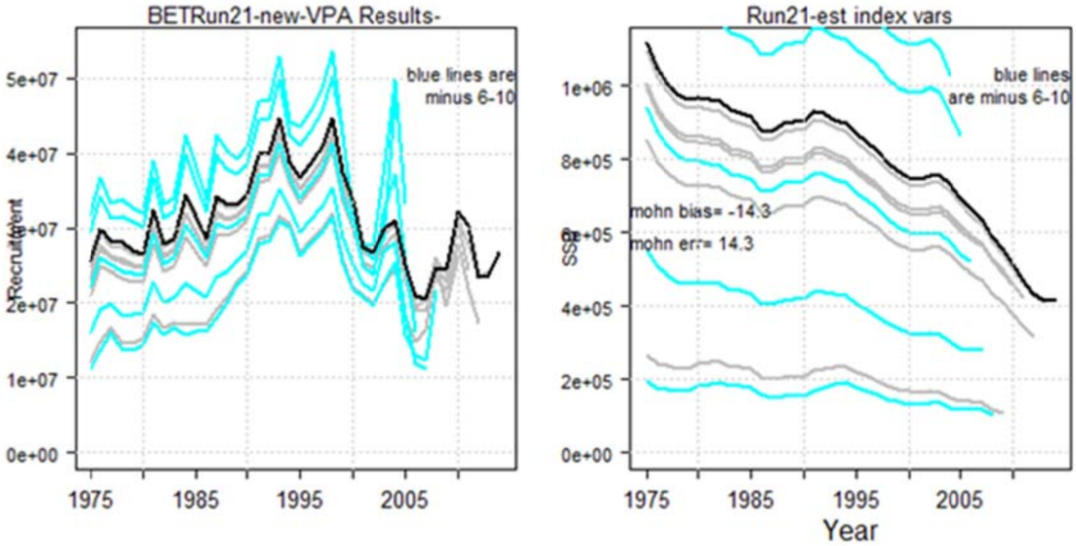


Figure A2. Retrospective recruits and SSB for Run 21. Black lines it the full model run. Gray lines are minus 1-5 and blue lines are mins 6-10.