REPORT OF THE 2011 ICCAT YELLOWFIN TUNA STOCK ASSESSMENT SESSION

(San Sebastián, Spain - September 5 to 12, 2011)

1. Opening, adoption of agenda and meeting arrangements

The Meeting was held at the INASMET-Tecnalia Center in San Sebastián from September 5 to 12, 2011. Dr. Josu Santiago (SCRS Chair), opened the meeting and welcomed participants ("the Working Group").

Dr. Craig Brown (USA), meeting Chairperson, welcomed meeting participants and thanked AZTI for hosting the meeting and providing all the logistical arrangements. Dr. Brown proceeded to review the Agenda which was adopted without 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:

Items 1, 9 and 10	P. Pallarés
Item 2	H. Murua and D. Gaertner
Items 3.1, 3.2 and 3.3	J. Ariz, A. Delgado de Molina, and A. Amorin
Item 3.4	M. Ortiz and C. Palma
Item 4	G. Díaz and P. De Bruyn
Item 5.1, 6.1 and 7.1	D. Die, K. Satoh, H. Ijima, E. Chassot
Item 5.2, 6.2 and 7.2	S. Cass-Calay
Item 6.3	G. Scott and C. Brown
Item 8	G. Scott and J. Santiago
Coordinator of model inputs, figures and tables	J. Walter

2. Review of Biological historical and new data

Yellowfin tuna is a tropical and subtropical species distributed mainly in the epipelagic oceanic waters of the three oceans. The sizes exploited range from 30 cm to over 170 cm; maturity occurs at about 100 cm. Smaller fish (juveniles) form mixed schools with skipjack and juvenile bigeye, and are mainly limited to surface waters; while larger fish form schools in surface and sub-surface waters. Reproductive output among females has been shown to be highly variable. The main spawning ground is the equatorial zone of the Gulf of Guinea, with spawning primarily occurring from January to April. Juveniles are generally found in coastal waters off Africa. In addition, spawning occurs in the Gulf of Mexico, in the southeastern Caribbean Sea, and off Cape Verde, although the relative importance of these spawning grounds is unknown. Although such separate spawning areas might imply separate stocks or substantial heterogeneity in the distribution of yellowfin tuna, a single stock for the entire Atlantic is assumed as a working hypothesis, taking into account that data indicates yellowfin is distributed continuously throughout the entire tropical Atlantic Ocean and tag are recovered on a regular base from west to east. Males are predominant in the catches of larger sized fish.

Natural mortality is assumed to be higher for juveniles than for adults as showed from tagging studies in other oceans. The natural mortality rates have been showed to be size-dependant in bigeye, skipjack and yellowfin tuna in the western tropical Pacific Ocean using tagging data (Hampton, 2000). In summary, this work demonstrated that M was an order of magnitude higher in the smallest size-class in comparison to fish of midsized. Moreover, it showed that mortality changed from high to low around 40 cm FL, approximately the size at which the three species recruit to the PS fishery in the western Pacific. The results of this work underline the importance of accounting for size- or age-specific natural mortality rates. In that sense, variable mortality for yellowfin was discussed by the group and it was agreed to continue using variable M in the assessment. Growth rates have been described as relatively slow initially, increasing at the time the fish leave the nursery grounds. Nevertheless, questions remain concerning the most appropriate growth model for Atlantic yellowfin tuna. A recent study (Shuford *et al.*, 2007) developed a new growth curve using daily growth increment counts from otoliths. The results of this study, along with other recent hard part analyses, did not support the concept of the two-stanza growth model (initial slow growth) which is currently used for ICCAT yellowfin tuna stock assessments. This discrepancy should be addressed at inter-sessional meetings.

Only one document (SCRS/2011/141) on the biology of yellowfin was presented during the 2011 Working Group. This preliminary study, using pop-up tags, investigates the habitat use of yellowfin in the Gulf of Mexico. Yellowfin residence time at different depths depending on the difference between the temperature at depths and the surface were studied. Results show that yellowfin tuna spent 25.1% of time in the surface mixed layer in darkness, but only 4.3% during daylight hours. The ranges and means for the observed proportions of time spent at temperatures relative to the surface temperature were reflected in the observed percentage of time spent at depth, with greater exploration of deeper, colder waters during daylight periods. The majority of time was spent at depths shallower than 80 m. Although yellowfin tuna vertical distributions are influenced by temperature (other environmental factors also play a role), this study shows that yellowfin are able to tolerate cooler temperatures for brief periods during the day, which should be taken into account in the standardization of catch rates of different fleets for the assessment. The tabulated Delta-T percentiles reported in the document provide direct input variables required for habitat standardization models.

The Group was also informed that NMFS laboratory in Miami is currently conducting electronic tagging experiments in the Gulf of Mexico. Large yellowfin (around 130 cm FL) were tagged with pop-up tags from longliners. Preliminary results showed different types of movements, including migration outside the Gulf of Mexico. The Group welcomes this type of studies and encourages the authors to continue and to present more conclusive results at future ICCAT tropical species working groups due to their importance for the understanding of stock structure, migration patterns, and other ecological characteristics of yellowfin in the Gulf of Mexico.

The table below summarizes the biological parameters adopted by the SCRS and used in the 2011 Atlantic yellowfin assessments.

Parameter	*Yellowfin*
Natural mortality	Assumed to be 0.8 for ages 0 and 1, and 0.6 for ages 2+
Assumed “birth date” of age 0 fish	February 14 (approximate mid-point of the peak spawning season).
Plus group	Age 5+
Growth rates	Length at age was calculated from the Gascuel *et al.* (1992) equation: $FL (cm) = 37.8 + 8.93 * t + (137.0 – 8.93 * t) * [1 – \exp(-0.808 * t)]^{7.49}$
Weights -at-age	Average weights-at-age were based on the Gascuel *et al.* (1992) growth equation and the Caveriviere (1976) length-weight relationship: $W(kg) = 2.1527 \times 10^{-5} * L(cm)^{2.976}$
Maturity schedule	Assumed to be knife-edge at the beginning of age 3.
Partial recruitment	Based on output from age-structured VPA (see section addressing yield-per-recruit).

3. Review of fishery statistics: Effort and catch data, including size frequencies and fisheries trends

The Secretariat presented, at the beginning of the meeting, updated (as of 2011-09-02) versions of Task I catch statistics and Task II size information of yellowfin tuna available in the ICCAT database. Some specific Task II catch and effort statistics (e.g., Dakar based BB fisheries, European PS fisheries by fishing mode FAD/FSC, etc.) were also prepared to be used in various studies. The information was revised by the Working Group, corrected whenever required, and used in the assessment

3.1 Description of fisheries

Yellowfin tuna are caught in the entire tropical Atlantic, between 45ºN and 40ºS, by surface gears (purse seine, baitboat and handline) and by longline (**Figures 1 and 2**.). **Table 1** presents the yellowfin landings by flag and gear.

− *Baitboat*

In the East Atlantic, the baitboat fisheries exploit concentrations of juvenile yellowfin in schools mixed with bigeye and skipjack. There are several baitboat fisheries that operate along the African coast.

The most important, in terms of catch, is the Ghanaian baitboat fishery based at Tema. This fleet began to use FADs (fish aggregating device/floating object, which can be natural or artificial) in the early 1990s to enhance the capture of the species together with other tunas. Over 70-80% of these catches in recent years are on FADs; the mean weight of the captured fishes has remained relatively stable at around 2 kg (mode around 48cm).

There is another baitboat fishery based in Dakar that began operation in 1956 in the coastal areas off Senegal and Mauritania. Other baitboat fisheries operate in the various archipelagos in the Atlantic (Azores, Madeira, Canary Islands and Cape Verde), which target different species of tuna, including yellowfin according to the season. The average weight of yellowfin tuna taken by these fleets is highly variable (between 7 and 30 kg); lengths range from 38 cm to 80 cm with the mode around 48 cm. Since the early 1990s, the fleets in Dakar and the Canary Islands have operated using a different method, i.e. using the boat as a FAD, to aggregate various species of tuna, including yellowfin tuna.

In the West Atlantic, Venezuelan and Brazilian baitboats target yellowfin together with skipjack and other small tuna. The sizes of yellowfin are between 45cm and 175 cm for the Venezuelan fleet and from 45 to 115 cm, with the mode at 65 cm for the Brazilian fleet.

− *Purse seine*

The East Atlantic purse seine fisheries began in 1963 and developed rapidly in the mid-1970s. They initially operated in coastal areas and gradually extended to the high seas. Purse seiners catch large yellowfin in the Equatorial region in the first quarter of the year, coinciding with the spawning season and area. They also catch small yellowfin in association with skipjack and bigeye. Since the early 1990s, several purse seine fleets (France, Spain and associated fleets) have operated mainly on or associated with fishing aggregating devices (FADs), between 45 and 55% of the total purse seine catch being taken by this method, while previously, the proportion of the catch taken on natural floating objects was around 15% of the total purse seine catch. The Ghanaian purse seine fleet predominantly fishes off FADs (80%-85%) with fishing collaboration between the purse seine fleet and the baitboats. Frequently, FADs with accumulations of fish are first located by baitboats, who call in a purse seiner to make the set if the accumulation is large. In this situation, the catch is shared between the purse seiner and the baitboat.

Although the fleets are fishing on floating objects throughout the year, the main catches occur in the first and fourth quarter of the year, with skipjack as the dominant species together with lesser quantities of yellowfin and bigeye. The species composition of the schools associated with floating objects is very different from that of free schools. Yellowfin catches from floating object represented between 14% and 21% of the total catch in the years between 1991 and 2010 (16% in 2010) for the French, Spanish and associated fleets.

The East Atlantic purse seine fishery shows a bimodal distribution in the size classes for yellowfin, with modes near 50cm and 150 cm but with very few intermediate sizes and a high proportion of big fish (more than 160cm). The average weight of yellowfin tuna caught by the European and associated purse seine fleets was 9.4 kg in 2010 (3.1 kg with FADs and 30.4kg unassociated fishes). The sizes of yellowfin caught by the Ghanaian purse seiners has ranged around 48-52 cm for the recent decade.

The catch series available for these stock assessments include catches of "faux poisson" (fish sold in the local markets of the landing ports, which are not reported in the manner of the rest of the catches). The "faux poisson" catches made by the European purse seine fleets from 1981 until now have been calculated by species and reported to ICCAT.

In response to new developments in the purse seine fishery and to concerns over increased fishing mortality rate on bigeye tuna, a voluntary closed season/area for fishing with artificial FADs for a period of three months in a wide area of the equatorial Atlantic was implemented in 1997. In 1998 the Commission formally adopted the area closures [Rec. 98-01] and then extended the closure to all surface fleets in 1999 [Rec. 99-01]. Starting in 2005, those restrictions were discontinued, and instead a new management strategy (Piccolo) was established which prohibited all surface fishing in a much smaller area and only for the month of November [Rec. 04-01].

In the West Atlantic, Venezuela and Brazil have operated purse seine fisheries since 1970 off the coast of Venezuela and in the south of Brazil. Landings were sporadic in the 1970s but increased through the 80s and 90s and have generally been higher than western baitboat landings except in the most recent time period where they are approximately equal. Yellowfin size range caught by western Atlantic purse seiners (35 to 75 cm) is smaller compared to the eastern purse seiners, with the majority of fish being of intermediate size (mode 40 cm).

− *Longline*

The longline fishery began at the end of the 1950s and soon became important, with significant catches being taken by the early 1960s. Since then the catches have gradually decreased. Longline fisheries capturing yellowfin tuna are found throughout the Atlantic (**Figure 2**). The degree of targeting toward yellowfin varies across the longline fleets. In the Gulf of Mexico, both U.S. and Mexican longline vessels target yellowfin (the average weight of yellowfin was between 32 and 39 kg during the period from 1994 to 2006). Venezuelan vessels also target yellowfin, at least seasonally. In contrast, Japanese and Chinese Taipei vessels began in the mid-1970s and in the early-1980s to shift targeting away from yellowfin and albacore, respectively, toward bigeye tuna through the use of deep longline. Uruguayan longliners also capture yellowfin in the south western Atlantic, with FL sizes between 52 and 180 cm (mode at 110 cm or 26 kg; Domingo, et al, 2009).

Since 2000, a small-size fleet off Cabo Frio City, Rio de Janeiro-RJ State, Brazil (22^{o} to 24^{o}S and 40^{o} to 44^{o}W) has started fishing. This fleet is growing in number and in 2010 it had about 350 boats, representing 15% of the RJ total yield. This fleet targets dolphinfish using different equipment and catches yellowfin mainly with handline (55%) and mid-water longline (8%) (SCRS/2011/143).

3.2 Catches

The historical Task I catches have not undergone major updates since the 2010 SCRS. Only the most recent three years have changed slightly (< 1% in total) with various revisions made by several CPCs in accordance with the SCRS revision rules. Some provisional estimates of IUU since 2006, however, could add from 5,000 to 20,000 t per year to the overall catches in the recent past (SCRS/2011/016).

3.2.1 Yellowfin

Table 1 and **Figures 3** to **6** show the development of yellowfin catches in the total (by area and by gear), East and West Atlantic. Total Atlantic yellowfin catches in 2010 amounted to 108,343 t, in the East Atlantic was 86,133 t and in the West was 22,210 t.

Yellowfin catches increased from 1950s to an average of 150,000 t in the 1980s, they reached the highest figure in 1990 with catches of 193,536 t. Since then the catches had gradually declined, with recent years being at a similar level to those at the beginning of the 1970s. In the recent years, several European purse seiners have returned to the Atlantic Ocean with a resulting increase in catches.

− Baitboat

Total catch by this gear for the whole Atlantic was 9,568 t in 2010, lower compared to the catch in 1993 of nearly 25,000 t.

In the East Atlantic some fleets, with significant catches at the beginning of the fishery (22,135 t in 1968, e.g., Angola, Cape Verde or Japan), have decreased landings (8,132 t in 2010)

In the West Atlantic (**Figure 6**) baitboat catches started in 1974, increased regularly from 1,300 t in 1974 to 7,000 t in 1994, and later decreased to about 1.450 t in 2010.

− Purse seine

Yellowfin catches by this fleet reached 74.172 t (68%) for the entire Atlantic in 2010. In the East Atlantic, catches increased rapidly in the early years of the fishery (**Figure 5**), from 10,000 t in the 1960s to 100,000 t in 1980, stabilizing at this level until 1983 followed by a sharp decrease in 1984 (74,173 t). This occurred as a result of the drastic decrease in effort which took place following the fall in yield of large sized yellowfin, mainly due to the French, Spanish and associated purse seine fleets abandoning the fishery. Catches later increased, with a record catch in 1990 of over 129,000 t, followed by a decreasing trend in subsequent years, reaching 58,319 t in 2006. In the follow years the catch increased again, reaching 69.953 t in 2010 due to reentry of purse-seine effort into the Atlantic. For the "faux poisson", the estimates corresponding to yellowfin show that the highest figure was 2,750 t in 1993, with 533 t in 2010.

The Working Group on Ghanaian statistics, which met in 2011, provided new information on the Ghanaian fisheries trends. Based in the data provided by the Ghanaian scientists and with additional information from other sources, the Working Group was able to reconstruct detailed catch, effort and size data as well as detailed information on fleets and geographical distribution of catches. As an example, **Figures 7** to **9** show the catch distribution of Ghanaian catches in the historical period (1969-1980), before the development of the FAD fishery, and in the recent period (2008-2010). These figures show the extension of the fishery from a coastal area to an area similar to that of the European and associated fisheries on FADs (**Figure 10**). Incomplete monitoring of the Ghanaian fleet catches since 2006 may have resulted in a potentially large underreporting of YFT catch.

In the West Atlantic (**Figure 6**) catches increased since the beginning of the fishery in the early 1960s to 1983 when they reached 25,000 t. Catches in the following years show considerable variation as a part of this fleet moved to the Pacific Ocean. Caches in 2010 were 4,219 t. Most of the catch in the West Atlantic is taken by the Venezuelan purse seine fishery (in some years being 100% of the total catch).

− Longline

After a maximum of over 50,000 t reached in 1959-1961, longline catches decreased to a level of around 30,000 t in the early 1970s. Longline catch levels in the 2000s have been about 23,000 t. Longline catches in 2010 reached 19,302 t. The main fisheries are those of Chinese Taipei, Japan, United States, Mexico and Brazil. The appearance of important catches, beginning in 1985, by NEI fleets in unknown areas is of concern as it is uncertain to what extent these catches actually occurred in the Atlantic.

A multi-gear fleet in the western Atlantic fishing from Cabo Frio City, Rio de Janeiro, Brazil caught about 11 t of yellowfin in 2003. Catches increased to 183 t and 137 t in 2006 and 2007, respectively, and decreased to 8 t in 2010 (SCRS/2011/143).

3.3 Fishing effort

In general, in multi-species fisheries such as the surface tropical tunas fisheries, it is difficult to discriminate fishing effort by species. Beginning in the 1990s, important changes have taken place in the East Atlantic main surface fisheries which have further complicated the estimation of effective effort, including the greatly increased in the number of FADs used by purse seiners and baitboats, as well as the use of baitboats as floating objects.

As indicators of the nominal effort in the East Atlantic, the carrying capacity of the purse seine and baitboat fleets has traditionally been used. **Figure 11** shows the development of carrying capacity of the surface fleets in the East Atlantic for the period 1972-2010, including new information from Ghanaian fleets. The baitboat carrying capacity has remained stable since the late 1970s at around 10,000 t. The carrying capacity of the purse seine fleet, on the other hand, has undergone significant changes during the whole period under consideration, with a constant increase from the start of the fishery until 1983, when carrying capacity exceeded 70,000 t. After that, carrying capacity decreased considerably to 37,000 t in 1990, due in part to the fleet abandoning this fishery. There was a slight increase in the following two years (1991 and 1992) followed by a progressive decline, with capacity at around 29,700 t in the year 2006 and then an increase to 39,600 t between 2006 and 2010 due to movement of effort into the Atlantic mainly from the Indian Ocean (SCRS/2011/137, SCRS/2011/130, SCRS/2011/136).

Document SCRS/2011/137 shows the development of both nominal fishing effort measures for EC and associated purse seiners: the number of 1-degree rectangles explored and the number with effort greater than 1 fishing day, and total purse seiners fishing days (1991-2010). It can be observed that, the searching area remained at the same level from 1991 until 2007, after which both searching area and the number of fishing days increased.

For the West Atlantic, there have been substantial recent changes in the amount and distribution of fishing effort in the Brazilian longline fishery. Until 1995, sharks were the primary target species (58% of the total catches). However, since 1993, the proportion of sharks declined, being replaced by swordfish as the dominant species in this fishery (swordfish now represent 48% of the total catches). Effort in the Venezuelan surface fisheries has been high since 1992 (more than 8000 t vessel carrying capacity). Effort in the U.S. longline fishery, which is active in the north western Atlantic and in the Gulf of Mexico, has declined somewhat in the last few years.

Japanese longline effort for yellowfin tuna has also declined in recent years. This fleet mainly targets other species (bigeye and bluefin).In contrast, Venezuelan and Mexican longline effort for yellowfin tuna has increased in recent years.

Effort in the multi-gear fleet fishing out of Rio de Janiero, Brazil is around 350 vessels (SCRS/2011/143).

3.4 CAS and CAA estimations

The Secretariat presented at the beginning of the meeting, an update of the yellowfin catch-at-size (CAS) matrix estimations for the period 1970-2010. The standard proceedings and substitution rules were applied. As a standard procedure, the CAS output is standardised in 1 cm lower limit size frequencies, keeping always the maximum time-area granularity of the size information used. As recommended in the 2008 assessment, the period between 1975 and 1982 was revised and updated, in addition to the years 2007 to 2010. The remaining CAS series (periods 1970-1974 and 1983-2006) were revised and corrected to make the CAS weight equivalent with Task I (by year/fleet/gear/stock combinations). The yellowfin substitution tables (not here included given their sizes) used to build the yellowfin CAS, are available upon an explicit request to the Secretariat.

A CAS revision of Japan was presented during the meeting (SCRS/2011/128) for the period 1995-2010. Upon a detailed explanation for such revision, the Working Group agreed to replace this series in the overall CAS matrix. The Working Group also agreed not to revise the Japanese historical CAS data. This pending issue will be updated by the Secretariat for the next assessment.

A final version of the CAS was made at the meeting (which incorporates the new Japanese CAS and the new Task I figures adopted in **Table 1**) and finally adopted by the Working Group. **Table 2** and **Figure 12** presents the overall CAS matrix in number of yellowfin tuna caught by year and 2 cm length classes.

Figure 13 shows the estimated CAS frequency distribution of yellowfin by year and by the main gear groups, purse seine (PS), longline (LL), baitboat (BB) and others (OT). Both BB and PS size frequency shows a catch primarily of fish between 35 and 70 cm, while LL mainly catch larger fish.

The Secretariat informed that after the “Tropical Tuna Species Group Inter-sessional Meeting on the Ghanaian Statistics Analysis (Phase II)” (SCRS/2011/016), some revised data were received. These revisions were pending corrections and harmonization of the catch-at-size data which precluded their use in the current assessment. The Group noted that the final incorporation of these data also needs the review and approval of the other tropical species working groups. For this meeting, only an estimate of the Task I updated from the Ghanaian statistics was considered.

The catch-at-age (CAA) matrix was estimated with a slicing program (SCRS/2011/142) for the final version of the CAS. SCRS/2011/142 describes an alternative slicing technique for estimating the CAA matrix from the CAS matrix. Briefly the method proposed to include observed variance of size at age into the ageing protocol. The observed variance of size was estimated from daily increment reading from yellowfin otoliths (Shuford, *et al* 1992). Although the size sample is low, these represent fish collected from the Gulf of Guinea and North Carolina fisheries. The Group recommended that further analysis of the ageing protocol be performed, possibly including more hard parts for age samples from other Atlantic fisheries.

The CAA matrix selected by the group was estimated using the slicing protocol as defined in past assessments, with the upper size bounds defined for each age-quarter group (**Table 3**) based on the predicted growth of yellowfin assuming the two-stanza growth formulation presented by Gascuel *et al* (1992). During the meeting, the definitions of fisheries fleets that should be associated with a particular index of abundance were also revised (See section 4.1).

Table 4 and **Figure 14** summarize the trends of age distribution by year for the total catch of yellowfin for 1970-2010. Since 1970, there has been an increase in the proportion of ages 0 and 1 in the catch. This primarily due to the increase proportion of catch from the FAD associated fleets. **Figure 15** also provides the catch in weight distribution by age class.

3.5 Other information (tagging)

The Secretariat provided a summary of the current tagging data available for yellowfin tuna with maps of its distribution.

4. Review of catch per unit effort series and other fishery indicators

The Group noted that a large number of CPUE series were developed for the previous assessment and that in order for there to be continuity between the assessments, all of these indices should at least be revisited. In many instances, revised/updated CPUE series were available. In the case where no new indices were presented, the indices from the prior (2008) assessment (Anon. 2009) were used. When updated indices were provided, these updated indices were generally used.

4.1 Surface fisheries (purse seine and baitboat indices)

Document SCRS/2011/130 presented data about catches, fishing effort, catch per unit of effort and sampling coverage of the Spanish tropical tuna fleet (purse seiners and baitboats) that fish in the Atlantic Ocean. This paper included a CPUE series calculated for the Spanish PS fleet, while Document SCRS/2011/136 described the fishing activities of the French purse seiners targeting tropical tunas in the Atlantic Ocean between 1991 and 2010. Two major fishing modes were considered for the fishery: log-associated and free swimming schools. Information was provided on fishing effort (fishing days, searching days, and fishing sets), catch, catch rates, and mean weights for the major tropical tuna species with a particular focus on the year 2010. Document SCRS/2011/137 presented statistics for the EU and associated tuna fisheries in the Atlantic Ocean between 1991 and 2010.

For the previous assessment, CPUE indices for the EU PS fleets had been divided into three separate indices. For the sake of continuity, this was again done, with a Tropical Free School Index being developed from the Task II catch and effort data after separating the effort by fishing mode (FAD and free schools). The Tropical Free School Index assumed a 1% increase in catchability over the duration of the time series which begins in 1991 up to 2009. Data are not available to separate by fishing mode prior to this time although log sets represented a rather small portion of the data prior to this time. A FAD series was produced by combining the French, Spanish and associated fleets FAD data resulting in a nominal CPUE series for this sector of the fishery. Lastly, a nominal EU PS series (1970-1990) was created assuming a 3% increase in catchability per year beginning in 1980 through to 1990. The 3% increase was assumed in the past and thus this was again assumed. This series was revisited using methodology developed in the 2008 assessment session in Florianopolis, taking into account changes in q (coming from a production model using all indices except the PS index and a VPA analysis: The purse seine fleet is known to have increased its efficiency through time. Following the criteria that has been applied for the previous assessment, an assumed 3% annual increase in fishing efficiency was assumed from 1980. There was concern regarding the 3% increase as it was suggested that this may be an under-estimation of q for the years in the middle of the series as indicated by Gascuel, *et al* (1993). To evaluate this, an analysis was conducted which confirmed that a higher rate increase (7%) prior to the year 2000 would have been consistent with both the CPUE trends from the purse seine fleet and with the estimated biomass trends from production models (**Appendix 7**). Therefore, it was agreed to use the 7% increase PS CPUE series from 1970 to 1990. Lastly, a nominal EU PS series (1970-2010) was created assuming a 3% increase in catchability per year beginning in 1980 through to 2010.

The EU Dakar baitboat fishery CPUE was updated during the meeting from the previous assessment. The full details of the standardization are included in **Appendix 5**.

4.2 Recreational fisheries

Document SCRS/2011/139 presented and updated time series of the U.S. rod and reel recreational fishery. The Group discussed that the model was unbalanced because more than 80% of all observations were from one region (mid-Atlantic, state of North Carolina) and one season. Therefore, the estimated index might not reflect yellowfin tuna abundance over the entire area covered by the data. However, the estimated index showed a trend that is consistent with anecdotal information from the entire geographical range covered by the index. The author indicated that an index developed using data only from North Carolina was almost identical to the index developed using all the data. The Group suggested developing separate indexes for each area, but it was indicated that some areas have low sample sizes, therefore, precluding the estimation of such indexes. The Group also suggested examining the residuals estimated for areas other than North Carolina. The author also indicated that the estimate (from a small sample size) average weight of the yellowfin tuna caught by this fishery was approximately 12 kg, but the fishery catches fish ranging from juveniles to fully mature individuals. The Group finally suggested that yellowfin tuna indexes of abundance should also be developed using data from other U.S. data collection surveys to compare the general trends.

4.3 Longline indices

Document SCRS/2011/128 presented a CPUE series for the Japanese longline fleet for the period 1965-2010. The Group observed that the estimated nominal CPUE for year 2007 was very high compared to other values in the same period. The authors indicated that the high value seemed to correspond to high catches recorded for that year off of West Africa. The estimated standardized series did not show a high value for year 2007.

Document SCRS/2011/129 detailed the standardization of catch per unit effort for yellowfin tuna caught by the Chinese Taipei longline fleet as estimated by a general linear mixed model with log-normal error structure on the yearly and quarterly basis. The lowest abundance in the index was calculated to be during the 1970s, and fluctuation occurred after 1990. The current estimated abundance level in 2008 and 2009 was likely equivalent to the levels in 1980s after reaching its recent highest level in 2005. The Group discussed that the data used to estimate the CPUE correspond to four distinct periods with different levels of aggregation and/or levels of information about gear configuration. The author estimated 4 different models (one for each of the four periods mentioned) using the same factors in all four models. It was pointed out that although the CPUE was presented in the paper as one continuous series, it should actually be treated as four temporally distinct series (1968-1980, 1981-1992, 1993-2002 and 2003-2009) due to the way the CPUE was calculated. The author has confirmed this interpretation. The full details of this temporal separation are provided in the document.

A CPUE series for the Brazilian longline fleet was presented in document SCRS/2011/144. The Group noted several concerns with the document. First, the models were developed using data sets differing in the number of observations so that AIC should not be used to guide model selection. There was also concern that a Poisson distribution may not be the best model for continuous data possessing a high proportion of zeroes. The Group also noted that the year effect should be calculated as a balanced mean across all factors, equivalent to the least square means estimator, whereas SCRS/2011/144 calculated the mean of the predicted values for only the sample observations which are not balanced. In response to these concerns, the group agreed to revise the analyses (**Appendix 6**).

The Group observed that significant changes in fishing effort targeting yellowfin occurred during the course of the fishery (Hazin, *et al*, 2011). In the original construction of the model there was very little divergence between the nominal and standardized values, despite these changes in targeting strategy, which suggested that the standardization did not adequately account for the changes in targeting. The CPUE series was re-estimated using a delta log normal model with the index calculated as the least square mean. The resulting model predictions diverged from the nominal values, in a manner more consistent with the changing targeting of the fleet from yellowfin to swordfish and the re-calculated index appeared to have a more plausible trend. The revised delta lognormal model was recommended by the Group, yet concerns remained related to whether the modeling adequately accounted for the substantial changes in targeting.

For future treatments of CPUE data from the very complex Brazilian longline fleets, it was recommended that gear characteristics of fleets/vessels be recorded or, if they are recorded, be used in standardization, when possible. Furthermore, the Group reiterated the need for simulation studies to test different methods to account for changes in targeting. The Group concluded with an observation that CPUE indices for species in other strategies (e.g., BET, BUM) have been very noisy and without a clear trend. However, the indexes estimated for species in strategy 1 (e.g., YFT, WHM) show a very similar trend and the Group wondered if these similarities were a reflection of common population trends or an artifact of the data used and the standardization procedure

The U.S. longline index for the Atlantic Ocean was presented in document SCRS/2011/138. The Group discussed some of the factors included in the model. There was some concern of the use of time (AM and PM) to define time of sets since some captains have been known to record times in logbooks using the time zone of the port of departure instead of that of the fishing area. The author also indicated that some observations had unrealistically high records of the number of hooks between floats (e.g., in the order of 900). The Group indicated that, in the future, those observations should not be used to develop the indexes. The Group also suggested that, given the management changes observed in the U.S. northeast distant fishing area (NED), an index be developed without using data from that area. Given that the observed differences were minimal and that model diagnostics were available only for the original CPUE, it was decided to incorporate only this original index into the assessment process. However, there was a suggestion that future analyses should attempt to address the effect of management actions in order to avoid potential bias. When these effects cannot be estimated with the current data, one approach may be to eliminate data before and after a substantial management action was implemented, such as removing the NED data. The Group noted that CPUE in weight were estimated using the CPUE in numbers and an average weight for each year estimated from Observer data. The Group discussed that the use of other weight data with higher resolution, such as commercial landings data at the trip level, should also be explored.

Document SCRS/2011/140 provided abundance indices for yellowfin tuna in the Gulf of Mexico for the period 1992-2011. These were estimated using data obtained through pelagic longline observer programs conducted by Mexico and the United States by applying the model developed during prior analyses to the currently available data (through 2010 for the U.S. fishery and through 2006 for Mexico). Standardized catch rates were estimated through generalized linear models by applying a Poisson error distribution assumption. There was a question as to whether there was imbalance in the model as the two fleets (Mexican and U.S.) are effectively separated by area and have little overlap. The way the model selection has been conducted, however, should reduce this problem as collinear factors tend to be removed during the selection procedure. It was also pointed out that although the catch data is dominated by the Mexican fleet, the standardization procedure should account for this and thus this series can be considered a true reflection of the activities of both fleets.

A comparison of the Gulf of Mexico series (USA and Mexico) and the U.S. longline series for the Atlantic Ocean was made. Although the series were largely similar, it was noted that there are some years for which the two series diverge. These years correlate to years when the Mexican catch rate is higher than the US catch. The observer program data covers a broader area and has more factors that can be considered for standardization than the Gulf of Mexico series, but has a shorter temporal coverage. There was a suggestion to exclude the NED) from standardization of the U.S. logbook CPUE series. Differences between the series including NED and excluding it are however very small. Removal of NED will require re-establishing weightings by area as an additional large area will now be excluded (although catch of yellowfin in that area is low). As the regulations in the NED would result in decreased catch rates of yellowfin, it was agreed that removing the NED (throughout the time-series) may be the most appropriate way of standardizing this CPUE series due to the changes in catchability. In the end it was decided to keep the NED in order to prevent having to rerun diagnostics. It must be recommended however that the NED should be removed in the future, or that the issue should be investigated further.

4.4 Indices used for assessment

The various indices proposed for incorporation in the different stock assessment models are provided in **Table 5**. These indices were chosen by the Group based on continuity from the last assessment as well as changes and needs discussed during the meeting. Where these series have been updated during the present stock assessment session or whether they have merely been carried over from the past assessment is indicated. The stock assessment model which utilized each index is also noted. Fleet definitions used to construct fleet-specific partial catches at age for the VPA and to assign landings in ASPIC are shown in **Table 6**.

4.5 Other indicators: Non equilibrium Beverton-Holt estimator of total mortality

It is widely admitted that mean length in a fish population is inversely related to the total mortality rate. With this idea in mind, Beverton and Holt (1956) developed a functional relationship between the mean length in the catch and the total mortality rate (Z). Such approach was generalized by Gedamke and Hoenig (2006) to allow mortality rate to change in nonequilibrium situations.

For the sake of simplicity, it was assumed that yellowfin growth curve followed the conventional von Bertalanffy equation with parameters, K=0.728 Linf=151.7. Based on visual inspection of yearly catch at size, the size at full recruitment (Lc) was fixed at 48 cm. To access whether there have been multiple changes in the mortality rates of yellowfin, different competing models (i.e., with different breaking dates and resulting number of parameters) were ranked according to the Akaike information criterion.

The selected model fits well with the mean length of the Atlantic yellowfin, even if the situation is less satisfactory in the recent years (**Figure 16**, left panel). The fitted values decrease gradually from 89.7 cm in the 1970s to 81.3 cm during the period 1983-1996, then at 71.9 cm since 1999. For these three homogeneous periods of time, Z was estimated at 1.08, 1.52 and 2.43, respectively (**Figure 16**, right panel). The clear downward trend in the late 1990s suggests an increase in mortality rate, followed however by a possible recovery in the recent period. Potential changes in selectivity by fishing gear over these three homogenous time periods should be explored before drawing definitive conclusions on the absolute change in total mortality over years. Methods and results are provided in greater detail in **Appendix 9**.

5. Methods and other data relevant to the assessment

5.1 Production models

5.1.1 Data inputs for surplus production models

The development of the combined indices used in the ASPIC model is described in **Appendix 4**. **Table 7** and **Figure 17** show the combined indices available for use by the production models. **Table 8** and **Figure 18** show the indices created by excluding one available index each, in order to evaluate the influence of each of those indices.

5.1.2 ASPIC

In 2008 ASPIC (Prager, 1992) was used to fit production models and four ASPIC cases where used to develop the advice in 2008 (cases 2, 4, 6 and 8 from Table 20, Anon. 2009). They all correspond to Logistic fits of the model with combined indices (cases 2 and 4) or with a set of 9 indices (cases 6 and 8). Cases 2, 6 and 8 had B1/K fixed to one and not estimated. Case 4 was the only one where B1/K was estimated. Case 6 used nine indices weighted equally, and case 8 used nine indices (Table 18,0Anon. 2009) weighted by the amount of area occupied by the fishery representing the index.

During the current assessment the version 5.34 of ASPIC was used. ASPIC has a limit of 10 individual indices, and in this assessment there were more than ten available. Therefore the decision was made to develop two types of runs, those with combined indices (**Appendix 4**) and those with 10 individual indices. Combined index runs had the advantage of allowing the group to use all available indices in the development of the combined index, and thus for all indices to influence the fit. A number of different runs were conducted during the assessment (**Table 9**).

− Continuity case

To see the effect of recent catches, as well as updating the same indices where possible and applying the index information with the same manner as in the last assessment, four ASPIC runs were developed (runs 05, 06, 07 and 08, **Table 9**). These four runs are therefore equivalent to runs 02, 04, 06 and 08 in the 2008 assessment (Table 20, Anon. 2009).

− Sensitivity runs

a) Using a single fleet index

Some initial model runs (Runs 1-4) were configured to use a single fleet index (Japanese longline), primarily for the purpose of ascertaining that the models and data were being set up correctly. These runs are detailed in **Appendix 8**.

b) Catchability increase for purse seine fleet

Beginning in 1991, detailed information on set type is available that permits tracking the catches separately by set type (free school vs. log). The Group decided that separate indices by set type would better reflect abundance trends and would be particularly useful for age-structured analyses. Prior to 1991, indices would be applied representing purse seine catch rates, assuming a particular trend in fishing power (either 3% or 7% annual increases, as described in **Appendix 7**). In order to estimate the effects of such change in the purse seine index ASPIC was run with a combined index calculated with a purse seine index that includes either a 3% annual increase (cases 9 and 10) or a 7% annual increase (cases 11 and 12).

c) Alternative estimates of Ghana catches

The Tropical Working Group on Ghanaian Statistics estimated alternative total catch for Ghana (SCRS/2011/016), especially during the recent period. To estimate the effects of such new estimated catch in the assessment, an ASPIC run with an update of Ghanaian statistics was carried out. This run (no. 14) uses the same model structure as run 11 (i.e., combined indices developed with the 7% PS index, the logistic model and B1/K fixed to one) but differs in that it uses updated Ghanaian catches.

d) Excluding specific indices

To see the effect of excluding specific fleets when processing the combined index, three runs were made using alternative combined indices each excluding one index. The excluded indices included Chinese Taipei longline index (run 15), Brazilian longline index (run 16) and the EU-purse seine with 7% increasing q (run 17).

− Base case

After examining the continuity cases and sensitivity runs, the Working Group decided to use runs 9, 10, 11 and 12 as the basis for providing the advice. They all include combined indices but differ on whether B1/K is estimated or fixed at 1 and on the rate of catchability increase assumed to have affected the purse seine.

− Retrospective analysis

Retrospective analyses were conducted by sequentially removing a single year of data and re-estimating model outputs. The purpose of this exercise was to determine how the addition of new data changes the perception of the stock.

5.1.3 PROCEAN model

The PROCEAN (PRoduction Catch / Effort ANalysis) model is a multi-fleet non-equilibrium biomass dynamic model developed in a Bayesian framework to conduct stock assessments based on catch and effort time series data (Maury 2000, 2001). The model was used here to run sensitivity analyses on input data and modelling choices made during the Working Group for the runs of ASPIC (section 5.1.2). In a first step, runs were performed on the two combined abundance indices covering the period 1965-2010, i.e., unweighted and weighted by area (run 9 of ASPIC), to assess the sensitivity of the results to the shape parameter (m) of the model. For the combined index weighted by area, the shape parameter m was first estimated and then fixed at 1.5 for comparison with ASPIC runs that considered a logistic model, i.e. making the implicit assumption that m is equal to 2. The initial value of biomass (1965) was set to 90% of the carrying capacity and a complementary run for the combined index weighted by area was conducted considering a value of 80%. In a second step, sensitivity runs were conducted by considering different selections of the abundance indices included for computing the combined abundance index (runs 15-17 of ASPIC).

In a third step, nine time series of CPUE indices (in weight) were selected during the working group based on objective criteria regarding their spatial representativeness of yellowfin fishing grounds (**Table 10**). The Uruguayan LL, Venezuelan PS, European-Senegalese Dakar BB, Brazilian BB, U.S. RR, and U.S. LL indices included in the estimate of the combined abundance index were removed because these fisheries do not represent a significant part of the total fishing area of the stock. The Chinese Taipei CPUE index was separated into four distinct indices covering the periods 1968-1980, 1981-1992, 1993-2002, and 2003-2009, respectively (SCRS/2011/129). Three different indices (yellowfin catch per searching day) were considered for the European purse seine fishery: an index for the whole European PS fishery during 1970-1990 assuming a yearly increase in catchability of 7% (**Appendix 7**), an index for the fishery on free swimming schools during 1991-2010 assuming a yearly increase in catchability of 1%, and an index for the fishery on log-associated schools during 1991-2010. Sensitivity runs to CPUE inputs were performed by progressively excluding the TAI-LL and BRA-LL indices from the model.

5.2 VPA

The parameter specifications used in the 2011 VPA base models were generally similar to those used in the 2008 base-case VPA model (Anon. 2009). Some exceptions are noted below and in the summary of the model control settings and parameters that appears in **Tables 11** and **12**.

All of the VPA runs performed during the 2011 assessment used the following specifications:

1. VPA models require the estimation or input (i.e. fixed) for the terminal year fishing mortality rates (F). As in the previous assessment, the 2011 base cases allowed terminal F values to be estimated for Ages 0-4. For the VPA models, the oldest age class represents a plus group (ages 5 and older) and the corresponding terminal fishing mortality rate is specified as the product of $F_{\text{age 4}}$ and an estimated ‘F-ratio’ parameter that represents the ratio of $F_{\text{age 5}}$ to $F_{\text{age 4}}$.

2. The indices of abundance were fitted assuming a lognormal error structure and equal weighting (i.e., the coefficient of variation was represented by a single estimated parameter for all years and indices).
3. The catchability coefficients for each index were assumed constant over the duration of that index and estimated by the corresponding concentrated likelihood formula.
4. The natural mortality rate was assumed to be age-dependent (Ages 0 and 1 = 0.8 yr^{-1}; Ages 2+ = 0.6 yr^{-1}) as in previous assessments.
5. The maturity vector was assumed to be knife-edged, with 100% maturity at Age-3 (i.e. Age 0-2 = 0, Ages 3+ = 1.0).
6. The fecundity proxy was assumed to be the product of maturity-at-age and weight-at-age at the peak of the spawning season (Feb. 14). The proxy was calculated using the accepted two-stanza growth curve and length-weight conversion parameters. The weight-at-age of the plus group was estimated using ages 5 to 10 and adjusted to account for natural mortality on ages 6-10. The resulting vector was as follows (Ages 0-2 = 0.000, Age 3 =34.68 kg, Age 4 = 62.10 kg, Age 5+ = 86.51 kg).

– *Description of model runs*

Two VPA base models were used to produce management advice during the 2008 assessment of yellowfin tuna. These were referred to as “Run 5” and “Run 10”. The first, Run 5, used the partial catches at age from each fleet to estimate a single selectivity vector for each index (Butterworth and Geromont, 1999 - Eq.4). The second, Run 10 , was identical except that the longline indices were assumed to have fixed “flat-topped” selectivity patterns rather than the steeply “dome-shaped” patterns estimated from the partial catches. To accommodate this assumption, the selectivity patterns were fixed at the values estimated during “Run 5” until the fully selected age was reached. Then, full selection (1.0) was retained for older ages. These model assumptions were also explored during the 2011 assessment meeting. To simplify the discussion below, “Run 5” will hereafter be referred to as “USE PCAA” which is an abbreviation of “use partial catches at age”. Likewise, “Run 10” will be referred to as “FLAT-TOPPED”.

1. **DELTA CAA**: The “DELTA CAA” runs were performed to examine, in isolation, the effect of the updated catch at size information on the estimates of SSB/SSB_{MSY} and F/F_{MSY} in 2006 (the terminal year of the previous assessment).The years 1970-2006 were included in this model treatment. This comparison also retained the model settings, specifications, and indices of abundance from the previous assessment.

    a) As in the 2008 assessment, the “DELTA CAA” runs allowed the initial F-Ratio (1970) to be estimated, while subsequent years were permitted to vary according to a random walk with a standard deviation equal to 0.2 and a prior expectation equal to the previous annual estimate.

    b) As in the 2008 assessment, constraints were applied to restrict deviations in recent recruitment and recent vulnerability.

    c) As in the 2008 assessment, two VPA model runs were made that contrasted the assumed selectivity of the longline fleets, the “USE PCAA” and “FLAT-TOPPED” run as described above.

2. **CONTINUITY**: The “CONTINUITY” runs were performed (1970-2010) to examine the combined effects of including information through 2010, the updated catch at size and updated indices of abundance on estimates of SSB/SSB_{MSY} and F/F_{MSY} in 2006. The “continuity” runs retained the model settings, specifications and terminal year (2006) of the previous assessment and the “DELTA CAA” runs. The “USE PCAA” and “FLAT-TOPPED” runs were constructed as described above.

3. **BASE**: Four “BASE” runs were examined by the working group. These runs contained all of the new and updated data inputs made available to the working group during the 2011 stock assessment session. All four base runs used the available data from 1970-2010. The base runs differed from the “DELTA CAA” and “CONTINUITY” runs as follows:

    a) **BASE RUN 1 “USE PCAA”**:

        i) All new and updated indices recommended by the 2011 assessment working group were used.

        ii) A revised catch-at-age was developed by the Secretariat following adjustments recommended by the Working Group (see Section 3.4).

iii) Partial catch-at age -corresponding to the indices- was constructed using fleet definitions agreed upon by the Working group (**Table 6**).

iv) The penalty applied to restrict deviations in recruitment was removed from the 2011 base runs. The penalty to restrict deviations in recent vulnerability was retained.

v) "A single selectivity vector for each index was calculated using the partial catches at age (scaled to 1.0) and the Butterworth and Geromont technique.

vi) The initial F-Ratio (1970) was fixed at 0.7, and then allowed to vary annually according to a random walk with a standard deviation equal to 0.2 and a prior expectation equal to the previous annual estimate.

b) **BASE RUN 2 "FLAT-TOPPED"**: Same as BASE RUN 1 except that annual selectivity vectors for each index were calculated using the partial catches at age (scaled to 1.0). After the first fully selected age, full selection (1.0) was carried through the older ages.

c) **BASE RUN 3 "USE PCAA"**: This run is intended to explore the effect of a different assumed trend in the F-Ratio. For this run, the F-Ratio was fixed at 0.7 from 1970-1999, then allowed to vary annually according to a random walk with a standard deviation equal to 0.2 and a prior expectation equal to the previous annual estimate.

d) **BASE RUN 4 "FLAT-TOPPED"**: Same as BASE RUN 2 except that the F-Ratio was fixed at 0.7 from 1970-1999, then allowed to vary annually according to a random walk with a standard deviation equal to 0.2 and a prior expectation equal to the previous annual estimate.

The indices used during the various model runs are summarized in **Table 13**. The specifications for the indices and index selectivity are described in **Tables 14** to **16**.

6. Stock status results

6.1 Production models

6.1.1 ASPIC

− Updates of recent catch and relative abundance indices

Point estimates for population parameters are very similar between runs that only differ on whether the B1/K is estimated or not (**Table 17**). Greater differences in benchmarks are related to the assumption regarding the function of the production model.

− Continuity case

Including updated combined index and the same set of nine indices used in the 2008 assessment have strong effects on the benchmarks (**Tables 18** and **19**) as well as on the historical changes in biomass and fishing mortality ratios (**Figure 19)**.

− Sensitivity runs

a) Using a single fleet index

The results of Runs 1-4, using a single fleet index (Japanese longline), are detailed in **Appendix 8**.

b) Catchability increase for purse seine fleet

Including an index for the purse seine calculated with a seven percent increase in catchability has a small effect on the benchmarks (**Table 20**) and on the historical changes in biomass and fishing mortality ratios (**Figures 20** and **21**).

c) Alternative estimates of Ghana catches

Estimates of benchmarks differ by 5% or less for MSY, B_{2010}/B_{MSY} and equilibrium yield. The greatest changes are estimated for F_{MSY} and large changes for K, B_{MSY}, F_{2010}/F_{MSY} and yield at MSY (**Table 21**).

The pattern of biomass and fishing mortality ratios differ only for the most recent period (**Figure 22**), but suggest that the higher catches estimated for Ghana would lead to a more pessimistic assessment of the current state of the biomass and fishing mortality. Estimates of the most recent ratios of biomass and fishing mortality are highly uncertain for both runs but generally suggest a more pessimistic view for run 14 (**Figure 23**).

d) Excluding specific indices

Excluding each specific fleet has effects on the benchmarks (**Table 22**) and on the historical changes in biomass and fishing mortality ratios (**Figures 24** and **25**).

− Base case

Results from all four runs are quite similar indicating that neither the ratio of B1/K nor the rate of increase in q for purse seine has much influence on the fit of the production model. MSY values are similar for all runs, about 140,000 t with bootstrap estimates of the 10% and 90% ranging from about 100,000 t to 150,000 t. The median 2010 biomass relative to the B_{MSY} is estimated at about 0.7 with bootstrap estimates of the 10% and 90% ranging from about 0.55 to 1,0, suggesting an overfished stock. The median 2010 fishing mortality relative to the F_{MSY} is estimated at about 1.1 with bootstrap estimates of the 10% and 90% ranging from about 0.8 to 1.6. This suggests there is considerable uncertainty on whether there is overfishing or not.

− Retrospective analysis

The analysis of retrospective patterns indicates that F/F_{MSY} and B/B_{MSY} estimates are relatively stable for the terminal year when successive years of data are removed from the model (**Figures 26** and **27**). The primary result of increasing years of data is that the estimate of the intrinsic rate of population increase (r) and the carrying capacity (K) varied indicating that the successive addition of new years of data changes the perception of the productivity of the stock (**Figure 28**). Though the combined index is going up in the recent years, it is not increasing at the rate that would have been expected by the estimated values of intrinsic rate of increase from the 2008 assessment results (~ 0.68) given the observed catch levels since 2006. Hence, as we added years of data to the model, we appear to get a progressive decrease in the estimated intrinsic rate of increase (**Figure 28**).

6.1.2 PROCEAN model

Overall, model runs for the combined abundance indices yielded results similar to ASPIC for the biomass and fishing mortality trajectories. Ratios of current fishing mortality and biomass relative to MSY were within the range of values estimated with ASPIC, i.e., 1.13-1.18 and 0.65-0.74, respectively (**Table 23**). Model results were robust to changes in initial biomass assumption. Changes in the shape parameter of function of the production model did not modify the past trends of the stock and current status of overfishing but did affected the value of MSY estimated that were in the range of 139-145,000 t and generally larger than those derived from ASPIC runs. The exclusion of the TAI-LL and BRZ-LL indices when computing the combined index of abundance had little influence on model results. The exclusion of the EUR-PS index did result in a decrease in the MSY and a stock diagnostic in 2010 a little bit more pessimistic (F ratio of 1.24).

The model failed to convergence to a solution when including the 9 CPUE series in the model due to conflicting information between abundance indices. Convergence was reached only when removing the 3 TAI-LL indices after 1981. However, strong patterns were observed in the fishery-specific residuals of the fit to the remaining six CPUE indices (**Figure 29**). The general annual trends in fishing mortality and biomass were similar to those obtained when fitting the model with the combined abundance index. Changes in fishing mortality were, however, different in the recent years and characterized by a significant decrease in F that became lower than F_{MSY} in 2010, indicating a non-overfishing condition of the stock in 2010 (**Figure 30**).

6.2 VPA

This section summarizes the results from VPA analyses explained in Section 5.2. The executables, inputs, outputs and report files were archived following the assessment meeting and can be obtained through the ICCAT Secretariat.

– *Comparison of 2008 and 2011 VPA continuity models*

Two sets of model runs were made to examine the impact of updated data, without altering the settings and specifications of the 2008 assessment. The 2011 DELTA-CAA runs were constructed to examine the implications of the revised catch-at-size provided by the Secretariat and the CONTINUITY runs were constructed to examine the implications of the new catch-at-size information and updated indices of abundance.

The annual trends in stock status were compared to the 2008 model results. The results of the "DELTA CAA" models were nearly identical to the 2008 base assessment models (**Figure 31**) which suggest that revisions to the catch-at-size had very little effect on our perception of stock status from 1970-2006.

The 2006 stock status estimates of the CONTINUITY" models were somewhat more optimistic than the 2008 base assessment models (**Figure 32**). This indicates that updating the indices and extending the model through 2010 had a significant effect of the perception of stock status when all other model specifications were unchanged.

– *VPA base models*

Four VPA models were initially chosen by the working group to provide management advice. Annual trends in yield, total biomass, apical fishing mortality, recruits (Age 0), and spawning stock biomass (SSB) are shown in **Figures 33**–**36**. Management reference points and benchmarks for the VPA base runs are summarized in **Table 24.**

– *Diagnostics*

Fits to the CPUE series for the VPA continuity and base models are summarized in **Figures 37**-**40**. The fits to the base models show a substantial lack of fit to many indices, this is particularly true of Runs 2 and 4 for which annual index selectivity was fixed each year using information from the fleet-specific catch-at-age.

Early model runs included an index from the Canary Islands bait boats. The VPA model was not able to fit this index without a severe deviation, therefore this index was removed and the models were re-run. The base model fit statistics are summarized in **Table 25**.

– *Retrospectives*

A retrospective analysis was completed by sequentially removing inputs of catch and abundance indices from the 2011 base case models. The retrospective analyses showed unstable patterns in fishing mortality at age (**Figure 41**), numbers at age (**Figure 42**) and spawning stock biomass (**Figure 43**) for base run 2. Therefore, the Working Group recommended that this model not be used to develop management advice. The retrospective patterns were acceptably stable for the other base runs.

– *Sensitivity runs*

Sensitivity of the VPA model to individual indices was evaluated by performing a sequential removal of a single index series from the model (**Figures 44** and **45**). These plots reinforce the decision to remove model 2 from management advice as the effects of removing single index lead to vastly different model outcomes. For models 3 and 4 the divergence created by sequential removal occurs exclusively in later than 2000 and then only in estimated fishing mortality and recruitment levels. The greatest divergence in estimated recruits results from removal of the EU_FAD fishery index as this is the only index of recruitment in the model. In the absence of an index of recruitment, the VPA predicts much lower recent recruitment levels and, consequently higher fishing mortality rates. Regarding the effect of other indices on patterns of fishing mortality, SSB and recruits, there was no single index, except the EU-FAD that showed a particular influence on the model results.

– *Stock status*

The results of the three base VPA models are consistent. According to 2011 VPA median results, yellowfin tuna are currently overfished (SSB_{2010}/SSB_{MSY} ranged from 0.46 to 0.58) and undergoing overfishing ($F_{Current}/F_{MSY}$ = 1.25 to 1.43). Since 2006, the terminal year of the previous stock assessment, the spawning stock biomass has deteriorated somewhat (SSB_{2006}/SSB_{msy} ranged from 0.53 to 0.68). Uncertainty in the stock status was estimated by bootstrapping the index residuals. Five hundred bootstraps were run for each VPA base model. These are summarized in **Figure 46**.

To account for the effect of changes in selectivity on MSY based reference points, trajectories of annualized stock status were calculated according to the annual selectivity pattern. This method uses the VPA results and allows computation of annual MSY, F_{MSY} and SSB_{MSY} estimates that are not available from the VPA-2BOX report. The trajectories of stock status and MSY are summarized in **Figures 47** and **48.**

The results of this assessment do not capture the full degree of uncertainty in the assessments and projections. An important factor contributing to uncertainty is the accuracy of the growth curve and the age-slicing procedure. Age-slicing procedures are sensitive to small changes in slicing limits. Improved methods to estimate catch-at-age (e.g. stochastic approaches and/or directly observed age composition) have the potential to improve the reliability of age-structured models. Another important source of uncertainty is recruitment, both in terms of recent levels (which estimated with low precision in the assessment), and potential future levels. These models assume recruitment would continue at the level observed during 1970-2010. It is possible that changes in fishing pressure or environment could invalidate this assumption.

6.3 Synthesis of assessment results

Results from the various stock assessment models indicate that stock status differs from that estimated during the 2008 assessment. In 2008, the stock status determination was based on a combination of production model results obtained with ASPIC and age-structured (VPA) models. The 2011 stock assessment stock status determination was conducted applying these same types of models, configured in a similar fashion as in 2008 (although some model specifications were changed, as described previously), but with updated information. The bootstrapped results for current status estimates by base case model run are shown in **Figure 49**. Results from the age-structured models point to a more pessimistic stock status (in terms of spawning stock biomass) than did the production model results (fishable biomass), as shown in **Figure 50**, with VPA results generally indicating a lower relative biomass (a more overfished status) and a higher relative fishing mortality rate (higher level of overfishing). The final estimate of current stock status relative benchmarks (F/F_{MSY} and B/B_{MSY}) and uncertainty around the estimates was derived from the combined joint distribution (**Figure 51**) from these base cases (ASPIC runs 9, 10, 11, and 12, as well as VPA runs 1, 3, and 4). The various sensitivity runs, which were conducted applying alternative specifications or abundance index combinations, were considered by comparing the resulting point estimates to the base case joint distribution. This was also done for the alternative models that were run (PROCEAN). The estimates of current stock status (in terms of relative F and relative biomass) developed from the combined base runs of ASPIC and VPA are summarized in **Table 26.**

– *Impacts of the recent increased purse seine effort on the Atlantic yellowfin tuna stock*

Purse seine fishing effort has increased in the Atlantic (**Figure 52**) since 2006, as a number of vessels have left the Indian Ocean and have instead been fishing in the Atlantic. These vessels tend to be newer, with a larger carrying capacity, than the typical vessels fishing in the Atlantic. Overall carrying capacity of the European and associated fleet in 2010 has increased to about the same level as in the 1990s and FAD based fishing has accelerated more rapidly than free school fishing (although both have substantially increased), with the number of sets on FADs reaching levels not seen since the mid-1990s. The impacts on yellowfin tuna of this increased purse seine effort was evaluated in several ways. It was noted that this impact is likely different from that on bigeye since only a minor proportion of the yellowfin catch (in tonnage) occurs in FAD fishing.

The overall catches of yellowfin estimated for 2008-2010 were about 10% or higher than the recent low of 2007. The relative contribution of purse seine gear to the total catch has increased by about 20% since 2006 (**Figure 53**). The current total catch remains below the historical peak, when the overall fishery selectivity was different. Estimates of fishable biomass trends from production modeling indicate a slow, continued rebuilding tendency (**Figure 54**), but estimates of spawning stock biomass trend from the age-structured assessment indicates recent decline and corresponding increasing F on mature fish (**Figure 55**). In either case, continued increasing catches are expected to slow or reverse rebuilding of fishable biomass and accelerate decline in spawning stock biomass.

7. Projections

Bootstrap results from ASPIC and VPA were projected into the future for different levels of catch (from 50,000 to 150,000 t in 10,000 t steps). It was assumed that the catch in 2011 would be the same as the catch in 2010, and the biomass during 2011 constitutes the first projection. Projections for 15 years (until 2026) were carried out. Future selectivity was assumed constant and in the case of VPA it was assumed to be equal to the geometric mean of the selectivity pattern estimated for 2007-2010.

7.1 ASPIC model projections

These were done for each of the 500 bootstraps of runs 09, 10, 11 and 12. For all runs examined median values of projected biomass ratios suggest that in order for the stock biomass to rebuild catches need to be lower than 130,000 t (**Figure 56**). Catches of 120,000 t only allow a slow rebuilding to B_{MSY} by 2023 or 2024. Catches of 100,000 t rebuild the biomass faster, and projected median B_{MSY} is reached by 2017. Similarly median fishing mortality ratios only consistently reduce towards F_{MSY} for catch levels below 130,000 t (**Figure 57**). The projected reduction of fishing mortality to F_{MSY} is achieved faster than the increase of biomass towards B_{MSY}. Catches of 120,000 t are projected to reduce fishing mortality below median F_{MSY} by 2018, and catches of 100,000 t by 2012.

7.2 VPA model projections

– *Specifications*

The projections for yellowfin tuna were based on the 500 bootstrap replicates of the fishing mortality-at-age and numbers-at-age matrices produced by the VPA-2BOX software. The Group agreed that projections and benchmarks should be computed using a re-sampling of observed recruitments during 1970-2009. This resulted in a constant recruitment at the mean value of the time series. This is in agreement with the approach used during the 2008 assessment. Projections that used various levels of constant catch employed a restriction that the fully-selected *F* was constrained not to exceed 5 yr^{-1}.

– *Results*

VPA projections of total biomass, yield, fishing mortality, SSB and recruitment are shown in **Figures 58-61**. Projection results of the three base VPA case scenarios indicated that catch of 120,000 t or less would allow with 50% probability, the spawning stock biomass to increase. However, only catches at 110,000 t or below would allow with 50% or greater probability SSB to be at the SBB level corresponding to MSY before 2020. Also, catches of 120,000 t or less would reduce fishing mortality from current levels (F_{2010}). Similarly, only catches at 110,000 t or below would allow with at least 50% probability, F to be below the fishing mortality at MSY (F_{MSY}) before 2020.

8. Recommendations

The Group recommended that historical and present samples of size frequency (in contrast to raised and substituted size-frequency) be recovered and provided to the Secretariat in support of conducting stock evaluations that make use of the sampling fraction in calculations.

The Group recommended the evaluation of market information sources or other alternative ways to improve the accuracy of catch estimates coming from logbooks.

Due to the incidence of the technological improvements of the different fleets in the CPUE standardization the Group recommended consideration of vessel and gear characteristics when conducting this type of analysis.

Recalling the previous SCRS recommendation, the Group reaffirmed that catch and catch at size necessary for fine-scale scientific analysis be reported by CPCs in at most 5x5 degree resolution.

The Group recommended that procedures for collection of size samples should be reviewed to assure that there is no size bias in sampling, as the Group suspects that such size-bias may be occurring in certain fisheries.

The Group recommended that analysis of CPUE should incorporate methods to include the full time-series of catch-effort statistics for fisheries to avoid fore-shortening of time series.

The Group recommended that the sensitivity of assessment to alternative forms of ageing catch at size should be evaluated in advance of the next assessment.

The Group recommended that implications of growth in the plus group used in the VPA should be evaluated in advance of the next assessment.

The Group recommended re-evaluation of the length -weight and associated relationships which were developed on historical information. It is possible that such relationships have changed as the stock condition has changed over time.

In order to accommodate review of these, and other, recommendations, the Group considers advance data preparation work and a preparatory meeting a necessary step to take in advance of the next assessment

9. Other matters

No additional matters were discussed.

10. Adoption of the report and closure

The Group agreed to adopt the report through correspondence. Dr. Brown thanked the participants, the AZTI staff and the Secretariat for their hard work and adjourned the meeting.

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Table 1. Task I nominal catch best estimate by the tropical YFT Working Group calculated for the stock assessment 2011.

Stock	GearGrp2	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	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
ATE	PS														1300	7225	8279	15658	18722	29745	44314	33387	32218	46948	44554	53093	83013	85260	90552	98098	92291	97026	115312	112161	103986	50970	86648	85464	87074	74049	103025	128729	99402	101987	94880	92050	88770	89882	79339	84771	75260	74670	95612	89572	77481	59011	58776	57024	50392	69407	76550	69953
	BB						200	5723	9187	10304	5775	11247	9839	10557	17785	21116	18486	15050	16761	22135	15673	9660	10576	13141	14746	19696	9658	12794	10943	8980	13715	7737	9789	13211	11507	14694	16120	15301	16750	16020	12168	19648	17772	15095	18471	15652	13496	13804	12907	17330	19256	13267	19071	13432	11513	15354	12012	10434	8896	11721	10949	8132
	LL								10347	13987	32761	40606	40940	17492	23263	19027	27663	12931	17741	22711	21358	16572	15099	18506	20629	19535	15575	12837	15662	11290	6777	12508	7986	10456	6143	8146	9520	5779	6624	8956	7566	10253	9082	6518	8537	14638	13723	14236	10495	13872	13561	11369	7570	5790	9075	11442	7317	7219	13437	8566	6321	6229
	Others	1200	1200	2600	3600	3400	4100	111	323	45	112	125	202	274	60	34	13	12	1		5	115	121	110	109	103	84	129	384	878	1375	574	5347	3224	3904	2407	1516	2296	2932	2646	2586	2175	3748	2450	2122	2030	1989	2065	2136	1674	1580	2424	2074	1826	2540	2928	3062	3615	2726	1731	2843	1819
ATE Total		1200	1200	2600	3600	3400	4300	5834	19857	24336	38648	51978	50981	28323	42408	47402	54441	43651	53225	74591	81350	59734	58014	78705	80038	92427	108330	111020	117541	119246	114158	117845	138434	139052	125540	76217	113803	108839	113379	101671	125345	160805	130004	126050	124009	124369	117977	119987	104877	117647	109656	101730	124327	110619	100608	88735	81166	78292	75452	91424	96663	86133
ATW	PS														199	126			218	114			17	3410	2250	339	1577	634	1073	3662	1035	4870	2822	12112	25749	23203	20994	9822	6665	6034	11647	6800	14414	11359	16081	19612	6338	10784	11710	9157	6523	7870	13108	7966	4607	3217	2634	4442	2341	2067	1365	4219
	BB																								26	1278	408			1012	605	392	1917	2970	3603	3698	5478	2421	5468	5822	4834	4718	5359	6276	6383	7094	5297	4560	4275	5511	5349	5649	5315	6009	3764	4868	3867	2695	2304	886	1331	1436
	LL							612	3539	15962	19121	16515	7822	29200	21891	21300	13181	14985	6682	9518	13121	14422	16135	12214	12517	12747	14084	12774	11374	9572	9277	6735	11323	9926	7620	8855	10193	18490	14291	19046	17128	18851	13667	16594	11439	11790	11185	11882	11554	11671	13493	15760	14872	11921	10166	16019	14449	14254	13563	13197	13028	13073
	Others		158	187		7		151	302	283					100	100	100	100	100	100	100	299	299	299	302	350	397	532	1025	552	2442	901	1642	1282	3345	2077	6150	7101	5557	3692	3293	2362	3457	3483	4842	9719	12454	5830	4801	4581	5345	5241	7027	3763	6445	7134	5118	6880	5959	1973	3285	3482
ATW Total			158	187		7		763	3841	16245	19121	16515	7822	29200	22190	21526	13281	15085	7000	9732	13221	14721	16451	15923	15095	14714	16466	13940	13472	14798	13359	12898	17704	26290	40318	37833	42815	37834	31982	34594	36902	32731	36897	37712	38745	48215	35274	33056	32341	30919	30710	34519	40323	29660	24982	31238	26068	28272	24167	18123	19008	22210
Grand Total		**1200**	**1358**	**2787**	**3600**	**3407**	**4300**	**6597**	**23698**	**40581**	**57769**	**68493**	**58803**	**57523**	**64598**	**68928**	**67721**	**58736**	**60225**	**84323**	**94571**	**74455**	**74465**	**94628**	**95133**	**107141**	**124796**	**124960**	**131013**	**134044**	**127517**	**130743**	**156138**	**165342**	**165857**	**114050**	**156619**	**146673**	**145361**	**136265**	**162247**	**193536**	**166901**	**163762**	**162753**	**172584**	**153251**	**153043**	**137218**	**148566**	**140366**	**136249**	**164650**	**140279**	**125590**	**119972**	**107234**	**106564**	**99619**	**109548**	**115671**	**108343**
Stock	**Flag**	**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**	**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**
ATE	Angola	1200	1200	2600	3600	3400	4100	3734	2610	2049	1387	2472	2241	2065	2209	3635	1941	1331	885	1087	390	361	498	611	603	839	55	1005	2085	2296	904	558	959	1467	788	237	350	59	51	246	67	292	510	441	211	137	216	78	70	115	170	35	34	34	34	34	111		405	98	98	98
	Belize																																														1		3			5										273
	Benin																														48	95	100	113	49	65	60	19	3	2	7	1	1	1	1	1	1	1	3	1	1	1	1									
	Cambodia																																																		7											
	Canada																45	646	680	655	936	191	44		61																																					
	Cape Verde																					346	296	455	445	410	360	115	104	470	581	864	5281	3500	4341	2820	1901	3326	2675	2468	2870	2136	1932	1426	1536	1727	1781	1448	1721	1418	1663	1851	1684	1802	1868	3236	7154	8112	4057	8413	3273	4492
	Cayman Islands																															602	1460	100																												
	China P.R.																																												139	156	200	124	84	71	1535	1652	586	262	1033	1030	1112	1056	1000	365	214	169
	Chinese Taipei													66	95	94	44	904	2147	7458	7910	4407	3842	3955	1695	1130	1469	678	208	203	190	71	432	203	452	87	146	254	193	207	96	2244	2163	1554	1301	3851	2681	3985	2993	3643	3389	4014	2787	3363	4946	4145	2327	860	1707	807	1180	532
	Congo																															140	50				11	20	15	15	21	22	17	18	17	14	13	12														
	Côte D'Ivoire																																																2			673	213	99	302	565	175	482	216	626	90	470
	Cuba																535	367	2412	1224	940	1120	1760	3240	4900	3426	2000	2400	3000	2339	3168	5128	2945	2251	1916	1467	1585	1332	1295	1694	703	798	658	653	541	238	212	257	269													
	EU.España													1502	3009	3256	3179	1502	3124	3347	5696	7087	7829	9294	14055	16077	24713	33423	35525	33636	40083	38759	51428	54164	51946	40049	66874	61878	66093	50167	61649	68603	53464	49902	40403	40612	38278	34879	24550	31337	19947	24681	31105	31469	24884	21414	11795	11606	13584	24409	32793	25560
	EU.Estonia																																										234																			
	EU.France						200	2100	6900	8300	4500	8900	7800	6100	13050	18970	19200	21950	23350	31350	28473	24123	26069	31244	31687	38206	46669	51624	49948	55192	47776	54372	55085	45717	40470	7946	12304	17756	17491	21323	30807	45684	34840	33964	36064	35468	29567	33819	29966	30739	31246	29789	32211	32753	32429	23949	22672	18940	11330	16115	17261	20280
	EU.Ireland																																																				3									
	EU.Latvia																																										255	54	16		55	151	223	97	25	36	72	334	334	334	334	334				
	EU.Lithuania																																										332																			
	EU.Poland																																	20																												
	EU.Portugal																										1	3		125	185	77	208	981	1333	1527	36	295	278	188	182	179	328	195	128	126	231	288	176	267	177	194	4	6	4	5	16	274	865	300	990	554
	EU.United Kingdom																																																												0	
	Faroe Islands																																																			1										
	Gabon																															47	1												12	88	218	225	225	295	225	162	270	245	44	44	44	44				
	Gambia																																									2	16	15																		
	Georgia																																										25	22	10																	
	Ghana																							2	112	274	763	945	621	546	1426	1974	5510	9797	7689	9039	12550	11821	10830	8555	7035	11988	9254	9331	13283	9984	9268	11720	15437	17657	25268	17662	33546	23674	18457	15054	17493	11931	15463	14250	18355	12512
	Guatemala																																																								2906	5265	3461	3736	2603	3124
	Guinea Ecuatorial																																																1												892	892
	Guinée Conakry																																																													730
	Honduras																																											2			4	3	4	3												
	Japan								10347	13987	32761	40606	40940	18590	23974	21062	28962	15888	16664	19369	12072	4421	5492	8315	9051	8513	3021	5238	2647	1722	1241	2217	2863	4815	3062	4344	5765	3634	4521	5808	5882	5887	4467	2961	2627	4194	4770	4246	2733	4092	2101	2286	1550	1534	1999	5066	3088	4206	8496	5266	3563	3037
	Korea Rep.																	293	365	1600	4200	8020	6900	7800	9008	11832	10304	7636	11060	8625	6449	5349	4288	4010	1629	1917	1668	965	1221	1248	1480	324	259	174	169	436	453	297	101	23	94	142	3	8	209	984	95	4	303	983	375	324
	Libya																																																				208	73	73							
	Maroc																									290	1048	1574	2167	3440	2986	3243	4817	4540	2331	614	2270	2266	1529															79	108	95	183	95	102	110	110	44
	Mixed flags (FR+ES)																																319	341	484	110	72	138	933	932	825	1056	2220	2455	2750	1898	1172	1166	981	1124	1369	1892	1427	599	992	1052	933	1063	655	626	459	533
	Namibia																																													35	14	72	69	3	147	59	165	89	139	85	135	59	28	11	1	9
	NEI (ETRO)																																	3121	5388	1104			2077	3140	5436	12601	4856	10921	9875	8544	8970	9567	6706	7225	5418	5448	10169	8209	5396	4294	1781	219				
	NEI (Flag related)																																		103	54	76	150	285	206	280	1115	2310	1315	1157	2524	2975	3588	3368	5464	5679	3072	2090	133	466							
	Netherlands Antilles																																															3183	6082	6110	3962	5441	4793	4035	6185	4161		1939	1368	7351	6293	5302
	Norway																								344													813	418	493	1787	1790																				
	Panama																							510	3709	3172	2016	2892	1736	1477	739	1661	341	1933	1568	1653	3100	1944	1858	1239	901	1498	7976	8338	10973	12066	13442	7713	4293	2111	1315	1103	574	1022		1887	6170	8557	9363	6175	5813	5048
	Philippines																																																	126	173	86	0	50	9	68	13	30	88	53	10	21
	Russian Federation																																										3200	1862	2160	1503	2936	2696	4275	4931	4359	737					4	42	211		33	
	S. Tomé e Príncipe																										25	15	45	39	28	31	97	193	194	177	180	180	178	298	299	164	187	170	181	125	135	120	109	124	114	122	122	122	122	134	145	137		160	165	169
	Senegal																																								2	90	132	40	19	6	20	41	208	251	834	252	295	447	279	681	1301	1262	819	588	1279	1212
	Seychelles																																																			6		11								
	South Africa														71	285								54	65	57	18	6	167	281	4595	540	178	49	456	759	382	55	68	137	671	624	52	69	266	486	183	157	116	240	320	191	342	152	298	402	1156	1187	1063	351	303	235
	St. Vincent and Grenadines																																																					5		14		101	209	83	74	28
	U.S.A.																		918	5827	18791	9029	3764	12021	3017	5621	13960	1706	6400	8131	2884	1614	1472	636																												
	U.S.S.R.															100	535	770	2680	2674	1942	529	1420	1104	1186	2505	1856	1652	1794	687	806	448	541	1004	1282	2168	3768	1851	1275	3207	4246	3615																				
	UK.Sta Helena																					100	100	100	100	75	52	108	34	37	69	55	59	97	59	80	72	82	93	98	100	92	100	166	171	150	181	151	109	181	116	136	72	9				344	177	97	104	65
	Ukraine																																										215																			
	Vanuatu																																																								24	145	483	450	331	421
	Venezuela																																				634																									
ATE Total		1200	1200	2600	3600	3400	4300	5834	19857	24336	38648	51978	50981	28323	42408	47402	54441	43651	53225	74591	81350	59734	58014	78705	80038	92427	108330	111020	117541	119246	114158	117845	138434	139052	125540	76217	113803	108839	113379	101671	125345	160805	130004	126050	124009	124369	117977	119987	104877	117647	109656	101730	124327	110619	100608	88735	81166	78292	75452	91424	96663	86133
ATW	Argentina											2	25	23	78	129	100		23	139	100		150	400	129	112	108	57	43	4			8	7			44	23	18	66	33	23	34	1						0						327	327					
	Barbados																									48	79	94	58	67	81	40	30	36	51	90	57	39	57	236	62	89	108	179	161	156	255	160	149	150	155	155	142	115	178	211	292	197	154	156	79	129
	Belize																																																									143	1164	1160	988	1785
	Brasil									1740	5920	4700	4400	1400	2400	1624	696	464	812	812	464	812	347	233	153	232	260	715	1302	852	1353	1008	2084	1979	2844	2149	2947	1837	2266	2512	2533	1758	1838	4228	5131	4169	4021	2767	2705	2514	4127	6145	6239	6172	3503	6985	7223	3790	5468	2749	3313	3617
	Canada																											161		318								2	40	30	7	7	29	25	71	52	174	155	100	57	22	105	125	70	73	304	240	293	276	168	53	166
	China P.R.																																																	628	655	22	470	435	17	275	74	29	124	284	248	258
	Chinese Taipei													212	304	302	139	339	876	1426	4292	3583	1096	1362	1305	1500	1200	1284	164	181	848	616	435	407	87	559	780	1156	709	1641	762	5221	2009	2974	2895	2809	2017	2668	1473	1685	1022	1647	2018	1296	1540	1679	1269	400	240	315	211	292
	Colombia																																	3	29		180	211	258	206	136	237	92	95	2404	3418	7172	238	46	46	46	46	46	46	46	46	46	46				
	Cuba														1700	900	219	443	580	652	615	480	340	360		374	600	1200	900	661	232	689	1997	1503	793	2538	1906	2081	1062	98	91	53	18	11	1	14	54	40	40	15	15			65	65	65	65	65				
	Dominica																																									18	12	23	30	31	9				80	78	120	169	119	81	119	65	103	124	102	110
	Dominican Republic																																																	89	220	226	226	226	226	226	226	226				
	EU.España																							489			762		266	2029	1052				1957	3976	1000			1	3	2	1462	1314	989	7	4	36	34	46	30	171						1	84	81	69	27
	EU.France																							2600	1677	339	440				86																															
	EU.Netherlands																																																											0	1	
	EU.Portugal																																																								151	60	88	179	260	99
	Grenada														100	100	100	100	100	100	100	100	100	100	100	100	100	100	364	166	148	487	64	59	169	146	170	506	186	215	235	530	620	595	858	385	410	523	302	484	430	403	759	593	749	460	492	502	633	756	630	673
	Jamaica																																															21	21													
	Japan							612	2851	13172	11310	10216	1669	24547	14620	16558	10369	11757	2687	4158	3600	4313	9052	4155	2510	3985	2756	3069	1408	1647	1707	1117	2983	3288	1218	1030	2169	2103	1647	2395	3178	1734	1698	1591	469	589	457	1004	806	1081	1304	1775	1141	571	755	1194	1159	437	541	986	1431	1668
	Korea Rep.																	4	67	670	1782	3486	3001	3278	4547	5400	7718	4574	6522	4259	4414	1933	3325	2249	1920	989	1655	853	236	120	1055	484	1	45	11			84	156								580	279	270	10	52	56
	Mexico																															16	42	128	612	1059	562	658	33	283	345	112	433	742	855	1093	1126	771	826	788	1283	1390	1084	1133	1313	1208	1050	943	896	961	1220	924
	NEI (ETRO)																																																				36									
	NEI (Flag related)																																		651	352	450	806	1012	2118	2500	2985	2008	2521	1514	1880	1227	2374	2732	2875	1730	2197	793	42	112							
	Netherlands Antilles																					151	151	151	151	151	151	151	151	173	173	173	173	173	173	173	150	150	160	170	170	170	150	160	170	155	140	130	130	130	130	130										
	Panama																							28	1978	1114	1191	1283	582	1440	102	807	262	675	62	246		5278	3289	2192	1595	2651	2249	2297							5							2804	227	153	288	2134
	Philippines																																																	36	106	78	12	79	145	299	230	234	151	167	142	67
	Seychelles																																																			32										
	St. Vincent and Grenadines																																								1	40	48	22	65	16	43	37	35	48	38	1989	1365	1160	568	4251		2680	2989	2547	2274	854
	Sta. Lucia																					48	48	48	51	51	54	69	67	67	28	27	25	26	23	56	79	125	76	97	70	58	49	58	92	130	144	110	110	276	123	134	145	94	139	147	172	103	82	106	97	223
	Trinidad and Tobago																																		232	31				1	11	304	543	4	4	120	79	183	223	213	163	112	122	125	186	224	295	459	615	520	629	788
	U.S.A.		158	187		7		151	302	283	111			17	207	126			218	114			17	321	573		375	546	808	1616	298	553	1688	1095	2553	2180	9735	9938	9661	11064	8462	5666	6914	6938	6283	8298	8131	7745	7674	5621	7734	7051	6703	5710	7695	6516	5568	7091	5529	2473	2788	2648
	UK.Bermuda																										10	11	10	12	26	35	21	22	10	11	42	44	25	23	22	15	17	42	58	44	44	67	55	53	59	31	37	48	47	82	61	31	30	15	41	37
	UK.British Virgin Islands																																																									1		0		
	UK.Turks and Caicos																																																							0		0	1	0		
	Uruguay																																67	214	357	368	354	270	109	177	64	18	62	74	20	59	53	171	53	88	45	45	90	91	95	204	644	218	35	66	76	122
	Vanuatu																																																							681	689	661	555	873	816	748
	Venezuela								688	1050	1780	1597	1728	3001	2781	1787	1657	1978	1637	1661	2268	1748	2149	2398	1921	1308	662	626	827	1306	2811	5397	4500	14426	26576	21879	20535	11755	11137	10949	15567	10556	16503	13773	16663	24789	9714	13772	14671	13995	11187	10558	18651	11421	7411	5774	5097	6514	3911	3272	3198	4783
ATW Total			158	187		7		763	3841	16245	19121	16515	7822	29200	22190	21526	13281	15085	7000	9732	13221	14721	16451	15923	15095	14714	16466	13940	13472	14798	13359	12898	17704	26290	40318	37833	42815	37834	31982	34594	36902	32731	36897	37712	38745	48215	35274	33056	32341	30919	30710	34519	40323	29660	24982	31238	26068	28272	24167	18123	19008	22210
Grand Total		**1200**	**1358**	**2787**	**3600**	**3407**	**4300**	**6597**	**23698**	**40581**	**57769**	**68493**	**58803**	**57523**	**64598**	**68928**	**67721**	**58736**	**60225**	**84323**	**94571**	**74455**	**74465**	**94628**	**95133**	**107141**	**124796**	**124960**	**131013**	**134044**	**127517**	**130743**	**156138**	**165342**	**165857**	**114050**	**156619**	**146673**	**145361**	**136265**	**162247**	**193536**	**166901**	**163762**	**162753**	**172584**	**153251**	**153043**	**137218**	**148566**	**140366**	**136249**	**164650**	**140279**	**125590**	**119972**	**107234**	**106564**	**99619**	**109548**	**115671**	**108343**

Table 2. CAS (number of fish by size) matrix for yellowfin tuna 1970-2010 for all gears.

FL cm	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
30	8760	507	18552	0	0	2963	0	0	3015	2739	3507	24022	21770	27150	5953	7689	10768	54857	49072	43777	68515	125368	132198	146032	99758	70737	62076	76283	137746	82714	117412	94748	48608	107882	113615	75135	83164	80982	104669	76278	50693
32	4432	166	7602	1634	5990	6437	238	1488	5020	3198	4276	57859	38237	59216	15951	19944	16042	119577	114348	100481	141065	263063	287949	308715	208173	142922	142363	173393	184940	211357	265238	246876	97186	206121	211116	160851	165225	144662	198612	126767	113972
34	8507	1364	13780	5454	29522	13209	11497	12444	10941	14860	12086	148191	81389	147717	59730	62441	60374	250027	241146	254853	264636	474589	580414	594663	381803	260129	260339	385056	333659	402978	512492	418813	175274	414034	438853	315893	301363	314785	333511	228481	234679
36	9807	4150	10152	6319	62407	32286	70520	61133	23999	94095	66651	524775	180098	331398	172407	308702	122987	461316	418305	464675	503633	709138	880114	907472	523861	357747	345915	440545	485132	640731	697866	723823	299742	686453	725600	490467	397032	534417	450574	351193	420741
38	11941	13424	24610	13807	124524	74774	143425	116791	63290	178701	154337	880650	249331	474669	373687	594076	258470	707349	517596	659735	617419	685718	986263	949085	489446	362084	384535	470482	445142	626837	772065	1229435	375357	798534	670121	525917	348658	611156	489848	459129	542534
40	29350	30991	42152	36241	163037	158502	197335	127197	183189	236974	250482	921737	397088	748035	510560	679313	478751	983642	620155	968803	1024439	905909	1060365	1057905	442091	444817	439644	475276	482972	725217	963775	1238666	564864	930370	865446	712325	441328	871355	754813	699853	820906
42	44661	58948	65612	56366	171824	209869	224502	123836	170811	229761	313690	859518	576458	952798	614581	674302	676210	1160227	881874	1304611	1145301	908106	1019946	1670362	690579	740426	735624	630017	674000	882752	1285935	1980979	857602	1088109	983494	928459	546096	1231009	1217648	794867	1047078
44	48666	74301	72614	57187	157500	223650	265805	114396	171933	197354	255096	934149	588086	763554	561469	834907	738084	1137810	1014250	1179284	1821747	1401379	941671	2512264	938128	1217770	1164555	749627	980188	1718169	1686450	1953218	1638164	1283265	1376875	1134989	751835	1455597	2167204	1312327	1397236
46	172923	188815	153204	125757	241470	271333	346102	187235	266785	395309	645231	1362054	1347669	1154800	720936	963074	1090229	1235989	1423470	1580395	1817648	1387131	1050872	1343131	1356711	1509442	1661482	1063110	1254476	2283602	1926545	1701801	2354089	1714558	1841091	1552010	1320273	1540464	2347245	1078329	1191494
48	233741	209259	200246	164175	324171	307508	331893	193203	286483	424914	723604	1066438	1398336	1026661	740886	814171	1082380	994573	1290493	1268563	1370149	1044743	1140127	1326120	1683237	1672982	1729465	1443668	1300501	2537478	1752798	1888446	2739995	1736114	1857257	1624609	1116151	1407105	1833185	987482	964665
50	247461	179034	187893	131025	287570	282742	213570	171572	231497	242743	476356	539634	851515	445074	581798	515682	595482	492070	591885	469595	911246	688826	678827	640676	1044150	984806	1038818	1088339	1225705	2206066	1330225	1355722	2212359	1316555	1305529	1441449	670701	917226	840827	693045	605546
52	286443	195456	182510	127089	275257	206610	196282	210839	235395	244902	480012	472504	803119	398031	565149	443086	415995	462402	514974	356128	563177	508936	499197	529276	875279	656652	829657	1228489	1240062	1404684	1112201	1462245	1472385	1039254	781605	974345	541621	619693	416961	428182	409403
54	310085	224042	204020	131616	243796	169851	233512	255611	299080	291178	492756	418718	738820	318084	629954	388548	317253	360544	361640	238407	365048	397943	318812	438719	338046	371914	432592	550846	1003434	881399	572671	1106942	791723	738973	672278	724237	283422	376360	385331	453583	492373
56	316164	281539	284287	179191	259017	138172	349180	335075	415133	393290	562650	467553	789651	354889	646907	317250	372561	392093	341391	284747	326812	393513	228419	405231	369573	326184	297490	368068	670672	514025	434457	1002130	455463	439873	386899	572627	352289	234643	209356	331078	462652
58	243029	267402	276363	193908	254210	97150	396106	339529	421482	326569	450260	427922	641284	337049	500164	279781	330684	384228	301844	229148	272460	334199	201895	304484	318726	193957	278064	336172	446529	297652	249902	694464	253796	266885	183388	255591	236989	181501	177390	262814	319162
60	188554	209483	226870	172022	213009	75236	405193	405517	333965	285724	322625	361132	430373	326090	531200	262009	361241	326417	261614	106700	248773	293708	177889	269422	251744	191568	215329	209243	272187	198783	313227	519687	173117	213428	161635	219856	205198	124669	119052	270075	198768
62	121875	137050	156746	133486	167505	57525	293183	281011	192010	186980	161785	213343	246187	258139	414606	236351	317915	197998	208657	66473	162237	205317	154365	200292	166214	199913	151980	164601	244097	159453	252102	374308	122615	112078	76496	134428	167377	85742	91947	240765	188963
64	85587	100326	127004	114064	147985	48210	184331	231150	155844	130368	122754	154903	197762	182316	365082	164139	206737	142512	205871	73473	194952	173896	153424	208271	253311	275326	206124	198025	320604	233421	228504	309288	160456	186414	107764	221511	163384	97703	84419	164790	95685
66	66674	70975	94492	80746	97896	35978	128154	136323	135726	87815	74183	97498	142657	144779	433581	156632	148080	119564	164472	53108	196208	151267	157613	170243	189944	188155	139756	143880	204421	135598	112389	134865	73203	93891	51372	164108	80813	73751	57802	256201	177180
68	46177	51974	73750	59813	60979	24733	110438	85915	78976	62228	53904	66365	110241	135191	278078	155856	101625	111660	139842	53729	148787	104221	147538	184020	216637	146264	125574	134616	173888	116587	109010	163748	102292	113053	87514	160219	96347	46966	67739	180754	98653
70	49923	63524	70241	65739	67732	27874	110574	81192	87294	60416	43089	63913	113530	94372	304726	192912	118022	126672	129878	47134	202757	118446	160787	141836	142423	125658	108888	109981	160360	103882	47721	118353	77305	80533	63736	74520	51406	54275	49084	193780	119013
72	47783	73606	69754	62238	72861	29134	87862	71351	83639	63444	41925	65618	109966	83232	188844	141449	88719	120823	106642	53824	171959	98732	151012	156727	161955	145957	117442	147084	155549	134987	53754	112997	96014	79330	80340	93232	67184	39402	50932	106705	58042
74	43967	72346	62678	52026	66513	30194	132801	70138	62982	50892	33920	58487	112585	77292	231263	126224	82344	100886	83777	41442	113978	100651	112738	104718	81564	99228	90898	119175	154451	133019	49082	68859	89241	71170	42002	71062	47840	56445	42584	123231	77015
76	36740	65107	52664	44258	47623	26130	96869	54838	55823	41837	35389	59173	95857	57787	157939	116521	69909	86754	73277	33240	110597	94310	106497	117478	180517	118330	109860	124592	116449	131212	76573	132599	145212	124231	77084	72880	58697	44644	43557	55698	22292
78	36102	56627	42711	36133	37160	27585	96570	58497	53566	43564	38105	56348	82397	69576	139094	71162	62968	92583	68984	52397	60627	158834	52789	119145	135416	122467	106448	121491	178809	110246	60794	81023	76311	97103	55098	66792	55371	44911	36157	63319	58838
80	25706	47533	39489	35089	34727	24686	61220	40076	37258	46938	28616	49510	69990	76982	127741	83997	65846	87628	56777	61766	56474	91216	44538	49647	88641	73412	77650	84408	70549	154871	58053	83831	50920	48611	30179	58410	50297	25953	22763	58588	57973
82	23643	42700	36712	33612	34490	28390	49689	38721	32729	50906	24435	48255	73568	90305	142853	73528	58120	80483	49892	40357	43801	62328	26305	44011	83007	62392	53966	57378	56912	76400	59530	113231	89490	96953	63213	66998	77320	26950	27033	44162	26988
84	25893	44139	39592	38169	36501	32048	47007	44227	37443	50483	24437	55933	82314	121184	93053	73104	67396	84913	51684	36822	46926	54744	41512	36944	61942	49757	53413	63480	68655	93061	47011	58419	45837	52097	41771	39352	54121	29438	20287	29600	33404
86	27508	53589	50859	52868	57027	30137	65503	52285	42292	42284	29544	56816	87516	68028	128688	84374	67916	93638	57420	40293	31556	78165	35745	50803	93075	72617	63303	69879	137258	77577	65041	54903	63942	60894	64019	48253	65810	22276	21363	45983	29508
88	36336	55453	61076	62702	65020	34924	54339	54856	43508	42251	39998	57972	83795	82990	89824	84239	58098	69825	54552	41311	43346	59106	38078	34786	67982	49334	43666	68878	63059	132213	54550	61030	62064	61921	57832	40204	57787	21644	19426	29400	27957
90	42735	66890	75249	79295	81578	38964	51253	61130	49729	35492	42054	63746	81536	64164	95090	91867	69403	78796	64067	41390	37096	57986	45106	45217	111688	58295	58223	65959	72187	91734	78641	83060	71316	52501	82294	52848	68735	26146	23427	51283	36421
92	36420	58582	69803	68860	74139	46936	51500	64311	54876	35721	35281	58648	73872	65123	69126	101055	76498	73590	59663	40035	37938	58733	43045	40234	84503	51149	36297	42509	53884	83589	46656	55758	48932	39905	54859	37126	54803	24839	20290	40496	38114
94	29230	47871	62150	52219	49309	50499	43753	62944	63959	39385	40568	61928	72417	67172	65934	95200	69973	87940	60335	40290	39341	59182	59102	44733	122436	85692	61487	65359	86209	73248	66106	46941	47277	42591	63366	47066	63895	23767	27329	24542	25067
96	30736	51869	68705	53872	51107	55103	48437	66643	65632	44994	42461	60377	74357	72022	89035	116498	100874	81861	65378	37444	41993	50135	49907	45158	145584	66731	43152	43407	49528	88245	48347	40244	45447	32354	50226	33617	48902	19438	24615	20669	28163
98	29672	54389	73711	46113	44275	65814	41008	72878	79896	39211	50010	65497	68665	77453	68662	110920	70710	75536	50822	40462	46532	58878	54097	42242	174301	69323	47166	42180	31411	57577	68454	65232	68072	37910	63785	40873	57308	20976	27981	25796	28054
100	27620	56447	83963	52558	49500	67175	41818	77241	78320	46568	62832	73411	76410	72825	74429	106028	58384	62102	56331	43973	54643	44488	61277	37238	136429	71594	52843	51982	49028	59190	54507	61345	38126	44137	44996	37516	61403	29746	28676	33504	43937
102	25656	62379	81323	51824	46771	64221	38104	75696	87607	39303	65642	73716	62020	65888	64171	102578	54829	68710	57490	53971	51756	51792	74453	50431	135283	69610	58919	59354	77230	58049	97070	64915	64471	56452	88606	61337	79077	27878	41229	29283	40915
104	29622	70181	91689	54649	50850	64591	38171	71682	87319	54653	70583	84773	70968	98757	52483	93603	52579	82339	55965	57319	63109	54856	67352	54156	119145	73073	55512	52432	48833	97790	56525	44241	40793	36623	45730	27432	51962	30493	44128	28806	42783
106	25837	64614	84881	54531	57018	62087	43534	81816	75165	63798	67794	71487	56590	90532	59093	92423	38295	73732	49140	57034	50748	46960	65516	52355	127366	68057	62700	65320	36186	49685	114378	66568	51804	49145	59492	42968	60682	43851	47098	29197	38606
108	29663	65424	87748	61192	71606	62784	42916	86857	76400	60524	83164	86881	58870	75092	75578	99871	44774	70529	58434	55605	42237	70276	69039	63033	95429	68538	57471	47406	38903	53263	60120	55065	40160	49767	51269	35817	55675	35273	53775	29234	41644
110	28454	61833	72195	64459	78586	64996	37396	65813	68366	81186	88558	99467	56271	75685	81603	88144	45093	70842	54842	48286	42769	72290	72074	66041	109764	97759	87256	72612	61873	48588	136908	67957	54487	72993	63969	46706	75893	48568	53191	32453	38556
112	28501	55770	63763	61897	68935	58832	32152	57314	58784	58008	67156	79110	49227	68602	83652	108714	44664	69716	54524	49346	42145	71841	73495	58042	81379	66370	56371	36205	34113	60275	48118	50062	43350	57222	48744	22004	57700	52421	39855	31299	45113
114	31093	48393	56939	63078	70446	53477	25856	52913	50208	49414	66948	73905	46103	100247	51366	72789	47263	61070	53246	44562	35433	54262	53302	67633	86405	82456	77821	53708	44896	32853	110789	52299	42918	57255	57629	31354	43144	55765	44937	33973	35245
116	22197	37653	47189	55358	65113	49612	23491	54430	48261	39834	58666	52864	44448	76348	70305	75076	59034	55549	70733	50404	35079	60636	51095	50296	58890	62753	50377	36399	32468	35340	41811	65730	42704	35207	40599	21044	25714	43034	31883	27139	42037
118	27699	33125	50481	59055	76153	59504	32703	55903	57091	45099	68730	66119	57756	74944	65225	71602	56979	65996	75034	52569	46664	75700	74823	86892	96941	110432	85187	71605	53748	33171	101057	80272	55335	45343	49112	28922	35451	49946	29297	33597	49205
120	31978	36395	54618	56418	70774	54254	34206	55508	66998	45239	80949	74105	74887	127682	68221	64452	76048	62887	80873	67243	53308	56123	80139	44236	79346	102889	98264	70828	61052	64400	47641	70722	50392	44135	46071	20652	46454	34978	25228	27574	39884
122	32765	41157	59382	55630	68327	57724	40653	56604	75165	44734	56448	56360	64789	146699	57668	57294	86023	59221	90394	76481	50168	71627	66396	63968	50226	68350	63853	38738	36569	34718	43074	61743	46292	41943	45686	20889	26224	33182	22383	22391	43171
124	38419	39282	60910	57114	69587	57311	42446	61912	81235	51242	71764	74199	75830	155673	69776	68604	99616	69417	97595	77997	71158	77039	83256	95670	74742	90144	89179	65220	55272	48860	82334	77085	51745	49285	49215	31796	48993	34496	26174	22635	32933
126	32228	30727	48826	46424	52588	42756	38778	56795	76706	44699	47639	48015	62227	88274	59747	66370	85278	59097	88592	75090	67793	76381	81675	69048	67706	70495	77676	55193	48245	41748	55390	63306	45624	44368	47655	26043	39360	27313	22220	23486	34849
128	35316	28580	51034	48278	59606	49426	53004	59719	85065	53945	62621	58169	73643	99281	53924	65953	93559	56399	98974	100772	87727	89672	93284	99025	73825	78952	86589	61896	57828	48705	73746	85010	53741	43417	47775	28913	37668	33145	22677	29478	31866
130	43813	26037	53831	47600	50268	52111	49944	58763	84596	59594	60003	62109	92933	85814	69975	83856	102219	66270	102263	100999	104448	78126	93955	70139	63339	73640	92865	62901	61819	64549	62318	86852	56041	41885	46558	30729	35594	29290	26446	33658	37124
132	47604	26441	49692	51169	58010	55767	67408	68377	103531	81332	61818	68631	96908	101198	60925	88876	107663	77366	116247	107264	123531	82479	101699	84644	73460	79767	87316	65135	59445	51014	79818	93630	62949	49242	55833	39996	45099	38991	35960	37209	35968
134	47272	25314	59082	56586	55672	54263	65074	62467	108096	89291	72283	86586	112728	100731	62945	90358	111554	81052	107910	105653	133904	95025	97807	98534	82218	91646	105525	76862	72008	67876	61869	96809	73956	55418	53942	43637	42999	35383	38627	45684	37291
136	52207	27263	56514	52724	57167	60771	73376	73843	116543	103879	74691	84445	121340	108878	56318	112022	111561	98262	109819	113809	160457	129914	106495	100201	87886	96514	108126	80379	75458	72112	72270	103411	79689	66347	61895	51204	48366	38933	51717	56183	39551
138	45138	29215	54725	53912	56229	65490	81688	86506	116546	111211	78404	91410	117720	100398	58127	113317	112986	106746	106570	131629	164834	111190	108641	116975	96771	103511	121541	90515	82325	71342	72692	98782	90114	72192	62519	55542	45512	46623	57238	60373	46804
140	59237	33425	47199	53145	54313	67000	77527	82357	104710	111977	101508	96841	115317	107399	47014	115857	107203	104619	93101	127155	169793	108836	113429	112975	100245	102096	114514	92823	86385	73829	75606	95925	92975	72651	61142	61627	54334	51512	66716	71171	43366
142	45743	29212	41850	50731	53629	70137	79468	88643	100999	112238	90841	95738	111537	123580	44590	113926	102903	106743	89731	129022	161023	115743	108166	112845	96829	97313	112921	91453	89477	72693	64421	87825	89786	66909	59503	62242	50489	53611	62657	71152	48100
144	38525	29803	40598	49579	54239	69236	69109	79085	78915	96425	76546	92757	98828	94907	35460	106202	95701	98440	78945	116078	129330	105881	98810	109641	101011	95705	103840	90750	93130	74213	61525	86613	87827	63060	57782	61375	51825	54047	64136	68889	45980
146	40377	29318	36205	44533	46688	72627	74609	77658	73790	88601	82917	91931	92519	84799	32767	97525	91408	90865	81160	120442	136485	104218	97199	110268	97641	88405	93506	84363	88124	72699	58704	79501	82671	63145	56724	57753	51474	49633	64603	73843	52562
148	40218	37065	39619	49328	53845	83483	83327	88038	78786	88212	88465	106590	97846	90660	32725	96488	88720	89675	68425	124522	147026	108912	104566	114593	109178	89964	94546	91333	92339	70603	61242	76437	85037	68158	58194	61887	55592	52664	71517	79244	60410
150	48184	39471	42093	57762	64863	95768	87045	93420	76384	93626	101503	115841	104525	90240	32107	102963	93319	95935	66490	131475	162320	117609	114892	120367	116048	95833	90971	90907	96344	69145	60656	73504	84646	71153	59422	64376	63017	57500	76934	90144	65268
152	37254	34187	33205	47239	56031	89301	82870	81458	65338	80864	82066	109499	94173	80291	29048	82660	83664	77759	57295	117697	138960	111221	111097	112217	105894	83535	85834	81567	95228	64943	56269	68941	75018	67006	54239	62002	61400	64464	75789	86096	68805
154	34612	35188	34830	46172	50361	89165	70832	69124	50945	65821	65125	88265	74298	64933	22209	63435	62699	57690	42553	95845	111118	88741	91963	88603	84835	67088	67934	66444	81276	56021	47713	54137	61417	57680	47513	49473	51515	53191	63611	74179	62460
156	29267	30740	30058	37129	37408	72639	61539	58173	42576	49429	53630	69629	63935	56348	17493	48472	47661	46778	31862	74856	88696	73267	71787	65395	62489	49294	49097	55398	61484	42498	38878	44744	46742	48713	38997	41379	46758	47065	56166	61248	54663
158	26186	25984	26819	33868	36821	67633	54954	47098	33428	40180	41517	56635	50591	41913	13969	32817	34423	31017	23421	56273	69335	54994	55835	45055	49452	35114	35421	35176	48162	33970	31984	32341	34265	36543	32542	33108	37224	36448	43963	54455	51053
160	24016	21846	23267	26661	30836	54793	41723	33957	23641	26316	34535	39526	41071	33023	9587	21662	22652	27296	14703	36059	46987	38341	37308	27122	30042	24149	23670	26231	34347	24290	24067	22970	23805	25504	25404	24010	30132	29849	34368	37852	38875
162	23213	16999	20076	23013	23806	44939	37551	28653	19457	24313	22649	32829	29841	24216	7301	17596	16759	15473	10989	28402	37751	26496	25107	17238	19897	16300	16305	16290	23813	17693	19340	14917	15946	20640	21042	17249	25790	26177	24404	28279	33344
164	15467	14336	15849	20290	19295	36828	32849	25508	16191	19802	20643	23926	24309	17625	4857	10944	11583	10563	6874	19133	26752	19655	18504	12949	15794	12789	12448	11475	18742	13366	15008	11943	11698	15729	17497	14160	18911	17552	19025	21734	26267
166	14374	12826	13456	16076	18030	33584	30442	24162	14305	16324	17695	21021	19707	16161	4148	9546	10010	12541	4844	16837	24351	15769	15726	11844	10798	9711	10142	9010	14951	11466	12897	10949	9551	14771	17249	13456	18311	15886	18250	19691	23358
168	12184	11477	13798	15172	16155	26866	24853	18948	10465	12132	11585	14322	13591	11892	3582	6087	6496	6427	3346	12098	17089	13402	13201	8855	10309	7626	6681	11813	12607	8782	9495	7607	6848	12333	13037	9663	12677	14597	15201	15582	21587
170	9450	7947	9348	12037	12307	19974	19309	13608	6913	9474	18088	9537	10573	10797	2154	3615	4291	3732	1919	7735	11966	9089	8070	6500	6199	5317	4987	3991	8616	5967	6863	16885	4616	9639	11036	6765	9322	11179	11406	11345	15010
172	4984	4721	5194	8329	8466	14696	12868	9165	5157	7560	6163	6069	6789	6484	1668	2024	2869	2166	1049	5192	7434	6756	5046	3692	3658	2804	2740	2392	5118	3518	4739	3488	2904	7573	9487	4949	8177	9509	6690	7324	10068
174	4409	3475	3257	5120	6136	8303	8424	5195	4123	4688	3770	3834	3717	4161	888	813	1411	4777	503	2508	3911	3620	2502	2613	2171	2196	1484	1567	3180	2003	2899	2177	1829	5502	6692	2852	4549	5401	5149	5086	6403
176	1515	1252	1312	2680	3735	5103	4278	2688	3690	3072	1463	1189	1027	2615	329	385	515	274	135	1143	1601	1587	1594	1011	1462	1011	316	509	1428	912	1594	1147	1000	3503	4205	1266	2710	3515	2958	2997	3402
178	960	756	1165	1797	1734	4327	3916	1580	2501	1720	1150	839	997	1342	195	239	271	362	741	851	938	952	771	599	485	1844	218	283	1371	539	1443	4413	499	4188	8968	1376	2069	3109	2492	2212	1901
180	2826	1167	6596	2122	2461	5100	8316	4708	10401	5245	1612	2135	1092	2548	73	62	69	26	35	347	555	2999	567	1136	557	424	341	141	594	1161	2545	25419	286	2121	4854	6063	2069	5388	3611	3371	2702

Table 3. Two model growth stanza formulation of Gascuel *et al* (1992).

Upper size bin slicing limits

	Quarter			
Age	**1**	**2**	**3**	**4**
0	42	45	48	53
1	60	69	78	89
2	100	110	120	128
3	136	143	148	153
4	157	161	163	166

Table 4. Two model growth stanza formulation of Gascuel *et al* (1992).

Year	**Age_ 0**	**Age_ 1**	**Age_ 2**	**Age_ 3**	**Age_ 4**	**Age_5+**
1970	361776	2229282	593364	621980	315542	81372
1971	344554	1977663	1315680	460985	273141	68834
1972	370213	2051307	1497373	772718	272525	88296
1973	242931	1575149	1241212	774961	347241	98839
1974	886762	2494098	1259808	863172	377903	110350
1975	892977	1542160	1161517	733661	615604	227896
1976	1574652	2880496	1021576	765312	572312	193826
1977	735140	2856105	1381594	792849	620597	151454
1978	995154	2827661	1388907	1120807	523267	104121
1979	1507403	2557960	978996	1209609	540212	104912
1980	1865461	3792223	1070132	1105421	544221	88779
1981	5812444	4246191	1509157	928273	794654	135181
1982	2959857	7181640	1446979	1196724	718324	136863
1983	4332732	4610440	1631049	1233889	697719	126978
1984	2894182	6654936	1754477	811188	207877	29586
1985	4261953	4067190	2045252	922916	731009	67933
1986	3704102	4308330	1247018	1292519	581649	68075
1987	6279916	4271363	1446399	1027094	644899	67571
1988	5072132	4970769	1099831	1301054	472094	43260
1989	5872560	4110454	893590	1165237	935875	120851
1990	6833164	5882732	954633	1322798	1053288	177889
1991	6322190	5456945	1142253	1067159	840468	128168
1992	6174316	4967199	1197647	1245505	782175	124224
1993	8740693	5765337	1202960	1209268	753292	82589
1994	5009395	6336340	2127323	1061787	758724	100416
1995	5362509	5432656	1581459	969994	653248	79338
1996	5500625	5552249	1252940	1160937	673444	76355
1997	4994965	5878058	1151428	832959	697806	78889
1998	5250980	7305716	1357519	828950	707442	129035
1999	5714767	10764172	1732531	803176	510091	90469
2000	8683543	6169850	1230563	1063225	462001	96723
2001	7732917	10813671	1596162	1249154	538304	114164
2002	7213105	8198565	963157	885666	614047	75185
2003	6680900	7108788	1031178	783196	503963	104813
2004	7170668	5818468	1175770	830968	394965	129735
2005	5795023	6796195	898043	574569	441148	88817
2006	4581371	3884286	1180028	607500	413828	103043
2007	7247074	3749663	768822	585943	396546	114446
2008	10135640	2330743	711240	526007	506027	127693
2009	5533339	4229168	833232	545769	589537	131250
2010	6088993	4053330	740386	523963	467021	158608

Table 5. Indices considered in the assessment.

Flag/Gear	JAP_LL (n)	JAP_LL (w)	EU PSFS 1%	TROP_PS (w)	MEX_USA_LL (n)	MEX_USA_LL (w)	USA_RR (n)	USA_RR (w)	BR_LL (n)	BR_LL (w)	URU_LL (n)	URU_LL (w)	TAI_LL (n)	TAI_LL (w)	CAN_BB (w)	VEN_PS (w)	BR_BB (w)	ES_FAD_PS (w)	USA_LL (n)	USA_LL (w)	USA_LL Atl and Gulf (w)	EUDKR_BB(w)	VEN_LL_ no update (n)	VEN_LL_ no update (w)	EU_PS_3%	BR_LL(W) continuity	BR_LL(N) continuity	EU_PS_7% (w)
Period	1965-2010	1965-2010	1991 -2009	1980-2006	1992-2010	1992-2010	1986-2010	1986-2010	1980-2010	1980-2010	1981-2007	1981-2007	1968-2009	1968-2009	1980-2007	1983-2005	1981-2006	1991-2010	1987-2010	1987-2010	1987 - 2010	1969-2010	1991-2001	1991-2005	1970-2010	1986-2006	1986-2006	1970-1990
Start year	1965	1965	1991	1980	1992	1992	1986	1986	1980	1980	1981	1981	1968	1968	1980	1983	1981	1991	1987	1987	1987	1969	1991	1991	1970	1986	1986	1970
End year	2010	2010	2009	2006	2010	2010	2010	2010	2010	2010	2007	2007	2009	2009	2007	2005	2006	2010	2010	2010	2010	2010	2001	2001	2010	2006	2006	1990
Used in ASPIC model	N	Y	N	N	N	Y - combined	N	Y - combined	N	Y - combined	N	Y - combined	N	Y - combined	Y-combined	Y-combined	Y-combined	N	N	Y-combined	Y	Y-combined	N	Y- combined	Y - combined	Y-combined	N	N
Used in VPA model	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	Y	Y	Y (ages 0-1)	Y	N	N	Y	Y	N	Y	N	Y	Y
Updated in 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	N	N	Y	Y	Y	Y	Y	N	N	Y	N	N	Y
1965	2.58	102.91																										
1966	1.8	71.57																										
1967	3.54	140.87																										
1968	2.9	115.4											4.09	134.51														
1969	2.54	101.34											2.6	99.16								0.95						
1970	1.92	76.38											1.48	62.17								0.92			5.06			2.94
1971	1.55	63.24											1.25	44.79								0.91			4.32			2.35
1972	2.19	84.33											1.2	33.37								0.92			4.79			2.43
1973	1.53	56.67											1.11	31.27								0.85			4.83			2.29
1974	2	80.62											0.8	18.88								1.31			4.41			1.95
1975	1.42	58.17											0.78	17.89								0.59			4.74			1.97
1976	1.57	60.45											0.63	17.7								0.66			4.69			1.82
1977	1.29	47.04											0.61	15.52								0.98			4.61			1.67
1978	1.85	68.95											0.53	12.05								0.4			4.2			1.42
1979	2.54	83.22											0.63	15.55								0.9			4.17			1.32
1980	1.39	50.27		0.25					1.27	42.5			0.55	11.55	0.01							NA			3.46			1.02
1981	1.8	65.42		0.65					0.54	11.85	6.55	144.96	0.83	25.61	0.02		1.39					1.45			3.71			1.06
1982	1.53	56.87		0.39					0.45	12	8.9	196.75	0.95	28.17	0.09		0.21					1.38			3.17			0.87
1983	1.54	54.65		0.49					1	27.41	3.33	84.81	0.7	21.35	0.17	13.59	0.58					1.41			2.75			0.72
1984	1.62	59.17		0.17					0.59	11.71	1.48	42.08	0.89	26.83	0.62	6.03	0.28					2			2.17			0.55
1985	1.03	38.7		0.6					0.35	8.67	3.55	75.43	0.8	22.9	0.27	10.17	0.21					1.54			3.73			0.91
1986	1.37	48.58		0.57			2.21	37.36	0.59	16.93	4.12	116.43	0.9	24.28	0.17	5.98	0.21					2.31			4.03	5.03	1.36	0.95
1987	1.41	50.66		0.62			1.22	20.57	1.03	29.11	3.98	112.29	0.75	19.32	0.39	4.57	0.29		1.35	1.56	1.44	2.6			3.53	6.36	1.72	0.8
1988	1.47	50.7		0.57			0.7	9.76	0.74	13.78	7.61	142.61	0.79	20.32	0.4	6.3	0.33		1.59	1.85	1.42	2.51			3.34	5.28	2.17	0.73
1989	1.14	40.8		1			0.75	16.9	1.07	21.84	2.08	56.76	1.71	53.58	0.24	13.66	0.3		1.29	1.48	1.41	0.63			4.16	5.34	2.01	0.87
1990	1.5	52.92		0.96			0.43	6.99	1.15	33.18	1.9	51.86	1.3	47.81	0.61	7	0.62		1.3	1.42	1.27	2.32			4.53	9.04	2.41	1.21
1991	1.13	40.91	7461.9	0.69			0.7	11.39	0.83	23.45	6.85	186.62	1.16	32.08	0.53	7.15	0.19	1.1	1.13	1.2	1.19	0.86	1.04	37.99	4.27	4.96	1.36	
1992	1.21	46.69	9352.89	0.61	1.64	62.8	0.47	7.7	1.23	23.06	6.55	293.02	0.9	28.46	0.31	4.81	0.29	0.81	1.34	1.41	1.34	2.31	1.14	55.7	3.88	2.07	0.84	
1993	0.63	22.25	7506.25	0.5	1.25	48.01	1.25	20.33	2.4	107.41	1.25	55.95	1.21	35.22	0.14	5.51	0.35	1.23	0.96	0.79	0.79	1.97	1.68	80.18	3.73	2.4	0.41	
1994	1.06	37.07	7990.04	0.63	1.79	65.16	2.55	51.8	0.86	24.7	4.85	214.31	1.47	46.77	0.08	6.72	0.21	0.97	1.12	0.75	0.74	1.27	0.63	38.11	3.66	2.67	0.71	
1995	0.72	26.86	7455.48	0.6	1.14	42.68	1.98	64.87	1.59	37.65	3.71	88.01	1.81	53.54	0.04	3.03	0.1	1.19	1.29	1.16	1.06	0.72	0.69	26.08	3.68	1.81	0.59	
1996	0.76	28.73	8032.39	0.56	0.76	28.91	0.45	15.34	2.26	52.7	7.16	166.94	1.94	62.9	0.54	6.78	0.29	1.2	0.87	1.08	0.95	0.9	0.9	33.28	3.5	4.65	1.53	
1997	0.63	22.17	9385.55	0.69	1.1	41.23	0.42	6.93	1.7	38.74	2.4	54.75	1.49	50.65	0.06	4.57	0.42	0.73	0.95	0.96	0.92	0.63	0.5	20.35	3.23	3.68	1.24	
1998	0.72	25.85	8060.58	0.53	1.01	34.74	0.88	12.1	1.1	25.03	2.71	62.02	1.33	42.68	0.76	3.7	0.32	0.56	0.68	0.62	0.64	0.26	0.87	34.8	3.42	4.69	1.58	
1999	0.76	26.8	7494.81	0.44	1.51	51.8	1.56	20.09	1.8	48.12	3.26	125.6	1.03	34.57	0.07	5.43	0.11	1.14	0.81	0.88	1.08	0.66	0.85	31.78	2.83	4.39	1.26	
2000	0.87	29.63	5706.66	0.4	1.04	38.95	1.43	22.66	1.36	41.78	4.27	165.54	1.15	34.2	0	6.62			0.86	0.84	0.96	0.29	0.63	9.85	3.36	4.58	1.15	
2001	0.58	19.9	7368.75	0.51	0.83	36.06	1.41	22.18	1.06	28.66	2.64	NA	0.75	22.99	0	13.24	0.68	0.74	0.77	0.82	0.95	0.45	2.07	32.39	3.65	3.68	1.04	
2002	0.57	19.96	9930.81	0.7	0.86	35.31	1.01	19.3	0.69	24.05	1.8	100.35	0.98	33.57	0.02	8.18	0.29	0.82	0.68	0.56	0.73	0.77			3.99	2.91	0.64	
2003	0.69	23.96	5788.73	0.79	1.05	46.19	1.07	16.69	0.92	40.06	2.56	152.4	1.37	46.66	0.05	4	0.24	1.37	0.62	0.47	0.67	0.81			3.73	6.17	1.09	
2004	0.87	30.91	8673.79	0.53	0.79	32.85	0.86	14.97	0.62	31.18	2.55	109.59	1.43	51.65	0.04	2.39	0.09	0.98	1.06	0.97	1.08	0.7			3.07	7.54	1.16	
2005	0.62	23.01	6225.15	0.5	0.73	31.28	0.84	11.96	0.52	4.92	5.94	231.08	1.74	71	0.01	1.23	0.1	1.04	1.05	0.94	0.99	0.47			3.31	0.92	0.75	
2006	0.89	31.05	7724.12	0.6	0.69	27.38	1.05	16.4	0.66	10.45	2.33	90.83	1	42.01	0.02		0.38	0.9	1.07	1.04	1.15	0.53			4.04	2.31	1.11	
2007	1.01	36.15	6967.36		0.76	32.02	0.87	16.41	0.7	24.77	0.81		0.76	32.23	0.07			0.99	1.22	1.33	1.21	0.54			3.17			
2008	0.82	32.17	9231.59		0.69	29.03	0.44	8.12	0.83	9.03			0.63	28.84				0.61	0.58	0.64	0.68	0.41			3.86			
2009	0.9	32.29	6899.21		0.8	33.71	0.21	3.9	0.57	29.59			0.7	30.84				1.25	0.6	0.51	0.6	0.45			3.22			
2010	0.67	24.61			0.57	21.77	0.24	4.96	0.54	37.37								1.36	0.8	0.72	0.73	0.97			2.76			

Table 6. Fleet definitions used to construct fleet-specific partial catches at age (PCAA).

Index	**EU Purse Seine 3% pre-1990**	**EU Purse Seine Free School**	**EU Purse Seine FAD**	**EU Dakar**	**Uruguay Long line**	**Chinese Taipei Long line**	**Canary Islands Baitboat**	**Brazil Bait boat**	**Brazil Long line**	**Japan Long line**	**U.S.-Mexico GOM Longline**	**U.S. Rod and Reel**	**U.S. Pelagic Long line (ATL)**	**Venezuela Longline**	**Venezuela Purse Seine**
StockID	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL	ALL
FlagName	N/A	N/A	N/A	N/A	Uruguay	Chinese Taipei	N/A	Brasil	Brasil	Japan	U.S.A., Mexico	U.S.A.	U.S.A.	Venezuela	Venezuela
Fleet Code	ANT-AN-ETRO CPV-ETRO EU.ESP EU.ESP-ES-ETRO EU.FRA EU.FRA-FR-ETRO GTM.ETRO MIX.FR+ES NEI.001 NEI.001-BLZ NEI.001-GHA NEI.001-GIN NEI.001-GTM NEI.001-ITA NEI.001-LBR NEI.001-MAR NEI.001-MLT NEI.001-MUS NEI.001-MYS NEI.001-NOR NEI.001-SLV NEI.001-SYC NEI.001-VCT NEI.001-VEN NEI.001-VUT PAN-PAN-ETRO	ANT-AN-ETRO CPV-ETRO EU.ESP EU.ESP-ES-ETRO EU.FRA EU.FRA-FR-ETRO GTM.ETRO MIX.FR+ES NEI.001 NEI.001-BLZ NEI.001-GHA NEI.001-GIN NEI.001-GTM NEI.001-ITA NEI.001-LBR NEI.001-MAR NEI.001-MLT NEI.001-MUS NEI.001-MYS NEI.001-NOR NEI.001-SLV NEI.001-SYC NEI.001-VCT NEI.001-VEN NEI.001-VUT PAN-PAN-ETRO	ANT-AN-ETRO CPV-ETRO EU.ESP EU.ESP-ES-ETRO EU.FRA EU.FRA-FR-ETRO GTM.ETRO MIX.FR+ES NEI.001 NEI.001-BLZ NEI.001-GHA NEI.001-GIN NEI.001-GTM NEI.001-ITA NEI.001-LBR NEI.001-MAR NEI.001-MLT NEI.001-MUS NEI.001-MYS NEI.001-NOR NEI.001-SLV NEI.001-SYC NEI.001-VCT NEI.001-VEN NEI.001-VUT PAN-PAN-ETRO	EU.ESP-ES-ETRO EU.FRA-FR-ETRO SEN SEN-SEN-DAKAR MIX.FR+ES	N/A	N/A	ESP-ES-CAN	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gear Grp Code	PS	PS	PS	BB	LL	LL	BB	BB	LL	LL	LL	RR	LL	LL	PS
Samp Area Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	LLYF13	N/A	ALL EXCEPT LLYF13	N/A	N/A
School Type	ALL	2	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 7. Indices of abundance in weight used to estimate the different combined indices. The indices were scaled to the mean values of the period 1993-2001 (see text for details).

Year	JAP LL	MEX_USA LL	USA RR	BRA LL	URU LL	CH_TAI LL	CAN BB	VEN PS	BRA BB	USA LL	EUDKR BB	VEN LL	EU PS 3%	BRA LL	EU PS 1%	EU PS FAD	EU PS 7%
1965	3.87																
1966	2.69																
1967	5.3																
1968	4.34					3.16											
1969	3.81					2.33					1.2						
1970	2.87					1.46					1.16		1.47				2.94
1971	2.38					1.05					1.15		1.25				2.35
1972	3.17					0.78					1.16		1.39				2.44
1973	2.13					0.73					1.07		1.4				2.29
1974	3.03					0.44					1.65		1.28				1.95
1975	2.19					0.42					0.74		1.37				1.97
1976	2.27					0.42					0.83		1.36				1.82
1977	1.77					0.36					1.23		1.34				1.67
1978	2.59					0.28					0.5		1.22				1.42
1979	3.13					0.36					1.13		1.21				1.32
1980	1.89				0	0.27	0.05				0		1	0.95			1.02
1981	2.46				1.4	0.6	0.1		4.47		1.83		1.07	0.26			1.06
1982	2.14				1.9	0.66	0.5		0.68		1.74		0.92	0.27			0.87
1983	2.06				0.82	0.5	0.88	2.2	1.85		1.77		0.8	0.61			0.73
1984	2.23				0.41	0.63	3.27	0.98	0.9		2.52		0.63	0.26			0.55
1985	1.46				0.73	0.54	1.42	1.65	0.67		1.94		1.08	0.19			0.91
1986	1.83		1.42	1.39	1.12	0.57	0.91	0.97	0.67		2.91		1.17	0.38			0.95
1987	1.91		0.78	1.76	1.08	0.45	2.04	0.74	0.95	1.77	3.27		1.02	0.65			0.80
1988	1.91		0.37	1.46	1.38	0.48	2.13	1.02	1.05	2.11	3.16		0.97	0.31			0.73
1989	1.53		0.64	1.48	0.55	1.26	1.26	2.21	0.96	1.68	0.79		1.21	0.49			0.87
1990	1.99		0.27	2.5	0.5	1.12	3.2	1.13	1.99	1.62	2.92		1.31	0.74			1.21
1991	1.54		0.43	1.37	1.8	0.75	2.83	1.16	0.6	1.37	1.08	1.11	1.24	0.52	0.97	1.14	
1992	1.76	1.46	0.29	0.57	2.83	0.67	1.64	0.78	0.95	1.6	2.91	1.63	1.13	0.51	1.22	0.84	
1993	0.84	1.12	0.77	0.66	0.54	0.83	0.75	0.89	1.12	0.9	2.48	2.35	1.08	2.39	0.98	1.27	
1994	1.39	1.51	1.97	0.74	2.07	1.1	0.45	1.09	0.67	0.85	1.6	1.12	1.06	0.55	1.04	1.00	
1995	1.01	0.99	2.47	0.5	0.85	1.26	0.19	0.49	0.33	1.32	0.91	0.77	1.06	0.84	0.97	1.23	
1996	1.08	0.67	0.58	1.29	1.61	1.48	2.85	1.1	0.93	1.23	1.13	0.98	1.01	1.17	1.05	1.24	
1997	0.83	0.96	0.26	1.02	0.53	1.19	0.34	0.74	1.35	1.09	0.79	0.6	0.94	0.86	1.22	0.75	
1998	0.97	0.81	0.46	1.3	0.6	1	4.03	0.6	1.04	0.71	0.33	1.02	0.99	0.56	1.05	0.57	
1999	1.01	1.2	0.77	1.22	1.21	0.81	0.38	0.88	0.36	1	0.83	0.93	0.82	1.07	0.98	1.18	
2000	1.11	0.9	0.86	1.27	1.6	0.8	0.01	1.07	0	0.96	0.37	0.29	0.97	0.93	0.74		
2001	0.75	0.84	0.84	1.02		0.54	0	2.14	2.19	0.94	0.57	0.95	1.06	0.64	0.96	0.77	
2002	0.75	0.82	0.74	0.8	0.97	0.79	0.13	1.32	0.93	0.64	0.97		1.16	0.54	1.30	0.85	
2003	0.9	1.07	0.64	1.71	1.47	1.09	0.24	0.65	0.76	0.53	1.02		1.08	0.89	0.76	1.41	
2004	1.16	0.76	0.57	2.08	1.06	1.21	0.2	0.39	0.29	1.1	0.88		0.89	0.69	1.13	1.01	
2005	0.87	0.73	0.46	0.25	2.23	1.67	0.03	0.2	0.33	1.07	0.59		0.96	0.11	0.81	1.07	
2006	1.17	0.64	0.62	0.64	0.88	0.99	0.08		1.21	1.19	0.67		1.17	0.23	1.01	0.93	
2007	1.36	0.74	0.62			0.76	0.35			1.52	0.68		0.92	0.55	0.91	1.02	
2008	1.21	0.67	0.31			0.68				0.73	0.52		1.12	0.20	1.20	0.63	
2009	1.21	0.78	0.15			0.72				0.59	0.57		0.93	0.66	0.90	1.29	
2010	0.93	0.51	0.19							0.82	1.22		0.8	0.83		1.40	

Table 8. Estimated weighted combined indexes of abundance. Refer to text for explanation of each index.

Year	*Index 1*	*Index 2*	*Index 3*	*Index 4*
1965	2.443	2.43	2.537	2.581
1966	1.645	1.69	1.765	1.795
1967	3.235	3.327	3.473	3.533
1968	3.089	3.803	4.019	4.14
1969	2.659	3.21	3.408	3.529
1970	1.913	2.178	2.341	2.521
1971	1.429	1.665	1.785	1.913
1972	1.503	1.754	1.894	2.051
1973	1.217	1.4	1.521	1.654
1974	1.172	1.364	1.484	1.601
1975	1.043	1.173	1.27	1.35
1976	0.971	1.144	1.244	1.319
1977	0.685	0.987	1.079	1.138
1978	0.827	0.97	1.065	1.112
1979	1.017	1.278	1.398	1.437
1980	0.628	0.855	0.928	0.945
1981	1.065	1.212	1.305	1.284
1982	1	1.121	1.202	1.178
1983	1.011	1.069	1.157	1.118
1984	0.986	1.102	1.175	1.146
1985	0.834	0.946	1.004	0.98
1986	0.899	1.114	1.183	1.148
1987	0.926	1.075	1.132	1.1
1988	1.16	1.108	1.169	1.128
1989	1.114	1.11	1.166	1.131
1990	1.399	1.296	1.363	1.348
1991	0.996	1.049	1.002	1.005
1992	0.982	1.046	1.025	1.029
1993	0.757	0.919	0.845	0.852
1994	0.887	0.916	0.908	0.916
1995	0.799	0.911	0.862	0.868
1996	0.932	0.976	0.96	0.968
1997	0.738	0.77	0.806	0.812
1998	0.767	0.736	0.713	0.718
1999	0.769	0.838	0.796	0.802
2000	0.802	0.76	0.745	0.751
2001	0.655	0.607	0.59	0.595
2002	0.741	0.674	0.671	0.676
2003	1.01	0.765	0.76	0.766
2004	1.104	0.781	0.798	0.804
2005	0.754	0.53	0.543	0.546
2006	0.866	0.632	0.631	0.636
2007	1.105	0.727	0.726	0.733
2008	0.91	0.579	0.563	0.569
2009	0.852	0.645	0.677	0.683
2010	0.571	0.676	0.757	0.765

Table 9. Description of ASPIC cases.

Run number	*B1/K*	*Production function*	*Abundance index*
01	fix	LOGISTIC	Only Japanese longline
02	fix	GENERALISED	
03	estimate	LOGISTIC	
04	estimate	GENERALISED	
05	fix	LOGISTIC	Combined (weighted) - continuity
06	estimate	LOGISTIC	
07	fix	LOGISTIC	Separate nine indices (equal weight, see Table 10)
08	fix	LOGISTIC	Separate nine indices (weighted by area, see Table 10)
09	fix	LOGISTIC	New combined PS 3% inc. q
10	est	LOGISTIC	
11	fix	LOGISTIC	New combined PS 7% inc. q
12	est	LOGISTIC	
14	fix	LOGISTIC	New combined 7% inc.q and new Ghana catch (index up to 2006)
14b	fix	LOGISTIC	New combined 7% inc.q and new Ghana catch (index up to 2010)
15	fix	LOGISTIC	Excluding TWN-LL index when processing new combined index
16	fix	LOGISTIC	Excluding BR-LL index when processing new combined new combined index
17	fix	LOGISTIC	Excluding EC-PS 7% inc. q index when processing new combined new combined index

Table 10. Area-weight for ASPIC run 08 in the 2011 assessment. The weight are calculated by coverage of each fleet of 5x5 counts summed by quarter within year (from 1965 to 2010), which is provided during the meeting.

	2011 Assessment weight by area for continuity run 08	*2008 Assessment*
YFT-JAP-LL(w)	0.3447	0.3770
YFT-USA-RR(n); converted to weight base	0.0282	0.0160
YFT-BRZ-LL(n); converted to weight base	0.0920	0.0560
YFT-USA-LL(w)	0.0609	0.0740
YFT-URU-LL(n); converted to weight base	0.0037	0.0040
YFT-VEN-PS(w)	0.0112	0.0090
YFT-BRZ-BB(w)	0.0243	0.0110
YFT-EUDKR-BB(w)[1]	0.0228	0.0230
EU PS[2]	0.1201	0.0500
Others: remaining catch	0.2920	0.3800

[1] The EUDKR-BB corresponds to the fleets (from 1950 to 1990; EU.ESP-ES-ETRO, EU.FRA, EU.FRA-FR-ETRO, SEN, SEN-SEN-DAKAR. From 1991 to 2011; EU.ESP-ES-ETRO, EU.FRA-FR-ETRO, SEN, SEN-SEN-DAKAR, MIX.FR+ES, NEI that operated in the eastern tropical (NEI.001, NEI.001-ANT, NEI.001-CPV and NEI.001-VCT)) .

[2] The EU-PS corresponds to the fleets (ANT-AN-ETRO, CPV-ETRO, EU.EPS, EU.ESP-ES-ETRO, EU.FRA, EU.FRA-FR-ETRO, GTM.ETRO, MIX.FR+ES, all NEI.001 (NEI.001-ANT, NEI.001-BLZ, NEI.001-CPV, NEI.001-GHA, NEI.001-GIN, NEI.001-GTM, NEI.001-ITA, NEI.001-LBR, NEI.001-MAR, NEI.001-MLT, NEI.001-MUS, NEI.001-MYS, NEI.001-NOR, NEI.001-SEN, NEI.001-SLV, NEI.001-SYC, NEI.001-VCT, NEI.001-VEN, NEI.001-VUT, PAN-PAN-ETRO)).

Table 11. Control file specifications used for VPA model runs.

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SEARCH ALGORITHM CONTROLS(USED FOR ALL RUNS)
-911    RANDOM NUMBER SEED
 50     MAXIMUM NUMBER OF AMOEBA SIMPLEX SEARCH RESTARTS
 3      NUMBER OF CONSECUTIVE RESTARTS THAT MUST VARY BY LESS THAN 1% TO STOP SEARCH
 0.4    PDEV (standard deviation controlling vertices for Initial simplex of each restart)

INDEX WEIGHTING CONTROLS     (USED FOR ALL RUNS)
 1      SCALE (DIVIDE INDEX VALUES BY THEIR MEAN)- ANY VALUE > 0 = YES
 1.0    INDEX WEIGHTING:(0)INPUT CV's, (+)DEFAULT CV, (-)DEFAULT STD. DEV., (999)MLE
 0      (0) MULTIPLICATIVE VARIANCE SCALING FACTOR or (1) ADDITIVE VARIANCE SCALING
FACTOR

CONSTRAINT ON VULNERABILITY (PARTIAL RECRUITMENT) - LINKS THE VULNERABILITIES IN
THE LAST N YEARS. (Number of years affected, Standard Deviation, First Age, Last Age)
  3  0.4  0  5   (USED FOR ALL RUNS) – PENALTY APPLIED

CONSTRAINTS ON RECRUITMENT - LINKS THE RECRUITMENTS IN THE LAST N YEARS (N Years,
  4   0.4   (USED FOR DELTA-CAA and CONTINUITY RUNS) – PENALTY APPLIED
  0  0.4   (USED FOR ALL 2011 BASE RUNS) – PENALTY APPLIED

PARAMETER ESTIMATION OPTIONS
  1         USE F'S AS TERMINAL YEAR PARAMETERS   (ALL RUNS)
 -1          ESTIMATE Q BY CONCENTRATED MLE's        (ALL RUNS)
```

Table 12. Parameter file specifications used for VPA model runs.

```
# TERMINAL F PARAMETERS: (lower bound, best estimate, upper bound, indicator, reference age)
#(USED FOR ALL RUNS)
#________________________________________X________________________________________
$        1        0        0.2      2        1        0.1      first age (AGE 0 in this case)
$        1        0        0.8      2        1        0.1
$        1        0        0.3      2        1        0.1
$        1        0        0.3      2        1        0.1
$        1        0        0.5      2        1        0.1      next to last age
#________________________________________X________________________________________

# F-RATIO PARAMETERS F{oldest}/F{oldest-1} (lower bound, best estimate, upper bound, indicator, std. dev. of
prior)
#   one parameter (set of specifications) for each year
#(USED FOR DELTA-CAA and CONTINUITY RUNS)
#_______________________________________X________________________________________
$        1        0.1      0.2      5        1        0.2      1970         estimated
$        40       0.1      0.2      5        3        0.2      1971-2010  random walk
#_______________________________________X________________________________________
#(USED FOR BASE RUNS 1 and 2)
#________________________________________X________________________________________
$        1        0.1      0.7      5        0        0.2      1970    fixed at 0.7
$        40       0.1      0.2      5        3        0.2      1971-2010  random walk
#_______________________________________X________________________________________
#(USED FOR BASE RUNS 3 and 4)
#________________________________________X________________________________________
$        30       0.1      0.7      5        0        0.2      fixed at 1.0 in 1970-1999
$        7        0.1      0.7      5        3        0.2      random walk 2000-2006
$        4        0.1      1.0      5        -0.1     0.2      fix at 2006 estimate

# NATURAL MORTALITY PARAMETERS: (lower bound, best estimate, upper bound, indicator, std. dev. of prior)
#   one parameter (set of specifications) for each age
#(USED FOR ALL RUNS)
#________________________________________X________________________________________
$        1        0        0.8      1        0        0.1
$        1        0        0.8      1        0        0.1
$        1        0        0.6      1        0        0.1
$        1        0        0.6      1        0        0.1
$        1        0        0.6      1        0        0.1
$        1        0        0.6      1        0        0.1
#________________________________________X________________________________________
# MIXING PARAMETERS: (lower bound, best estimate, upper bound, indicator, std. dev. of prior)
#   one parameter (set of specifications) for each age :not used here!
#(NO MIXING WAS USED FOR ANY 2011 YFT VPA RUN)
#________________________________________X________________________________________
$        6        0        0        0        0        0
#________________________________________X________________________________________
# STOCK-RECRUITMENT PARAMETERS: (lower bound, best estimate, upper bound, indicator, std. dev. of prior)
#   five parameters so 5 sets of specifications  : not used here!
#(THESE SETTINGS ARE USED TO CONTRAINT ON THE ESTIMATED S-R RELATIONSHIP. THIS WAS
NOT DONE FOR ANY 2011 YFT VPA RUN)
#________________________________________X________________________________________
0        0        0        0        0        maximum recruitment
0        0        0        0        0        spawning biomass scaling parameter
0        0        0        0        0        extra parameter (not used yet)
0        0        0        0        0        autocorrelation parameter
0        0        0        0        0        variance for penalty function
#________________________________________X________________________________________
# VARIANCE SCALING PARAMETER (lower bound, best estimate, upper bound, indicator, std. dev.)
#(USED FOR ALL RUNS. THESE SETTINGS ESTIMATE A SINGLE VARIANCE SCALAR FOR ALL
INDICES. THE SAME SCALAR IS USED FOR THE INTERANNUAL VARIANCE OF EACH INDEX. (EQUAL
WEIGHTING ACROSS YEARS AND INDICES).
#________________________________________X________________________________________
$ 1   0   0.5   1.0      1   0.1
$ 18  0   1.0   1.0   -0.1   0.1
```

Table 13. Indices of abundance used for VPA model runs.

Index	*DELTA-CAA*	*CONTINUITY*	*BASE RUNS 1-4*
Brazilian Baitboat (w)	Used 2008 Index	**Used 2008 Index** **** Not Updated ****	**Used 2008 Index** **** Not Updated ****
Brazilian Longline (n)	Used 2008 Index	**Used 2008 Index**	**Used 2011 Index**
Japanese Longline (n)	Used 2008 Index	**Used 2011 Index**	**Used 2011 Index**
USA-Mexico GOM Longline (n)	Used 2008 Index	**Used 2011 Index**	**Used 2011 Index**
USA Rod and reel (n)	Used 2008 Index	**Used 2011 Index**	**Used 2011 Index**
USA Pelagic longline (ATL) (n)	Used 2008 Index	**Used 2011 Index**	**Used 2011 Index**
Venezuela Longline (n)	Used 2008 Index	**Used 2008 Index** **** Not Updated ****	**Used 2008 Index** **** Not Updated ****
Venezuela Purse seine (w)	Used 2008 Index	**Used 2008 Index** **** Not Updated ****	**Used 2008 Index** **** Not Updated ****
EU FAD Purse seine (w)	Used 2008 Index	**Used 2011 Index**	**Used 2011 Index**
EU PS 3% Annual increase in Q (w)	Used 2008 Index 1970-1979	**Used 2011 Index** **1970-1979**	**Used 2011 Index**
EU TROP Purse seine (w)	Used 2008 Index	**Used 2008 Index**	
EU Dakar (w)	Used 2008 Index	**Used 2011 Index**	**Used 2011 Index**
Uruguay Longline (n)	Used 2008 Index		
Chinese Taipei Longline (n)	Used 2008 Index	**Used 2011 Index** **Single time period**	**Used 2011 Index** **Broken into 4 time periods**
Canary Islands Baitboat (w)	Used 2008 Index	**Used 2008 Index**	**Not Used**

Table 14. Index specifications for VPA DELTA-CAA models.

Index Number	PDF (0=do not use, 1=lognormal, 2=normal)	UNITS (1 = numbers, 2 = biomass)	SELECTIVITY (1 = fixed, 2 = fractional catches, 3 = Powers and Restrepo partial catches,4=Butterworth and Geromont eq 4)	TIMING (-1 = AVERAGE DURING YEAR, POSITIVE INTEGER = NUMBER OF MONTHS ELAPSED)	FIRST AGE	LAST AGE	TITLE	
DELTA CAA "Run 5 - USE PCAA"								
1	1	2	4	6	0	4	BRA_BB'	
2	1	1	4	6	0	5	BRA_LL'	
3	1	1	4	6	0	5	JPN_LL'	
4	1	1	4	6	0	5	USMEX_LL'	
5	1	1	4	6	0	5	US_RR'	
6	1	1	4	6	0	5	US_PLL_ATL'	
7	1	1	4	6	0	5	VEN_LL'	
8	1	2	4	6	0	4	VEN_PS'	
9	1	2	4	6	0	1	EUR-FAD-PS'	applies to YFT < 10kg
10	1	2	4	6	0	5	EUR-PS-3%'	
11	1	2	4	6	0	4	EU-DAKAR'	
12	1	1	4	6	0	5	URU-LL'	
13	0	1	4	6	0	5	BRA-URU-LL'	
14	1	1	4	6	0	5	CHIN-TAI-LL'	
15	1	1	1	6	3	5	TROP-PS'	applies to > 30 kg (SSB)
16	1	2	4	6	0	4	CAN-IS-BB'	
DELTA CAA "Run 10 - FLAT-TOPPED"								
1	1	2	4	6	0	4	BRA_BB'	
2	1	1	1	6	0	5	BRA_LL'	
3	1	1	1	6	0	5	JPN_LL'	
4	1	1	1	6	0	5	USMEX_LL'	
5	1	1	4	6	0	5	US_RR'	
6	1	1	1	6	0	5	US_PLL_ATL'	
7	1	1	1	6	0	5	VEN_LL'	
8	1	2	4	6	0	4	VEN_PS'	
9	1	2	4	6	0	1	EUR-FAD-PS'	applies to YFT < 10kg
10	1	2	4	6	0	5	EUR-PS-3%'	
11	1	2	4	6	0	4	EU-DAKAR'	
12	1	1	1	6	0	5	URU-LL'	
13	0	1	1	6	0	5	BRA-URU-LL'	
14	1	1	1	6	0	5	CHIN-TAI-LL'	
15	1	1	1	6	3	5	TROP-PS'	applies to > 30 kg (SSB)
16	1	2	4	6	0	4	CAN-IS-BB'	

Table 15. Index specifications for VPA CONTINUITY models.

Index Number	PDF (0=do not use, 1=lognormal, 2=normal)	UNITS (1 = numbers, 2 = biomass)	SELECTIVITY (1 = fixed, 2 = fractional catches, 3 = Powers and Restrepo partial catches,4=Butterworth and Geromont eq 4)	TIMING (-1 = AVERAGE DURING YEAR, POSITIVE INTEGER = NUMBER OF MONTHS ELAPSED)	FIRST AGE	LAST AGE	TITLE	
CONTINUITY "Run 5 - USE PCAA"								
1	1	2	4	6	0	4	BRA_BB'	
2	1	1	4	6	0	5	BRA_LL'	
3	1	1	4	6	0	5	JPN_LL'	
4	1	1	4	6	0	5	USMEX_LL	
5	1	1	4	6	0	5	US_RR'	
6	1	1	4	6	0	5	US_PLL_A	
7	1	1	4	6	0	5	VEN_LL'	
8	1	2	4	6	0	4	VEN_PS'	
9	1	2	4	6	0	1	EUR-FAD-I	applies to YFT < 10kg
10	1	2	4	6	0	5	EUR-PS-3	
11	1	2	4	6	0	4	EU-DAKAF	
12	1	1	4	6	0	5	URU-LL'	
13	0	1	4	6	0	5	BRA-URU-	
14	1	1	4	6	0	5	CHIN-TAI-	
15	1	1	1	6	3	5	TROP-PS'	applies to > 30 kg (SSB)
16	1	2	4	6	0	4	CAN-IS-BB'	
CONTINUITY "Run 10 - FLAT-TOPPED"								
1	1	2	4	6	0	4	BRA_BB'	
2	1	1	1	6	0	5	BRA_LL'	
3	1	1	1	6	0	5	JPN_LL'	
4	1	1	1	6	0	5	USMEX_LL	
5	1	1	4	6	0	5	US_RR'	
6	1	1	1	6	0	5	US_PLL_A	
7	1	1	1	6	0	5	VEN_LL'	
8	1	2	4	6	0	4	VEN_PS'	
9	1	2	4	6	0	1	EUR-FAD-I	applies to YFT < 10kg
10	1	2	4	6	0	5	EUR-PS-3	
11	1	2	4	6	0	4	EU-DAKAF	
12	1	1	1	6	0	5	URU-LL'	
13	0	1	1	6	0	5	BRA-URU-	
14	1	1	1	6	0	5	CHIN-TAI-	
15	1	1	1	6	3	5	TROP-PS'	applies to > 30 kg (SSB)
16	1	2	4	6	0	4	CAN-IS-BB'	

Table 16. Index specifications for VPA BASE models.

	Index Number	PDF (0=do not use, 1=lognormal, 2=normal)	UNITS (1 = numbers, 2 = biomass)	SELECTIVITY (1 = fixed, 2 = fractional catches, 3 = Powers and Restrepo partial catches,4=Butterworth and Geromont eq 4)	TIMING (-1 = AVERAGE DURING YEAR, POSITIVE INTEGER = NUMBER OF MONTHS ELAPSED)	FIRST AGE	LAST AGE	TITLE	
BASE 1 and BASE 3									
	1	1	2	4	6	0	4	BRA_BB'	
	2	1	1	4	6	0	5	BRA_LL'	
	3	1	1	4	6	0	5	JPN_LL'	
	4	1	1	4	6	0	5	USMEX_LL'	
	5	1	1	4	6	0	5	US_RR'	
	6	1	1	4	6	0	5	US_PLL_ATL'	
	7	1	1	4	6	0	5	VEN_LL'	
	8	1	2	4	6	0	4	VEN_PS'	
	9	1	2	4	6	0	1	EUR-FAD-PS'	applies to YFT < 10kg
	10	1	2	4	6	0	5	EUR-PS-3%'	
	11	1	2	4	6	0	4	EU-DAKAR'	
	12	1	1	4	6	0	5	URU-LL'	
	13	0	1	4	6	0	5	BRA-URU-LL'	
	14	1	1	4	6	0	5	CHIN-TAI-LL'	
	15	1	1	4	6	0	5	CHIN-TAI-LL'	
	16	1	1	4	6	0	5	CHIN-TAI-LL'	
	17	1	1	4	6	0	5	CHIN-TAI-LL'	
	18	1	2	4	6	3	5	EU-FS-1%'	applies to > 30 kg (SSB)
	19	0	2	4	6	0	4	CAN-IS-BB'	
BASE 2 and BASE 4									
	1	1	2	4	6	0	4	BRA_BB'	
	2	1	1	1	6	0	5	BRA_LL'	
	3	1	1	1	6	0	5	JPN_LL'	
	4	1	1	1	6	0	5	USMEX_LL'	
	5	1	1	4	6	0	5	US_RR'	
	6	1	1	1	6	0	5	US_PLL_ATL'	
	7	1	1	1	6	0	5	VEN_LL'	
	8	1	2	4	6	0	4	VEN_PS'	
	9	1	2	4	6	0	1	EUR-FAD-PS'	applies to YFT < 10kg
	10	1	2	4	6	0	5	EUR-PS-3%'	
	11	1	2	4	6	0	4	EU-DAKAR'	
	12	1	1	1	6	0	5	URU-LL'	
	13	0	1	1	6	0	5	BRA-URU-LL'	
	14	1	1	1	6	0	5	CHIN-TAI-LL'	
	15	1	1	1	6	0	5	CHIN-TAI-LL'	
	16	1	1	1	6	0	5	CHIN-TAI-LL'	
	17	1	1	1	6	0	5	CHIN-TAI-LL'	
	18	1	2	1	6	3	5	EU-FS-1%'	applies to > 30 kg (SSB)
	19	0	2	4	6	0	4	CAN-IS-BB'	

Table 17. Effects of updating recent catches and Japanese abundance index. Model parameters (median estimates from bootstraps) estimated by ASPIC for runs 01 (logistic, B1/K =1), 02 (generalized, B1/K =1), 03 (logistic, B1/K =est.) and 04 (generalized, B1/K =est.). The 10% and 90% percentiles are shown in parenthesis.

	Run 01		*Run 02*	
MSY (1000s t)	142	(131.6-149)	135	(110-136.7)
K (1000s t)	1051	(703.8-1,703)	1505	(1,401-3162.)
B_{MSY} (1000s t)	526	(351.9-851)	527	(448-807.9)
F_{MSY}	0.27	0.15-0.42)	0.26	(0.15-0.31)
B_{2006}/B_{MSY}	1.15		0.80	
F_{2006}/F_{MSY}	0.63		0.96	
B_{2010}/B_{MSY}	0.86	(0.7-1.02)	1.03	(0.92-1.21)
F_{2010}/F_{MSY}	0.92	(0.75-1.16)	0.80	(0.68-0.93)
Y equilibrium (1000s t)	140	(122.2-148)	112	(108-113.1)
Y F_{MSY} (1000s t)	140	(122.2-148)	112	(108-113.1)
	Run 03		*Run 04*	
MSY (1000s t)	142	(130.9-148)	135	(104-135.4)
K (1000s t)	1051	(717.8-1,790)	1511	(1,511-4414.)
B_{MSY} (1000s t)	526	(358.9-895)	529	(486-1356.)
F_{MSY}	0.27	0(.15-0.41)	0.26	(0.07-0.28)
B_{2006}/B_{MSY}	0.63		0.91	
F_{2006}/F_{MSY}	1.16		0.86	
B_{2010}/B_{MSY}	0.86	(0.69-1.)	1.02	(0.89-1.2)
F_{2010}/F_{MSY}	0.92	(0.77-1.19)	0.81	(0.68-0.97)
Y equilibrium (1000s t)	140	(121.2-147)	135	(95-136.5)
Y F_{MSY} (1000s t)	140	(121.2-147)	135	(95-136.5)

Table 18. Effects of simply updating the same data used in the last assessment. Model parameters (median estimates from bootstraps) estimated by ASPIC for runs 05 (logistic, B1/K =1, combined index), 06 (logistic, B1/K =est., combined index), 07 (logistic, B1/K =1, separate indices.) and 08 (logistic, B1/K =1, separate indices), which are corresponding runs 02, 04, 06 and 08 in 2008 assessment, respectively. In parenthesis are shown the 10% and 90% percentiles. Last column represent the percent difference between estimated median values of each runs.

	Run 05 in 2011		*Run 02 in 2008*		*Percent diff.*
MSY (1000s t)	136	(89-145)	147	(120-154)	-7%
B_{2006}/B_{MSY}	0.965	(-)	0.834	(0.745-0.965)	14%
F_{2006}/F_{MSY}	0.799	(-)	0.845	(0.615-1.149)	-6%
	Run 06 in 2011		*Run 04 in 2008*		
MSY (1000s t)	136	(90-144)	147	(96-153)	-7%
B_{2006}/B_{MSY}	0.965	(-)	0.834	(0.733-0.963)	14%
F_{2006}/F_{msy}	0.801	(-)	0.845	(0.631-1.206)	-5%
	Run 07 in 2011		*Run 06 in 2008*		
MSY (1000s t)	75	(-)	120	(99-142)	-38%
B_{2006}/B_{MSY}	0.845	(-)	0.944	(0.871-1.044)	-12%
F_{2006}/F_{MSY}	1.680	(-)	0.955	(0.749-1.308)	57%
	Run 08 in 2011		*Run 08 in 2008*		
MSY (1000s t)	135	(-)	150	(144-1.54)	-10%
B_{2006}/B_{MSY}	0.677	(-)	0.707	(0.669-0.764)	-4%
F_{2006}/F_{MSY}	1.190	(-)	0.948	(0.828-1.105)	20%

Table 19. Effects of simply updating the same data used in the last assessment. Model parameters (median estimates from bootstraps) estimated by ASPIC for runs 05 (logistic, B1/K =1, combined index), 06 (logistic, B1/K =est., combined index), 07 (logistic, B1/K =1, separate indices.) and 08 (logistic, B1/K =1, separate indices). The 10% and 90% percentiles are shown in parentheses.

	Run 05 in 2011		*Run 06 in 2011*	
MSY (1000s t)	136	(89-145)	136	(89-144)
K (1000s t)	1,930	(1,140-6,070)	1,970	(1,240-6,120)
B_{MSY} (1000s t)	967	(571-3,040)	983	(620-3,060)
F_{MSY}	0.141	(0.030-0.246)	0.138	(0.029-0.226)
B_{2010}/B_{MSY}	1.108	(0.862-1.298)	1.104	(0.865-1.339)
F_{2010}/F_{MSY}	0.728	(0.577-1.179)	0.732	(0.563-1.119)
Y equilibrium (1000s t)	134	(130-142)	134	(125-141)
Y F_{MSY} (1000s t)	111	(109-113)	111	(108-113)
	Run 07 in 2011		*Run 08 in 2011*	
MSY (1000s t)	75	(65-88)*	135	(125-142)*
K (1000s t)	584	(573-6,020)*	1,500	(542-1,070)*
B_{MSY} (1000s t)	2,920	(2,870-3,010)*	749	(1,080-2,150)*
F_{MSY}	0.026		0.180	
B_{2010}/B_{MSY}	0.785	(0.685-0.906)*	0.795	(0.709-0.905)*
F_{2010}/F_{MSY}	1.821	(1.348-2.448)*	1.027	(0.880-1.210)*
Y equilibrium (1000s t)	71.4		129	
Y F_{MSY} (1000s t)	59.2		109	

*These values were not derived from .bot file due to lack of output of these values. Therefore, these values were calculated from another output files (.det file) using simple percentile.

Table 20. Effects of different assumptions about the rate of catchability increases for the purse seine fishery. Model parameters (median estimates from bootstraps) estimated by ASPIC for runs 09 (logistic, B1/K =1 and 3% increase in purse seine q), 11 (same as 09 but for a 7% increase in purse seine q), 10 (logistic, B1/K =estimated and 3% increase in purse seine q), and 12 same as 09 but for a 7% increase in purse seine q). In parenthesis are shown the 10% and 90% percentiles. The last column represents the percent difference between estimated median values of each run.

	Run 09 (EU-PS 3% inc. q)		*Run 11 (EU-PS 7% inc. q)*		*Percent diff*
MSY (1000s t)	138.4	(107.3-148)	139.2	(97.6-149)	-1%
K (1000s t)	1251	(741.4-3,037)	1204	(704.-3,554)	4%
B_{MSY} (1000s t)	625.6	(370.7-1,519)	602.1	(352.-1,777)	4%
F_{MSY}	0.2213	(0.07-0.4)	0.231	(0.06-0.42)	-5%
B_{2010}/B_{MSY}	0.6968	(0.570.9)	0.692	(0.570-.93)	1%
F_{2010}/F_{MSY}	1.144	(0.85-1.66)	1.147	0(.83-1.62)	0%
Y equilibrium (1000s t)	125.7	(92.3-146)	126	(92.5-146)	0%
Y F_{MSY} (1000s t)			112.5	(106.4-120)	
	Run 10 (EU-PS 3% inc. q)		*Run 12 (EU-PS 7% inc. q)*		
MSY (1000s t)	138.4	(107-148.3)	139.2	(102-148.1)	-1%
K (1000s t)	1251	(726-3223.)	1204	(735-3474.)	4%
B_{MSY} (1000s t)	625.6	(363-1611.)	602.2	(368-1737.)	4%
F_{MSY}	0.2213	(0.06-0.41)	0.231	(0.06-0.4)	-4%
$B_{201}0/B_{MSY}$	0.6968	(0.58-0.92)	0.692	(0.57-0.98)	1%
F_{2010}/F_{MSY}	1.144	0(.84-1.51)	1.146	(0.85-1.63)	0%
Y equilibrium (1000s t	125.7	(93-143.9)	126	(92-143.4)	0%
Y F_{MSY} (1000s t)			112.5	(106-118.5)	

Table 21. Effects of revision of Ghana catch. Model parameters (median estimates from bootstraps) estimated by ASPIC for runs 11 (Task I catch) and 14 (including estimated revisions for Ghana). In parenthesis are shown the 10% and 90% percentiles. The last column represents the percent difference between estimated median values of run 14 and run 11.

		Run 11		*Run 14*	*Percent diff.*
MSY (1000s t)	139	(97.6-149)	144	(113-151.6)	-3%
K (1000s t)	1204	(704.-3,554)	975	(584-2806.)	19%
B_{MSY} (1000s t)	602	(352.-1,777)	487	(292-1403.)	19%
F_{MSY}	0.23	(0.06-0.42)	0.30	(0.08-0.52)	-28%
B_{2010}/B_{MSY}	0.69	(0.57-0.93)	0.66	(0.54-0.87)	5%
F_{2010}/F_{MSY}	1.15	(0.83-1.62)	1.34	(0.96-1.7)	-17%
Y equilibrium (1000s t)	126	(92.5-146)	127	(104-148.)	-1%
Y F_{MSY} (1000s t)	113	(106.4-120)	127	(122-135.1)	-13%

Table 22. Effects of the exclusion of specific indices. Model parameters (median estimates from bootstraps) estimated by ASPIC for runs 11 (Task I catch), 15 (excluding TAI-LL)), 15 (excluding BRA-LL), 17 (excluding EU-PS%7). The 10% and 90% percentiles are shown in parentheses.

	Run 11		*Run 15 (no TAI-LL)*		*Run 16 (no BRA-LL)*		*Run 17 (no EU-PS7%)*	
MSY (1000s t)	139	(97.6-149)	142	(125-148)	139	(94-148)	136	(74-149)
K (1000s t)	1204	(704.-3,554)	1,070	(759-2,010)	1,240	(742-4,020)	1,380	(693-4,930)
B_{MSY} (1000s t)	602	(352.-1,777)	536	(379-1,010)	487	(292-1403.)	691	(346-2,470)
F_{MSY}	0.23	(0.06-0.42)	0.264	(0.122-0.388)	0.225	(0.046-0.398)	0.197	(0.029-0.430)
B_{2010}/B_{MSY}	0.69	(0.57-0.93)	0.716	(0.608-0.871)	0.694	(0.577-0.976)	0.608	(0.48-0.74)
F_{2010}/F_{MSY}	1.15	(0.83-1.62)	1.096	(0.889-1.338)	1.147	(0.769-1.521)	1.322	(0.98-2.346)
Y equilibrium (1000s t)	126	(92.5-146)	130	(113-146)	126	(97-146)	115	(63-139)
Y F_{MSY} (1000s t)	113	(106.4-120)	114	(109-120)	112	(106-119)	110	(104-119)

Table 23. Maximum posterior estimates for PROCEAN parameters and fishery-derived indicators. CAI = Combined abundance index. * indicates that the parameters were fixed.

	m	*r*	*B0/K*	*K*	*MSY*	F/F_{MSY}	B/B_{MSY}
Base case runs							
CAI unweighted	2.3	0.81	0.9*	602224	145416	1.18	0.65
CAI weighted by area	1.85	0.76	0.9*	844301	143494	1.16	0.68
Initial biomass	1.93	0.84	0.8*	737754	146441	1.16	0.68
Shape parameter	1.5*	1.05	0.9*	896992	139065	1.13	0.74
Data inputs in the CAI							
Index without TAI	1.85*	0.64	0.9*	1020000	145052	1.08	0.68
Index without BRZ	1.85*	0.57	0.9*	1150000	145848	1.14	0.68
Index without EUR-PS	1.85*	0.5	0.9*	1230000	137451	1.24	0.62
Multiple indices							
6 CPUE indices	1.85*	0.51	0.9*	1310000	148245	0.89	0.78
5 CPUE indices (excl. TAI-LL 1968-2010)	1.85*	0.52	0.9*	1320000	148000	0.89	0.78
4 CPUE indices (excl. TAI-LL and BRA-LL)	1.26	0.67	0.9*	2350000	134237	0.9	0.86

Table 24. VPA estimates of management benchmarks and reference points.

BASE RUN 1

MEASURE	LOWER 80% CI	MEDIAN	UPPER 80% CI	Deterministic
F at MSY	0.827	1.115	1.425	1.448
MSY	129,904	135,518	141,568	140,880
Y/R at MSY	2.228	2.324	2.409	2.412
S/R at MSY	2.310	2.456	2.577	2.551
SPR AT MSY	0.222	0.237	0.248	0.246
SSB AT MSY	135,529	143,591	150,429	148,986
F at max. Y/R	0.827	1.115	1.425	1.448
Y/R maximum	2.228	2.324	2.409	2.412
S/R at Fmax	2.310	2.456	2.577	2.551
SPR at Fmax	0.222	0.237	0.248	0.246
SSB at Fmax	135,529	143,591	150,429	148,986
F 0.1	0.504	0.626	0.738	0.745
Y/R at F0.1	2.085	2.150	2.200	2.202
S/R at F0.1	3.859	4.168	4.436	4.428
SPR at F0.1	0.372	0.401	0.427	0.426
SSB at F0.1	226,518	243,532	258,609	258,589

BASE RUN 2

MEASURE	LOWER 80% CI	MEDIAN	UPPER 80% CI	Deterministic
F at MSY	0.771	0.823	0.880	0.874
MSY	130,326	136,842	143,451	141,066
Y/R at MSY	2.012	2.101	2.174	2.172
S/R at MSY	1.975	2.045	2.104	2.056
SPR AT MSY	0.190	0.197	0.203	0.198
SSB AT MSY	128,673	133,555	138,176	133,586
F at max. Y/R	0.771	0.823	0.880	0.874
Y/R maximum	2.012	2.101	2.174	2.172
S/R at Fmax	1.975	2.045	2.104	2.056
SPR at Fmax	0.190	0.197	0.203	0.198
SSB at Fmax	128,673	133,555	138,176	133,586
F 0.1	0.511	0.541	0.572	0.568
Y/R at F0.1	1.916	1.994	2.059	2.059
S/R at F0.1	3.278	3.384	3.487	3.416
SPR at F0.1	0.316	0.326	0.336	0.329
SSB at F0.1	213,472	221,025	228,657	221,927

BASE RUN 3

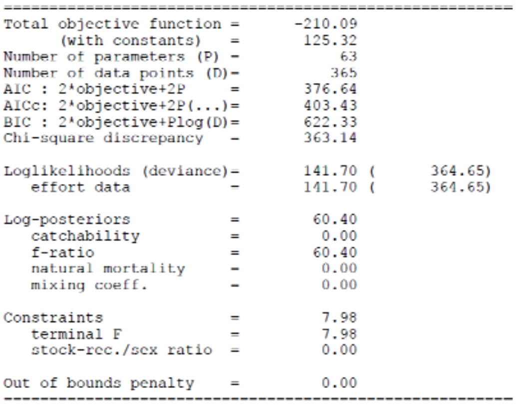
MEASURE	LOWER 80% CI	MEDIAN	UPPER 80% CI	Deterministic
F at MSY	0.774	0.897	1.083	1.181
MSY	125,263	129,884	134,989	135,917
Y/R at MSY	2.191	2.260	2.333	2.359
S/R at MSY	2.255	2.347	2.441	2.448
SPR AT MSY	0.217	0.226	0.235	0.236
SSB AT MSY	129,733	135,036	140,234	141,047
F at max. Y/R	0.774	0.897	1.083	1.181
Y/R maximum	2.191	2.260	2.333	2.359
S/R at Fmax	2.255	2.347	2.441	2.448
SPR at Fmax	0.217	0.226	0.235	0.236
SSB at Fmax	129,733	135,036	140,234	141,047
F 0.1	0.476	0.530	0.613	0.650
Y/R at F0.1	2.058	2.111	2.164	2.177
S/R at F0.1	3.751	3.941	4.122	4.191
SPR at F0.1	0.361	0.380	0.397	0.404
SSB at F0.1	215,614	226,339	237,522	241,450

BASE RUN 4

MEASURE	LOWER 80% CI	MEDIAN	UPPER 80% CI	Deterministic
F at MSY	0.755	0.801	0.934	0.819
MSY	121,278	126,628	131,870	130,809
Y/R at MSY	2.113	2.197	2.280	2.266
S/R at MSY	2.141	2.259	2.378	2.283
SPR AT MSY	0.206	0.218	0.229	0.220
SSB AT MSY	123,875	129,918	136,714	131,815
F at max. Y/R	0.755	0.801	0.934	0.819
Y/R maximum	2.113	2.197	2.280	2.266
S/R at Fmax	2.141	2.259	2.378	2.283
SPR at Fmax	0.206	0.218	0.229	0.220
SSB at Fmax	123,875	129,918	136,714	131,815
F 0.1	0.473	0.499	0.549	0.493
Y/R at F0.1	1.997	2.066	2.127	2.122
S/R at F0.1	3.548	3.752	3.986	3.833
SPR at F0.1	0.342	0.361	0.384	0.369
SSB at F0.1	204,911	215,775	229,975	221,249

Table 25. VPA base model fit statistics.

BASE RUN 1



```
=========================================================
Total objective function =       -210.09
      (with constants)   =        125.32
Number of parameters (P) =            63
Number of data points (D)=           365
AIC : 2*objective+2P     =        376.64
AICc: 2*objective+2P(...)=        403.43
BIC : 2*objective+Plog(D)=        622.33
Chi-square discrepancy   =        363.14

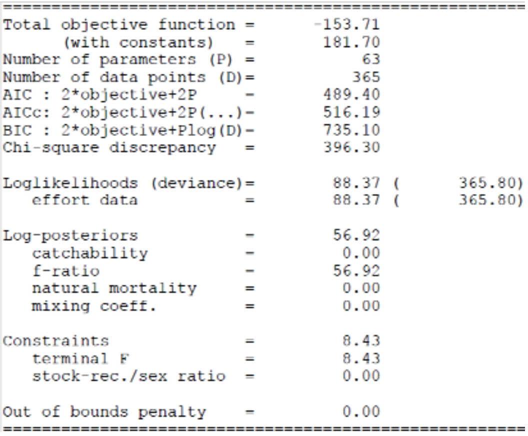
Loglikelihoods (deviance)=        141.70 (       364.65)
   effort data           =        141.70 (       364.65)

Log-posteriors           =         60.40
   catchability          =          0.00
   f-ratio               =         60.40
   natural mortality     =          0.00
   mixing coeff.         =          0.00

Constraints              =          7.98
   terminal F            =          7.98
   stock-rec./sex ratio  =          0.00

Out of bounds penalty    =          0.00
=========================================================
```

BASE RUN 2



```
=========================================================
Total objective function =       -153.71
      (with constants)   =        181.70
Number of parameters (P) =            63
Number of data points (D)=           365
AIC : 2*objective+2P     =        489.40
AICc: 2*objective+2P(...)=        516.19
BIC : 2*objective+Plog(D)=        735.10
Chi-square discrepancy   =        396.30

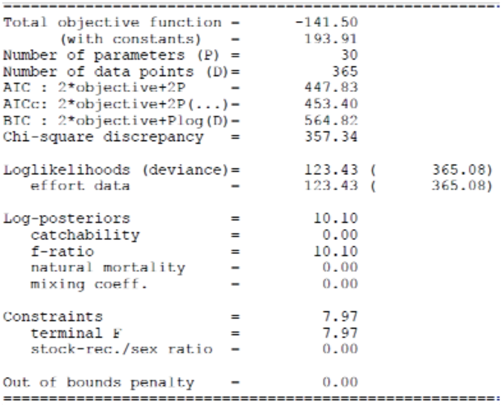
Loglikelihoods (deviance)=         88.37 (       365.80)
   effort data           =         88.37 (       365.80)

Log-posteriors           =         56.92
   catchability          =          0.00
   f-ratio               =         56.92
   natural mortality     =          0.00
   mixing coeff.         =          0.00

Constraints              =          8.43
   terminal F            =          8.43
   stock-rec./sex ratio  =          0.00

Out of bounds penalty    =          0.00
=========================================================
```

BASE RUN 3



```
=========================================================
Total objective function =       -141.50
      (with constants)   =        193.91
Number of parameters (P) =            30
Number of data points (D)=           365
AIC : 2*objective+2P     =        447.83
AICc: 2*objective+2P(...)=        453.40
BIC : 2*objective+Plog(D)=        564.82
Chi-square discrepancy   =        357.34

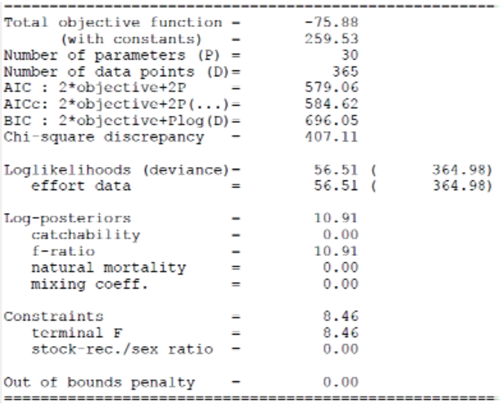
Loglikelihoods (deviance)=        123.43 (       365.08)
   effort data           =        123.43 (       365.08)

Log-posteriors           =         10.10
   catchability          =          0.00
   f-ratio               =         10.10
   natural mortality     =          0.00
   mixing coeff.         =          0.00

Constraints              =          7.97
   terminal F            =          7.97
   stock-rec./sex ratio  =          0.00

Out of bounds penalty    =          0.00
=========================================================
```

BASE RUN 4



```
=========================================================
Total objective function =        -75.88
      (with constants)   =        259.53
Number of parameters (P) =            30
Number of data points (D)=           365
AIC : 2*objective+2P     =        579.06
AICc: 2*objective+2P(...)=        584.62
BIC : 2*objective+Plog(D)=        696.05
Chi-square discrepancy   =        407.11

Loglikelihoods (deviance)=         56.51 (       364.98)
   effort data           =         56.51 (       364.98)

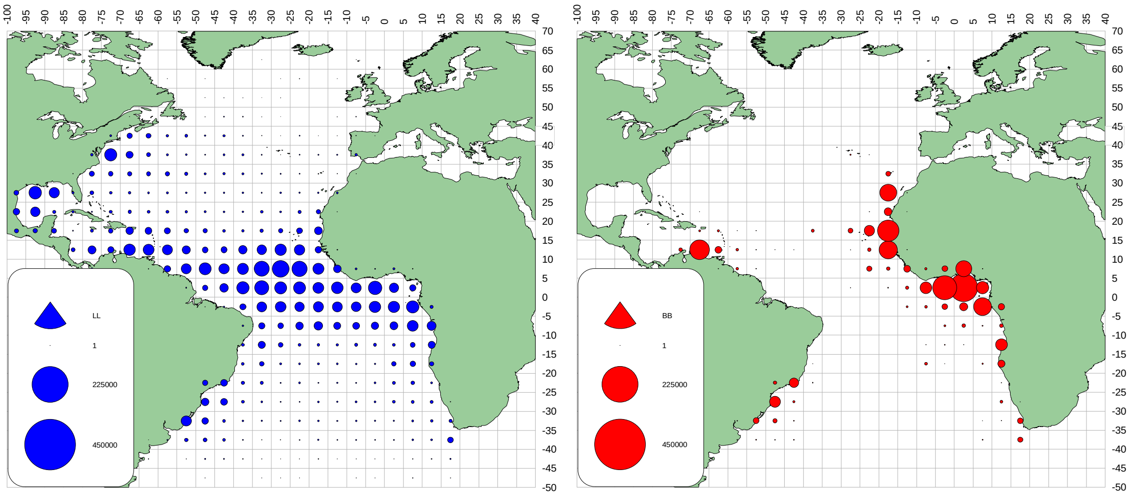
Log-posteriors           =         10.91
   catchability          =          0.00
   f-ratio               =         10.91
   natural mortality     =          0.00
   mixing coeff.         =          0.00

Constraints              =          8.46
   terminal F            =          8.46
   stock-rec./sex ratio  =          0.00

Out of bounds penalty    =          0.00
=========================================================
```

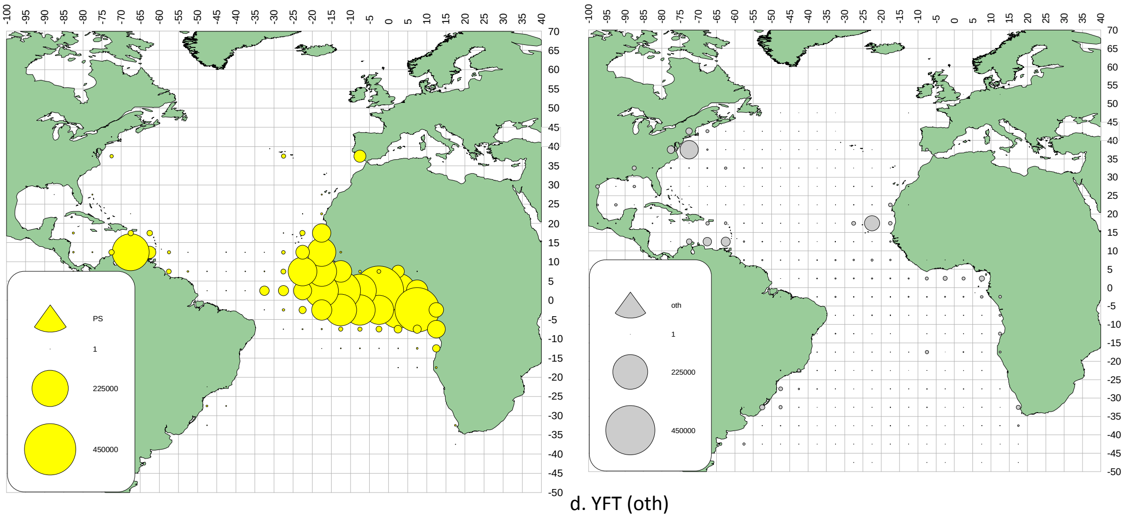
Table 26. Management benchmarks and references developed from the ASPIC/VPA joint distribution.

	Relative Biomass (SSB_{2010}/SSB_{MSY} for VPA, B_{2011}/B_{MSY} for ASPIC)		
Method	**Median**	**10th percentile**	**90th percentile**
Production model (ASPIC)	0.6946	0.5701	0.9243
Age-Structured model (VPA)	0.5248	0.4253	0.6722
Combined distribution (ASPIC and VPA)	0.6123	0.4551	0.8451
	Relative Fishing Mortality ($F_{current}/F_{MSY}$ for VPA, F_{2010}/F_{MSY} for ASPIC)		
Method	**Median**	**10th percentile**	**90th percentile**
Production model (ASPIC)	1.0861	0.7466	1.6255
Age-Structured model (VPA)	1.3222	1.1462	1.5056
Combined distribution (ASPIC and VPA)	1.2540	0.8545	1.5329



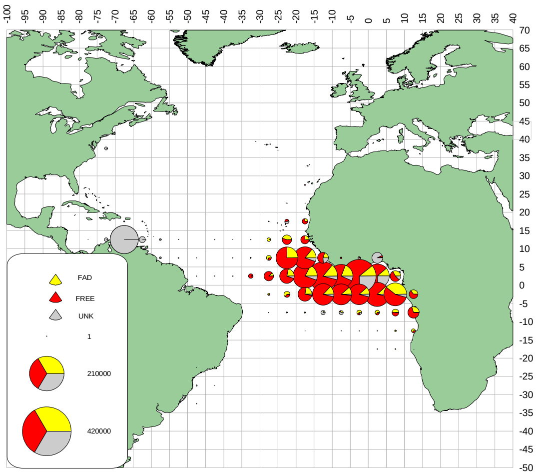
a. YFT (LL)

b. YFT (BB)



c. YFT (PS)

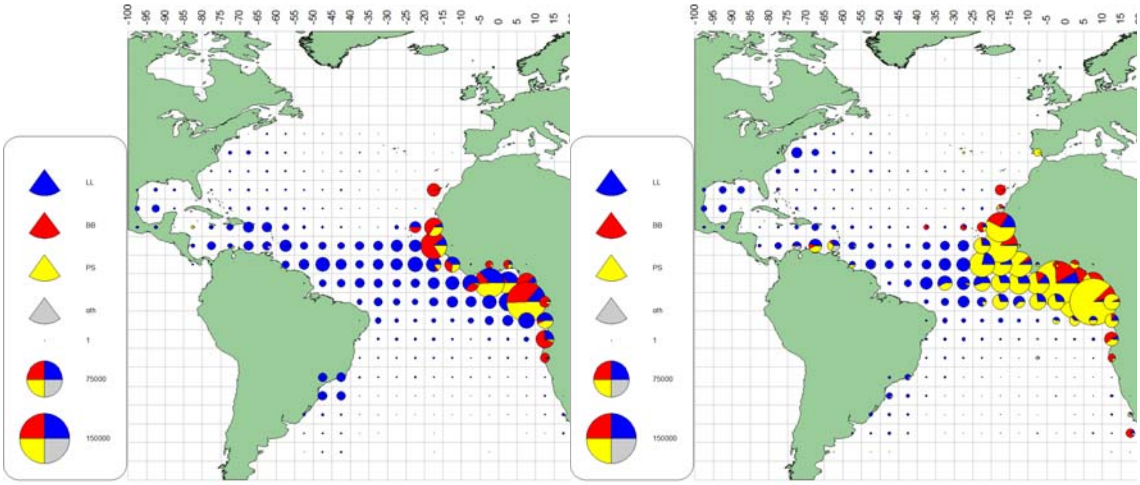
d. YFT (oth)



e. YFT (FAD/FREE 1991-09)

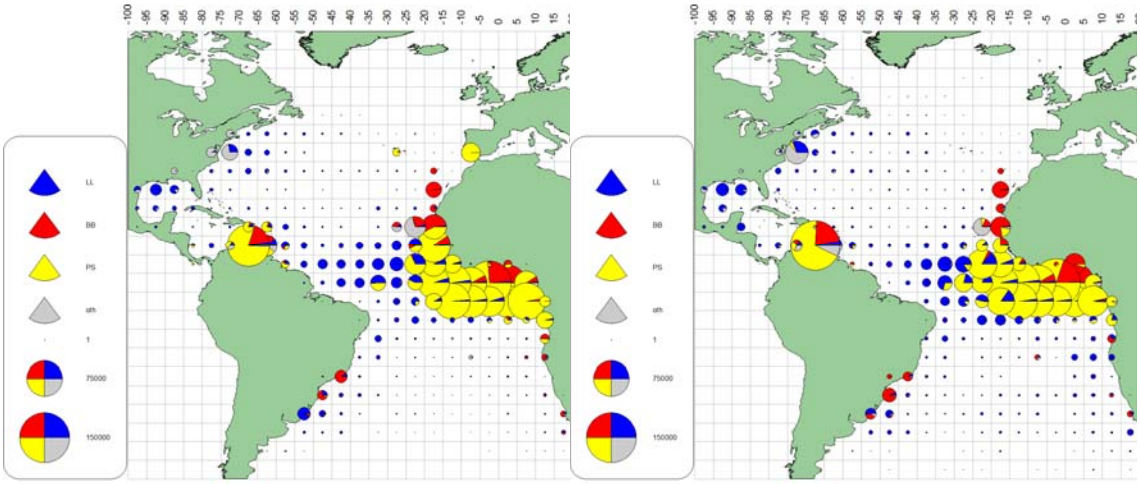
Figure 1. Geographical distribution of yellowfin catch (t) by major gears, for the entire 1960-2009 period. [e] For 1991-2009 catches are split by free school and FADs.

.



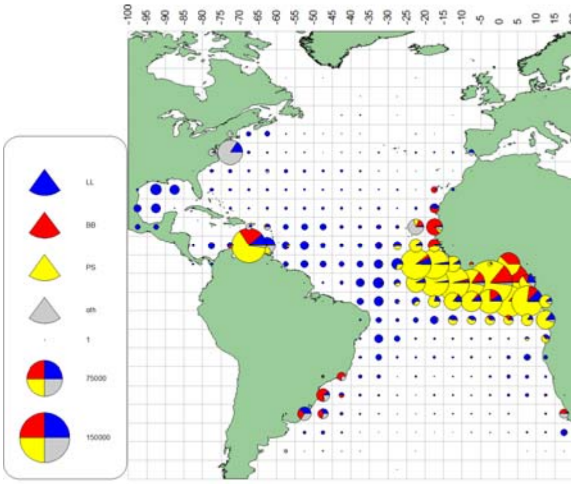
a. YFT(1960-69)

b. YFT(1970-79)



c. YFT(1980-89)

d. YFT(1990-99)



e. YFT (2000-09)

Figure 2. Geographical distribution of yellowfin catch by major gear and decade.

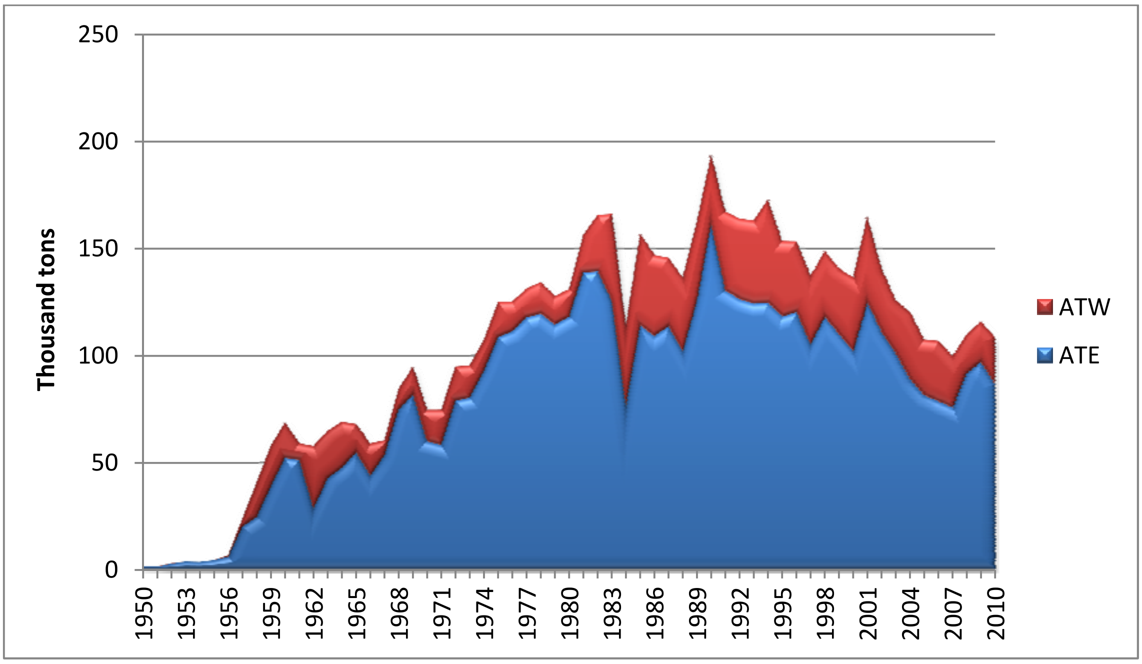


Figure 3. Atlantic yellowfin tuna catch by area.

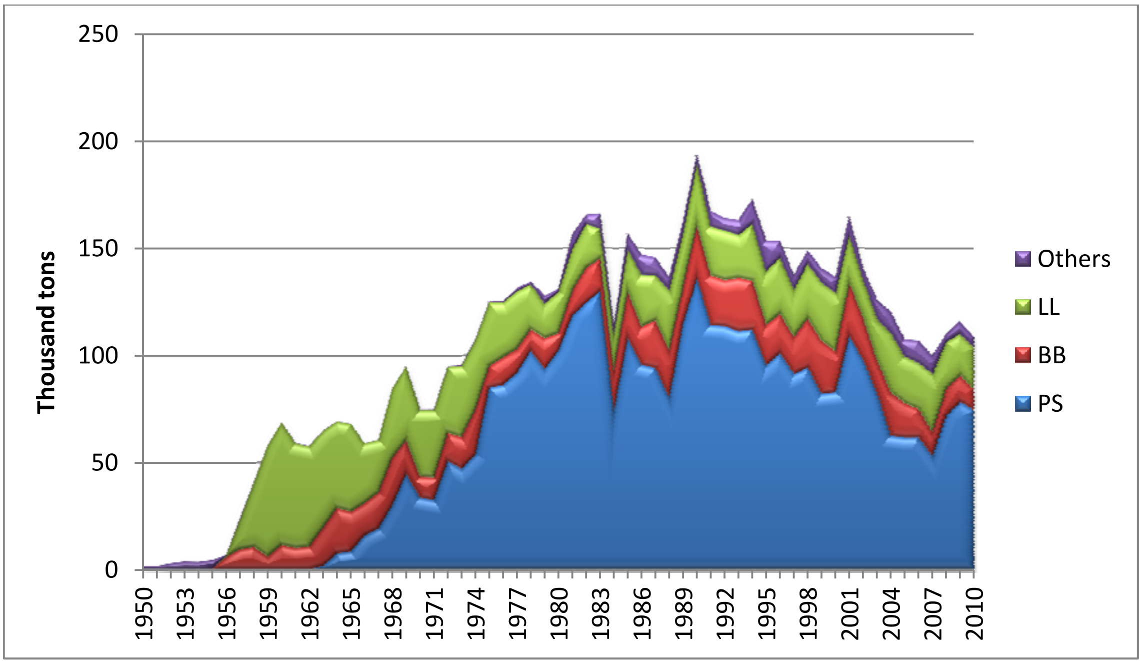


Figure 4. Atlantic yellowfin tuna catch by gear.

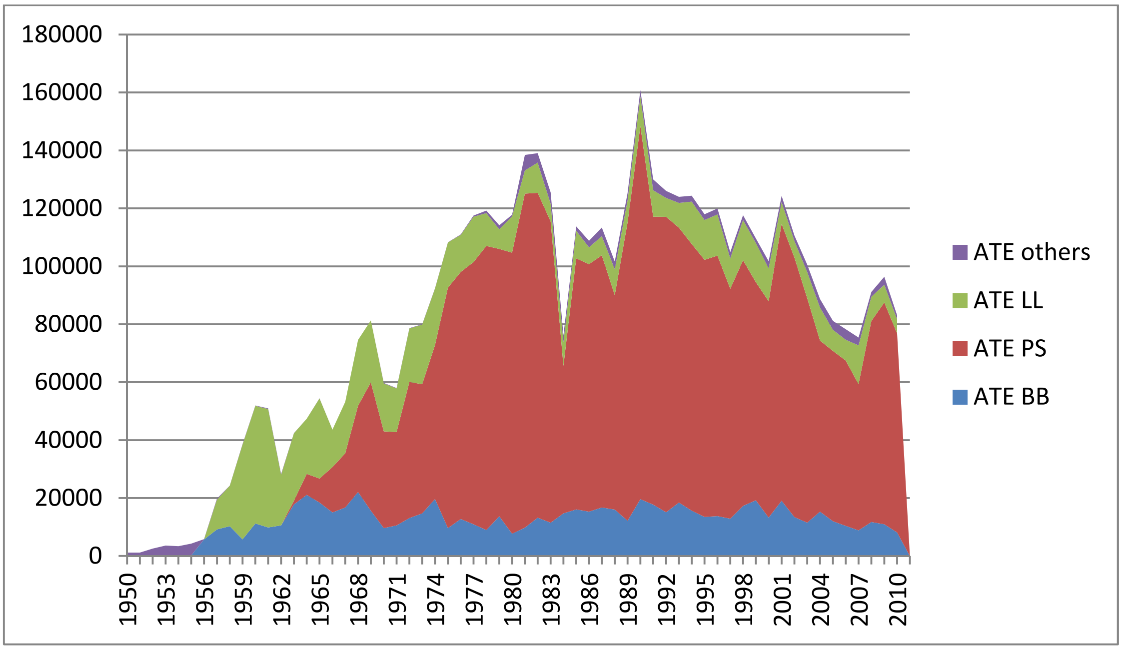


Figure 5. Catch by gear east.

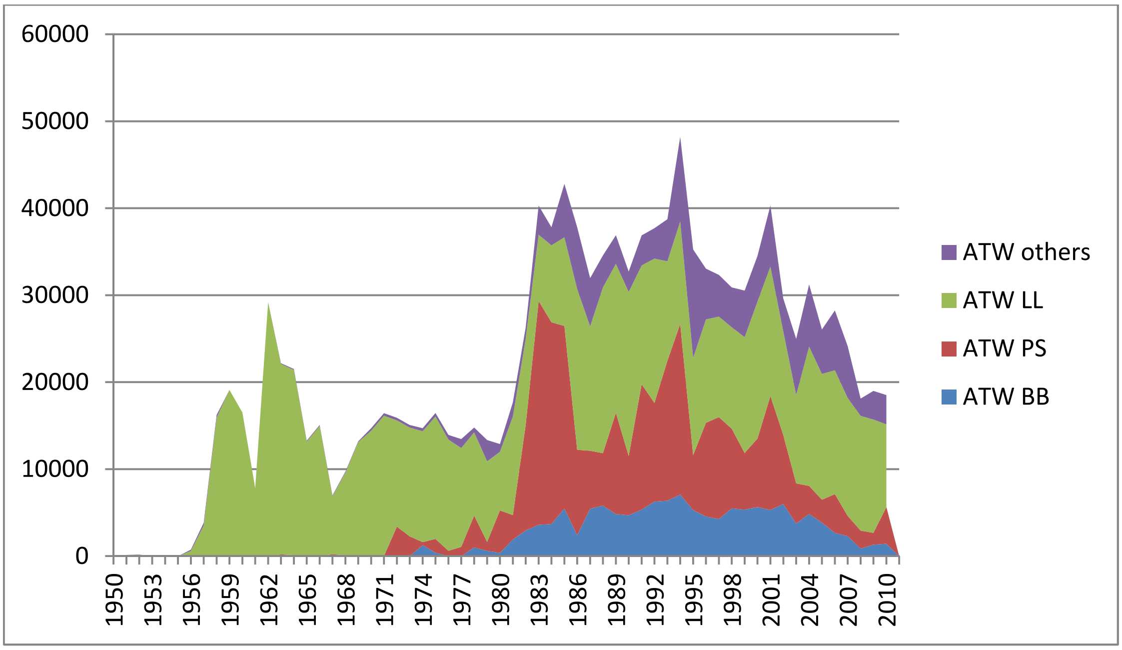


Figure 6. Catch by gear west.

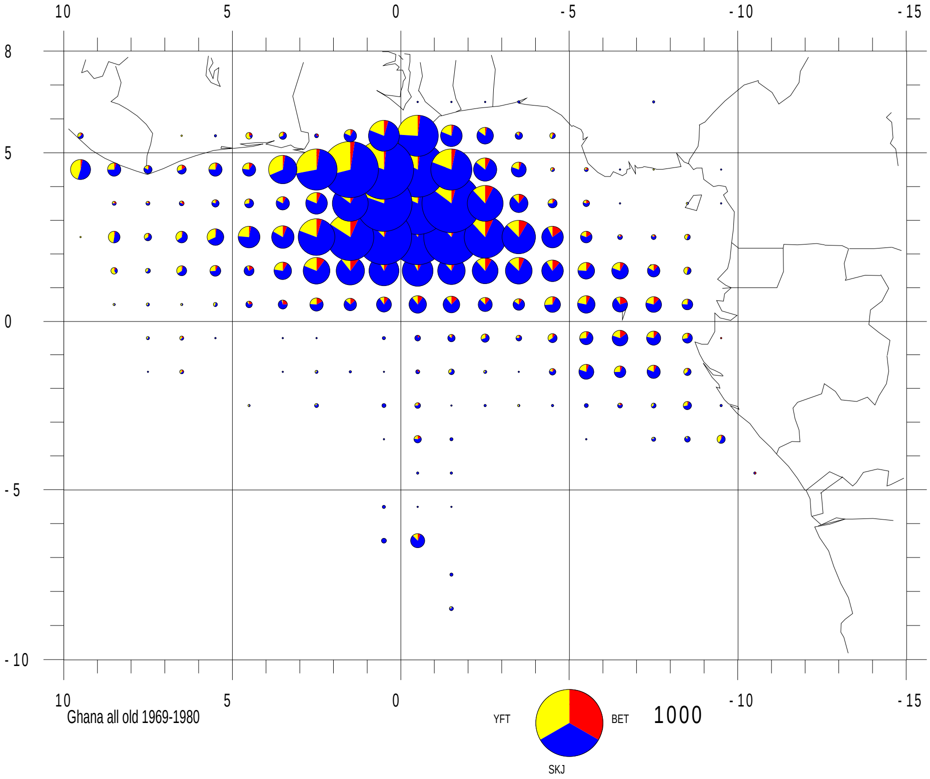


Figure 7. Catch distribution of Ghanaian catches in the historical period (1969-1980).

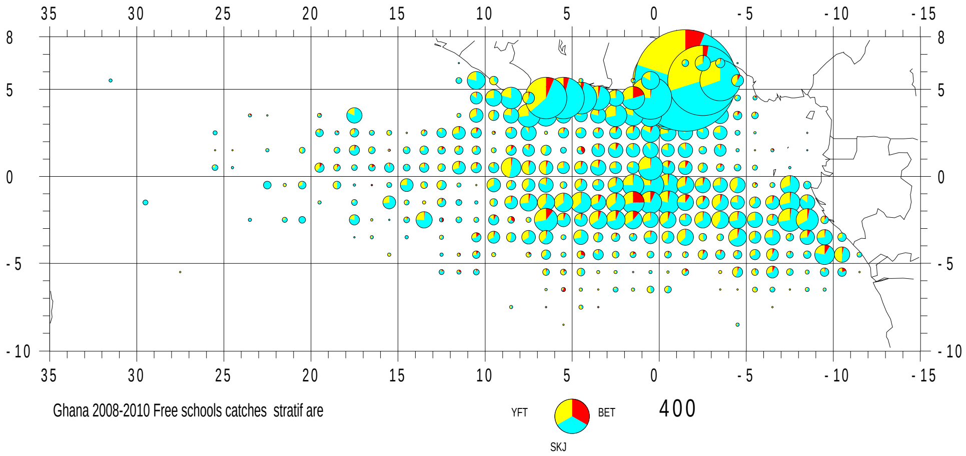


Figure 8. Ghanaian catches in free schools in the recent period (2008-2010).

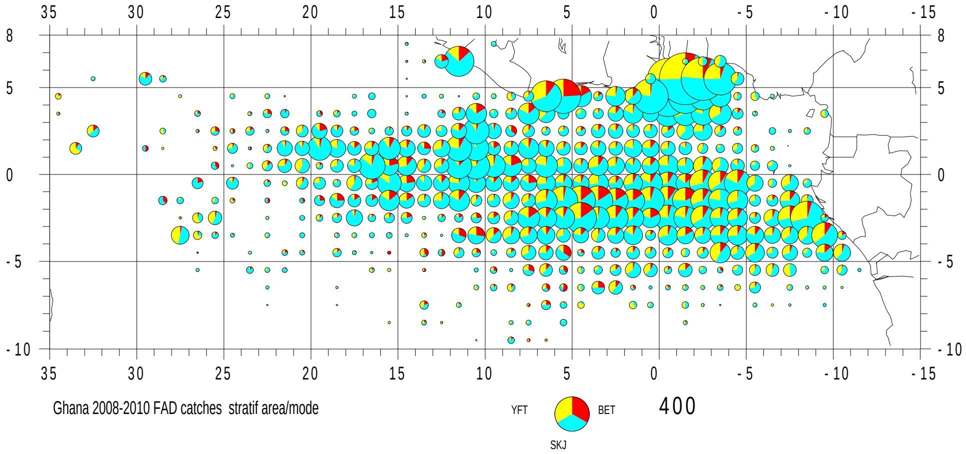


Figure 9. Ghanaian catches in FADs in the recent period (2008-2010).

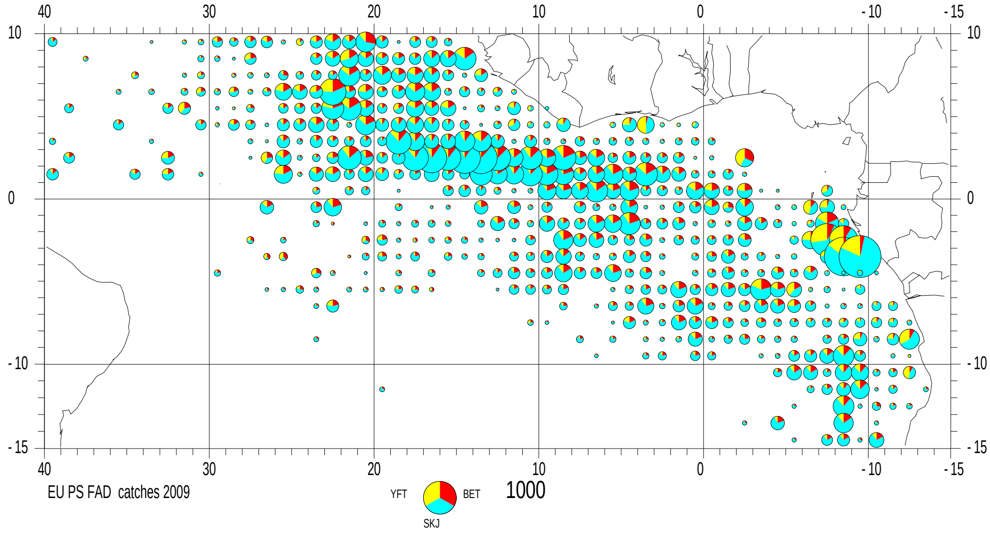


Figure 10. European and associated fishery catch on FADs in 2009.

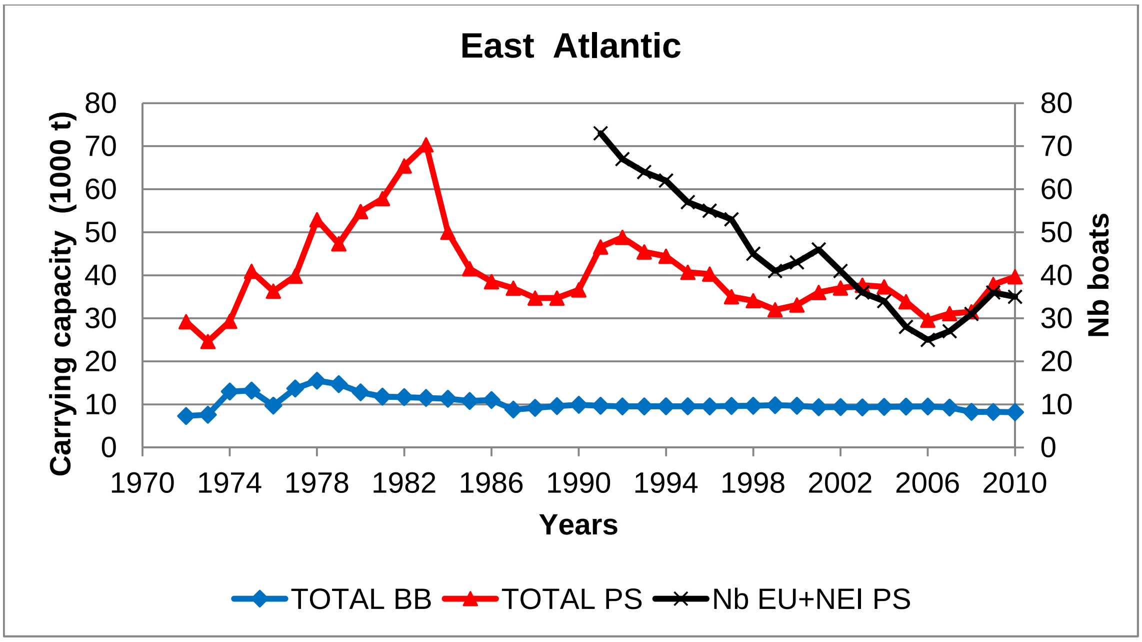


Figure 11. Carrying capacity of the surface fleets in the East Atlantic for the period 1972-2010.

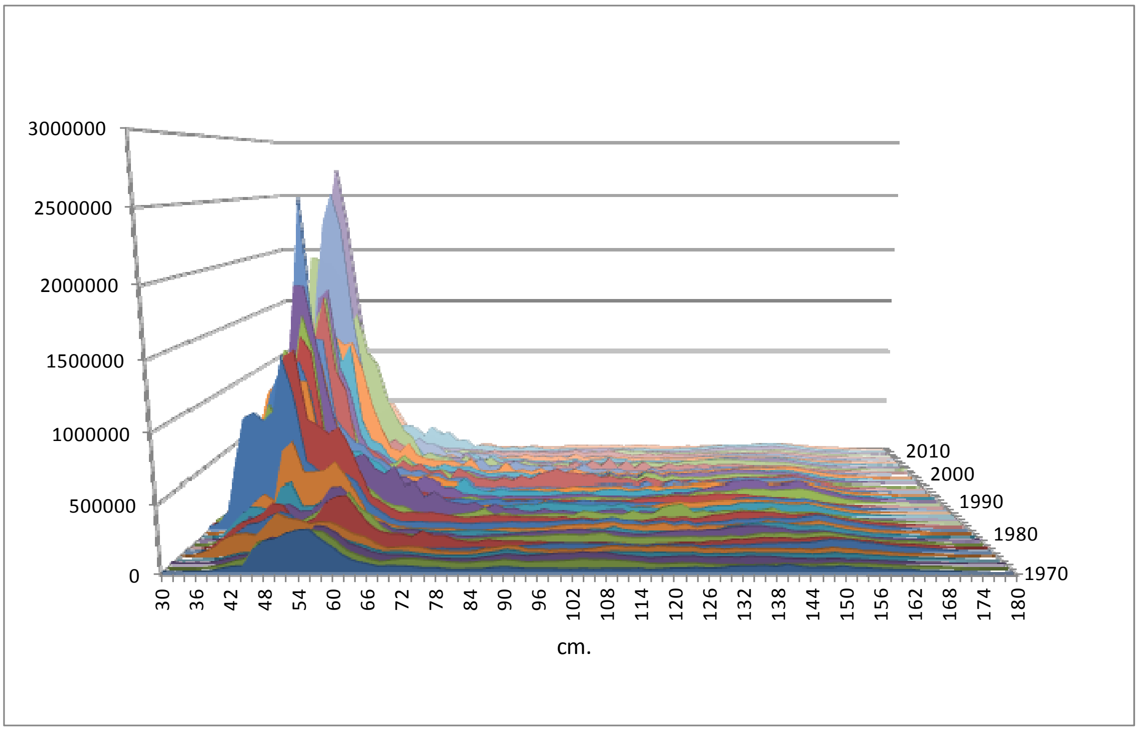


Figure 12. Catch at size frequency distribution of YFT by year (1970-2010).

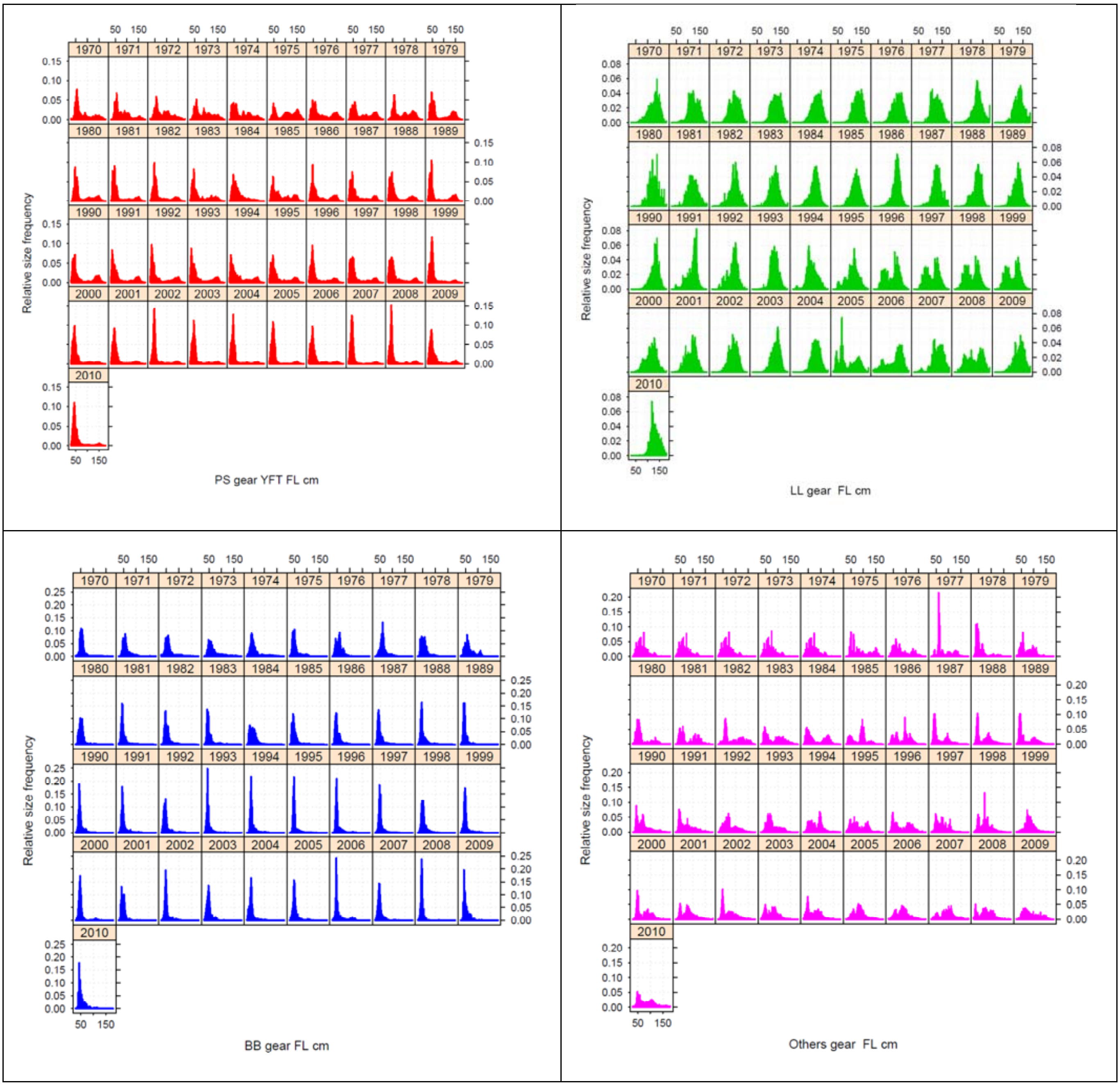


Figure 13. Estimated CAS frequency distribution of yellowfin by year and by main gear groups, PS (upper left), LL (upper right), BB (lower left) and others (lower right).

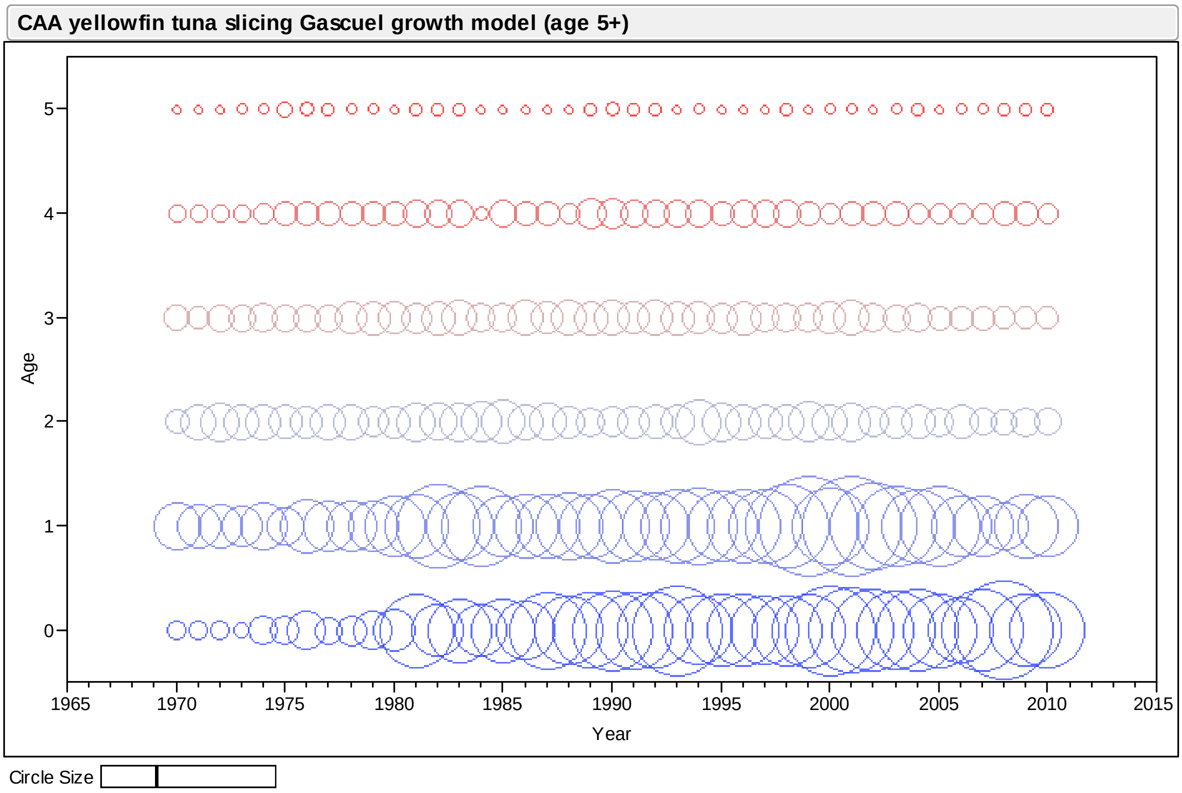


Figure 14. Catch at age of yellowfin tuna 1970-2010 estimated as input for the age structure model(s).

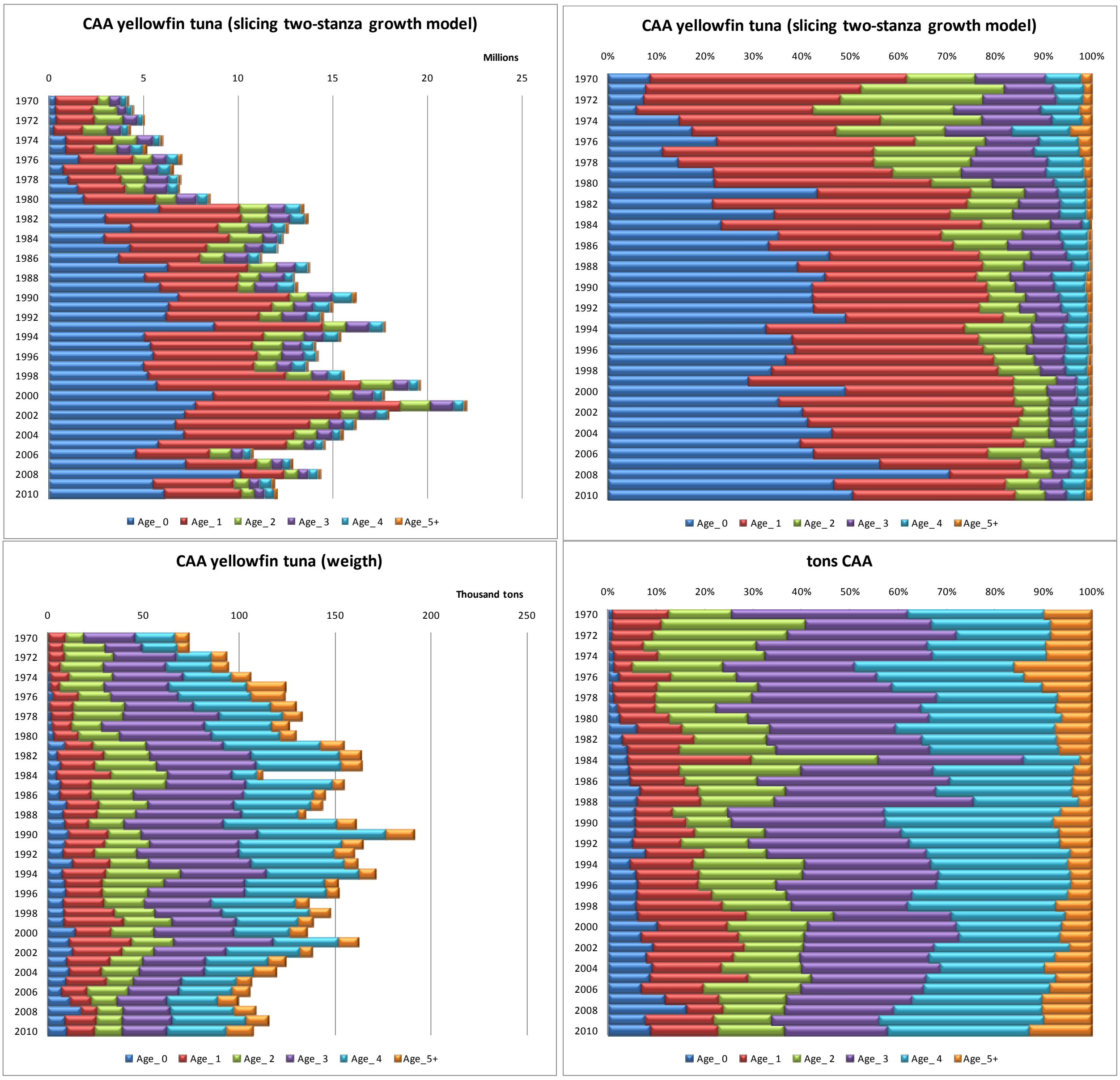


Figure 15. Catch at age distribution in numbers of fish (top row) and weight (bottom row) for yellow fin 1970-2010.

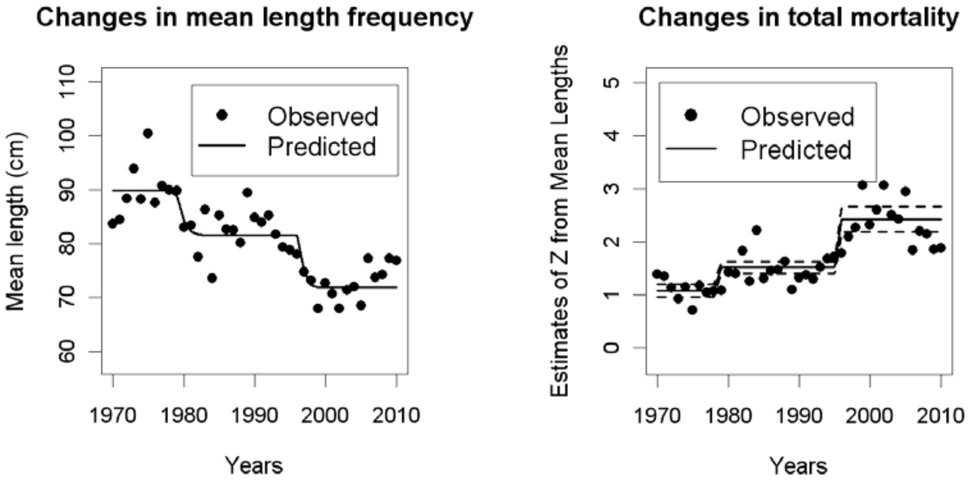


Figure 16. Mean lengths (left) and Beverton-Holt total mortality (right) for Atlantic yellowfin from 1970 to 2010, observed and predicted values by the transitional model of Gedamke-Hoenig in non-equilibrium situations

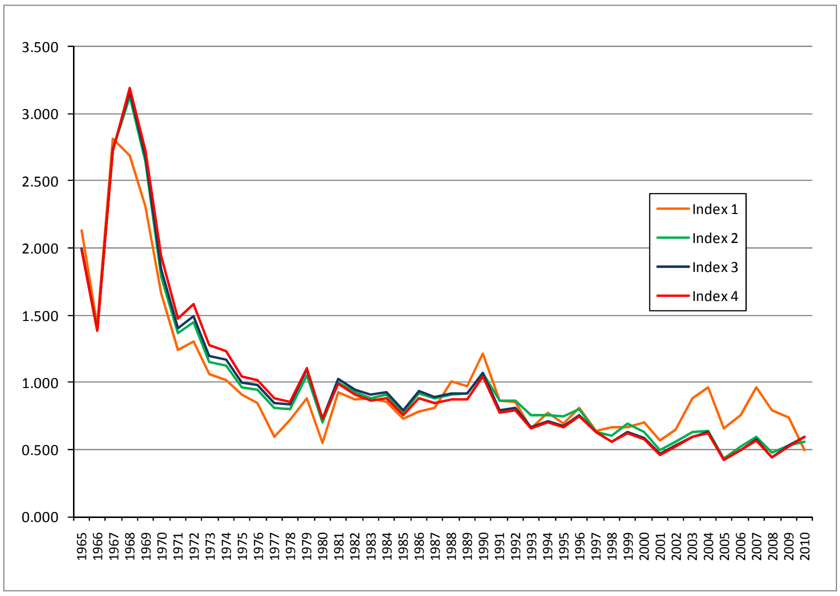


Figure 17. Estimated weighted combined indexes of abundance. For comparison purposes, each series was scaled to their average value. Refer to text for explanation of each series.

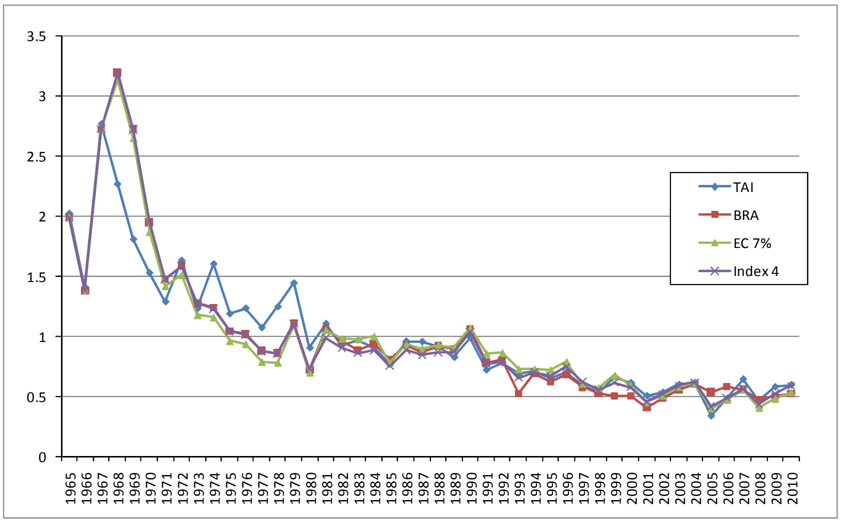
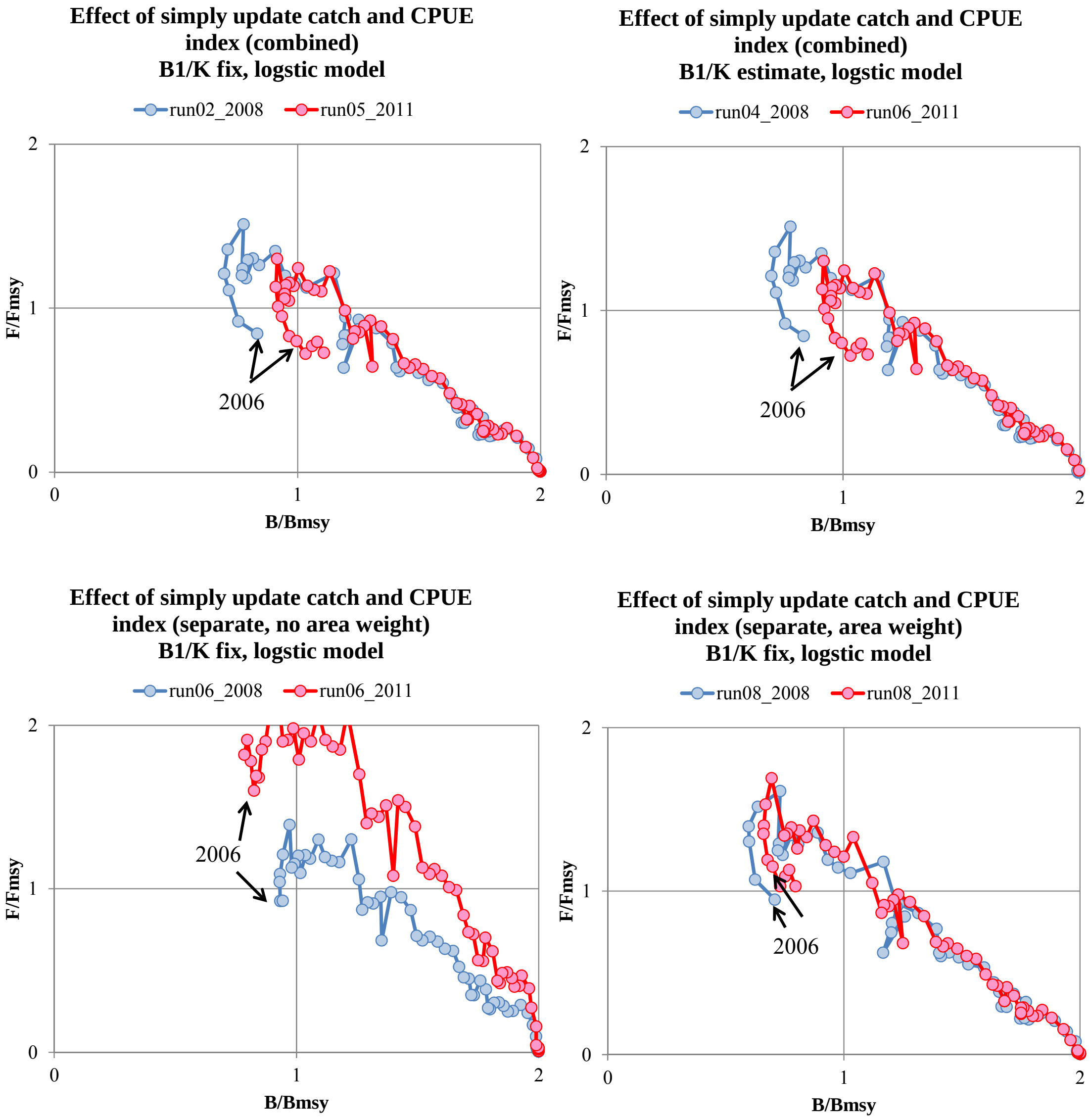


Figure 18. Weighted estimated indexes of abundance. The series labeled ‘Tai’ corresponds to the ‘Index 4’ estimated without the Chinese-Taipei longline index. Similarly, the series labeled ‘BRA’ and ‘EC7%’ correspond to the ‘Index 4’ estimated without the Brazilian longline and all EC PS fisheries, respectively. For comparison purposes, each series was scaled to their average value. Refer to text for explanation of the ‘Index 4’.


Effect of simply update catch and CPUE index (combined) B1/K fix, logstic model

Effect of simply update catch and CPUE index (combined) B1/K estimate, logstic model

Effect of simply update catch and CPUE index (separate, no area weight) B1/K fix, logstic model

Effect of simply update catch and CPUE index (separate, area weight) B1/K fix, logstic model

Figure 19. Effects of simply updating the same data used in the last assessment. Biomass ratios and fishing mortality ratios by year from ASPIC for runs 9 (3 % increase in catchability for purse seine) and 11 (7% increase in catchability for purse seine).

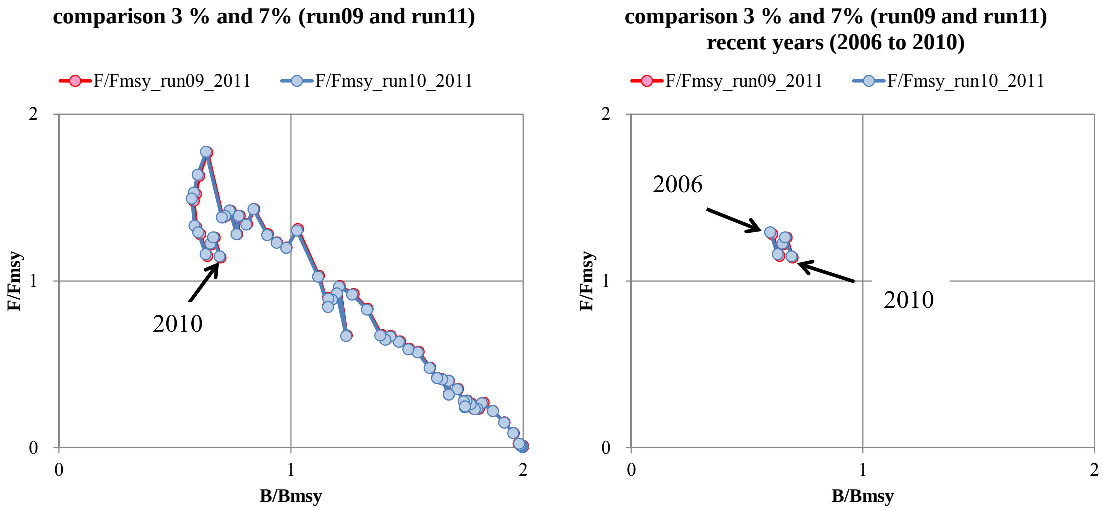


Figure 20. Effects of assumption on percent increase catchability in purse seine fleet . Biomass ratios and fishing mortality ratios by year from ASPIC for runs 9 (3 % increase in catchability for purse seine) and 11 (7% increase in catchability for purse seine). Left panel (whole time series 1950 to 2010), right panel (recent years 2006 to 2010).

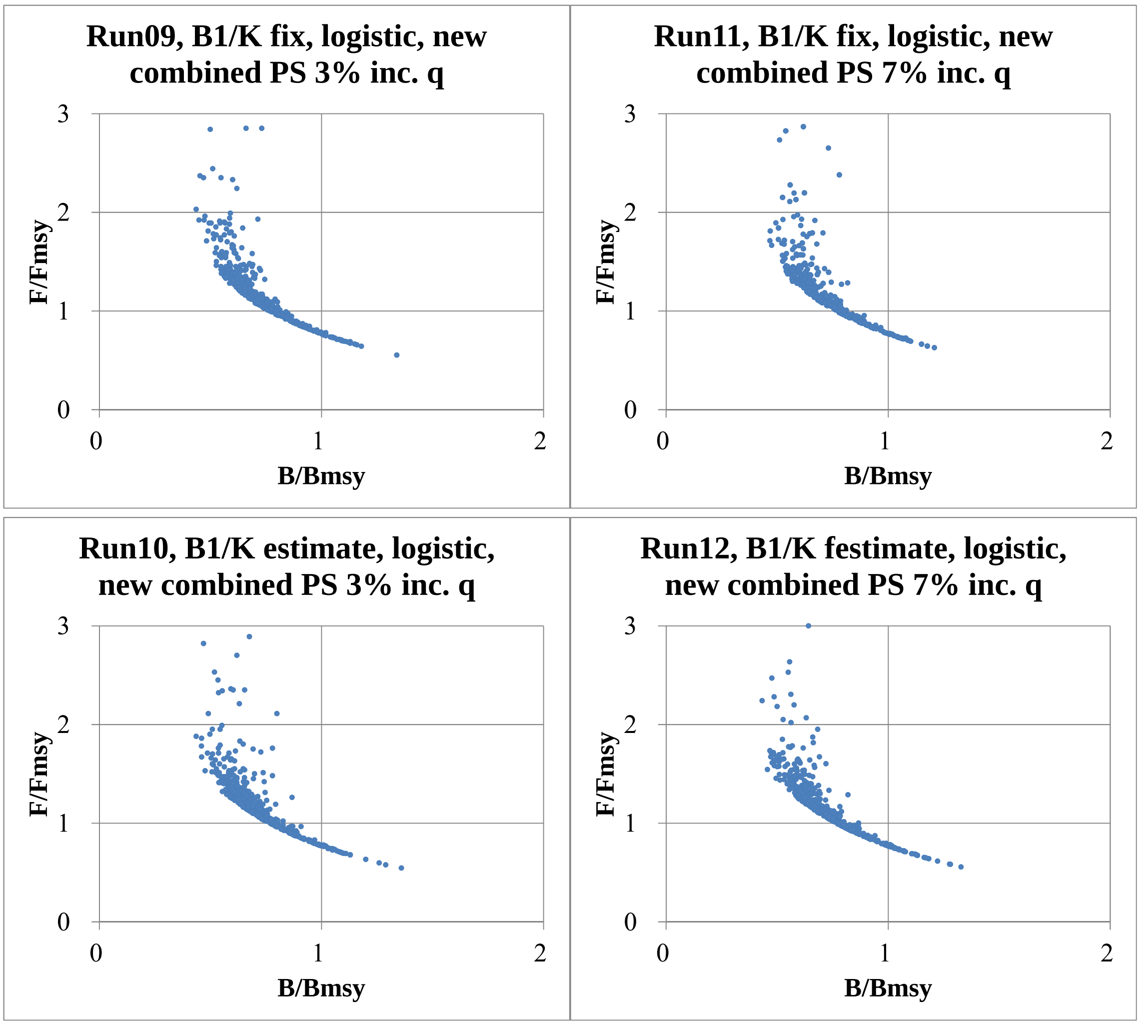
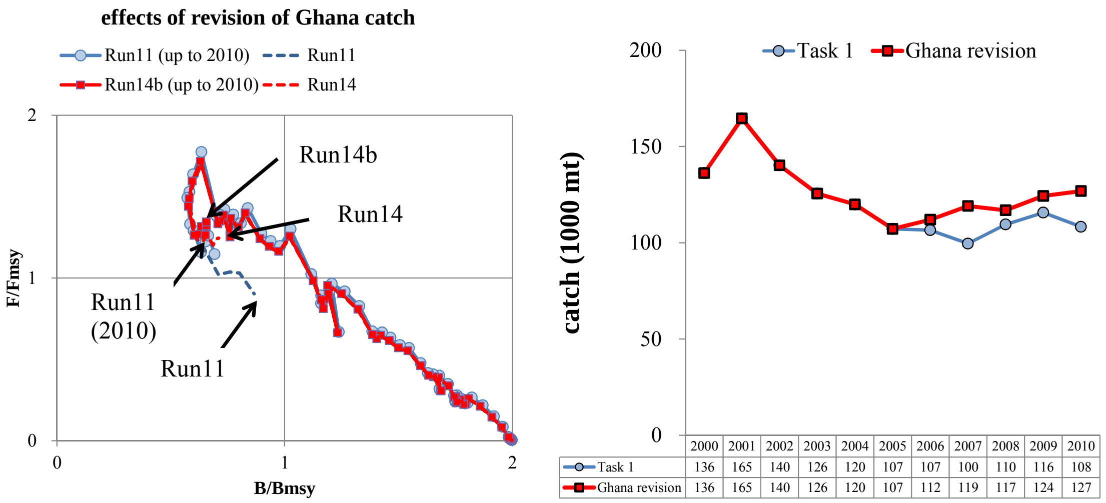


Figure 21. Results of bootstrap examination for Run 09 to Run 12.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Task 1	136	165	140	126	120	107	107	100	110	116	108
Ghana revision	136	165	140	126	120	107	112	119	117	124	127

Figure 22. Effects of revision of Ghana catch. Biomass ratios and fishing mortality ratios by year from ASPIC for runs 11 (Task I catch) and 14 (including estimated revisions for Ghana).

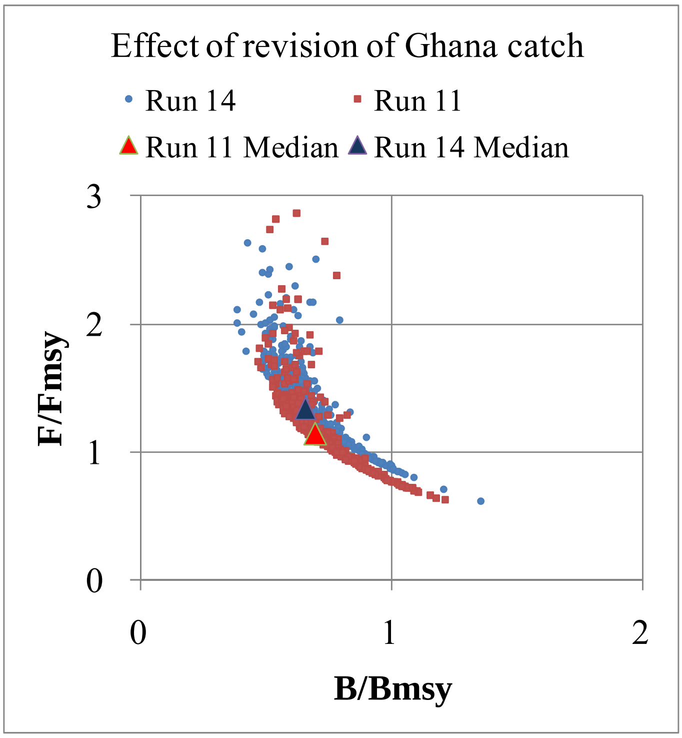


Figure 23. Effects of revision of Ghana catch. Biomass ratios and fishing mortality ratios for most recent year of assessment (2010) from ASPIC for runs 11 (Task I catch) and 14 (including estimated revisions for Ghana). Points represent 500 bootstraps, triangles correspond to median.

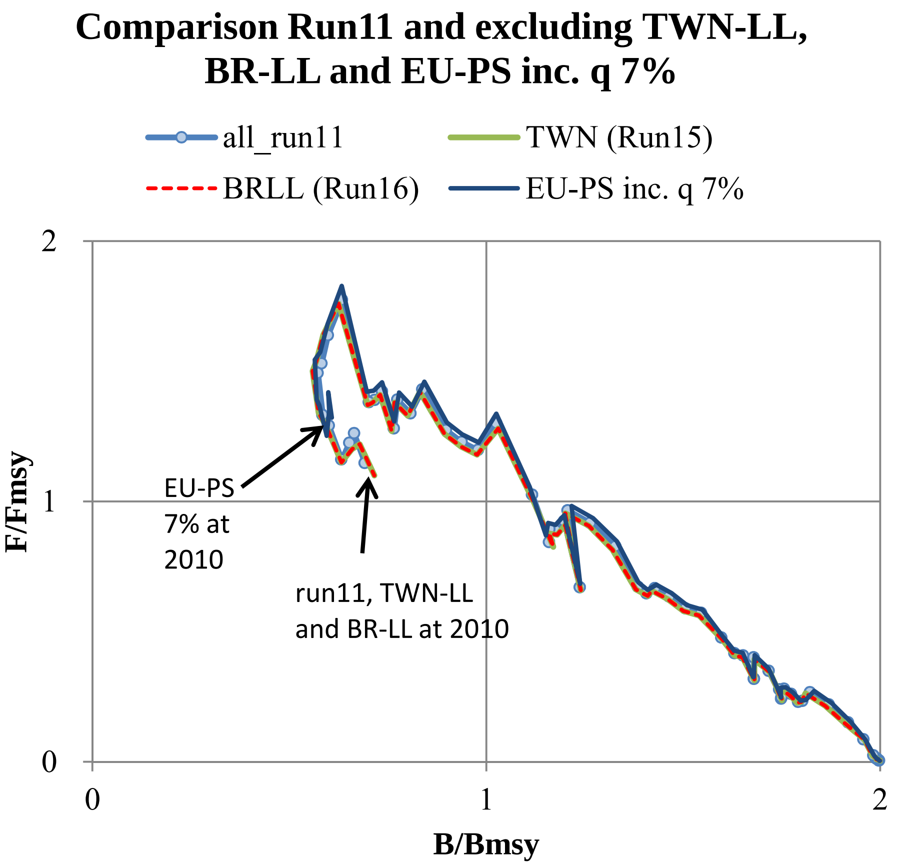


Figure 24. Effects of excluding of specific fleets when processing a combined index. Biomass ratios and fishing mortality ratios by year from ASPIC for excluding Chinese Taipei-LL (run 15), Brazilian-LL (run 16) and EU-PS 7% inc. q (run 17).

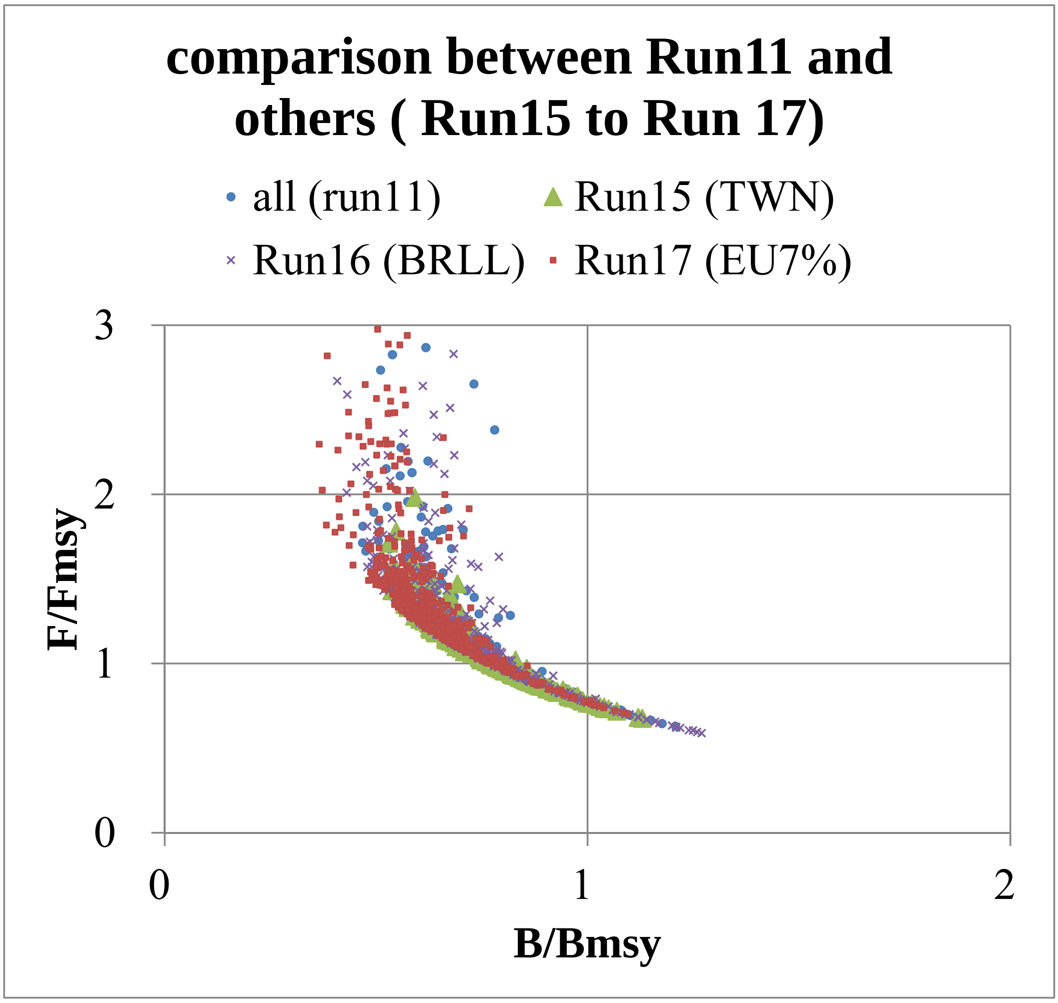


Figure 25. Effects of excluding of specific fleets when processing a combined index. Biomass ratios and fishing mortality ratios by year from ASPIC for excluding Chinese Taipei-LL (run 15), Brazilian-LL (run 16) and EU-PS 7% inc. q (run 17). Points represent 500 bootstraps, triangles correspond to median.

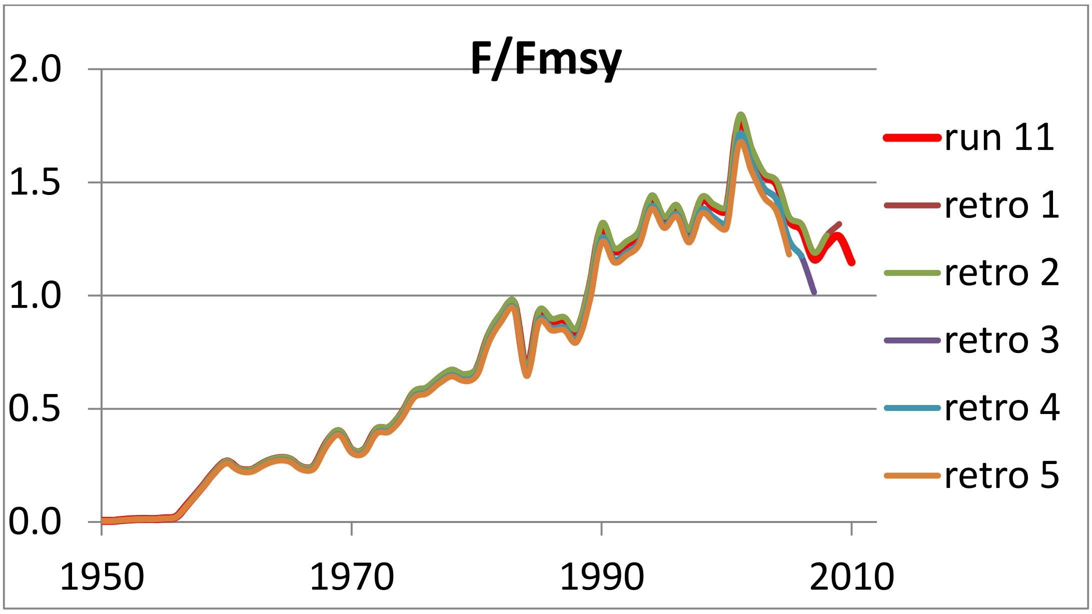


Figure 26. Retrospective patterns of F/F_{MSY} obtained by successively removing a single year of data from ASPIC run 11.

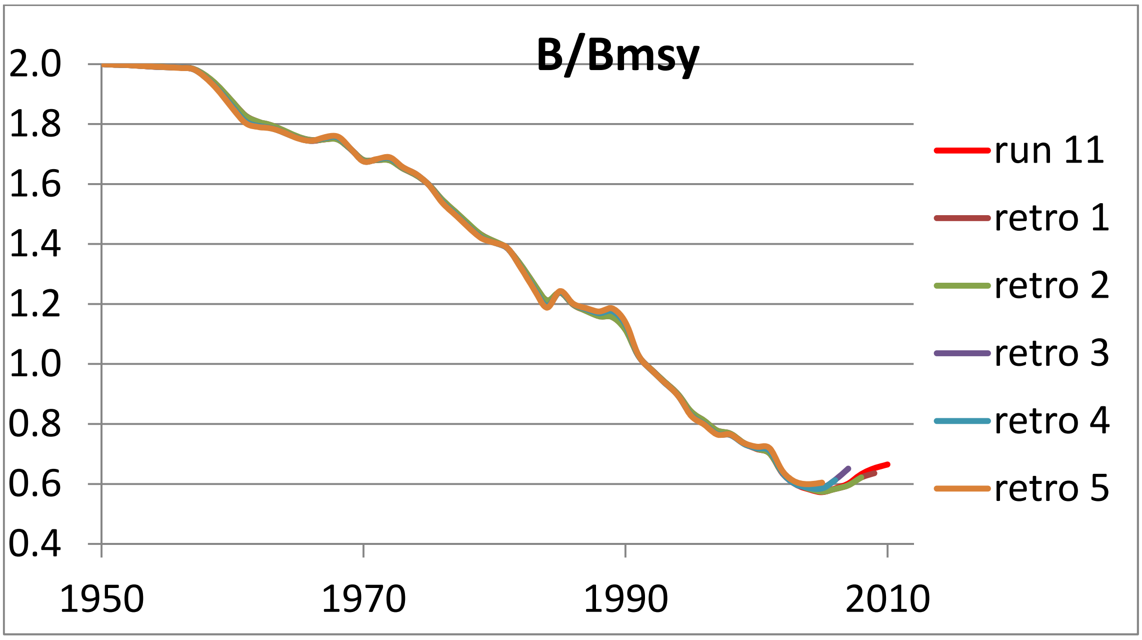


Figure 27. Retrospective patterns of B/B$_{MSY}$ obtained by successively removing a single year of data from ASPIC run 11.

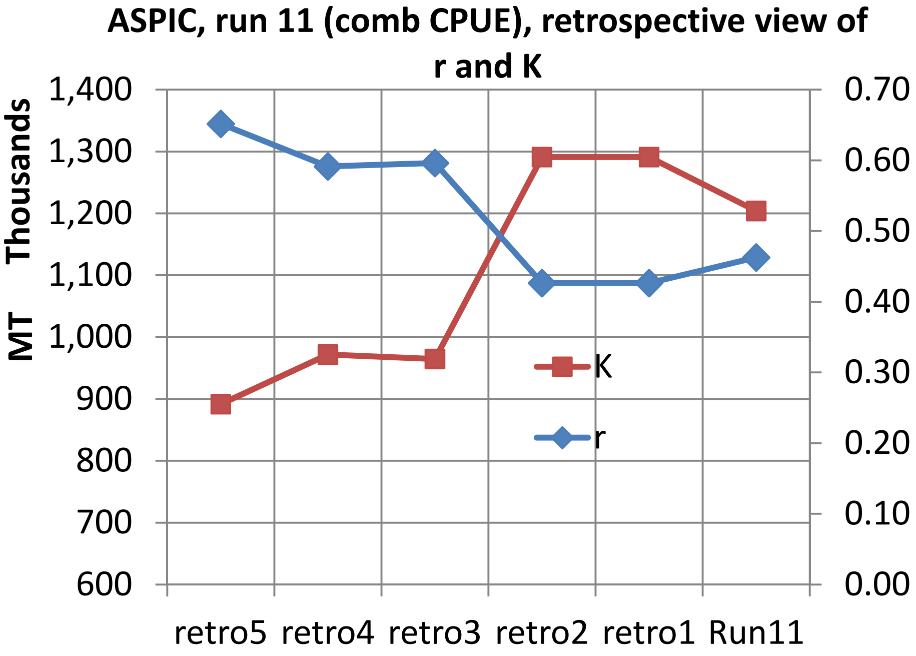


Figure 28. Retrospective view of r and K obtained by progressively eliminating successive years for ASPIC run 11 (combined CPUE with 7% increase in q on EU-PS)

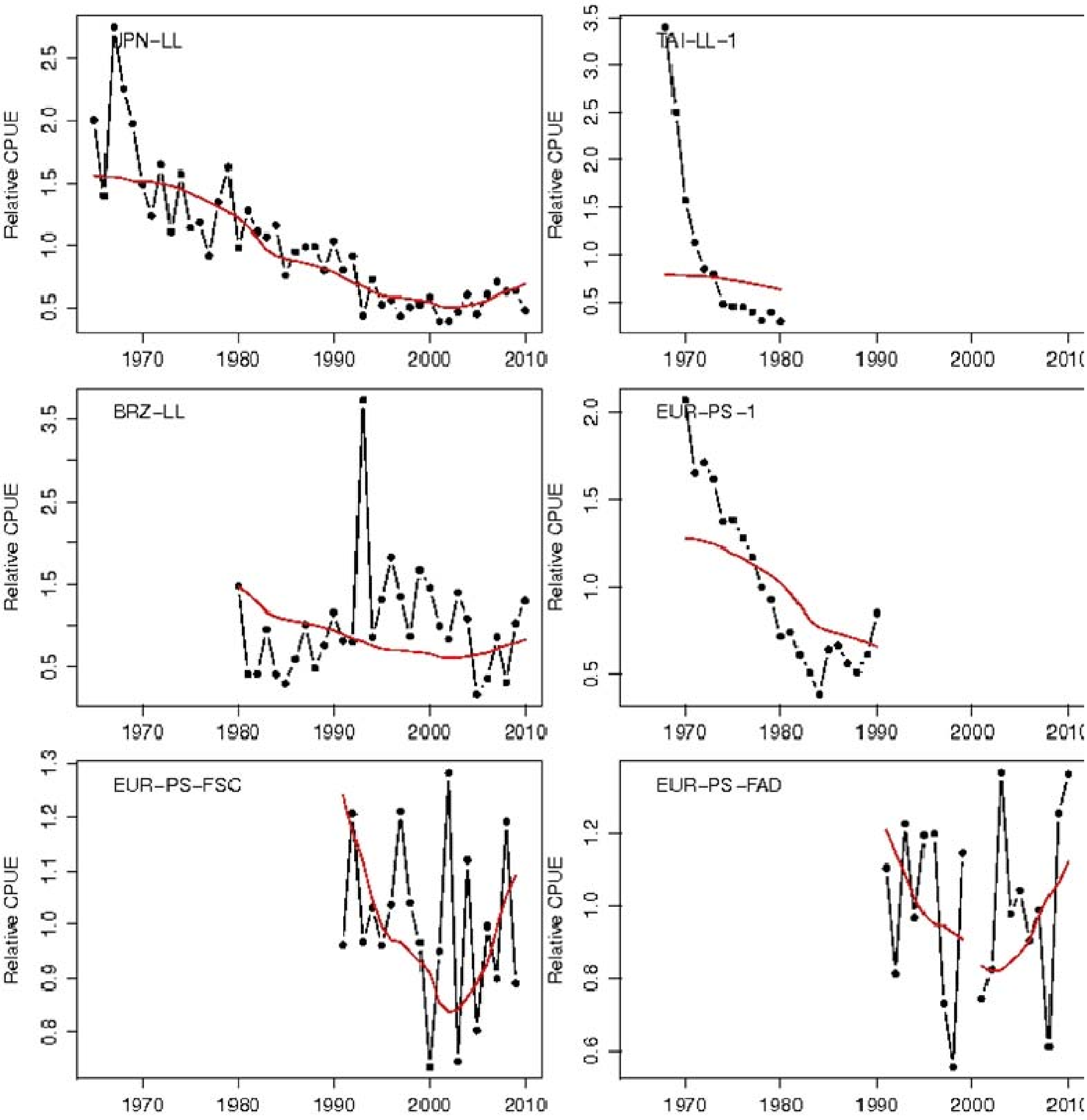


Figure 29. Fit of PROCEAN to the 6 time series of abundance indices

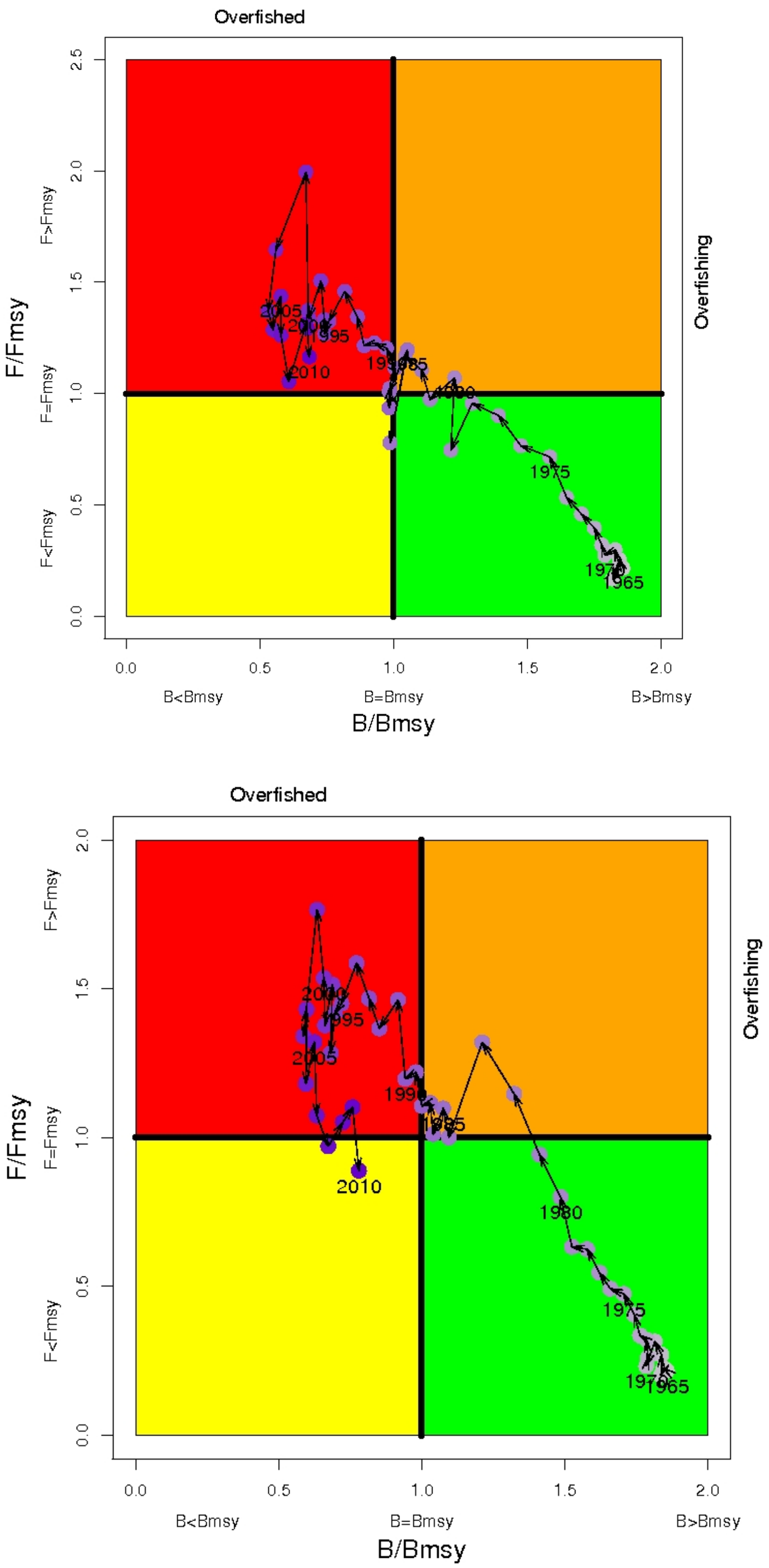


Figure 30. Phase diagram ("Kobe plot") representing the evolution of the annual fishing mortality relative to the fishing mortality at MSY (F/F_{MSY}) as a function of the annual biomass relative to the biomass at MSY (B/B_{MSY}). PROCEAN fits to the combined abundance index weighted by area (upper figure) and the abundance indices for the JPN-LL, TAI-LL (1968-1980), BRZ-LL, EUR-PS (1979-1990), EUR-PS-FSC(1991-2010) and EUR-PS-FAD (1991-2010) (lower figure).

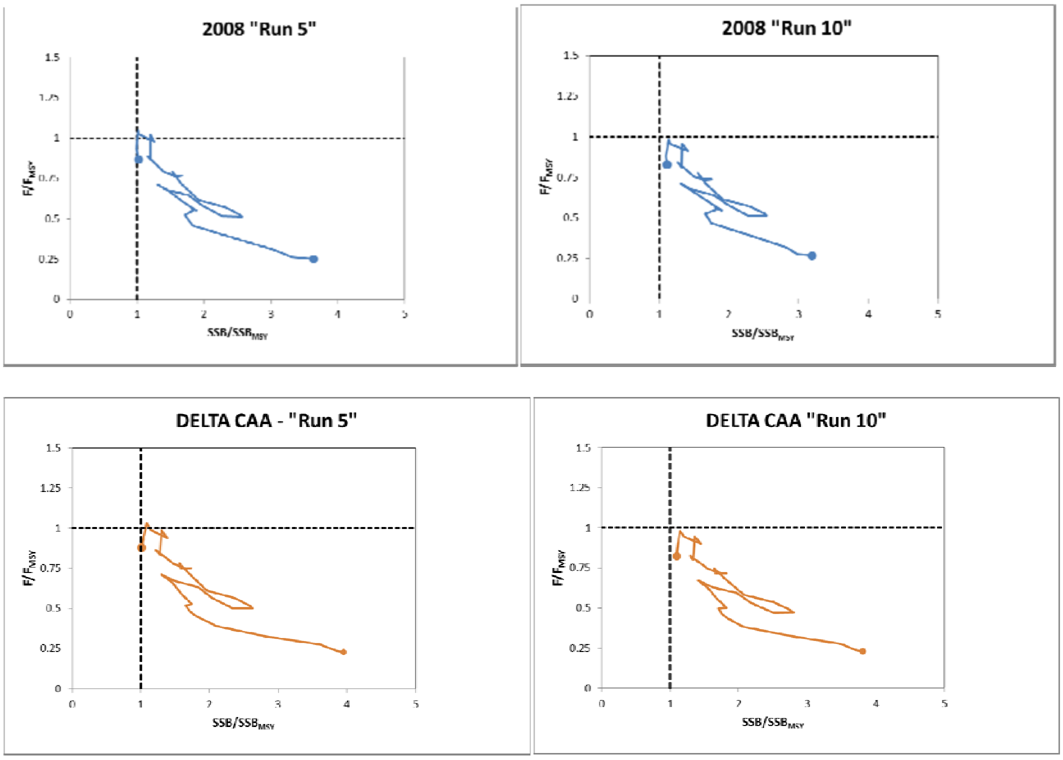


Figure 31. Comparison of the stock status trajectories from the 2011 “DELTA-CAA” and 2008 base runs. The 2006 stock status is shown by the filled circle.

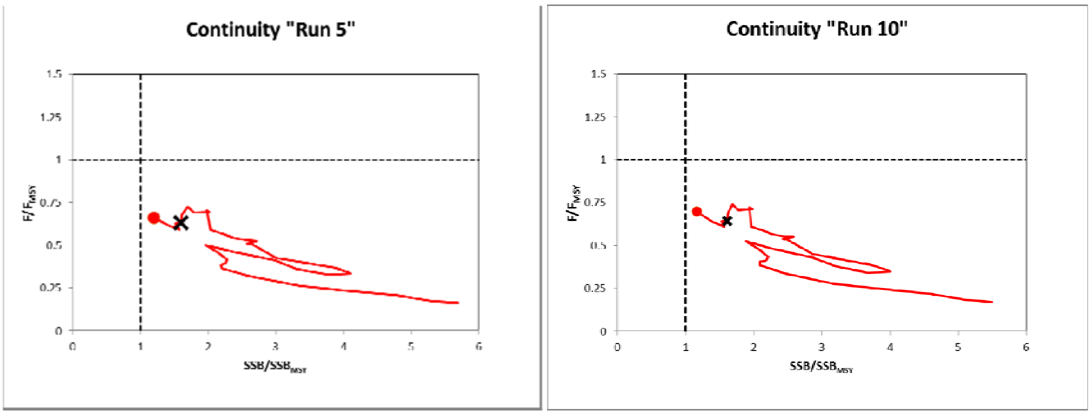


Figure 32. The stock status trajectory of the 2011 VPA “CONTINUITY” runs. The 2006 stock status is shown by the black X, the 2010 stock status by the filled circle.

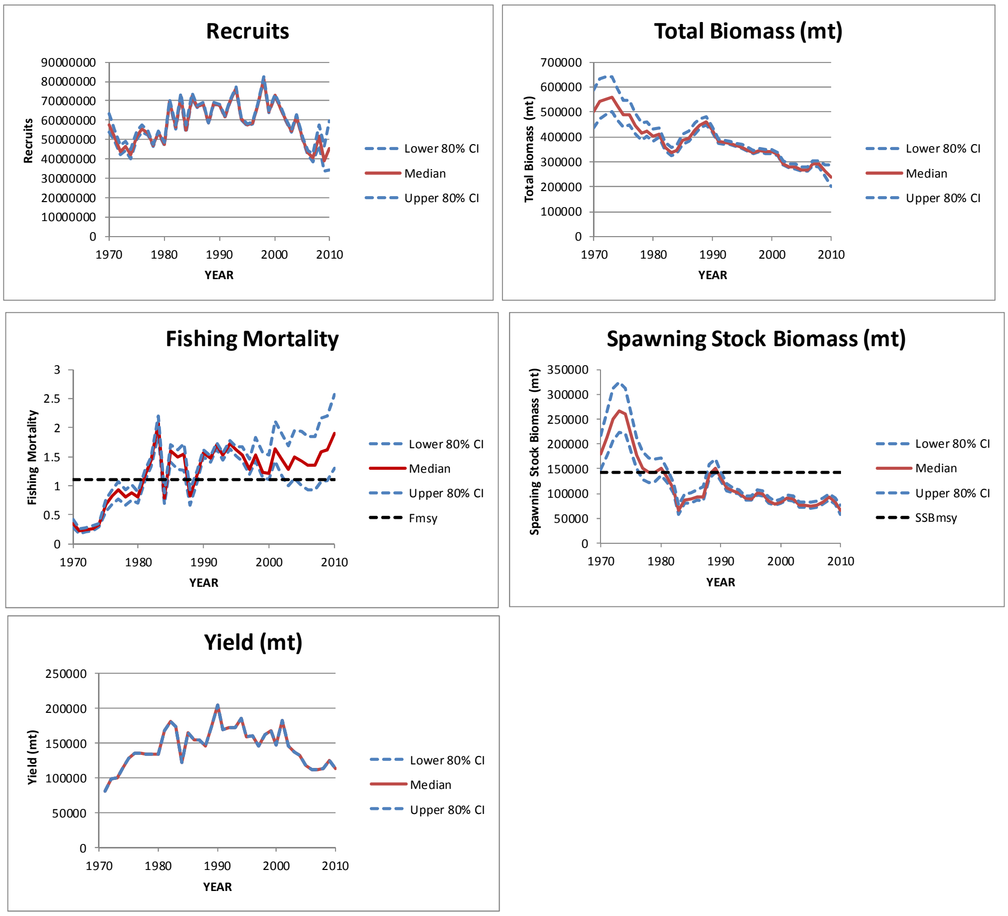


Figure 33. Results of VPA Base Run 1: annual trends in recruits (Age 0), total biomass, apical fishing mortality with regard to F_{MSY}, spawning stock biomass with regard to SSB_{MSY} and yield (t).

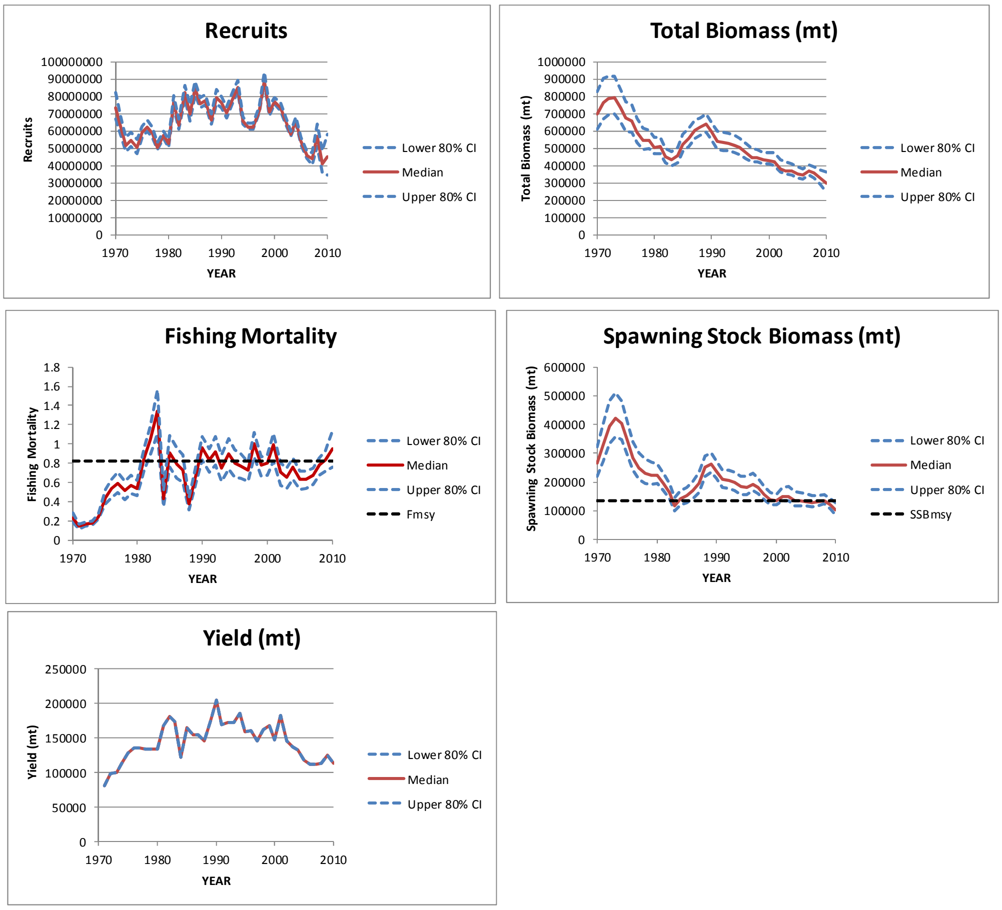


Figure 34. Results of VPA Base Run 2: annual trends in recruits (Age 0), total biomass, apical fishing mortality with regard to F_{MSY}, spawning stock biomass with regard to SSB_{MSY} and yield (t).

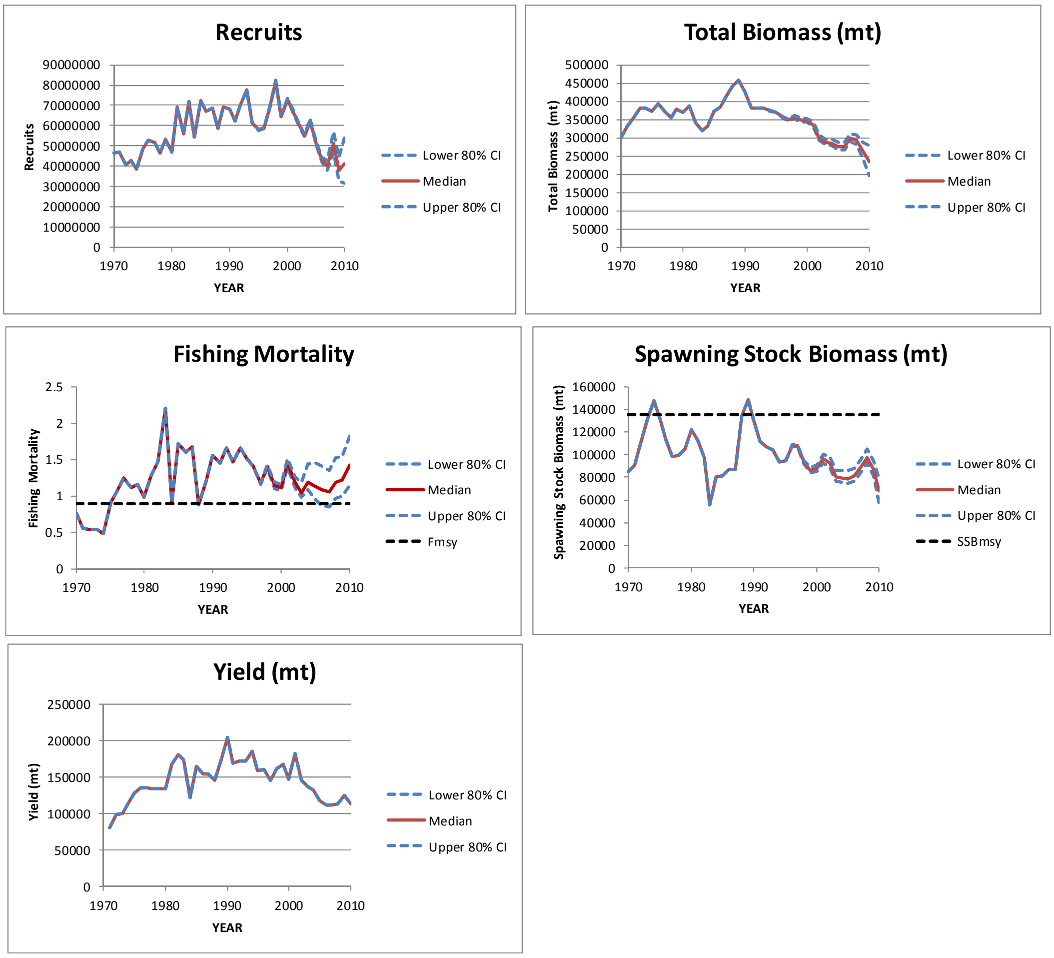


Figure 35. Results of VPA Base Run 3: annual trends in recruits (Age 0), total biomass, apical fishing mortality with regard to F_{MSY}, spawning stock biomass with regard to SSB_{MSY} and yield (t).

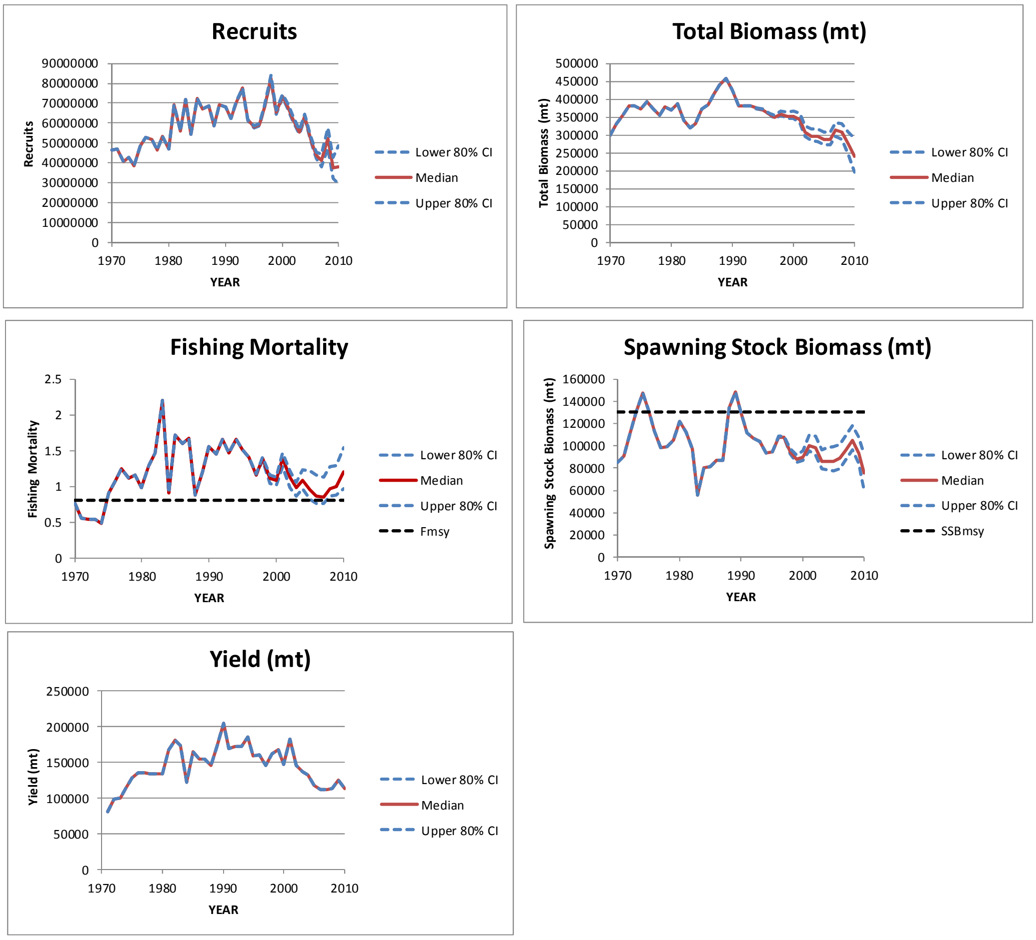


Figure 36. Results of VPA Base Run 4: annual trends in recruits (Age 0), total biomass, apical fishing mortality with regard to F_{MSY}, spawning stock biomass with regard to SSB_{MSY} and yield (t).

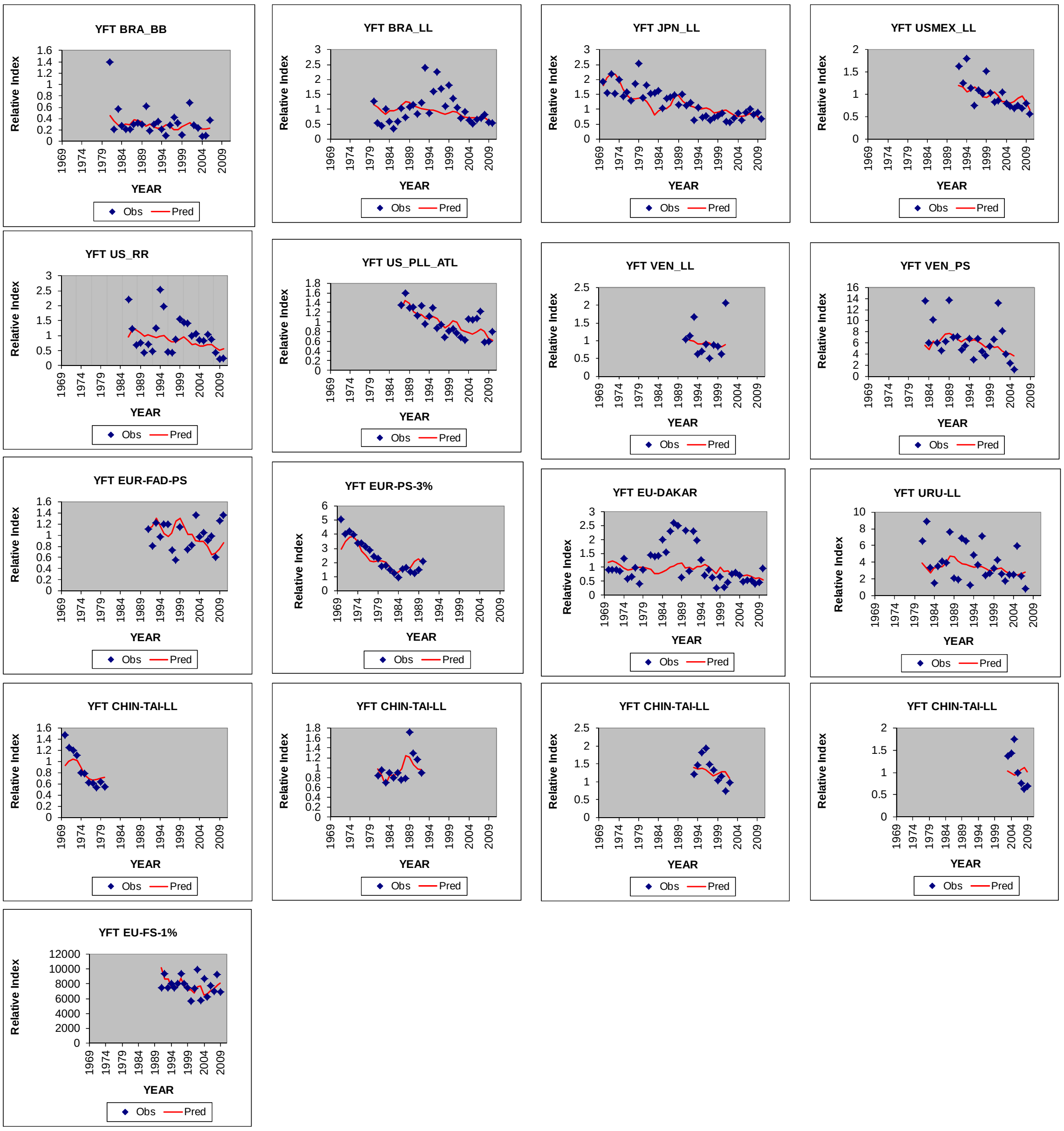


Figure 37. Fits to the indices of abundance for VPA base run 1.

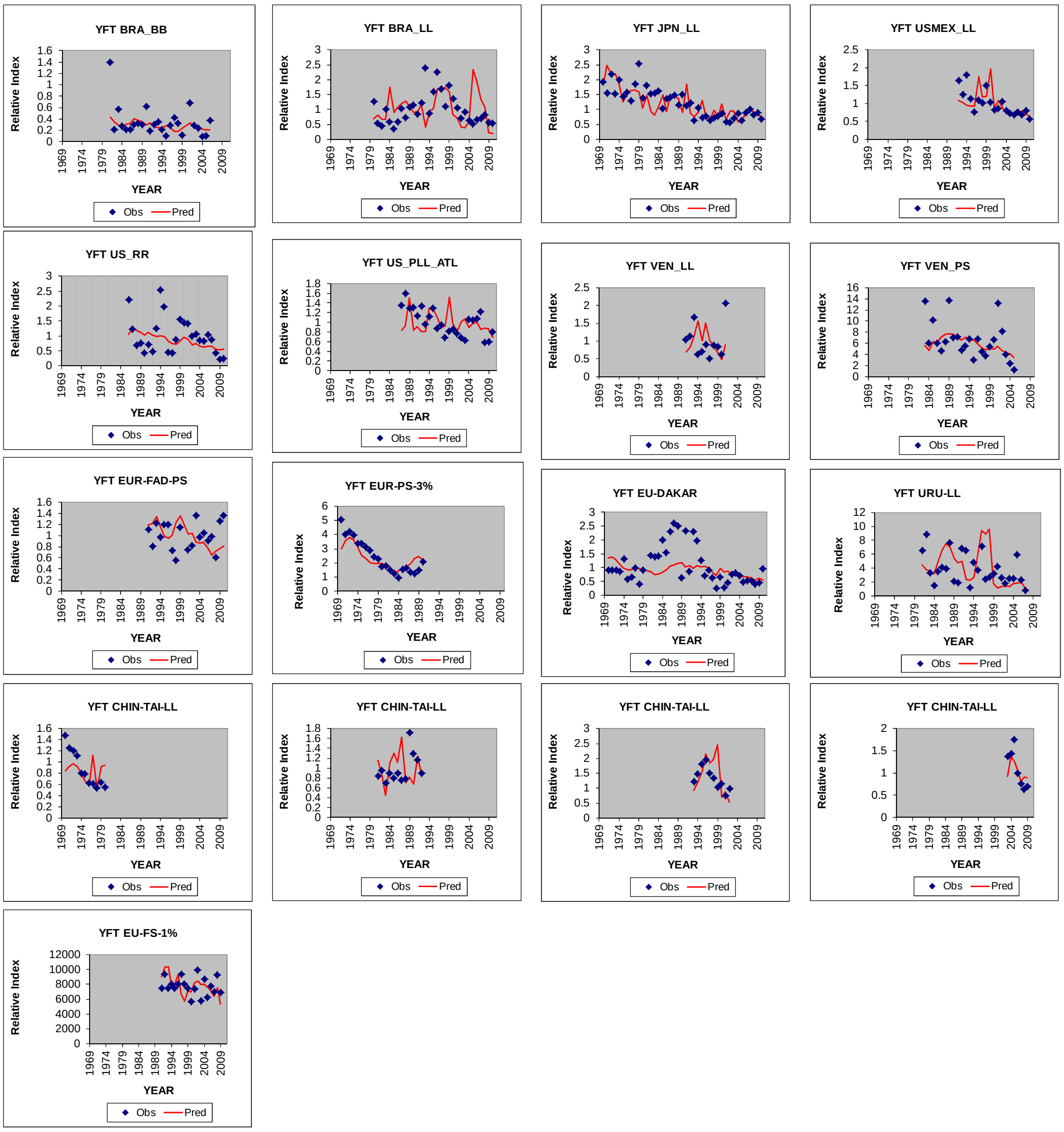


Figure 38. Fits to the indices of abundance for VPA base run 2.

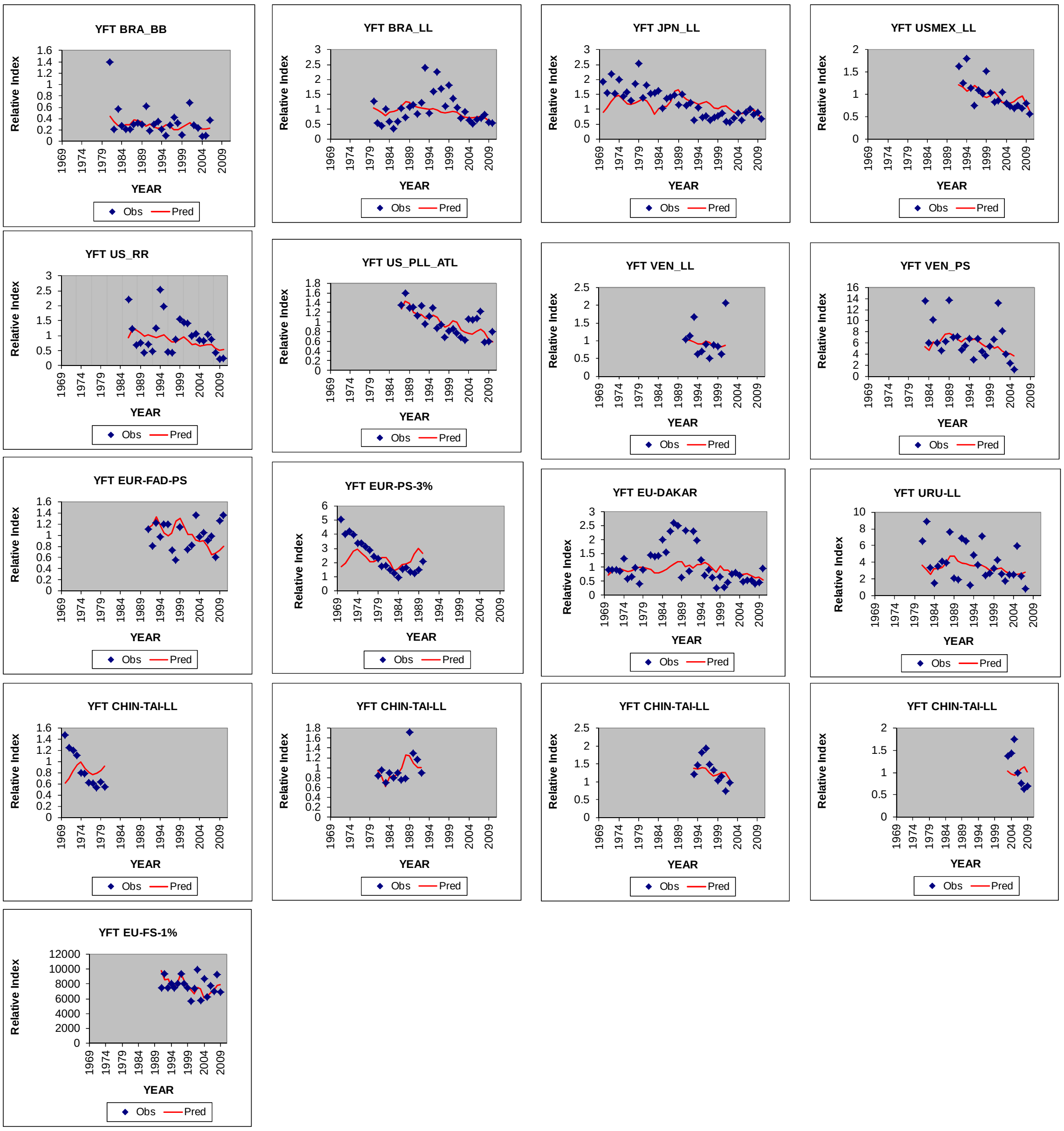


Figure 39. Fits to the indices of abundance for VPA base run 3.

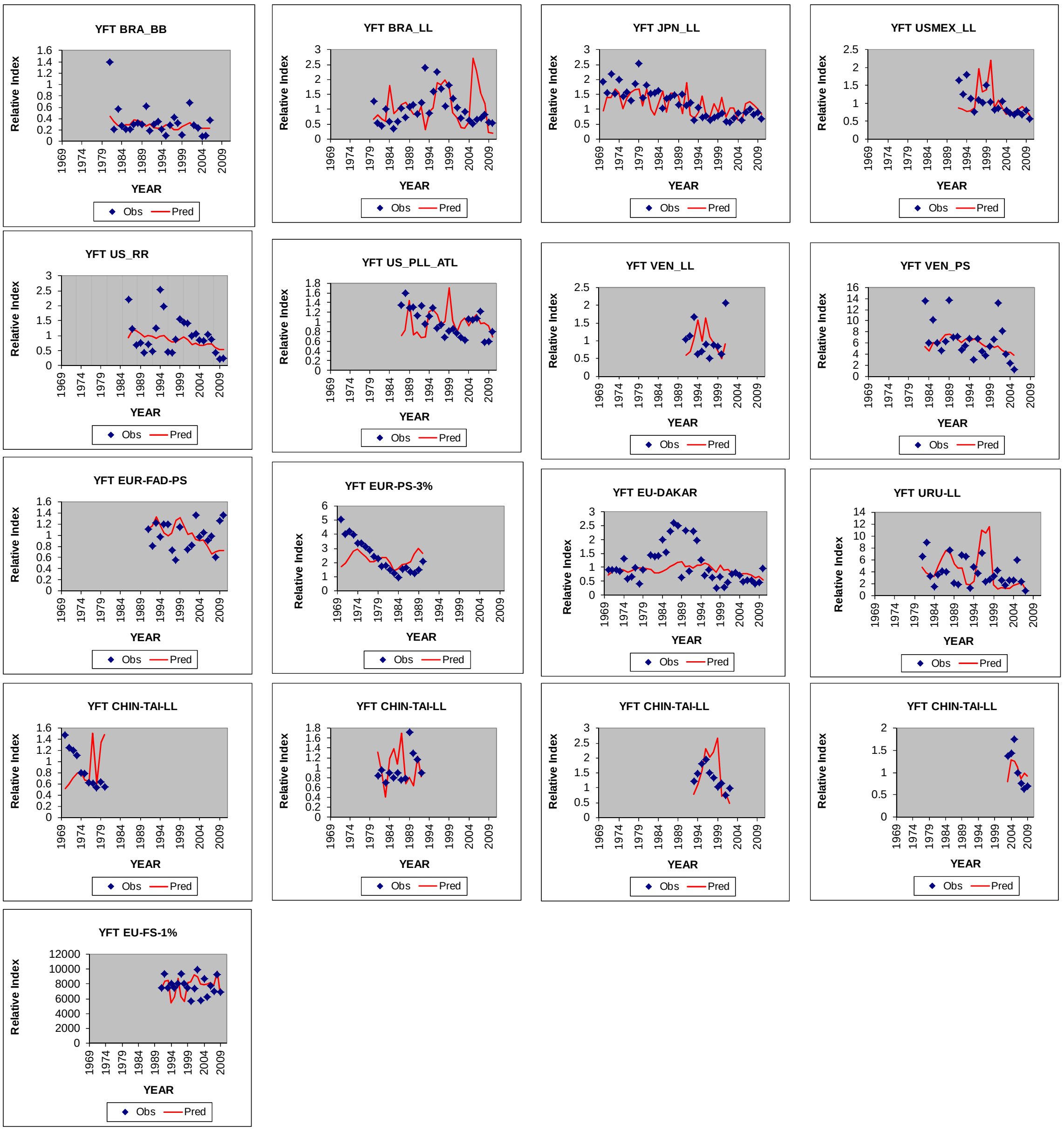


Figure 40. Fits to the indices of abundance for VPA base run 4.

Retrospective Analysis : Fishing Mortality at Age

Base Run1 Base Run 2 Base Run 3 Base Run 4

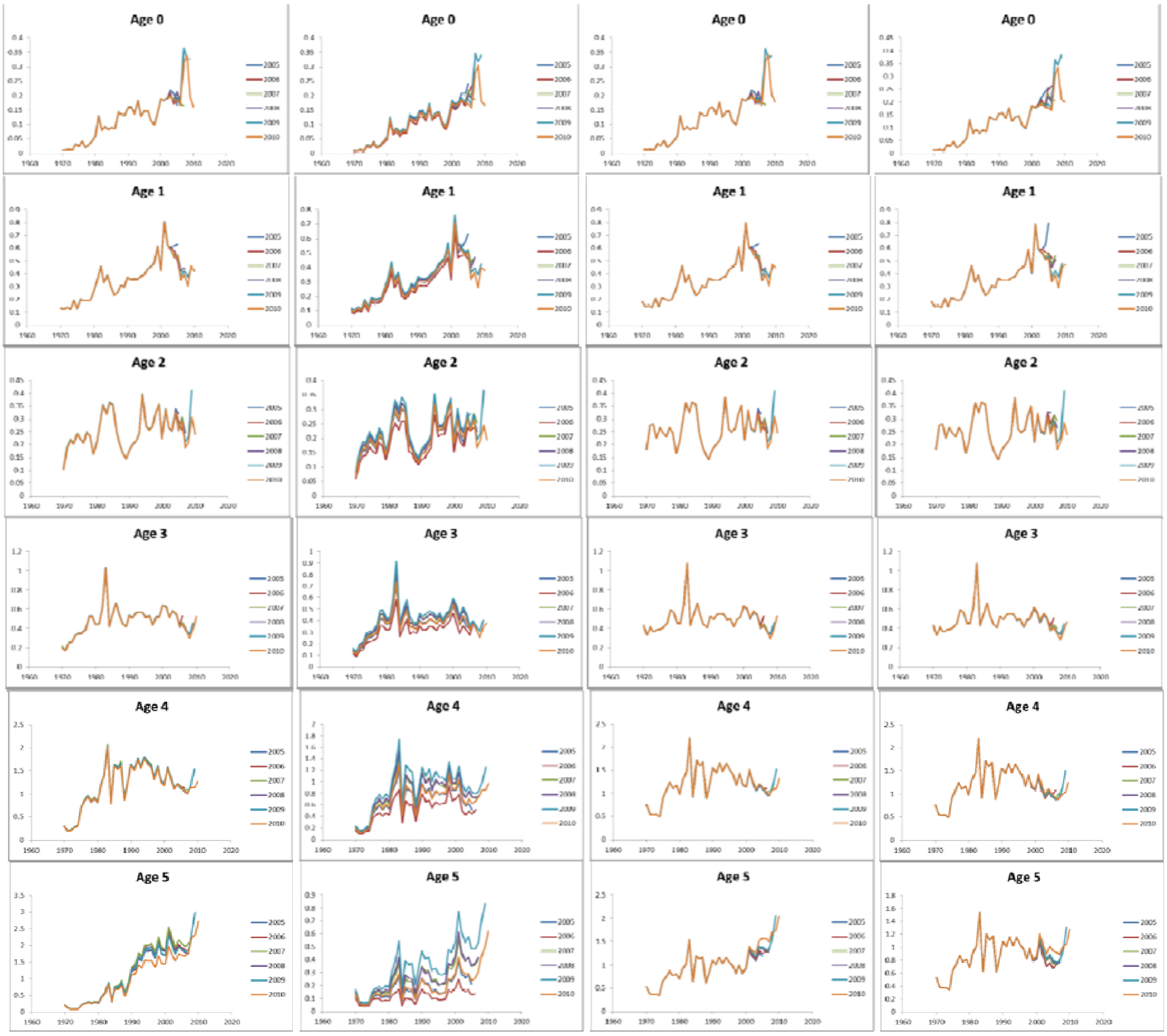


Figure 41. Retrospective patterns in fishing mortality at age for the VPA base runs.

Retrospective Analysis : Numbers at Age

Base Run1 Base Run 2 Base Run 3 Base Run 4

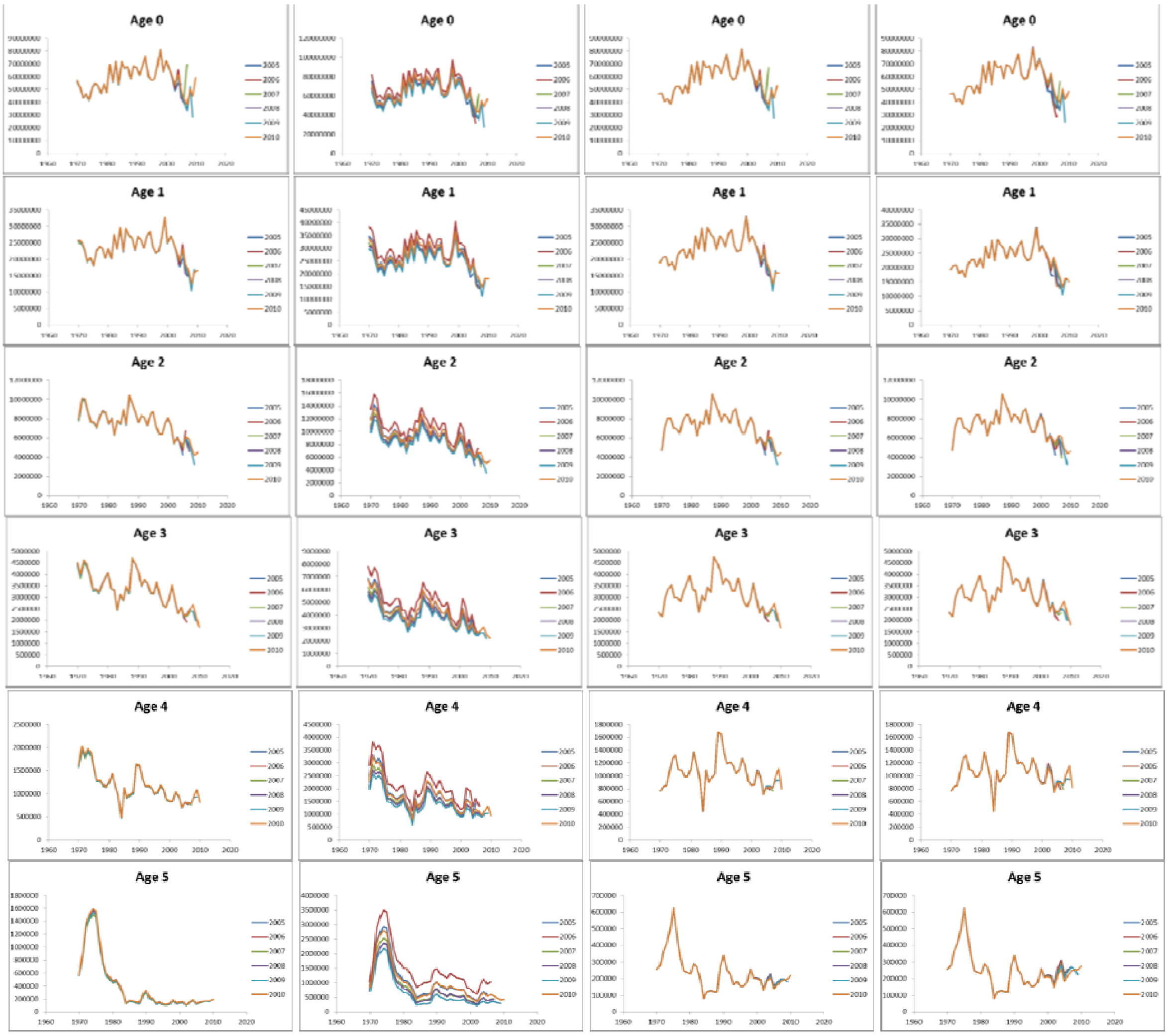


Figure 42. Retrospective patterns in numbers at age for the VPA base runs.

Retrospective Analysis : Spawning Stock Biomass

Figure 43. Retrospective patterns in spawning stock biomass for the VPA base runs.

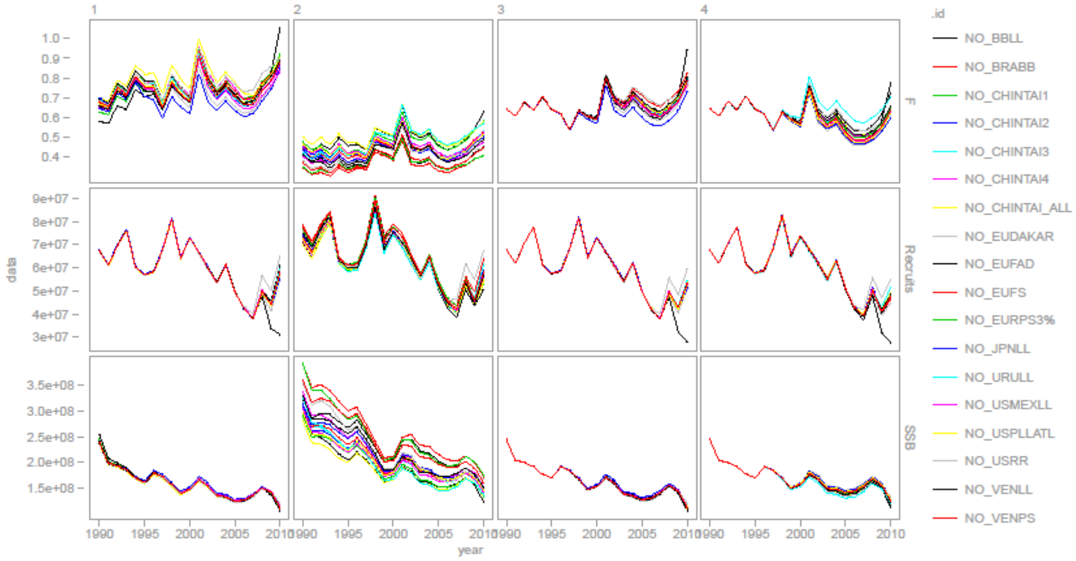


Figure 44. Jacknife analysis of average fishing mortality, recruits and SSB for the four VPA models obtained by sequential removal of a single index.

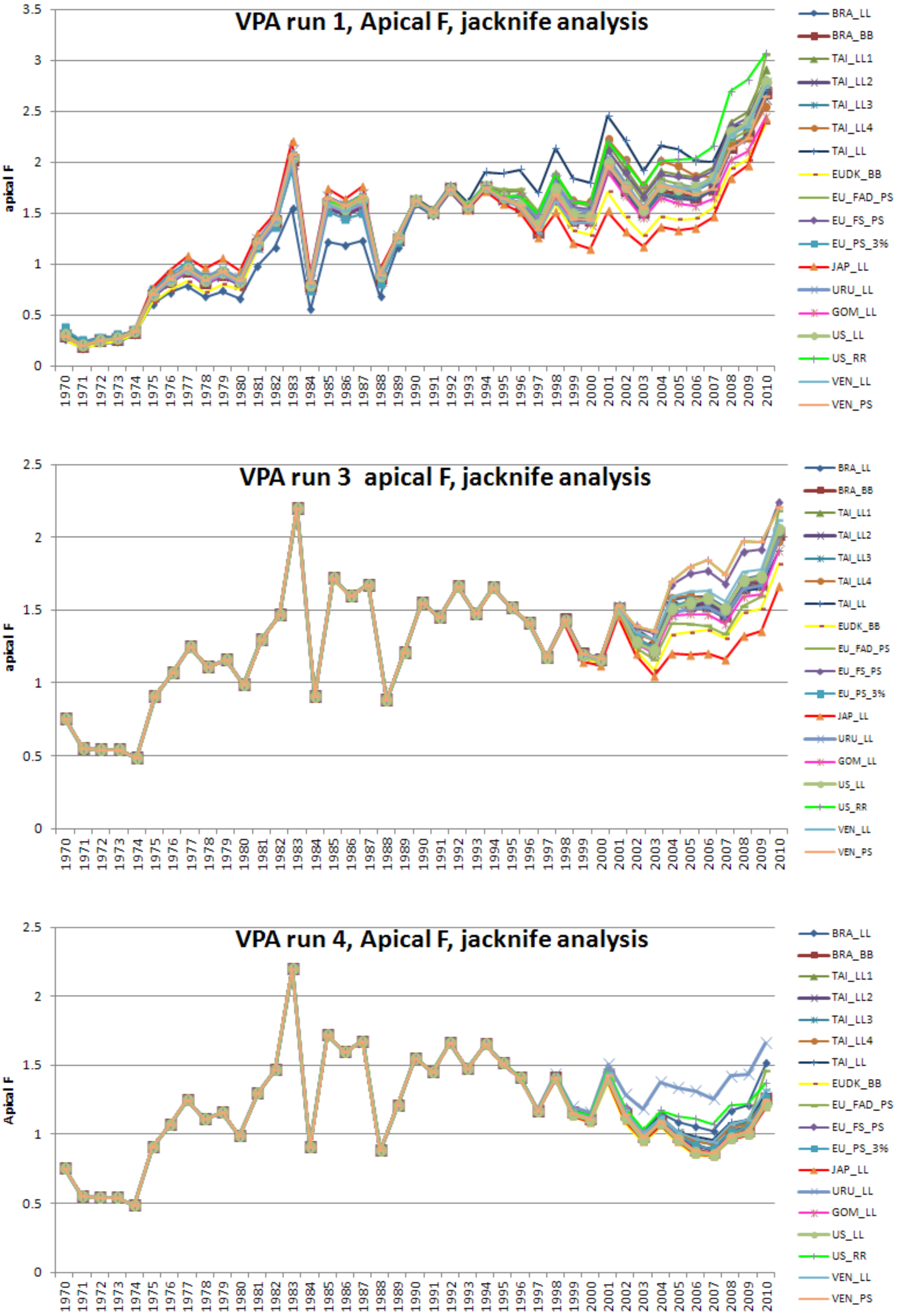


Figure 45. Results of the jackknife analysis on apical F for VPA runs 1,3, and 4.

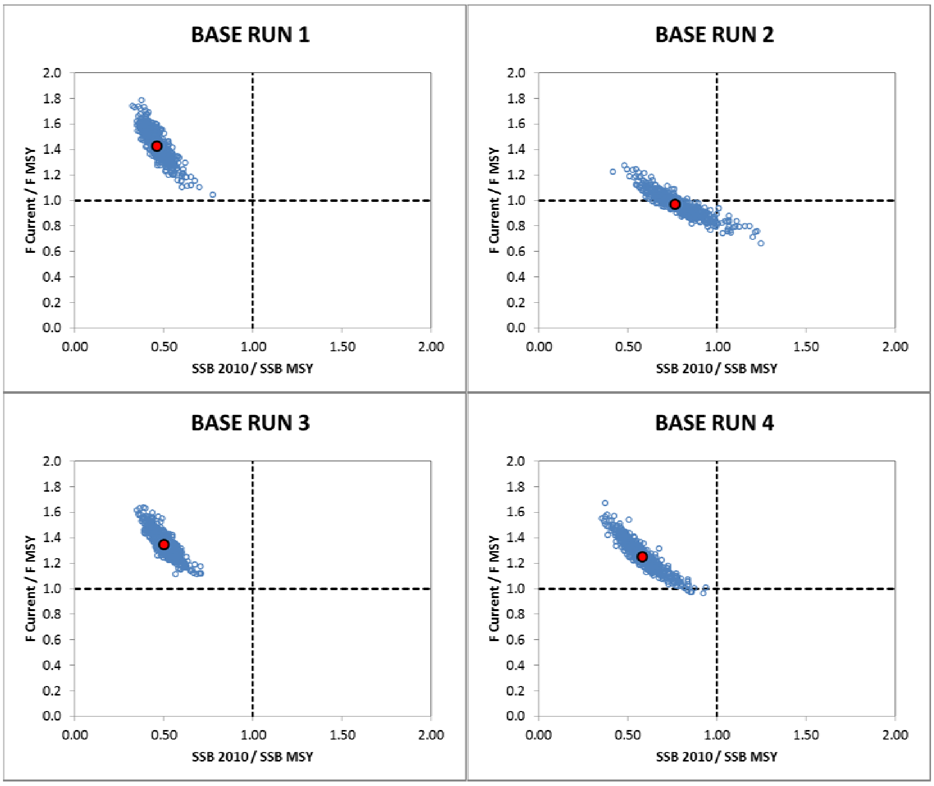


Figure 46. Phase plots indicating the median stock status of the VPA base runs (red circle) and the 500 bootstraps analyses.

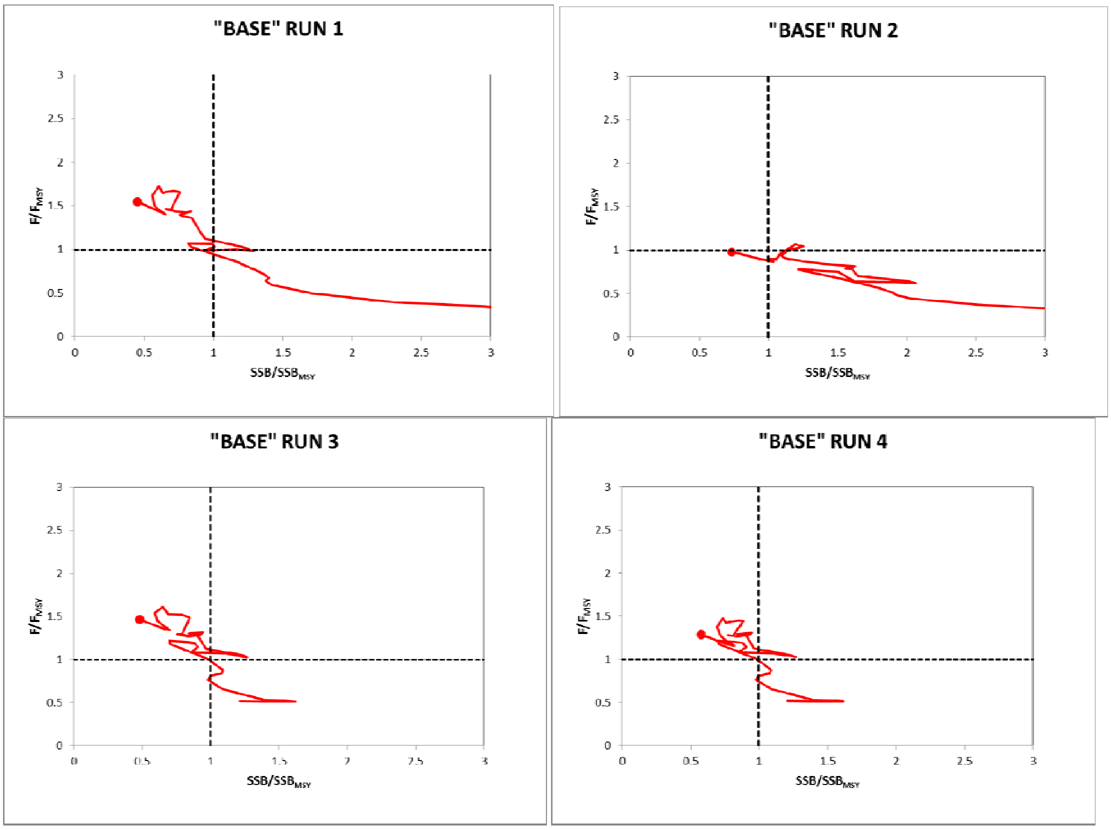


Figure 47. "Annualized" trajectories of stock status 1972-2010 (i.e., adjusted for the annual selectivity pattern). The 2010 stock status is indicated with a red circle.

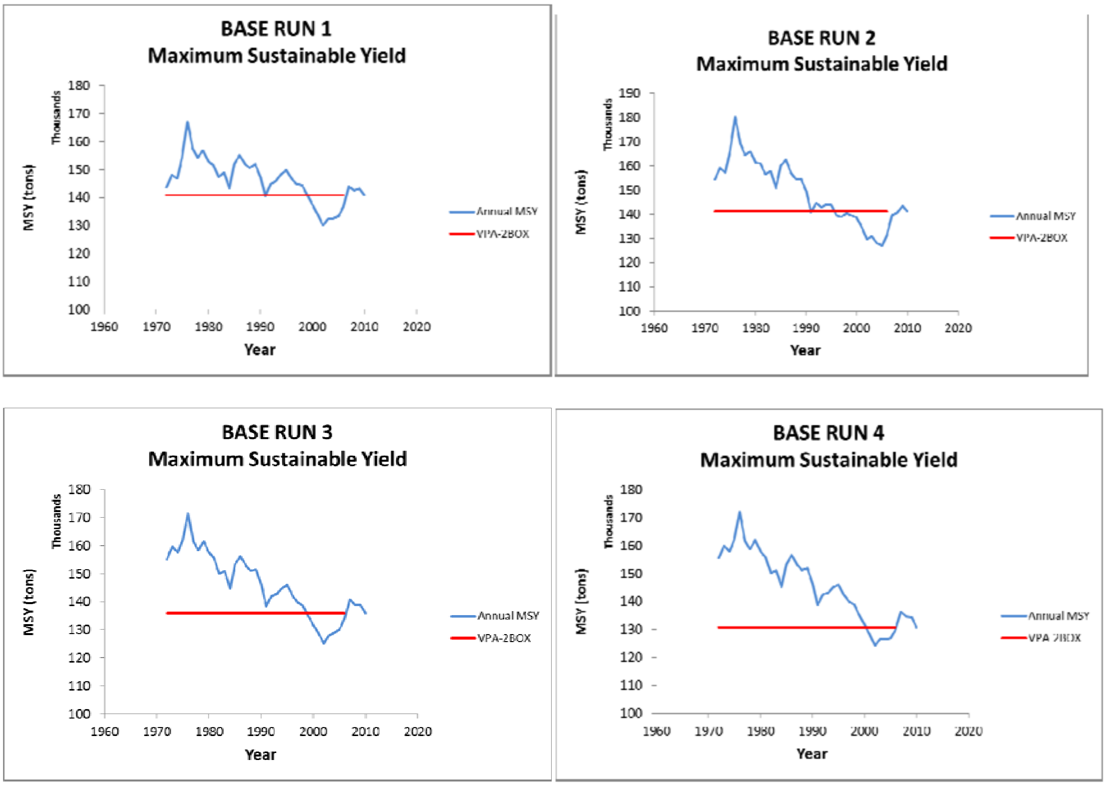


Figure 48. "Annualized" trajectories of MSY (i.e. adjusted for the annual selectivity pattern) compared to the MSY from VPA-2BOX using the 2006-2010 selectivity pattern.

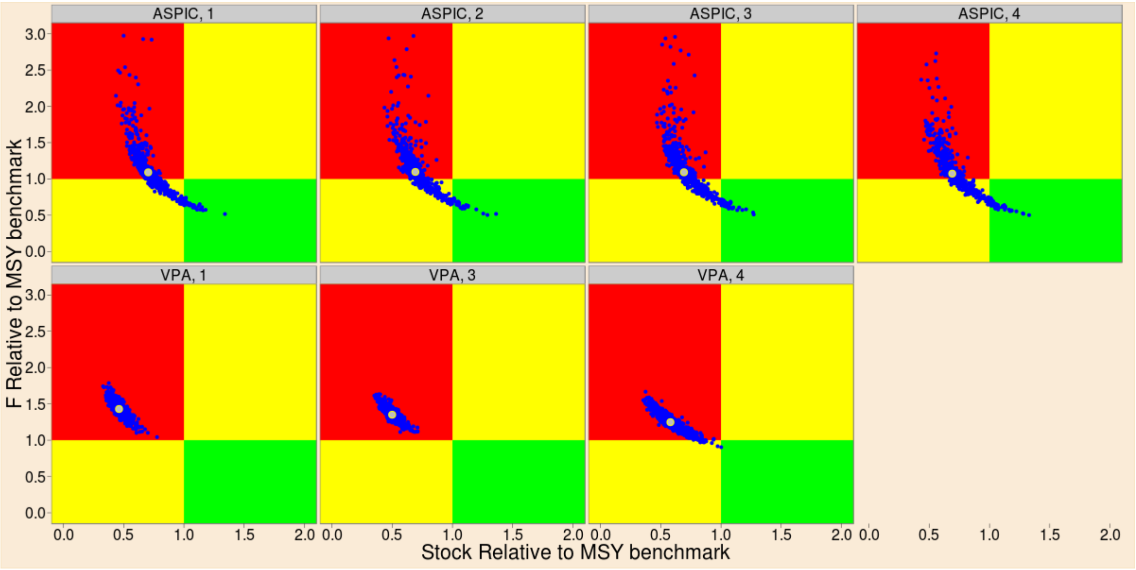


Figure 49. Phase plots of current stock status by bootstrapped assessment run; the medians for each run are indicated by a grey dot. Quadrants are defined for the stock and fishing mortality relative to B_{MSY} and F_{MSY}; i.e. red $B<B_{MSY}$ and $F>F_{MSY}$, green red $B \geq B_{MSY}$ and $F \leq F_{MSY}$ yellow otherwise.

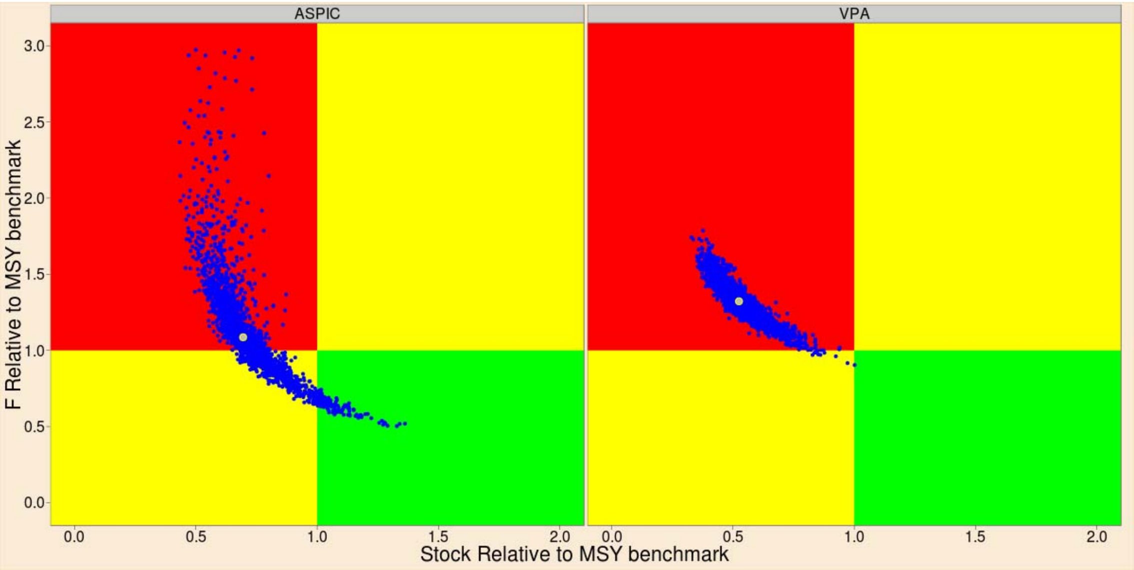


Figure 50. Phase plots of current stock status bootstrap results across runs for each method; Production model results (ASPIC) are on the left, and the results of the age-structured model (VPA) are shown on the right. The medians for each method are indicated by a grey dot. Quadrants are defined for the stock amd fishing mortality relative to B_{MSY} and F_{MSY}; i.e. red $B<B_{MSY}$ and $F>F_{MSY}$, green red $B\geq B_{MSY}$ and $F\leq F_{MSY}$ yellow otherwise.

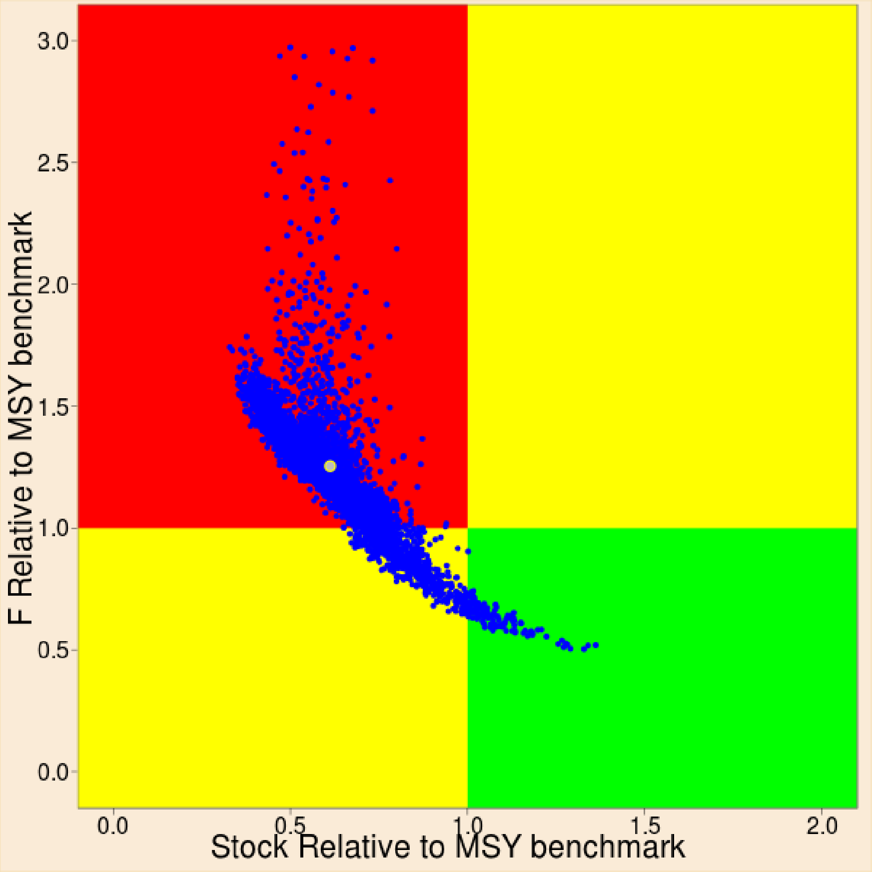
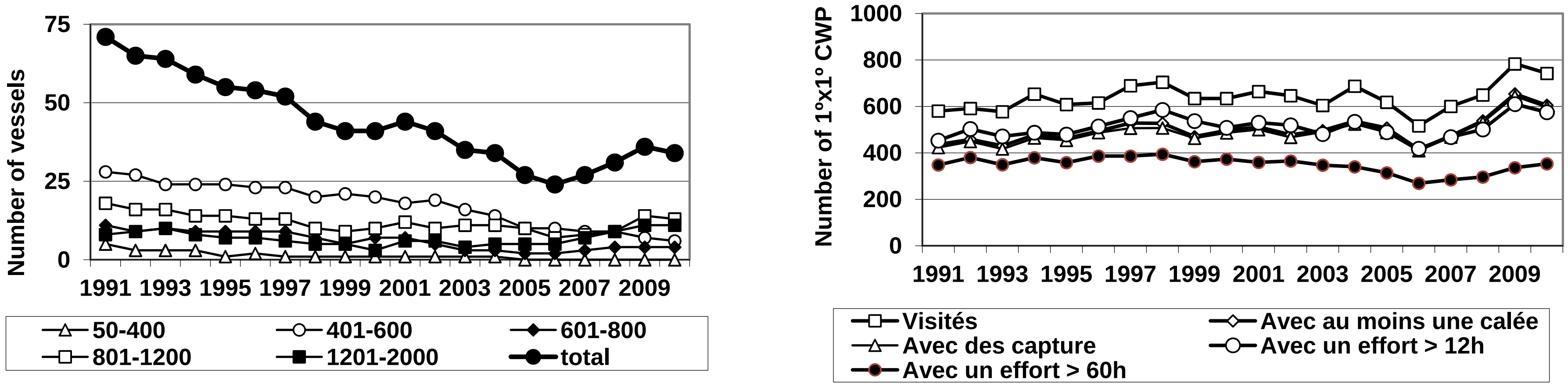
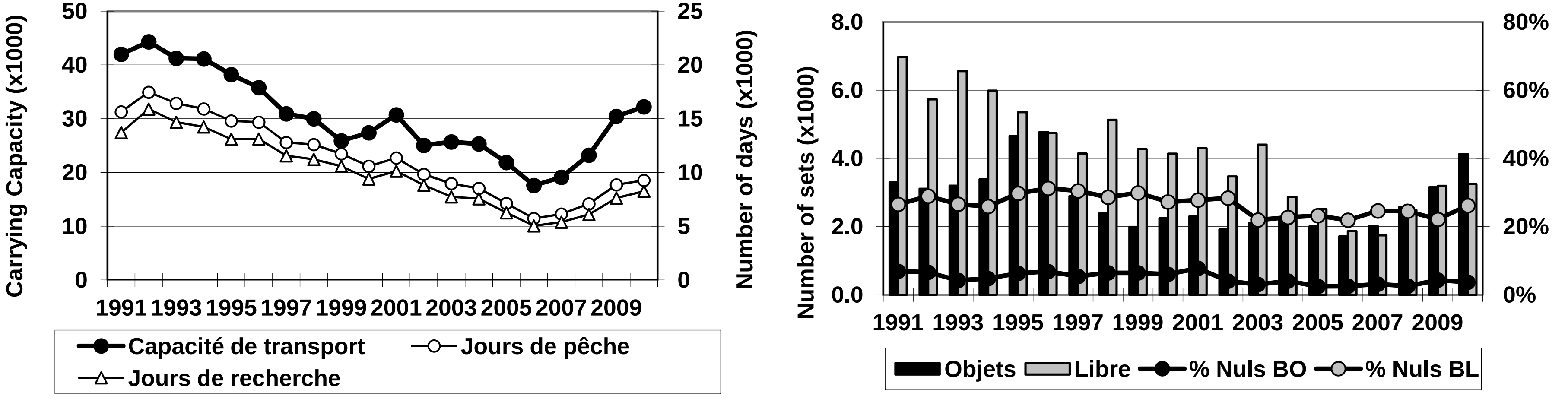


Figure 51. Biomass ratios and fishing mortality ratios describing current stock status from the combined joint distribution of ASPIC and VPA base case runs. Points represent a total of 4000 bootstraps. The median of the joint distribution is indicated by a grey dot. Quadrants are defined for the stock and fishing mortality relative to B_{MSY} and F_{MSY}; i.e. red $B<B_{MSY}$ and $F>F_{MSY}$, green red $B\geq B_{MSY}$ and $F\leq F_{MSY}$ yellow otherwise.



a) – Number of vessels by category (TRB)

b) – Number of 1ºx1º CWP explored by effort level



c) – Carrying Capacity and fishing days (fishing day=12 hours)

d) – Number of sets and percentage of nul sets by fishing mode (FAD (BO) and free school (BL))

Figure 52. Fishing effort of the European and associated purse seine fleet : a) Number of vessels by TRB category, b) Number of 1ºx1º CWP explored , c) Carrying capacity in tones and fishing days , d) Number of sets and percentage of nul sets by fishing mode.

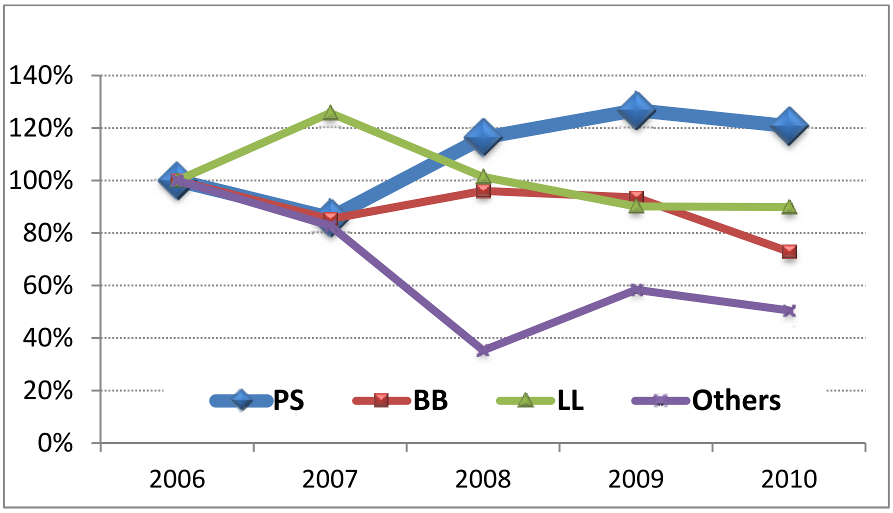


Figure 53. Proportional catch of YFT by gear expressed relative to 2006 catch levels by gear. In this case, only purse seine catch levels are higher (by about 20%) than 2006 catch levels.

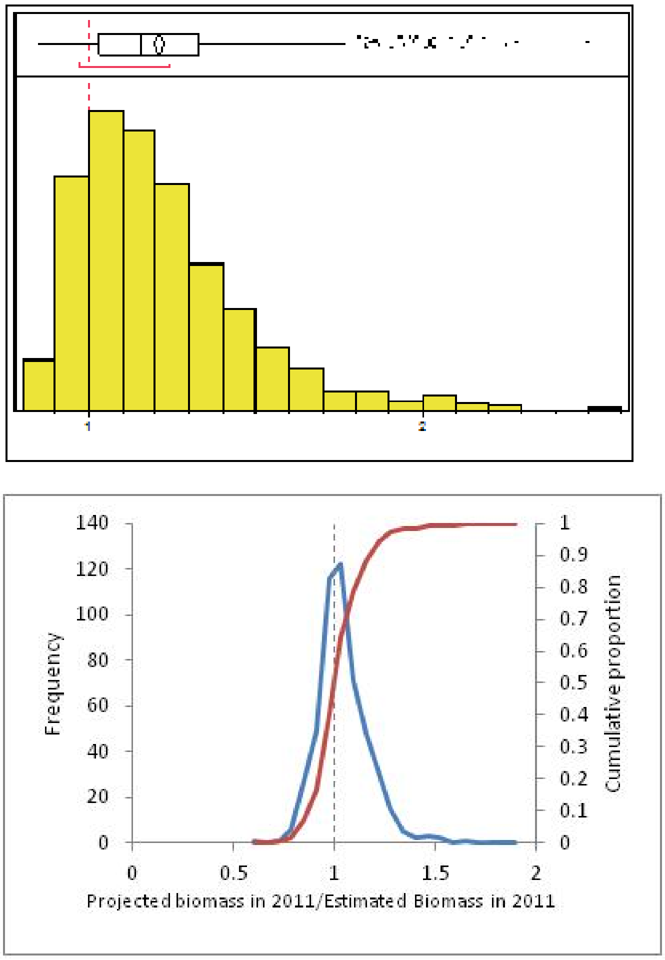


Figure 54. Upper Plate: Estimated fishable biomass in 2011 relative to estimated fishable biomass in 2006 from 2011 production model assessment bootstraps. Values above 1 indicate increase in fishable biomass relative to 2006; the median ratio indicates a 15% increase in fishable biomass since 2006. Bottom Plate: Projected biomass in 2011 considering only catches since 2006 expressed as a ratio to biomass estimated in 2011 considering catch and effort since 2006 across 500 bootstraps of the 2008 and 2011 production model assessments. In this case, the projections from the 2008 assessment are consistent with the estimates of biomass resulting from the 2011 assessment.

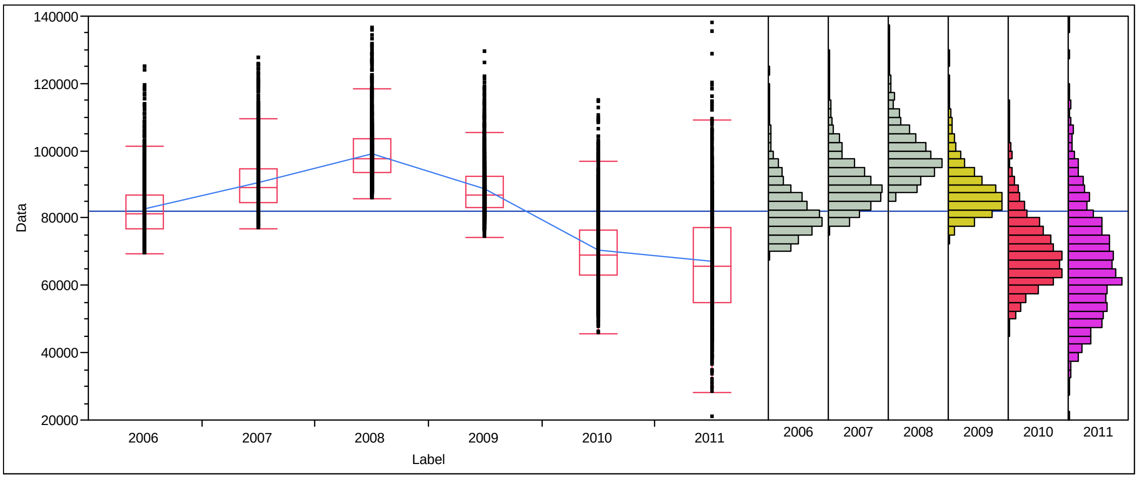


Figure 55. Estimated spawning stock biomass from the age-structured analysis indicating recent declines. Histograms on the right represent the bootstrap outcomes from the analysis

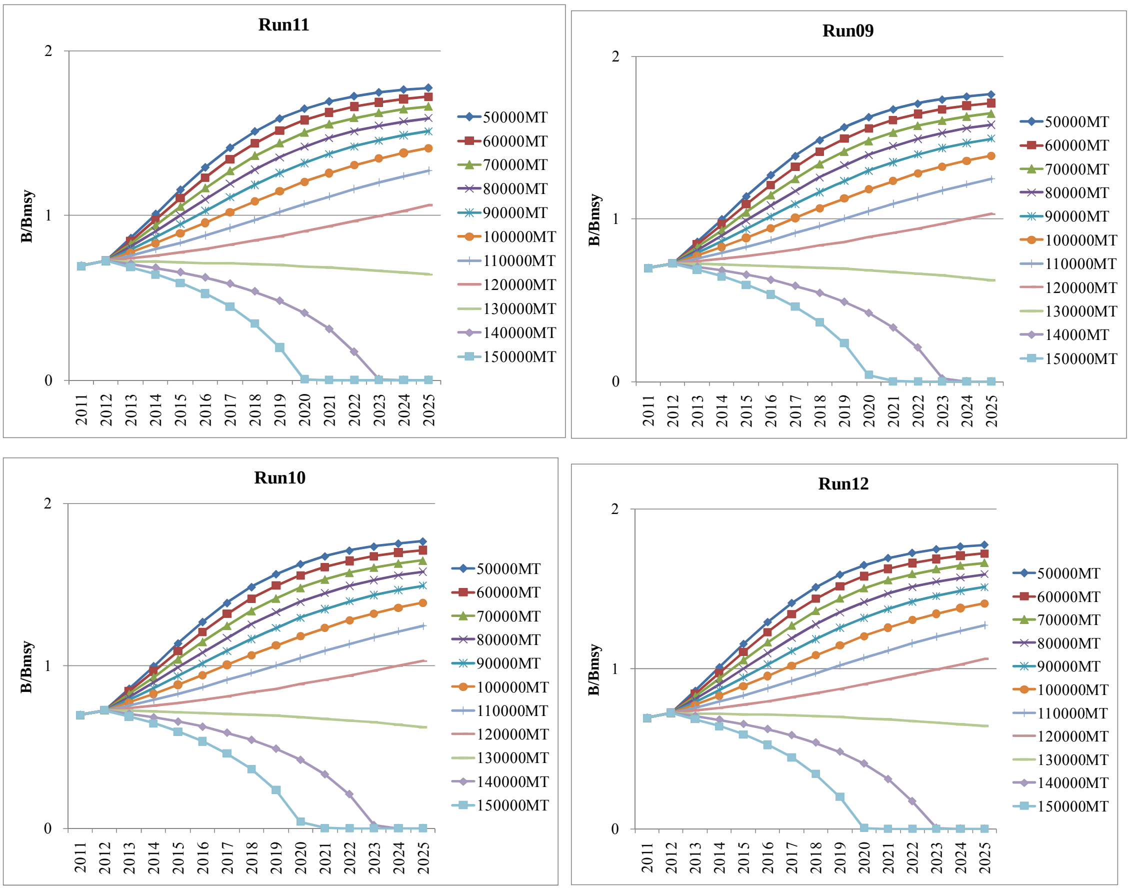


Figure 56. ASPIC projections of median biomass ratios for runs 09, 10, 11 and 12. Projections are conducted from 2011 until 2025. Catch levels vary from 50,000 until 150,000 t in 10,000 steps.

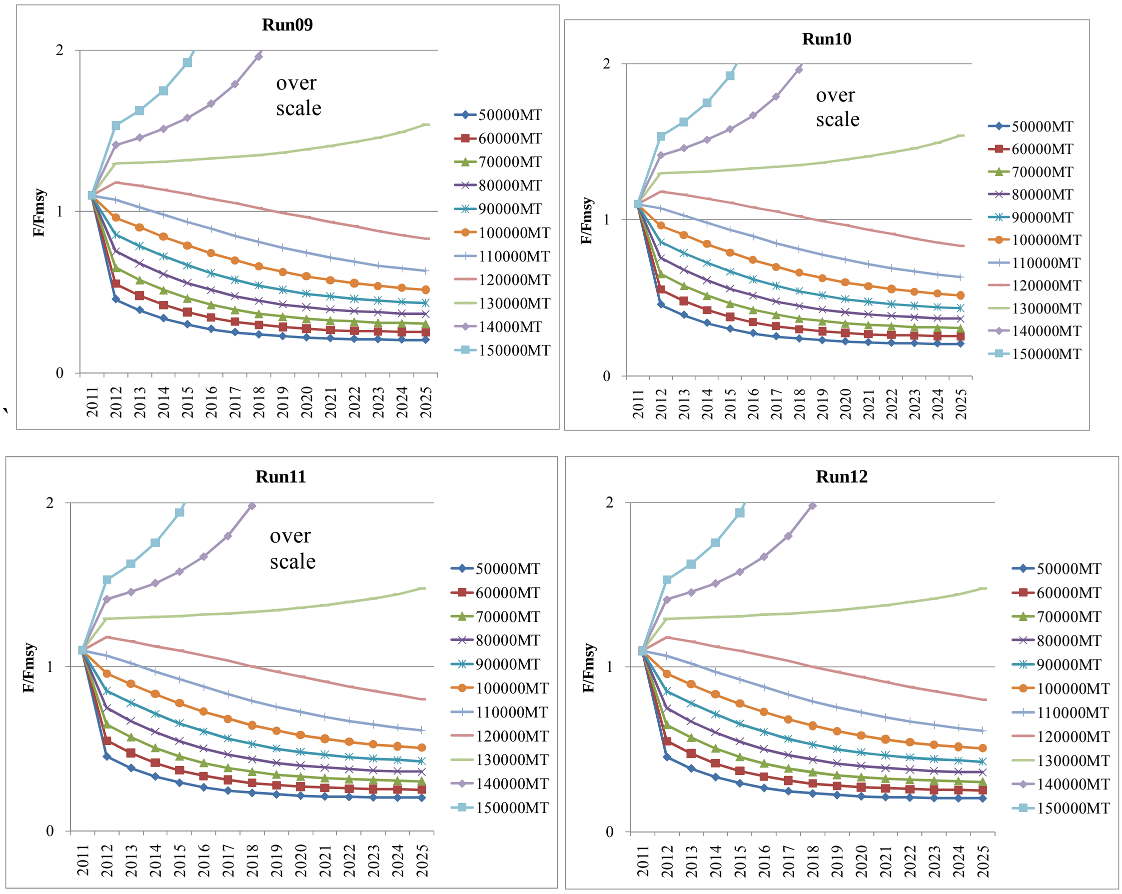


Figure 57. ASPIC projections of median fishing mortality ratios for runs 09, 10 , 11 and 12. Projections are conducted from 2011 until 2025. Catch levels vary from 50,000 until 150,000 t in 10,000 steps.

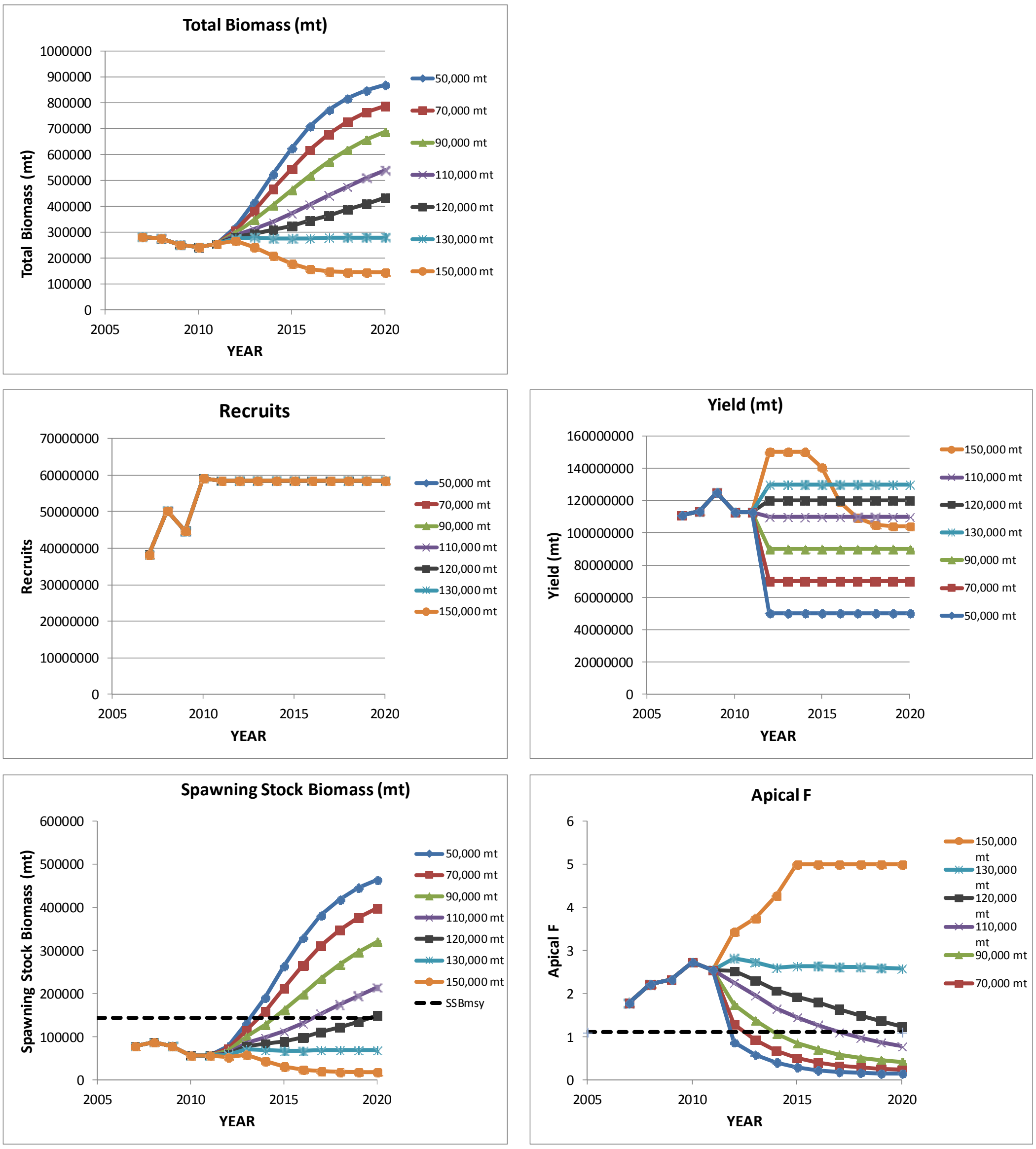


Figure 58. Projection results for the VPA RUN 1 base case.

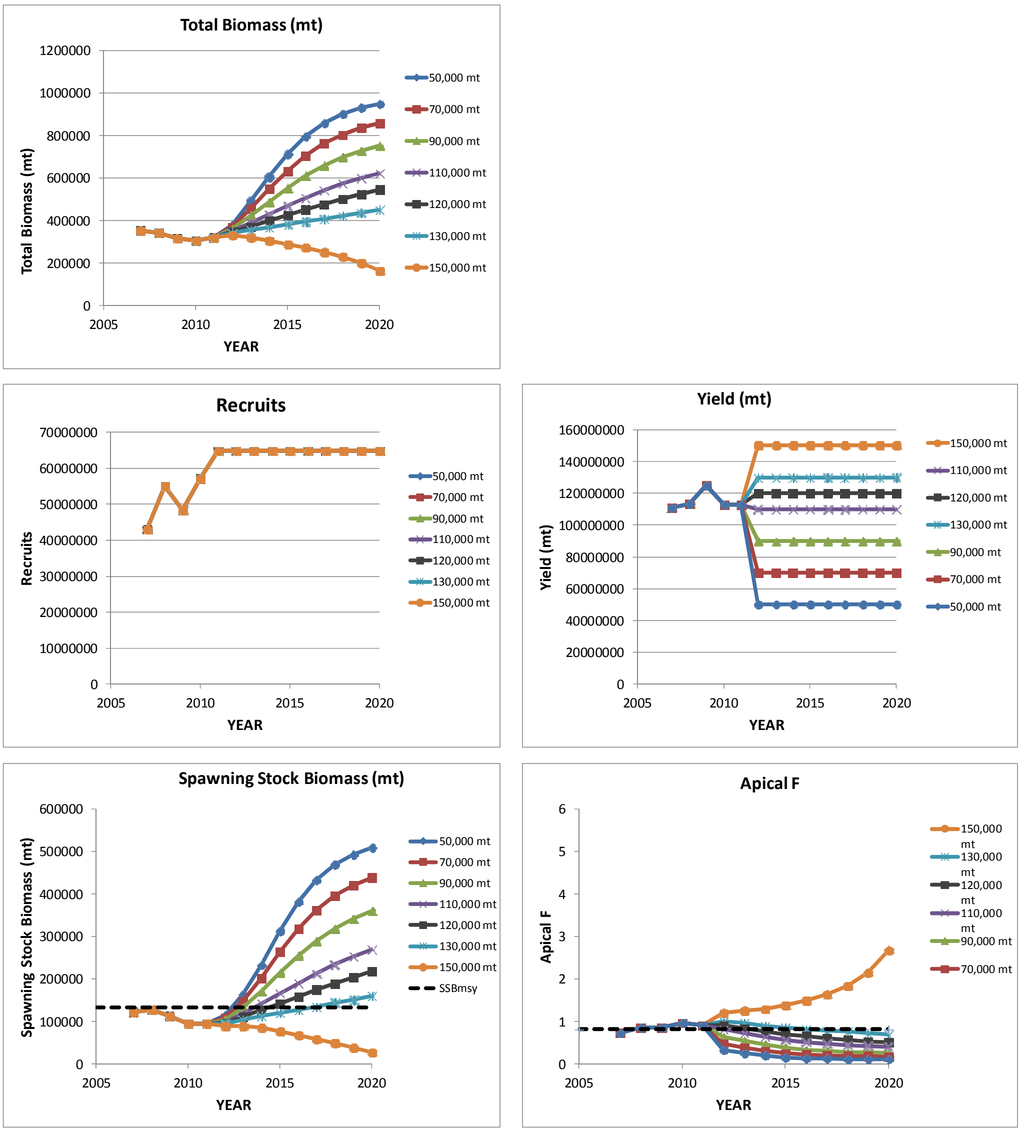


Figure 59. Projection results for the VPA RUN 2 base case.

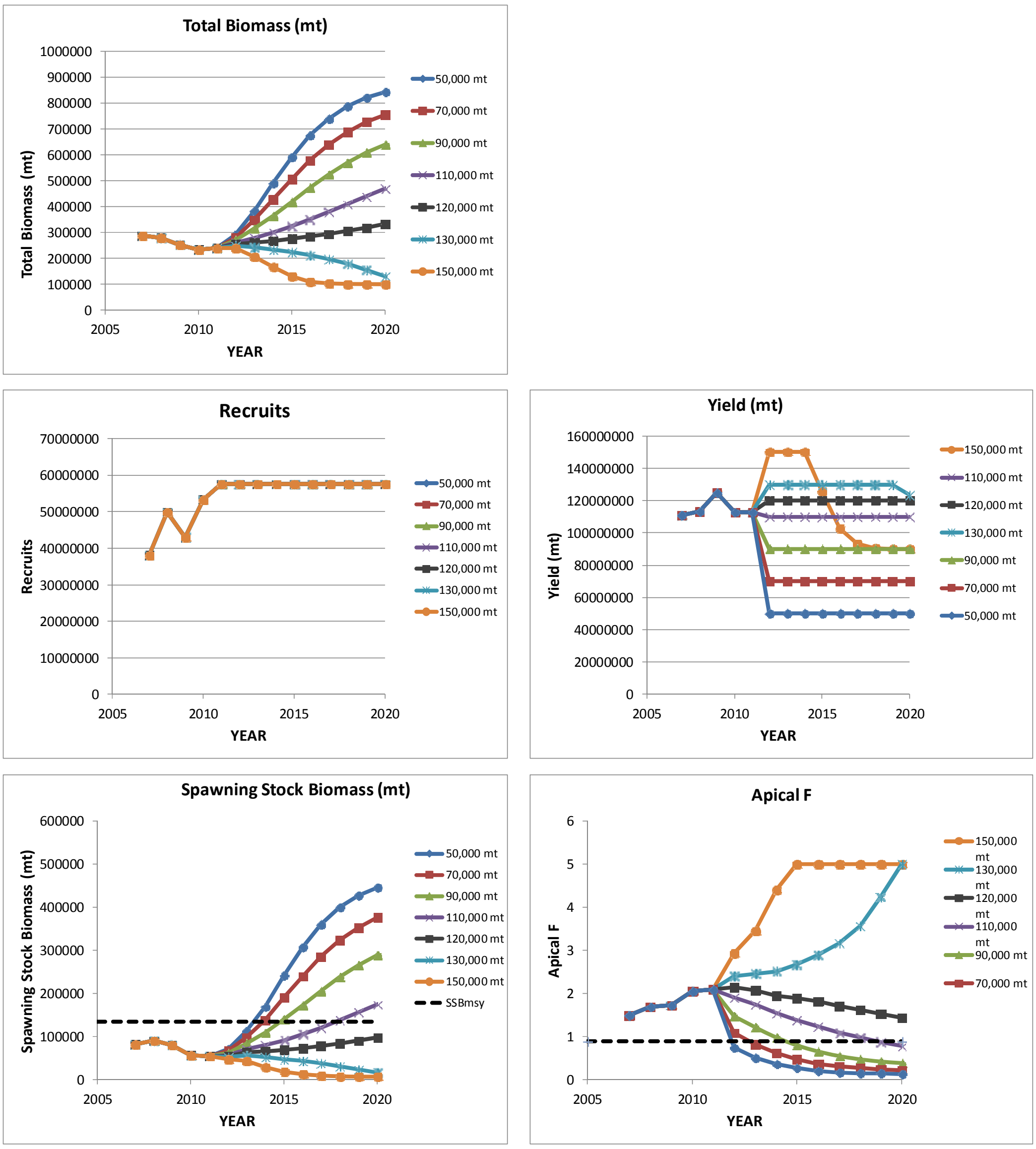


Figure 60. Projection results for the VPA RUN 3 base case.

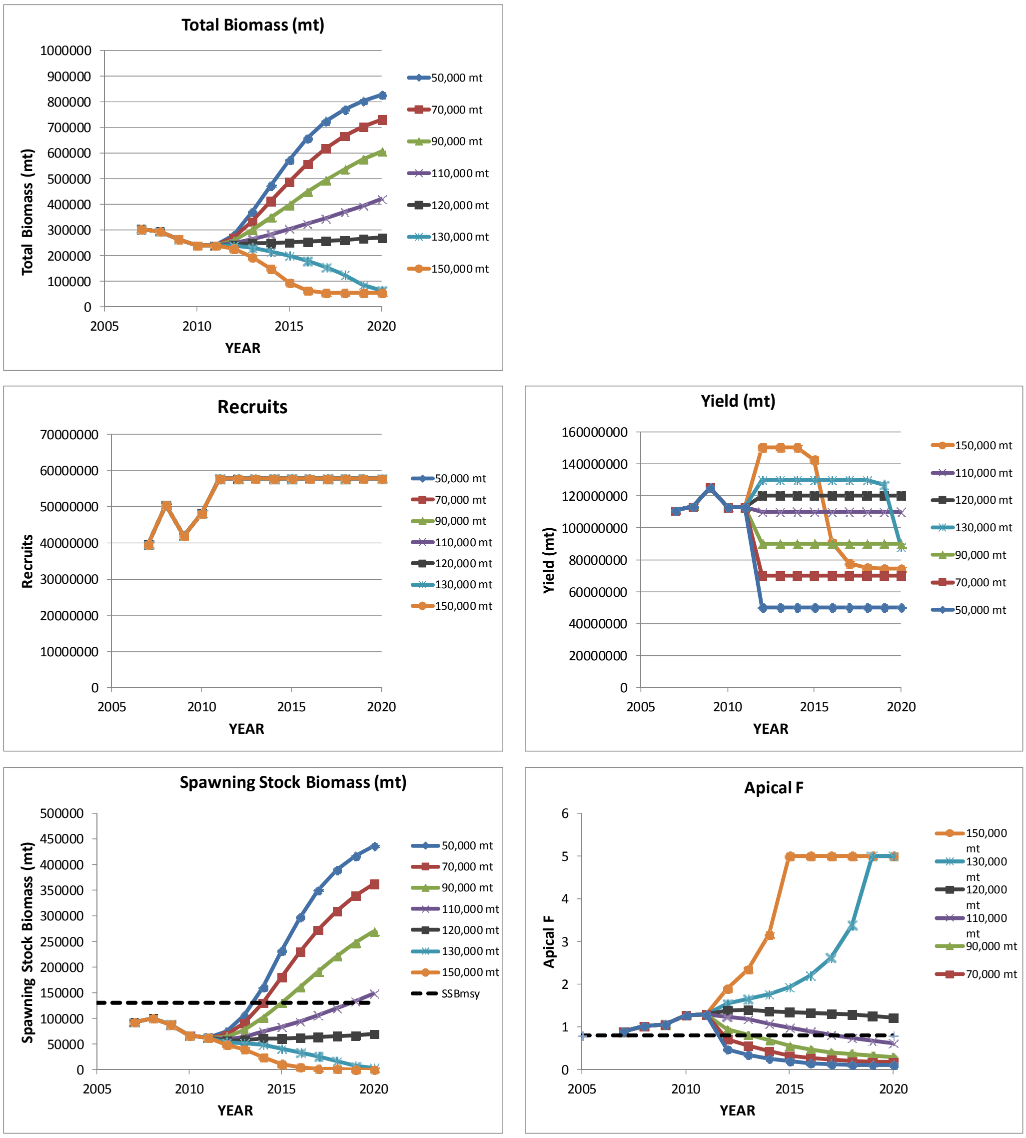


Figure 61. Projection results for the VPA RUN 4 base case.

Appendix 1

AGENDA

1. Opening, adoption of the Agenda and meeting arrangements
2. Review of Biological historical and new data.
3. Review of basic information
   2.1 Task I (catches)
   2.2 Task II (catch-effort and size samples)
   2.3 Other information (tagging)
5. Review of catch per unit effort series and other fishery indicators
6. Conversion of catch-at-size to catch-at-age
7. Stock assessment
   7.1 Methods and other data relevant to the assessment
   7.2 Stock status
   7.3 Projections
8. Evaluation of management scenarios
9. Recommendations
   9.1 Research and statistics
   9.2 Management
10. Other matters
11. Adoption of the report and closure

Appendix 2

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Kell, Laurie
Ortiz, Mauricio
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Appendix 3

LIST OF DOCUMENTS

SCRS/2010/090	Analysis of the catch rate of juvenile bigeye depending on the depth of the purse seine net used by the tropical fleet. Delgado de Molina, A., Ariz, J., Santana, J.C. and Sotillo, B.
SCRS/2011/087	Review of the available Ghana statistics on tropical fisheries. Palma C., Pallares P., Ortiz, M. and Kell, L.
SCRS/2011/127	Attempt to modify creating procedure of catch-at-size of yellowfin caught by Japanese longline tuna fishery in the Atlantic Ocean. Ijima, H., Satoh, K., Okamoto, H.
SCRS/2011/128	Japanese longline CPUE for yellowfin tuna (*Thunnus albacares*) in the Atlantic Ocean using GLM up to 2010. Satoh, K., Okamoto, H., Ijima, H.
SCRS/2011/129	Standardized abundance index of yellowfin tuna by the Taiwanese longline fleet in the Atlantic Ocean for 1968-2009. Hus, C.C.
SCRS/2011/130	Estadísticas españolas de la pesquería atunera tropical en el océano Atlántico hasta 2010. Delgado de Molina, A., Ariz, J., Santana, J.C. y Sabaté, I.
SCRS/2011/131	Datos estadísticos de la pesquería de túnidos de las Islas Canarias durante el periodo 1975 a 2010. Delgado de Molia, A., Delgado de Molina, R., Santana, J.C. y Ariz. J.
SCRS/2011/136	Statistics of the French purse seine fleet targeting tropical tunas in the Atlantic Ocean (1991-2010). Floch, L., Chassot, E., Damiano, A., Kouassi, Y., Pianet, R. and Chavance, P.
SCRS/2011/137	Statistiques de la pêcherie thonière Europeenne et assimilée dans l'océan Atlantique durant la période 1991-2010. Pianet, R., Delgado, A., Floch, L., Ariz, A., Damiano, A., Sabate, I., Kouassi, Y. et N'Gom Sow, F.
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SCRS/2011/141	Preliminary analysis of time spent at temperature relative to the surface temperature for yellowfin tuna monitored with pop-up satellite archival tags in the Gulf of Mexico. Hoolihan, J.P., Wells, R.J.D., Luo, J., Rooker, J.R. and Prince E.D.

SCRS/2011/142	Review ageing protocols for Atlantic yellowfin tuna (*Thunnus albacares*). Ortiz, M. and Palma, C.
SCRS/2011/143	Fishery analysis of yellowfin caught by Cabo Frio, Rio de Janeiro-Brazil small-size fleet (2003-2010). Pimenta, E.G., Rezende, M., Hazin, H.G., Hazin, F.H.V. and Amorim, A.F.
SCRS/2011/144	Standardization of a CPUE series of yelowfin tuna, *Thunnus albacares*, caught by Brazilian longliners in the southwestern Atlantic Ocean by generalized linear mixed models. Hazin, H., Hazin, F.H.V., Amorim, C.A., Travassos, P., Freduo, T.
SCRS/2011/145	Preliminary results on the catch composition in small-scale tuna fisheries associated to an offshore buoy in the western equatorial Atlantic. Silva, G.B., Azevedo, D.V.D., Chaves, D. C.B., Fonteles-Filho, A.A., Hazin, H.
SCRS/2011/146	An evaluation of a harvest control rule based on limits and targets: An example based on yellowfin tuna. Kell, L., Magnusson, De Bruyn, P. and Mosqueira, I.
SCRS/2011/147	An evaluation of the performance of the Kobe Strategy Matrix; An example based upon a biomass dynamic assessment mode. Kell, L., Magnusson, A., De Bruyn, P. and Mosqueira, I.
SCRS/2011/148	A Kobe Strategy Matrix Based upon Probabilistic Reference Points; An Example Using a Biomass Dynamic Assessment Model. Kell, L., Magnusson, A., De Bruyn, P. and Mosqueira, I.

Appendix 4

Estimation of Combined Indexes

Combined indexes were estimated using a GLM approach with the following model formulation:

$$\text{Log(index)} = \text{Year} + \text{Source} + \varepsilon$$

Where 'Source' identifies the index (fleet) included in the model and ε is the error term. Original indexes estimated as number of fish per unit of effort were transformed into biomass by multiplying the index value times the fleet specific annual average weight of the fish estimated from catch-at-size data expanded to the Task I data (file SOP_casYFT7010_v2.xsls provided by the Secretariat). Annual weighting factors (**Table Appendix 4.1)** were estimated for each fleet by counting the number of 5^ox5^o squares where each fishery operated and estimating the proportion to the total number of squares fished for each year. This approach allowed capturing the spatial expansion/contraction experienced by different fleets over time. The index weights were re-scaled so that they would add up to 1.0 each year.

Four different combined indexes were estimated. Values of the indexes used as input for the estimation of the different combined indexes are presented in **Table Appendix 4.2**. When possible, the input indexes were scaled to their respective mean value for the period 1993-2001. The first estimated combined index (Index 1) was prepared to run in the ASPIC continuity case. The 13 indexes used to estimate this combined index were the following:

Fleet	*Period*
Japan longline	1965-2010
Gulf of Mexico longline	1993-2010
U.S. rod and reel recreational	1986-2010
Brazil longline	1986-2006
Uruguay longline	1981-2006
Chinese Taipei longline	1968-2009

Canarias Islands baitboat	1980-2006
Venezuela purse seine	1983-2005
Brazil baitboat	1981-2006
U.S. longline (Atl. only)	1987-2010
EU Dakar baitboat	1969-2010
Venezuela longline	1991-2001
EU purse seine 3%	1970-2010

A second combined index (Index 2) was estimated by replacing the Brazil Longline index with an updated version that covered the period 1980-2010 and by splitting the Chinese Taipei into 4 different time periods (and, therefore, defining 4 new different fisheries): 1968-1980, 1981-1992, 1993-2002, and 2003-2009. However, by splitting the Chinese Taipei series into four different series, it was not possible to scale all of them to their mean value of the period 1993-2001. To scale those Chinese Taipei series that did not overlap with 1993-2001, an average value for all scaled series in each one of those time periods was estimated. The average value of the un-scaled Chinese Taipei index for that time period was then divided by the estimated average for the other fleets. Finally, each individual value of the Chinese Taipei index was divided by the ratio obtained in the previous step.

The third index (Index 3) was constructed with the same indexes used in the second case except for the EU purse seine index with a 3% increase in catchability (EU PS 3%). The original EU PS 3% covered the entire period 1970-2010. For this index only the period 1970-1990 was used, and for the period 1991-2010 two new indexes were introduced: an EU PS (free school) with a 1% increase in catchability and an EU-Spain PS FAD. Both new indexes were equally weighted using the same weighting factors previously applied to the EU PS 3% index.

The final combined index (Index 4) used the same indexes as in the third case, except that the EU PS 3% was replaced by an EU PS 7% index. All weighted combined indexes are shown in **Figure Appendix 4.1** and their values are presented in **Table Appendix 4.3**.

To better assess the influence of some indexes on the combined index (fourth case), 3 combined indexes were estimated by removing the Chinese Taipei (all four series), the Brazil Longline, and the EU PS 7% together with the EU PS 1% and the EU-Spain PS FAD indexes one at the time. The results indicated that of all those indexes, the Chinese Taipei index had the biggest influence of the estimated combine index (**Figure Appendix 4.2**).

Table Appendix 4.1. Weighting factors used in the calculation of the different combined indexes.

	LL							*BB*				*PS*	
Year	*JAP*	*BRA*	*Chi-Tai*	*GOM*	*USA Atl*	*URU*	*VEN*	*BRA*	*DKR*	*CAN*	*US RR*	*EU PS 3%*	*VEN*
1965	1												
1966	1												
1967	1												
1968	0.6580		0.3420										
1969	0.4723		0.4383						0.0894				
1970	0.4946		0.4219						0.0835				
1971	0.5393		0.3081						0.0770			0.0756	
1972	0.4808		0.3276						0.0843			0.1073	
1973	0.4444		0.3171						0.1003			0.1382	
1974	0.3778		0.4099						0.0815			0.1309	
1975	0.5011		0.3244						0.0492			0.1253	
1976	0.3869		0.4453						0.0389			0.1290	
1977	0.3366		0.4703						0.0421			0.1510	
1978	0.3451		0.4457						0.0299			0.1793	
1979	0.4265		0.3529						0.0500			0.1706	
1980	0.4038		0.3654						0.0470	0.0171		0.1325	0.0342
1981	0.4241		0.3298			0.0070		0.0297	0.0070	0.0140		0.1606	0.0279
1982	0.4360		0.3316			0.0067		0.0354	0.0067	0.0135		0.1431	0.0269
1983	0.3779		0.2939			0.0076		0.0305	0.0382	0.0153		0.1947	0.0420
1984	0.4032		0.2842			0.0071		0.0586	0.0355	0.0142		0.1208	0.0764
1985	0.4438		0.2695			0.0058		0.0461	0.0173	0.0115		0.0965	0.1095
1986	0.3705	0.0372	0.3497			0.0060		0.0268	0.0253	0.0119	0.0595	0.0967	0.0164
1987	0.3305	0.0470	0.2564		0.1396	0.0057		0.0356	0.0171	0.0114	0.0570	0.0855	0.0142
1988	0.3959	0.0509	0.1063		0.1907	0.0058		0.0320	0.0291	0.0116	0.0582	0.1063	0.0131
1989	0.4401	0.0404	0.0952		0.1905	0.0058		0.0390	0.0231	0.0115	0.0577	0.0851	0.0115
1990	0.4149	0.0432	0.1432		0.1676	0.0054		0.0311	0.0270	0.0108	0.0541	0.0878	0.0149
1991	0.3638	0.0509	0.2380		0.1008	0.0042	0.0062	0.0239	0.0125	0.0083	0.0416	0.1414	0.0083
1992	0.3072	0.0937	0.1667		0.1155	0.0044	0.0065	0.0370	0.0163	0.0087	0.0436	0.1863	0.0142
1993	0.2522	0.1429	0.1970	0.0236	0.1044	0.0039	0.0069	0.0266	0.0099	0.0079	0.0394	0.1724	0.0128
1994	0.2733	0.1320	0.2422	0.0226	0.0924	0.0038	0.0075	0.0160	0.0113	0.0075	0.0377	0.1433	0.0104
1995	0.2700	0.1240	0.2181	0.0211	0.1003	0.0035	0.0070	0.0176	0.0132	0.0070	0.0352	0.1733	0.0097
1996	0.2693	0.0873	0.2702	0.0223	0.0947	0.0037	0.0074	0.0149	0.0139	0.0074	0.0371	0.1606	0.0111
1997	0.2814	0.0932	0.2690	0.0228	0.1093	0.0038	0.0076	0.0095	0.0124	0.0076	0.0380	0.1369	0.0086
1998	0.2647	0.1373	0.2683	0.0214	0.1007	0.0036	0.0062	0.0143	0.0080	0.0071	0.0357	0.1275	0.0053
1999	0.2301	0.2190	0.2827	0.0204	0.0628	0.0034	0.0195	0.0042	0.0102	0.0068	0.0340	0.0985	0.0085
2000	0.2619	0.1456	0.3166	0.0185	0.0562	0.0031	0.0254	0.0108	0.0108	0.0062	0.0308	0.1063	0.0077
2001	0.2652	0.1518	0.2700	0.0192	0.0615	0.0032	0.0264	0.0112	0.0096	0.0064	0.0319	0.1350	0.0088

2002	0.2093	0.2257	0.3034	0.0196	0.0564	0.0033		0.0147	0.0114	0.0065	0.0327	0.1112	0.0057
2003	0.2621	0.1379	0.2825	0.0233	0.0485	0.0039		0.0350	0.0146	0.0078	0.0388	0.1369	0.0087
2004	0.2389	0.1639	0.3114	0.0198	0.0445	0.0033		0.0371	0.0115	0.0066	0.0329	0.1219	0.0082
2005	0.1988	0.1715	0.2471	0.0163	0.0980	0.0027		0.1307	0.0095	0.0054	0.0272	0.0803	0.0123
2006	0.2510	0.2181	0.2693	0.0232	0.0569	0.0039		0.0290	0.0106	0.0077	0.0386	0.0917	
2007	0.2354	0.1188	0.2915	0.0269	0.0650	0.0045		0.0370	0.0157	0.0090	0.0448	0.1513	
2008	0.2639	0.1298	0.2425	0.0258	0.0590	0.0086		0.0279	0.0236	0.0086	0.0429	0.1674	
2009	0.2639	0.1298	0.2425	0.0258	0.0590	0.0086		0.0279	0.0236	0.0086	0.0429	0.1674	
2010	0.2639	0.1298	0.2425	0.0258	0.0590	0.0086		0.0279	0.0236	0.0086	0.0429	0.1674	

Table Appendix 4.2. Indices of abundance in weight used to estimate the different combined. The indexes were scaled to the mean values of the period 1993-2001 (see text for details).

Year	*JAP LL*	*GOM LL*	*USA RR*	*BRA LL*	*URU LL*	*TAI LL*	*CAN BB*	*VEN PS*	*BRA BB*	*USA LL*	*EUDKR BB*	*VEN LL*	*EU PS 3%*	*BRA LL*	*EU PS 1%*	*EU PS FAD*	*EU PS 7%*
1965	3.87																
1966	2.69																
1967	5.30																
1968	4.34					3.16											
1969	3.81					2.33					1.20						
1970	2.87					1.46					1.16		1.47				2.943
1971	2.38					1.05					1.15		1.25				2.347
1972	3.17					0.78					1.16		1.39				2.435
1973	2.13					0.73					1.07		1.40				2.294
1974	3.03					0.44					1.65		1.28				1.954
1975	2.19					0.42					0.74		1.37				1.967
1976	2.27					0.42					0.83		1.36				1.818
1977	1.77					0.36					1.23		1.34				1.669
1978	2.59					0.28					0.50		1.22				1.420
1979	3.13					0.36					1.13		1.21				1.319
1980	1.89				0.00	0.27	0.05				0.00		1.00	0.945			1.022
1981	2.46				1.40	0.60	0.10		4.47		1.83		1.07	0.263			1.055
1982	2.14				1.90	0.66	0.50		0.68		1.74		0.92	0.267			0.867
1983	2.06				0.82	0.50	0.88	2.20	1.85		1.77		0.80	0.609			0.725
1984	2.23				0.41	0.63	3.27	0.98	0.90		2.52		0.63	0.260			0.551
1985	1.46				0.73	0.54	1.42	1.65	0.67		1.94		1.08	0.193			0.912
1986	1.83		1.42	1.39	1.12	0.57	0.91	0.97	0.67		2.91		1.17	0.377			0.947
1987	1.91		0.78	1.76	1.08	0.45	2.04	0.74	0.95	1.77	3.27		1.02	0.647			0.798
1988	1.91		0.37	1.46	1.38	0.48	2.13	1.02	1.05	2.11	3.16		0.97	0.306			0.728
1989	1.53		0.64	1.48	0.55	1.26	1.26	2.21	0.96	1.68	0.79		1.21	0.486			0.873
1990	1.99		0.27	2.50	0.50	1.12	3.20	1.13	1.99	1.62	2.92		1.31	0.738			1.211
1991	1.54		0.43	1.37	1.80	0.75	2.83	1.16	0.60	1.37	1.08	1.11	1.24	0.521	0.973	1.138	
1992	1.76	1.46	0.29	0.57	2.83	0.67	1.64	0.78	0.95	1.60	2.91	1.63	1.13	0.513	1.220	0.837	
1993	0.84	1.12	0.77	0.66	0.54	0.83	0.75	0.89	1.12	0.90	2.48	2.35	1.08	2.388	0.979	1.265	
1994	1.39	1.51	1.97	0.74	2.07	1.10	0.45	1.09	0.67	0.85	1.60	1.12	1.06	0.549	1.042	0.995	
1995	1.01	0.99	2.47	0.50	0.85	1.26	0.19	0.49	0.33	1.32	0.91	0.77	1.06	0.837	0.972	1.231	
1996	1.08	0.67	0.58	1.29	1.61	1.48	2.85	1.10	0.93	1.23	1.13	0.98	1.01	1.172	1.048	1.235	
1997	0.83	0.96	0.26	1.02	0.53	1.19	0.34	0.74	1.35	1.09	0.79	0.60	0.94	0.861	1.224	0.754	
1998	0.97	0.81	0.46	1.30	0.60	1.00	4.03	0.60	1.04	0.71	0.33	1.02	0.99	0.557	1.051	0.573	
1999	1.01	1.20	0.77	1.22	1.21	0.81	0.38	0.88	0.36	1.00	0.83	0.93	0.82	1.070	0.978	1.179	
2000	1.11	0.90	0.86	1.27	1.60	0.80	0.01	1.07	0.00	0.96	0.37	0.29	0.97	0.929	0.744		

2001	0.75	0.84	0.84	1.02		0.54	0.00	2.14	2.19	0.94	0.57	0.95	1.06	0.637	0.961	0.767
2002	0.75	0.82	0.74	0.80	0.97	0.79	0.13	1.32	0.93	0.64	0.97		1.16	0.535	1.295	0.848
2003	0.90	1.07	0.64	1.71	1.47	1.09	0.24	0.65	0.76	0.53	1.02		1.08	0.891	0.755	1.408
2004	1.16	0.76	0.57	2.08	1.06	1.21	0.20	0.39	0.29	1.10	0.88		0.89	0.693	1.131	1.006
2005	0.87	0.73	0.46	0.25	2.23	1.67	0.03	0.20	0.33	1.07	0.59		0.96	0.109	0.812	1.074
2006	1.17	0.64	0.62	0.64	0.88	0.99	0.08		1.21	1.19	0.67		1.17	0.232	1.007	0.933
2007	1.36	0.74	0.62			0.76	0.35			1.52	0.68		0.92	0.551	0.909	1.018
2008	1.21	0.67	0.31			0.68				0.73	0.52		1.12	0.201	1.204	0.628
2009	1.21	0.78	0.15			0.72				0.59	0.57		0.93	0.658	0.900	1.293
2010	0.93	0.51	0.19							0.82	1.22		0.80	0.831		1.404

Table Appendix 4.3. Estimated weighted combined indexes of abundance. Refer to text for explanation of each index.

Year	*Index 1*	*Index 2*	*Index 3*	*Index 4*
1965	2.443	2.430	2.537	2.581
1966	1.645	1.690	1.765	1.795
1967	3.235	3.327	3.473	3.533
1968	3.089	3.803	4.019	4.140
1969	2.659	3.210	3.408	3.529
1970	1.913	2.178	2.341	2.521
1971	1.429	1.665	1.785	1.913
1972	1.503	1.754	1.894	2.051
1973	1.217	1.400	1.521	1.654
1974	1.172	1.364	1.484	1.601
1975	1.043	1.173	1.270	1.350
1976	0.971	1.144	1.244	1.319
1977	0.685	0.987	1.079	1.138
1978	0.827	0.970	1.065	1.112
1979	1.017	1.278	1.398	1.437
1980	0.628	0.855	0.928	0.945
1981	1.065	1.212	1.305	1.284
1982	1.000	1.121	1.202	1.178
1983	1.011	1.069	1.157	1.118
1984	0.986	1.102	1.175	1.146
1985	0.834	0.946	1.004	0.980
1986	0.899	1.114	1.183	1.148
1987	0.926	1.075	1.132	1.100
1988	1.160	1.108	1.169	1.128
1989	1.114	1.110	1.166	1.131
1990	1.399	1.296	1.363	1.348
1991	0.996	1.049	1.002	1.005
1992	0.982	1.046	1.025	1.029
1993	0.757	0.919	0.845	0.852
1994	0.887	0.916	0.908	0.916
1995	0.799	0.911	0.862	0.868
1996	0.932	0.976	0.960	0.968
1997	0.738	0.770	0.806	0.812
1998	0.767	0.736	0.713	0.718
1999	0.769	0.838	0.796	0.802
2000	0.802	0.760	0.745	0.751
2001	0.655	0.607	0.590	0.595
2002	0.741	0.674	0.671	0.676
2003	1.010	0.765	0.760	0.766
2004	1.104	0.781	0.798	0.804
2005	0.754	0.530	0.543	0.546
2006	0.866	0.632	0.631	0.636
2007	1.105	0.727	0.726	0.733
2008	0.910	0.579	0.563	0.569
2009	0.852	0.645	0.677	0.683
2010	0.571	0.676	0.757	0.765

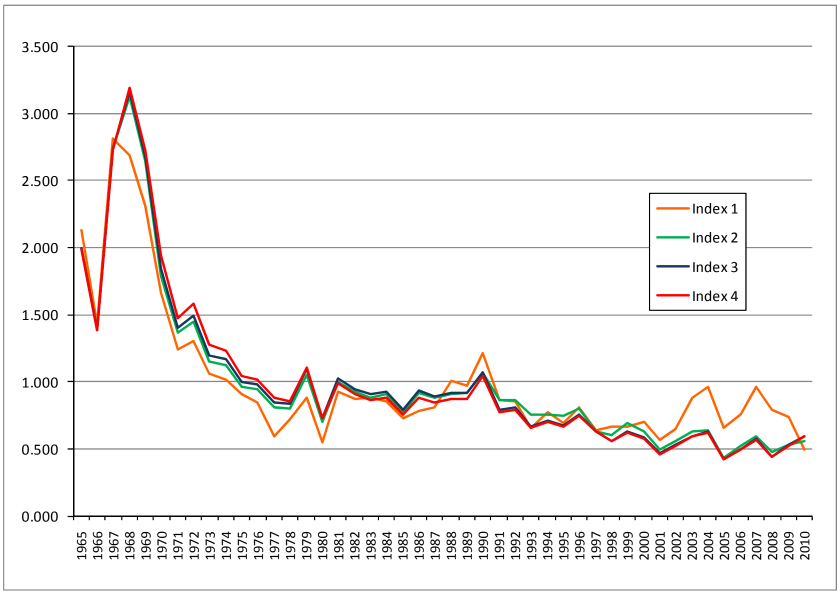


Figure Appendix 4.1. Estimated weighted combined indexes of abundance. For comparison purposes, each series was scaled to their average value. Refer to text for explanation of each series.

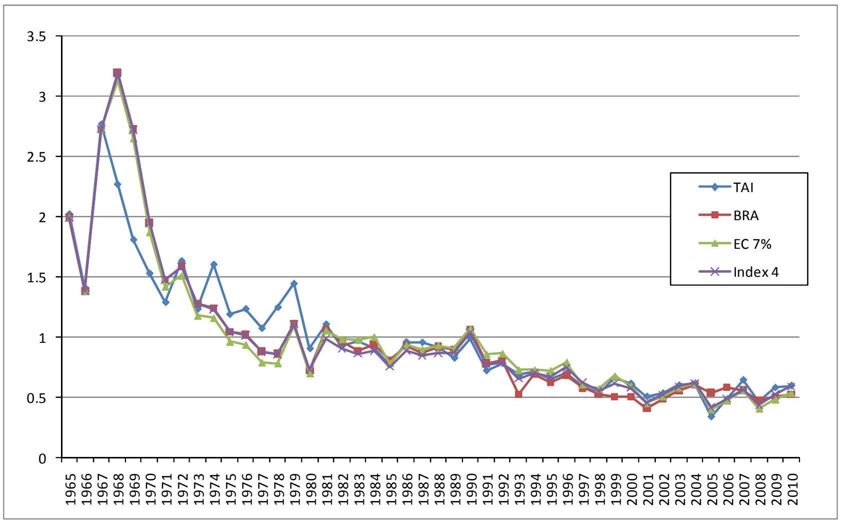


Figure Appendix 4.2. Weighted estimated indexes of abundance. The series labeled 'Tai' corresponds to the 'Index 4' estimated without the Chinese Taipei longline index. Similarly, the series labeled 'BRA' and 'EU7%' correspond to the 'Index 4' estimated without the Brazilian longline and all EU PS fisheries, respectively. For comparison purposes, each series was scaled to their average value. Refer to text for explanation of the 'Index 4'.

Appendix 5

STANDARDIZATION OF THE CATCH RATES OF THE EUROPEAN AND ASSOCIATED BAITBOAT FISHERY BASED IN DAKAR

Response variable: Log (CPUE+0.1)

Explanatory variables:

Year=c(1969,1970,1971,1972,1973,1974,1975,1976,1977,1978,1979,1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010),

Quarter=1:4,

Fleet=c("MIXFIS","ESPETRO","FRAETRO","NEISEN")))

Model

Mtot<-glm(log(UYFT+0.1) ~ Year + Quarter + Fleet + Year:Quarter, family = gaussian)

Model selection with library(MASS)

Mtot.step<-stepAIC(Mtot)

Mtot.step$anova (original model selected)

Predicted values performed with an R Lsmeans procedure

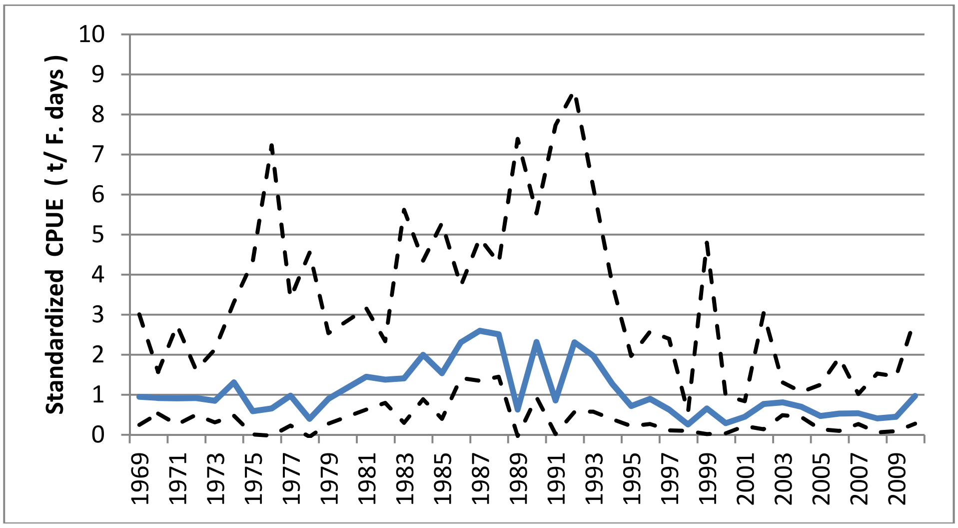


Figure Appendix 5.1. Standardized CPUE for baitboats operating from Dakar.

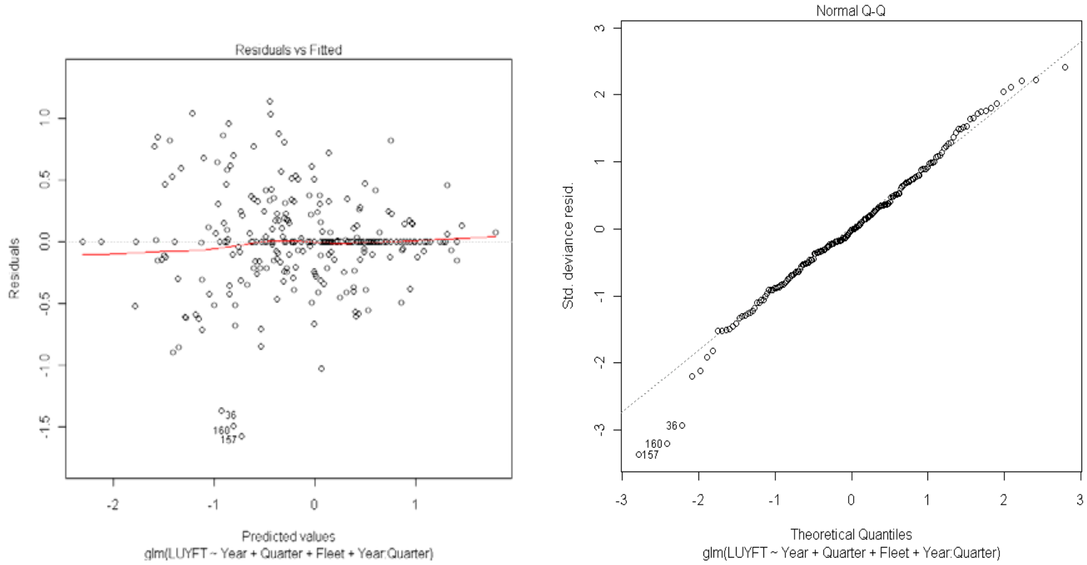


Figure Appendix 5.2. Diagnostics for standardized model.

Appendix 6

STANDARDIZATION OF BRAZILIAN LONGLINE CPUE SERIES CONDUCTED DURING THE ASSESSMENT MEETING

Recently, cluster analysis has been applied in the analysis of fishing data in Brazilian tuna longline fishery, aiming at categorizing fishing effort based on the proportion of the several species in the catches, as a way to detect changes in fishing tactics (target species). Presented for the first time in 2007, this approach generated a good discussion about its use in the standardizations performed by the Brazilian Delegation. The main advantage of such methods, instead of using the percentage of a single species as an expression of the targeting strategy, relies on the fact that they consider the frequency distribution of all species in each set, thus potentially avoiding spurious patterns caused by trends in a single species. However, this method could overestimate catch rates since fishing sets with low catches of the target species could be placed in a separate cluster rather than simply representing low catch rates.

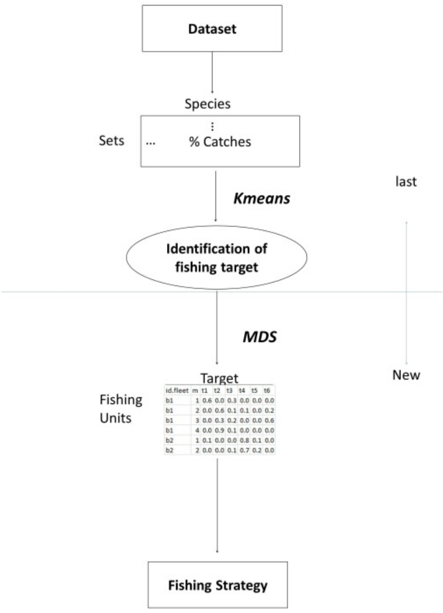
During previous meetings, the working group recognized the diverse characteristics of longline vessels fishing under the Brazilian flag and it was recognized that common standardization methods might not be appropriate for the Brazilian CPUE. While cluster analysis to account for the targeting strategy in CPUE standardization might induce bias, resulting in an artificially higher CPUE failing to account for changes in targeting strategy may cause an opposite bias since some part of the fishing effort deployed might not have been directed to the target species. To mitigate such biases, we used cluster analyses to identify specific fishing strategies and then used these clusters as factors in the CPUE modeling.

Fleet strategy methodology

Since 1956, when longline operations in the Southern Atlantic begun, several changes in fishing technology and strategies have occurred, strongly influencing catch composition. A number of models, such as GLM (Generalized Linear Model), have been applied to minimize the effects of operational variables on the estimation of CPUE, through standardization. However, information on fishing tactics and even technological changes is often not available, leading to serious errors in the estimation of abundance indices.

Previous analyses of the Brazilian longline fishery (Hazin, 2006, Carvalho *et al.* 2011) indicated that the different fleets operating in the Southwest Atlantic choose different fishing strategies targeting different resources and hence have a different catch composition. This analysis uses two different methods to partition the longline sets into different strategies: (*i*) identification from the species composition alone and (*ii*) identification from species composition and operational and gear characteristics combined (**Figure Appendix 6.1**).

Two methods were used to determine fishing strategy. The first one, Fleet Strategy I, followed the clustering procedures described in Hazin *et al*. 2011. In the second method (Fleet Strategy 2) a matrix was constructed similar to the first method but now considering the seasonal (month) and operational factors (time fishing: night and day, boat length: <25m and >25m, hooks/basket: 3-6; 7-10; >10) using Multidimensional Scaling (MDS).



id.fleet	m	t1	t2	t3	t4	t5	t6
b1	1	0.6	0.0	0.3	0.0	0.0	0.0
b1	2	0.0	0.6	0.1	0.1	0.0	0.2
b1	3	0.0	0.3	0.2	0.0	0.0	0.6
b1	4	0.0	0.9	0.1	0.0	0.0	0.0
b2	1	0.1	0.0	0.0	0.8	0.1	0.0
b2	2	0.0	0.0	0.1	0.7	0.2	0.0

Figure Appendix 6.1 Method used to partition the longline sets into different strategies.

Results and discussion

During the 2008 yellowfin tuna stock assessment meeting, the Brazilian CPUE series presented were estimated using the target species as a factor in the GLM. CPUE predictions were obtained for every year, fixing the level of remaining factors at the level with the highest number of observations. After years of discussion regarding the topic, now a consensus has been reached. The use of the current fleet-strategy factor in the Brazilian standardizations should be replaced

A new standardized CPUE series was built using GLMM. Three data sets were used for standardized CPUE: all data; fleets with 5 years of operations and fleets with 7 years of operations. The initial analyses obtained predicted values for each observation and then took the mean of these for each year. After some discussion, the Group suggested that the estimates should be calculated by creating a balanced prediction matrix similar to the SAS lsmeans so that the estimates are not unduly influenced by the unbalanced data. Both standardized series showed a decline after the year 2000 (**Figure Appendix 6.2**) but the new estimated CPUE presented a significant difference from the previous one, most notable in the divergences from the nominal in the early years. In the future it is recommended to use a balanced prediction matrix to calculate the year effect in a balanced manner.

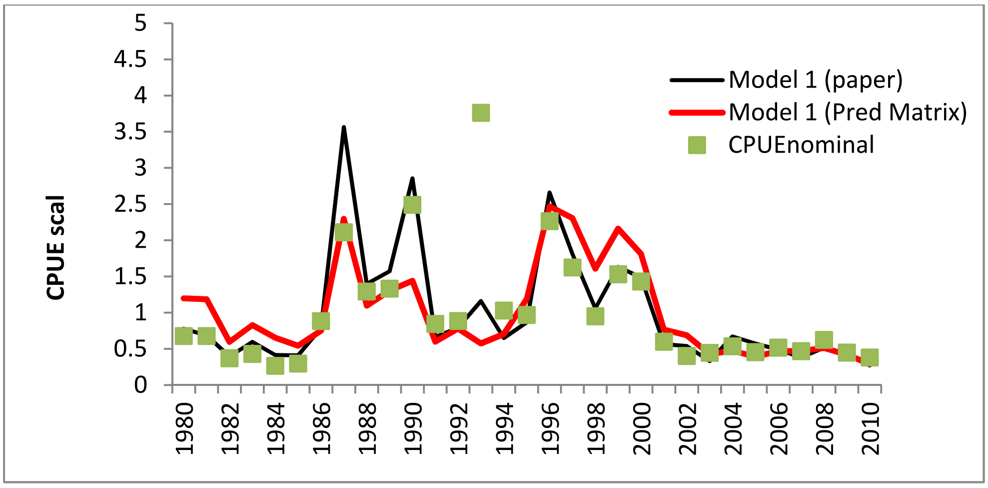


Figure Appendix 6.2. Standardized catch rate of yellowfin tuna in the South Western Atlantic by model 1 (paper) and model 1(pred matrix).

To compare the effect of using the prediction matrix in R or lsmeans in SAS, a comparison was performed using the two software packages and the same delta lognormal model structure. The two CPUE estimates were similar but did show some divergence which was likely because the R dataset was slightly different and included all of the data rather than a subset of the vessels (**Figure Appendix 6.3**). The Group decided to use the model constructed in R and this model was used in the VPA and ASPIC runs. The diagnostics for the Delta lognormal model (models 1 and 2) are presented in **Figures Appendix 6.4-6.6**.

Subsequently, the index constructed in R was revised to use the same dataset used in the SAS model which was subset for vessels that had at least 5 or 7 years of effort (**Figure Appendix 6.7**). The SAS and R models are almost exactly the same in this case. Unfortunately, this revision occurred too late in the modeling process to be included in the VPA or ASPIC runs; however, it is likely the model run most consistent with the decisions made by the Group.

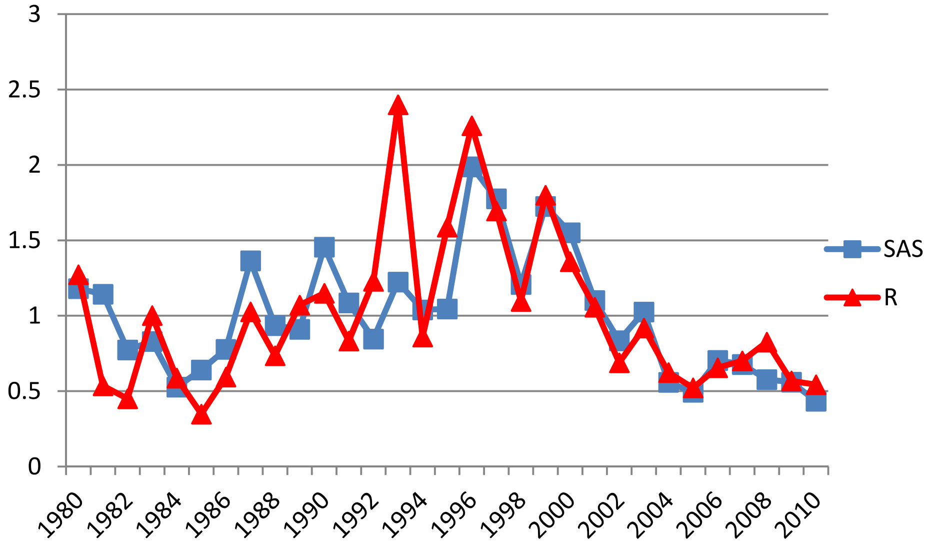


Figure Appendix 6.3. Standardized catch rates of yellowfin tuna in the South Western Atlantic by different delta lognormal models using SAS with lsmeans and R with a prediction matrix.

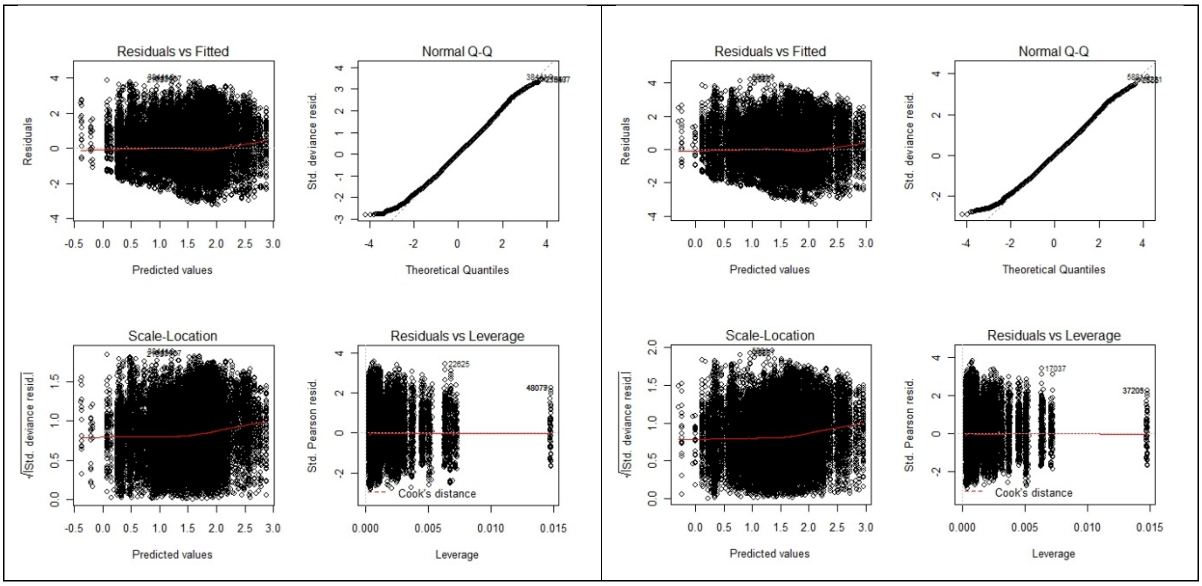


Figure Appendix 6.4. Residual analysis of the log-normal model fitting. Left: Model 1 delta lognormal and Right: Model 2 delta lognormal.

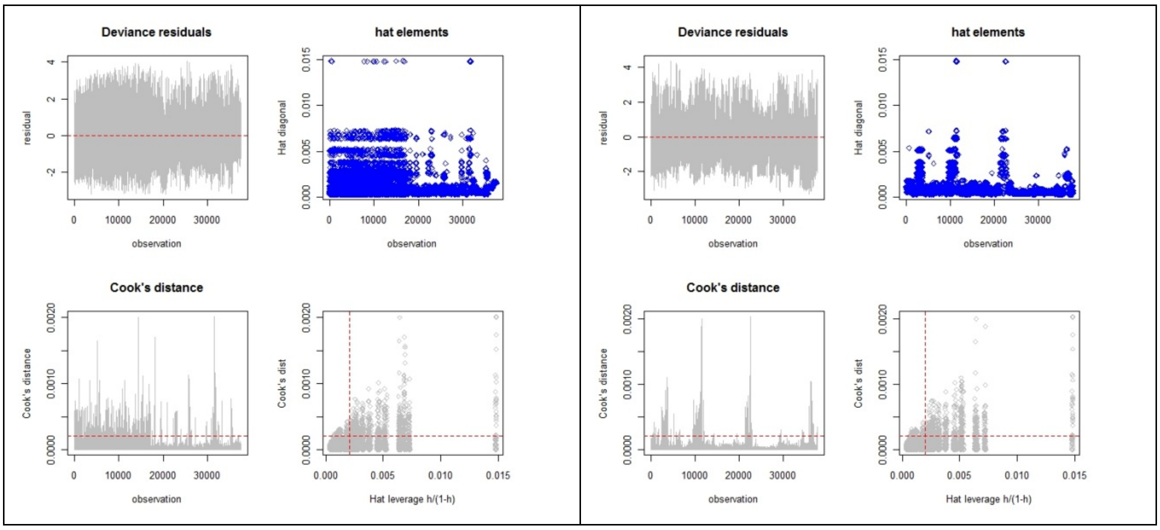


Figure Appendix 6.5. Residual analysis of the log-normal model fitting. Left: Model 1 delta lognormal and Right: Model 2 delta lognormal.

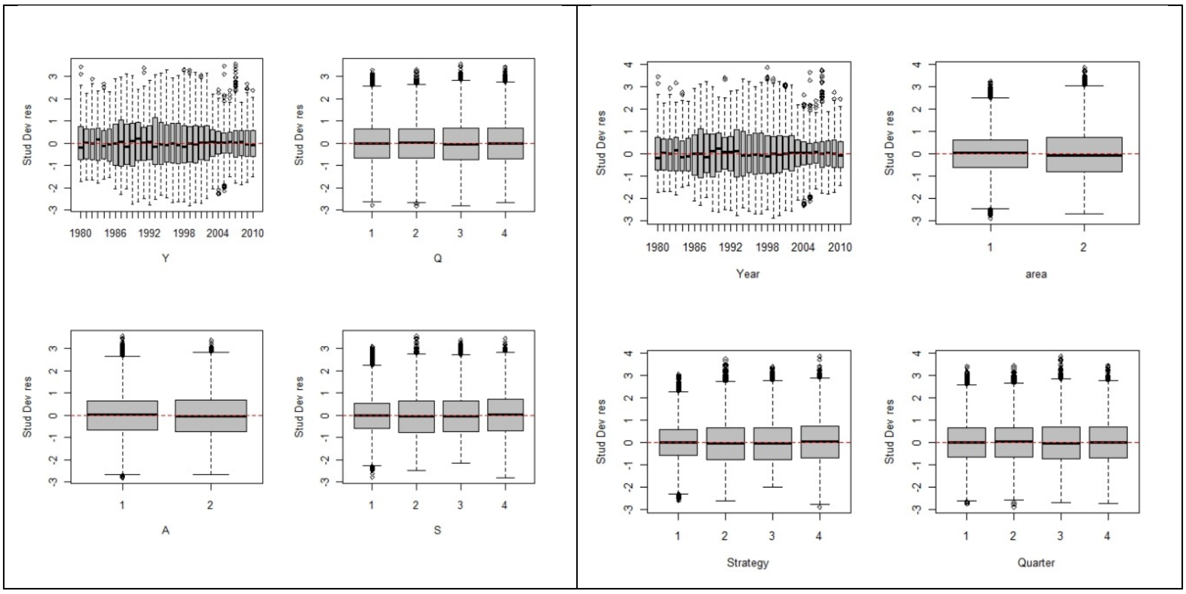


Figure Appendix 6.6. Plot standardized deviance residuals and explanatory variable of the linear predictor. Left: Model 1 delta lognormal and Right: Model 2 delta lognormal.

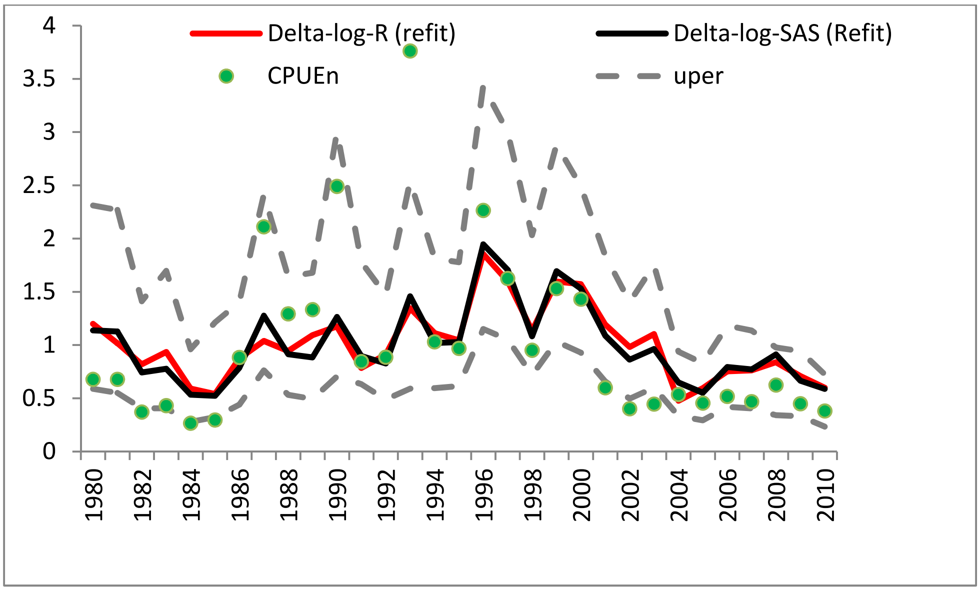


Figure Appendix 6.7. Standardized catch rate of yellowfin tuna in the South Western Atlantic revised to include only vessels with either a 5 or 7 year history.

Appendix 7

CHANGES IN FISHING POWER OF THE TROPICAL PURSE SEINE FLEET

Background

Many studies have reported that changes in technology and fishing strategy of the tropical tuna purse seine fleets have led to significant changes in capacity and fishing power of individual vessels (Gaertner and Sachi 2000, Suzuki *et al* 2003, Joseph 2005). Few studies, however, have estimated the magnitude of these changes for the entire fleet and calculated the increased catchability of tuna resulting from such fishing power increases. Gascuel *et al* (1993) estimated increases of 17% per year and 9% per year for the period of 1980-1990 for the French fleet and the Spanish fleet, respectively by using a VPA. Reid *et al* (2005) estimated with the data envelopment analysis method of Charnes, Cooper and Rhodes (1978) a 60% increase in the period 1994-2002 for the eastern tropical Pacific purse seine fleet that also targets tropical tunas.

The Tropical Working Group assumed in its 2008 yellowfin tuna assessment that a 3% annual increase in q would be an appropriate correction for the nominal CPUE purse seine indices. During that meeting, however, it was discussed that this assumption did not make these indices totally consistent with the indices from other fleets possibly indicating that the assumed rate in q increase was underestimated. During the 2008 yellowfin assessment meeting, the Working Group attempted to estimate which rate of catchability increase would generate a purse seine CPUE index that was more consistent with the biomass trend estimated by the assessment models. The estimate in the increase in q obtained during the 2008 assessment was of 5%. This Appendix reports further analyses of the type initiated by the Group in 2008.

Methods

The Working Group made the following assumptions:

- Production models and VPA provide an accurate description of fishing mortality and stock abundance of yellowfin,
- Nominal CPUE from the purse seine fishery provides a biased relative abundance index, with the amount of bias related to the unaccounted annual changes in catchability,
- Annual percent changes in catchability are approximately constant, for certain periods of the development of the fishery, so that:

$$q'_{year} = q'_{year-1}\left(1+\Delta q\right) \qquad (1)$$

Note that the above equation is the same used by Gascuel *et al* (1993) to estimate increases in q and it generates an exponential increase in the absolute value of q as a function of year, not a linear increase (**Figure Appendix 7.1**).

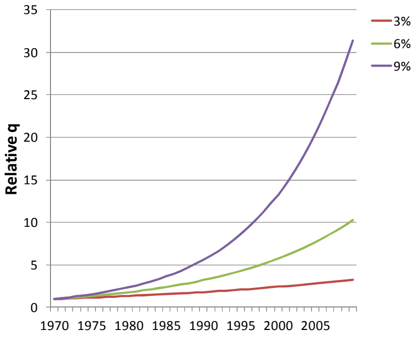


Figure Appendix 7.1. Changes in catchability for different annual rates of exponential increase.

Results from VPA run5 from the 2008 assessment were used to estimate relative q by year for the purse seine. This was accomplished by:

$$q_{year,ps} = \frac{F_{year,ps}}{f_{year,ps}} \qquad (2)$$

$$F_{year,age,ps} = F_{year,age}\frac{C_{year,age,ps}}{C_{year,age}} \qquad (3)$$

$$F_{year,ps} = \sum_{age} F_{year,age} \qquad (4)$$

$$_{rel}q_{year,ps} = \frac{q_{year,ps}}{_{mean}\left(q_{year,ps}\right)} \qquad (5)$$

Where	$f_{year,ps}$	nominal fishing effort (fishing days) in the purse seine for a given year
	${}_{rel}q_{year,ps}$	relative catchability of the purse seine scaled to its mean for a given year
	$F_{year,ps}$	fishing mortality produced by the purse seine in a given year for all age groups
	$C_{year,ps}$	catch of the purse seine for a given year for all age groups
	$F_{year,age,ps}$	fishing mortality by the purse seine in a given year for a given age
	$C_{year,age,ps}$	catch of the purse seine in a given year for a given year

Similarly relative catchability of the purse seine was calculated from production model estimates of biomass obtained in (2008) by using a logistic production model with MSY = 150,000, B_{MSY} = 237,131 and B_{1949} = K = 644,588. These parameters represent approximately case 08 from the 2008 yellwofin assessment.

$$F_{year,ps} = F_{year} \frac{C_{year,ps}}{C_{year}} \tag{6}$$

$$F_{year} = \frac{C_{year}}{\bar{B}_{year}} \tag{7}$$

$$\bar{B}_{year} = \frac{B_{year+1} + B_{year}}{2} \tag{8}$$

Where,

B_{year} is the estimated biomass by the production model for a given year which corresponds to the biomass at the end of the calendar year, and

$\bar{B}_{year}$ is the average biomass during the year.

The relative catchability for the purse seine from a given year was then calculated from equation (1), as it was the case for the VPA results.

Note that in the production model case, estimates of F and B were partially conditioned by the assumption made in 2008 that the annual increase in q for the purse seine was of 3%. Estimates of q obtained from the VPA were partially conditioned by the same assumption but only for the period 1970-because for the later period the free school and FAD indices were used and those indices were not corrected by an annual increase in q. Although it would be best to have used estimates of q not conditioned by the old assumption of the 3% annual rate of increase in q such estimates were not available. It is hoped that given that in both the production model and the VPA implementations conducted in 2008 purse seine indices did not fit the models well that those indices were not very influential in the model fit and the final estimates of biomass and fishing mortality.

Once the two sets of relative q were estimated, one from the VPA and one from the production model, the data were broken up into three periods where it was assumed that there would be a constant annual increase in q. The first period corresponded to the period prior to substantial development of the FAD fishery 1970-1989; the second the period of fast development of the FAD fishery 1990-1999 and the third the most recent period 2000-2006.

A single Δq_{period} was estimated for each period by minimizing the joined sum of squares:

$$SSQ = \sum_{period} \sum_{year} (q_{year} - q'_{year})^2_{VPA} + (q_{year} - q'_{year})^2_{PM}$$

Where q'_{year} was calculated from equation (1) for each period. It was assumed that the q calculated for the end of each period was the q for the beginning of the next period. As a result only two additional nuisance parameters were to be estimated, the q_{1970} for each the VPA estimates and the production model. Parameters were estimated with the non linear minimization routine provided by the SIMPLEX method (SOLVER) on Microsoft Excel. A total of six different models were attempted depending which parameters were considered to be period or method specific (**Table Appendix 7.1**). These models represent alternative nested hypotheses about model complexity and are thus suited for hypothesis testing with likelyhood ratio tests (**Figure Appendix 7.2**).

Table Appendix 7.1. List of models considered depending on the level of complexity considered and estimates of catchability parameters for each model.

								Delta q		
Model	*Delta q method specific*	*q1970 method specific*	*No of periods*	*SSQ*	*No. of params*	*Method*	*1970-1989*	*1990-1999*	*2000-2006*	*q1970*
A	no	no	2	2.013	3	Prod mod	0.073		0.017	0.226
						VPA				
B	no	yes	2	1.852	4	Prod mod	0.073		0.016	0.232
						VPA				0.214
C	no	no	3	2.013	4	Prod mod	0.072	0.073	0.016	0.228
						VPA				
D	no	yes	3	1.852	5	Prod mod	0.073	0.074	0.016	0.233
						VPA				0.214
E	yes	yes	2	1.440	6	Prod mod	0.088		0.009	0.164
						VPA	0.058		0.025	0.306
F	yes	yes	3	1.404	8	Prod mod	0.102	0.080	0.013	0.134
						VPA	0.053	0.064	0.021	0.329

Results

The most parsimonious model is one where the q_{1970} and the increase in catchability are different between the VPA estimates and the production model estimates but not between the first and second period. This model explains about 95% of the variance in relative catchability. It suggest an increase in catchability for the period 1970-1999 of 9% from the production model and 6% from the VPA. For the most recent period the estimates are of 1% from the production model and 2% for the VPA. A much simpler model, however, with a common q_{1970} and the same rate of increase in q for all periods and both data types explains 91% of the variance. This model suggests an annual increase in q of 6% per year.

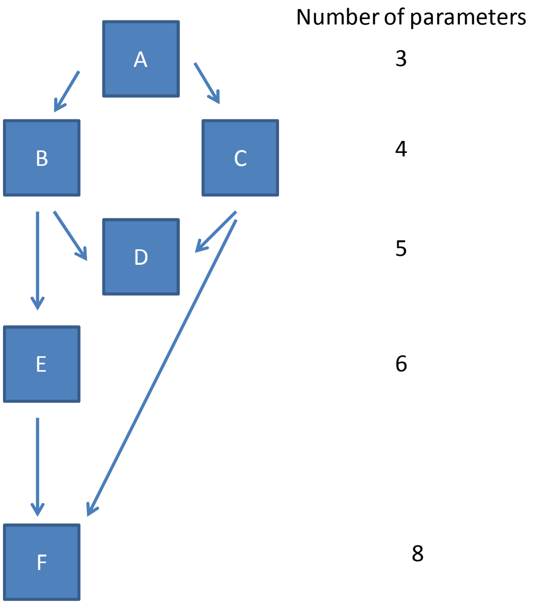


Figure Appendix 7.2. Schematic representation of the complexity and nested relationship between different models considered.

Table Appendix 7.2. Likelihood ratio test for competing models in Table Appendix 7.1.

Likehood ratio tests					*Increase in variance explained (%)*
		df	x^2	*p*	
	A vs B	1	4.36	***0.037***	0.55
	A vs C	1	0.00	0.946	0.00
	B vs D	1	0.00	0.976	0.00
	C vs D	1	4.35	***0.037***	0.55
	B vs E	2	13.07	**0.001**	1.40
	E vs F	2	1.31	0.520	0.12
	C vs F	4	18.73	**0.001**	2.07
	A vs F	5	18.74	**0.002**	2.07
	A vs E	3	17.43	**0.001**	1.95
	B vs E	2	13.07	**0.001**	1.40

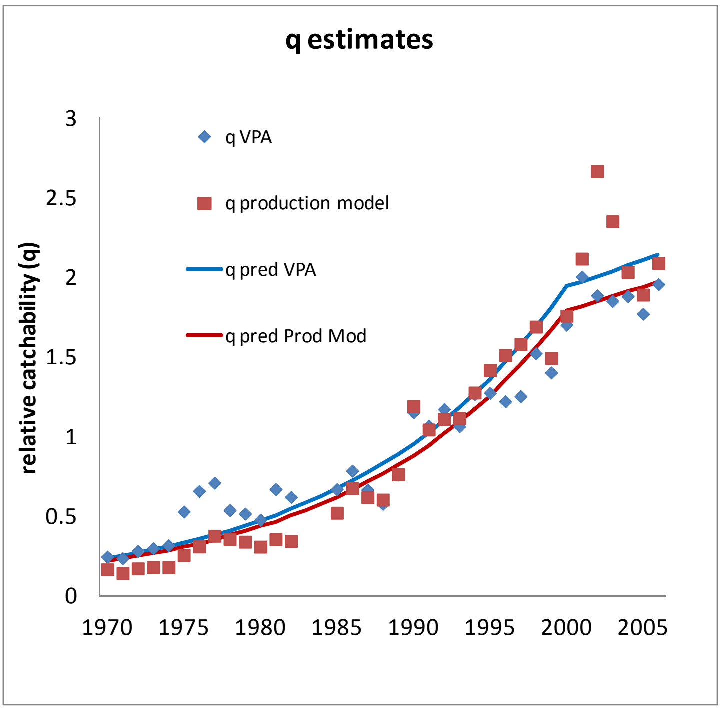


Figure Appendix 7.3. Estimates of annual relative catchability of purse seine from VPA (diamonds) and production models (squares). Fit corresponds to model B with a rate of annual increase of 7% for the period 1970-1999 and 1.5% from 2000 to 2006.

Discussion

Our estimates of annual increase in fishing power are similar to the 6% annual rates obtained by Reid *et al* (2005) for the purse seine fleet of the tropical eastern Pacific and much lower than the rates obtained by *Gascuel et al in 1993*. Both of these studies were conducted over a smaller range of years, and we do not discount that at certain periods the rate of increase may be greater than the average rate calculated herein. In addition, the study of Gascuel *et al* (1993) acknowledge that part of the gains in efficiency estimated in their study relate to the area fished, which tipically are not considered by other studies and are certainly not part of the non-spatially structured models used in the assessment of Atlantic yellowfin tuna. Finally, the study of Gascuel *et al* (1993) was conducted at a time where the data for 1980-1990 were recently obtained and it has been shown repeatedly in yellowfin assessment that the most recent estimates of biomass and fishing mortality from VPA suffer from retrospective trends, thus such estimates are less reliable than those obtained at a later time when more data have accumulated

Given that the purpose of this analysis was to determine period specific estimates of change in catchability, the Working Group decided to use the results from model B which explains 94% of the variance (**Figure Appendix 7.3**). This model suggests that the annual rate of increase in q was 7% from 1970 to 1999 and has been at about 1.5% from 2000-2006.

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Appendix 8

ASPIC PRODUCTION MODELS RUN WITH ONLY THE JAPANESE LONGLINE INDEX

The most influential abundance index for the production model fit is the Japanese longline index, both because of its length, and the relative high weight given to it in production models that use multiple indices. Four ASPIC models were run with updated catch estimates and updated Japanese longline index for the period 1965-2010. These four models differ in the type of production model function used (logistic or generalized) and in the initial biomass ratio in 1950/K (fixed to one or estimated)).

Point estimates for population parameters are very similar between runs that only differ on whether the B1/K is estimated or not (**Appendix Table 8.1**). Greater differences in benchmarks are caused by the choice of production function used.

Table Appendix 8.1. Effects of updating recent catches and Japanese abundance index. Model parameters (median estimates from bootstraps) estimated by ASPIC for runs 01 (logistic, B1/K =1), 02 (generalized, B1/K =1), 03 (logistic, B1/K =est.) and 04 (generalized, B1/K =est.). In parenthesis are shown the 10% and 90% percentiles.)

	Run 01		*Run 02*	
MSY (1000s t)	142	(131.6-149)	135	(110-136.7)
K (1000s t)	1051	(703.8-1,703)	1505	(1,401-3162.)
B_{MSY} (1000s t)	526	(351.9-851)	527	(448-807.9)
F_{MSY}	0.27	0.15-0.42)	0.26	(0.15-0.31)
B_{2006}/B_{MSY}	1.15		0.80	
F_{2006}/F_{MSY}	0.63		0.96	
B_{2010}/B_{MSY}	0.86	(0.7-1.02)	1.03	(0.92-1.21)
F_{2010}/F_{MSY}	0.92	(0.75-1.16)	0.80	(0.68-0.93)
Y equilibrium (1000s t)	140	(122.2-148)	112	(108-113.1)
Y F_{MSY} (1000s t)	140	(122.2-148)	112	(108-113.1)

	Run 03		*Run 04*	
MSY (1000s t)	142	(130.9-148)	135	(104-135.4)
K (1000s t)	1051	(717.8-1,790)	1511	(1,511-4414.)
B_{MSY} (1000s t)	526	(358.9-895)	529	(486-1356.)
F_{MSY}	0.27	(0.15-0.41)	0.26	(0.07-0.28)
B_{2006}/B_{MSY}	0.63		0.91	
F_{2006}/F_{MSY}	1.16		0.86	
B_{2010}/B_{MSY}	0.86	(0.69-1.)	1.02	(0.89-1.2)
F_{2010}/F_{msy}	0.92	(0.77-1.19)	0.81	(0.68-0.97)
Y equilibrium (1000s t)	140	(121.2-147)	135	(95-136.5)
Y F_{msy} (1000s t)	140	(121.2-147)	135	(95-136.5)

Appendix 9

Z BEVERTON-HOLT BASED ON LENGTH SIZE FREQUENCIES (GEDAMKE-HOENIG TRANSITIONAL METHOD FOR ACCOUNTING NON-EQUILIBRIUM CONDITION)

Beverton and Holt (1956) developed a functional relationship between the mean length in the catch and the total mortality rate (Z):

$$Z = K \frac{(L\infty - \bar{L})}{(\bar{L} - Lc)}$$

where $L\infty$ and K represent the conventional parameters of the von Bertalanffy's growth curve, Lc represents the length at which fishes are fully recruited, and $\bar{L}$ the average length for fish fully recruited.

However, this simple estimator requires some important assumptions, mainly that recruitments are constant over time and that mortality rates are constant as regards to age and also constant over time. Recently, Gedamke and Hoenig (2006) generalized the approach of Beverton and Holt to allow mortality rate to change in non-equilibrium situations.

From the simple expression of the mean length:

$$\bar{L} = \frac{\int_{tc}^{\infty} N_t L_t \, dt}{\int_{tc}^{\infty} N_t \, dt}$$

where *Nt* and *Lt* represent the abundance and body length of fish at age t, respectively, Gedamke and Hoenig (2006) stated that when a stock experiences a change in total mortality the mean length depicts a transitional phase before gradually approaching the new true value as the new equilibrium is reached. Thus, both in the numerator and in the denominator, the integrals should be broken down into a sum of two integrals respectively representing: (1) fish recruited after the change in mortality (these fish have experienced only the second mortality rate) and (2) fish recruited before the change (and consequently exposed to the old and to the new mortality rates). For example after a change in the total mortality from Z_1 to Z_2, the mean length in the population *d* years, after the change has occurred, is as follows:

$$\bar{L} = \frac{\int_{tc}^{tc+d} R\, e^{[-Z_2 (t - t_c)]} L_t\, dt + \int_{tc+d}^{\infty} R\, e^{[-Z_2 d]}\, e^{[-Z_1 (t - (t_c + d))]} L_t\, dt}{\int_{tc}^{tc+d} R\, e^{[-Z_2 (t - t_c)]}\, dt + \int_{tc+d}^{\infty} R\, e^{[-Z_2 d]}\, e^{[-Z_1 (t - (t_c + d))]}\, dt}$$

(for a general expression for the mean length after multiple changes in the mortality rate, see Appendix 2 in Gedamke and Hoenig, 2006).

Therefore, given a series of annual observations of mean length over time it is possible to estimate the original total mortality rate, the year in which it changed and the new mortality rate (possibly even the next breaking date and resulting change in mortality rate, etc.).

To assess whether there have been multiple changes in the mortality rates of yellowfin, different competing models (i.e., with different breaking dates and resulting number of parameters) were ranked according to the Akaike information criterion. The top-ranking model (i.e., smallest AIC) from this set was reported as the most parsimonious model, which is the model that best explains the variation in the data while using the fewest parameters.

Results

N. breaks	*N. par.*	*AIC*	*Breaking dates*
2	6	523.36	1979, 1996
3	8	533.11	1979-1980, 1996, 2005
1	4	536.01	1994
4	10	621.64	1979, 1984, 1995-1996, 2005

Model selection for determining mortality rates from mean length data in non-equilibrium situations for Atlantic yellowfin (1970-2010), with (N. breaks) number of change points in total mortality, (N. par.) number of parameters, (AIC) Akaike Information Criterion and breaking dates

Parameter	*Estimate*	*SE*	*t*
Z1	1.081	0.063	17.14
Z2	1.519	0.057	26.67
Z3	2.429	0.123	19.76
Y1	1978.623	0.655	14.69
Y2	1996.052	0.590	45.85
SD	310.044	34.267	9.05

Summary statistics for the best model estimating mortality from mean length data in non-equilibrium situations for Atlantic yellowfin (1970-2010) when three different levels of mortality and two years of change are estimated simultaneously.

Reference

Gedamke, T. and Hoenig, J. M. 2006, Estimating mortality from mean length data in non-equilibrium situations, with application to the assessment of goosefish. Trans. Am fish. Soc. 135: 476-487.