PRELIMINARY STOCK SYNTHESIS MODEL USING UPDATED DATA FOR NORTH ATLANTIC ALBACORE

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SUMMARY

The North Atlantic albacore Management Strategy Evaluation (MSE) provided the scientific support for the adoption of an interim harvest control rule by ICCAT in 2017. In 2020, a new MSE process started for this stock and one of its first task has been to develop a new assessment model that could serve as a benchmark to monitor the status of the stock and as the basis to develop a set of Operating Models. In this document, we show a preliminary configuration of Stock Synthesis based on the model developed using Multifan-CL in 2013. The current version is far from being fully developed and many aspects of the model development will need to be agreed with the albacore working group.

RÉSUMÉ

L'évaluation de la stratégie de gestion (MSE) du germon de l'Atlantique Nord a fourni le soutien scientifique nécessaire à l'adoption d'une règle de contrôle de l'exploitation provisoire (HCR) par l'ICCAT en 2017. En 2020, un nouveau processus MSE a débuté pour ce stock et l'une de ses premières tâches a été de développer un nouveau modèle d'évaluation qui pourrait servir de référence pour suivre l'état du stock et de base pour développer un ensemble de modèles opérationnels. Dans ce document, nous montrons une configuration préliminaire de Stock Synthesis basée sur le modèle développé au moyen de Multifan-CL en 2013. La version actuelle est loin d'être entièrement mise au point et de nombreux aspects du développement du modèle devront être convenus avec le Groupe d'espèces sur le germon.

RESUMEN

La evaluación de estrategias de ordenación (MSE) del atún blanco del Atlántico norte proporcionó el apoyo científico para la adopción de una norma provisional de control de las capturas por parte de ICCAT en 2017. En 2020, se inició un nuevo proceso de MSE para este stock y una de sus primeras tareas ha sido desarrollar un nuevo modelo de evaluación que pueda servir de referencia para supervisar el estado del stock y como base para desarrollar un conjunto de modelos operativos. En este documento, mostramos una configuración preliminar del modelo Stock Synthesis basada en el modelo desarrollado con Multifan-CL en 2013. La versión actual está lejos de estar completamente desarrollada y muchos aspectos del desarrollo del modelo tendrán que ser acordados con el Grupo de especies de atún blanco.

KEYWORDS

North Atlantic albacore, Management Strategy Evaluation, Harvest Control Rules, Operating Models, Management Procedures, Stock Synthesis

1. Introduction

This document presents a preliminary configuration for a stock assessment of North Atlantic albacore (*Thunnus alalunga*) including fishery data available in 2022. The assessment consists in an age-structured population model using Stock Synthesis (Methot Jr and Wetzel 2013). In 2013, another age-structure model was configured as a benchmark assessment for this stock, Multifan-CL (Kleiber, Hampton *et al.* 2012; Merino, De Bruyn et al. 2013). The Stock Synthesis model under development replicates the runs conducted in 2013 with a structure and assumptions comparable to the Multifan-CL base run with adaptations discussed in the albacore Working Group in 2020 and 2021.

In 2020, the albacore Group recommended that a new benchmark is developed using Stock Synthesis, and this configuration will also be used to build a new set of Operating Models (OM) for the North Atlantic albacore MSE (ICCAT 2020).

In 2021, the ICCAT Secretariat provided an overview of Catch, Effort, and Tagging data (ICCAT 2021). Summaries of the data available were provided in Catch at Size, CATDIS, Task 1 and Task 2 catch and effort, and size data. Also, the document SCRS/2021/090 presented a preliminary analysis of the data for North Atlantic albacore input for the Stock Synthesis model. The data reviewed includes catch, size frequency, catch-per-unit of effort and, tagging data. These data have been use to generate files for Stock Synthesis.

The present configuration is a first step towards a new Stock Synthesis model for North Atlantic albacore.

2. Update Stock Synthesis model

2.1 North Atlantic albacore

Albacore (*thunnus alalunga*) is a cosmopolitan highly migratory tuna species that inhabits tropical and temperate waters of all oceans including the Mediterranean. The management units of albacore in the Atlantic consist in three stocks (North Atlantic, South Atlantic and Mediterranean). North Atlantic albacore is distributed North of lat 05º and includes western and eastern areas of the North Atlantic.

Since the beginning of its exploitation, North Atlantic albacore has been harvested by a variety of gear types, from small-scale artisanal baitboat fisheries to large distant-water longline fleets. In the early years, North Atlantic albacore catch was concentrated in the Northeast part and in the most recent decades, despite a large proportion of catch being still concentrated in the Northeast, different fisheries have harvested albacore in all areas of the North Atlantic. North Atlantic albacore production reached a maximum between 1960 and 1970 and it decreased until 2010 where catch shows an increasing trend.

2.2 Model inputs

The data used for this first configuration of Stock Synthesis consists of catch and length composition data for the fisheries defined in the analysis and catch per unit of effort (CPUE) indices (**Figure 1**).

The details of the configuration of the fishery specific data, including the definition of fisheries is explained below:

2.2.1 Spatial stratification

The present configuration assumes a single area of distribution for North Atlantic albacore including Atlantic waters north of Lat 5ºN.

2.2.2 Temporal Stratification

The time period covered by the model is 1930-2021 representing the period for which catch data are available. Within the model period, the data is represented in years with four quarters or seasons.

2.2.3 Definition of fisheries

The current version of Stock Synthesis adopted equivalent fishery definitions used in the 2013 Multifan-CL model with modifications discussed in the albacore working group in 2020 and 2021. These fisheries represent relatively homogeneous fishing units with similar selectivity and catchability characteristics that do not vary over time. Fourteen fisheries have been defined based on location, time period, fishing gear and country (**Table 1**). The most important change relative to the 2013 model consists of the disaggregation of Chinese Taipei, Japanese and US longline fleets in North and South components, each one with its own selectivity.

2.2.4 Catch history

Catch data has been compiled based on the fisheries definitions (**Figure 2**). Nominal catch information from *t1nc-ALB_20201218.xls* is aggregated by species, stock, year, contracting party (CP), flag, fleet, area, gear and type. The main fleets and gears that represent 96% of the current catch (2010-2020) are shown in **Figure 3**. The model is configured assuming that catch information is accurate (CV=0.01) and that catches are negligible or zero before 1930.

2.2.5 CPUE indices

The assessments of 2013, 2016 and 2020 of North Atlantic albacore were built using CPUE data from the US, Japan, Chinese Taipei and Venezuelan longlines and Spanish baitboat. In this first configuration we have used the US longline index only, assuming that the index is based on numbers and the cv-s with an error type of lognormal distribution. Tests including Venezuelan longline and Spanish baitboat CPUE appear unstable, with Stock Synthesis being unable to estimate the Hessian. However, these problems will be analysed with the objective of considering all the available and reliable CPUEs in the assessment. The Japanese and Chinese Taipei CPUEs (SCRS/2021/111 and SCRS/2021/114) are not currently split in North and South components and therefore, they have not been included in this first configuration. When they are available, they will be included in the stock assessment model.

2.2.6 Length frequency data

Available length-frequency data for each of the defined fisheries are compiled into 2-cm size classes. A graphical representation of the length compositions of North Atlantic albacore tuna samples aggregated across time is shown in **Figure 4**. Due to the no availability of the number of independent samples, we introduce the number of samples as the logarithm of the total number fish measured by year-quarter and fleet. Length composition data series across fleets are shown in **Figure 5**. The mean length for each of the 14 fleets with 95% confidence intervals based on current sizes are shown in **Figure 6**. However, some of the length composition were not removed in this initial configuration due to the weird distribution observed in the fleet in comparison to other years: in BB the length composition from 1976-1977-1978, BB_isl 2001 and 2009, JpLL_N 1974, JpLL_S 1968 and 1998, and TAILL_S 1990 and 1994.

2.3 Model configuration and assumptions

2.3.1 Biology

The model assumes a spatially aggregated population (one single area) with the population comprised of 15 age classes. Biological parameters are based on the values agreed by the albacore working group (ICCAT 2016):

- Growth parameters are fixed assuming that spawning occurs at month 1, then fish will have one biological year at SS-age 1.5 with a size of 47.23 cm. The parameters of the growth equation are (Santiago and Arrizabalaga 2005) and the growth curve is represented in **Figure 7**:
  K=0.209 year^{-1}, Linf=122.198 cm, t0=-1.338 years.
- Length weight relationship parameters are a=1.339x10^{-5} and b=3.1066, taken from (Santiago 1993) (see **Figure 8**).
- Maturity: Albacore is assumed to reach 50% maturity at age 5 (90 cm) (Bard 1981) (**Figure 9**).
- Natural mortality was assumed 0.3 for all ages, as in the 2013 Multifan-CL reference case (ICCAT 2013; Merino, De Bruyn *et al*. 2013).
- Stock recruitment relationship is a Beverton-Holt model with steepness estimated with prior of 0.75 with normal distribution sd=0.15, equivalent to the relationship assumed in the 2013 Multifan-CL reference case (Merino, De Bruyn *et al.* 2013). SigmaR was fixed at 0.6 to allow for recruitment deviates.

- Advanced bias option for recruitment: Recruitment deviates are estimated from 1972 to 2017. The only CPUE available is the USLL and considering their estimated selectivity is assumed that the index give information of albacore age 3 and therefore index data of 2020 could provide information of the recruits in 2017.

2.3.2 Selectivity assumptions

The selectivity of the fleets that catch the smaller fish has been estimated using 3 knot splines. The longline fleets fishing in the southern area of the North Atlantic have been assumed logistic because they catch larger fish and the longliners fishing in the north have initially been parameterized assuming a double normal distribution. However, the length composition data of Chinese Taipei and US longline fleets operating in the northern area did not fit well under this assumption and therefore they have also been assumed logistic.

For the Japanese and Chinese Taipei longline data, in 2013, three periods were considered (early, transition and late). For this version, we assume two time blocks (early and aggregated transition-late periods).

In summary, splines were used to estimate selectivity for fleets 1, 2, 3, 4 and 14 while logistic selectivities are assumed for the longline fleets of Japan (South), Chinese Taipei, Venezuela, Other longlines and the mixed Korea, Panama and China (fleets number 5, 6, 7, 8, 9, 11, 12 and 13), (see fleets numbering in **Table 1**). For the northern component of Japanese longline, a double normal selectivity is assumed.

2.4 Preliminary model results

In this section we explore the model assumptions and parameter configuration to examine areas of the model that may need further development. The model run we show here is exploratory represents a continuity with the parameterization of the 2013 Multifan-CL model with less CPUE indices and a few different assumptions. The results shown here aim at facilitating discussions of model performance to continue its development. The current version is not intended for management advice.

2.4.1 Model fits

The model fits to the US longline indices (South and North) are shown in **Figures 10 and 11**.

The North component of the US longline index shows a marked increase in 2020 and 2021, exceeding twofold the largest values of the time series. The South component shows a moderate increasing trend since 2010 until 2019 and a small decline since.

The standardized residuals from the fits to the US longline indices are shown in **Figures 12 and 13**. These figures show the for the North, the expected value is within the season 2 and season 4 index for the North and seasons 1 and 3 for the South.

The fit to the length composition data is shown in **Figures 14 and 15**. **Figure 14** shows the aggregated length composition data and the estimated length composition. The largest differences are seen in baitboat (1_BB) and the northern component of the US longline composition data (9_USLL_N). **Figure 15** shows the residuals across time for each of the fleets. Note the large residuals for Japan LL North, US LL North, Chinese Taipei LL south, Other LL and Other Surface gears.

2.4.2 Model estimates

The estimated parameters in this preliminary model include: the overall population scale parameter (R0), the time series of recruitment deviates, the fishery selectivity parameters and the catchability parameters for the CPUE indices. Here, we focus on selectivity and recruitment deviates for exploratory purposes.

The age selectivity vectors for each fleet by size and by age are shown in **Figures 16 and 17**. The midwater trawl (4 MWT) and the trawl-gillnet fishery (3 TR_GN) show similar selectivities, reaching the full selection by age 3. Baitboat (1_BB) increases selectivity until age 3 too but decreases later and increases to full selection by age 7. Longline fleets other than 9 USLL reach full selection by size 100 cm approximately (age 10).

The model estimates a steepness of 0.79, however, first trials shows that this variable seems very variable depending on the settings of the model, for example if the USLL_N is downweighted then the model estimates steepness of 0.85 or USLL_S downweighted then 0.99.

The estimated recruitment deviates are shown in **Figure 18** and show a large increase in 2018. The bias adjustment (**Figure 19**) shows that the current bias settings (red) are very similar to the bias adjustment suggested by the model (blue), it was not possible to improve because the model with the suggested parameters in this run did not have hessian.

2.4.3 Reweighting of the length composition data

The Dirichlet method (Thorson and Johnson 2017) was used to estimate the reweighting of the length composition data however, only the parameter for the fleet OthLL was kept in the model because the value of the other fleets wer close to 5 and hitting the highest boundary. So the estimated ln(theta) for othLL fleet estimates was 3.85.

2.4.4 Replicate of spawning biomass and fishing mortality trends between the current SS3 model configuration and the MFCL base case model of 2013.

The model fits to SS3 are still very preliminary but in the next figures (**Figures 10-13**) we compare the general trends in spawning stock biomass obtained with SS3 and the data available in March 2022 and the Multifan-CL model runs, directly taken from the 2013 stock assessment report (ICCAT 2013). We also compare the catch at equilibrium curves of the preliminary SS3 and the 2013 MFCL base case model.

The trends in SSB and F follow comparable patterns with a unidirectional decreasing trends from larger SSB/SSBmsy values in the SS3 model. This is probably related to the shape of the production function, which is almost logistic in the MFCL run and very much skewed in the SS3 configuration.

The main difference between the 2013 stock assessment and the preliminary runs shown here is in the increase in the estimated maximum catch at equilibrium. The updated model (although very preliminary) suggest a notably larger productivity (MSY) (43970.7 tons) than the 2013 base case model (31,680 tons).

3. Discussion

This document describes the first steps for the configuration of a new Stock Synthesis model for North Atlantic albacore. The aim of this work is to start discussions on the different modelling choices that need to be agreed by the albacore working group. The present model configuration contains many of the features of the Multifan-CL model developed for this stock in 2013 with some small modifications.

The next steps will be to agree on specific components of the model.

3.1 Biology

- The current configuration uses a constant natural mortality vector. This assumption may not be aligned with the SS developments for tuna stocks in ICCAT and other RFMOs, where a age-specific vector with a decreasing natural mortality is being considered (Then, Hoenig *et al.* 2014).
- Also, further discussions are needed about the assumption of the steepness parameter. In particular, should the model estimate steepness from a prior or should steepness be fixed at different values as it is done in the recent tuna assessments in ICCAT?
- Standard deviation of Recruitment (SigmaR) is assumed with a value of 0.6 without further analysis and the group should discuss this value.
- The range of years where recruitment deviates are estimated should be discussed by the group.
- The bias correction to estimate the recruitment deviates was not possible to improve due to the convergency issues. The model considering both CPUEs (USLL_N, USLL_S) seems to have more issues to converge and this also have an impact on the fits of their length composition data.

3.2 Selectivity

The selectivity patterns assumed by fleetneed to be discussed too. Some of the length composition data seems very noisy and the convergency of the model could be improved by estimating their selectivity aggregating or by being a mirror of others.

Some of the length composition data seems to be very weird and in this preliminary run were removed, however, this matter should be discussed with the group.

3.3 CPUE

The seasonality of the USLL_N and USLL_S is quite strong, the model can not estimate so big jumps with only one recruitment per year, so how to treat this seasonality effects should be discuss with the experts. The model shows some convergency issues when both CPUE are estimated. In this run however, the model got a hessian however, the lack of fit of the southern LL CPUE are improved when USLL_S is downweighted. The model shows to be more robust if one of those 2 CPUEs is ignored. So the inclusion of additional CPUEs could improve the model too. For this, a new configuration for the Japanese and Chinese Taipei longline fleets may be necessary to account for the latitudinal component, as done for the US LL index. Furthermore, the temporal stratification may need additional discussions. In the current configuration recruitment occurs in the first season of the year and the impact of the spawning biomass may need further investigations.

Acknowledgements

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Table 1. Definition of fisheries for North Atlantic albacore Stock Synthesis model configuration.

FL	Fishery ID	Description	Time	Gear	Catch (FlagName* or FleetCode*)	Size (FleetCode*)
1	1 BB	Baitboat (Spain, France)	All years	BB	EU.ESP-ES-CANT ALB, EU.FRA-FR	EU.ESP-ES-CANT ALB, EU.FRA-FR
2	2 BB isl	Baitboat islands (Portugal Madeira/ Azores, Spain Canary)	All years	BB	EU.PRT-PT-AZORES, EU.PRT-PT-MADEIRA, EU.ESP-ES-CANARY, EU.ESP-ES-CANT_ALBaz, EU.ESP-ES-CANT_ALBcd	EU.PRT-PT-AZORES, EU.PRT-PT-MADEIRA, EU.ESP-ES-CANARY, EU.ESP-ES-CANT_ALBaz, EU.ESP-ES-CANT_ALBcd
3	3 TR+GN	Troll (Spain, France) + Gillnet (France, Ireland)	>1930	TR	TR: EU.ESP-ES-CANT ALB, EU.FRA-FR, EU.IRL, GN: EU.FRA-FR, EU.IRL, GBR	TR: EU.ESP-ES-CANT ALB, EU.FRA-FR, EU.FRA, GN: EU.FRA-FR, EU.IRL
4	4 MWT	Mid water trawl (France, Ireland)	All years	TW	EU.FRA-FR, EU.IRL, GBR	EU.FRA-FR, EU.FRA, EU.IRL
5	5 JP LL T N	Japan LL target north30	<=1969	LL	Japan (North of 30N)	JPN, JPN.OB.CAN, JPN.OB.USA (North of 30N)
5	5 JP LL t N	Japan LL transition north30	1970-1975			
5	5 JP LL b N	Japan LL late north30	>=1976			
6	6 JP LL T S	Japan LL target south30	<=1969	LL	Japan (South of 30N)	JPN, JPN.OB.CAN, JPN.OB.USA (South of 30N)
6	6 JP LL t S	Japan LL transition south30	1970-1975			
6	6 JP LL b S	Japan LL late south30	>=1976			
7	7 TW LL e N	Taiwan LL early north30	<=1986	LL	Chinese Taipei (North of 30N)	CTP (North of 30N)
7	7 TW LL t N	Taiwan LL transition north30	1987-1998			
7	7 TW LL l N	Taiwan LL late north30	>=1999			
8	8 TW LL e S	Taiwan LL early south30	<=1986	LL	Chinese Taipei (South of 30N)	CTP (South of 30N)
8	8 TW LL t S	Taiwan LL transition south30	1987-1998			
8	8 TW LL l S	Taiwan LL late south30	>=1999			
9	9 US CAN LL N	US and Canada LL north30	All years	LL	USA and Canada (North of 30N)	USA-US-Com, USA, Canada (North of 30N)
10	10 US LL S	US LL south30	All years	LL	USA (South of 30N)	USA-US-Com, USA (South of 30N)
11	11 Ven LL	Venezuela LL	>=1960	LL	Venezuela	VEN
12	12 MIX KR+PA	Korea, Panama, China LL	All years	LL	Mixed flags (KR+PA), China PR, Korea Rep., Panama	MIX.KR+PA, CHN, KOR, PAN
13	13 Oth LL	Other LL	>=1964	LL	all others	all others
14	14 Oth Surf	Other surface	All years		all others	all others

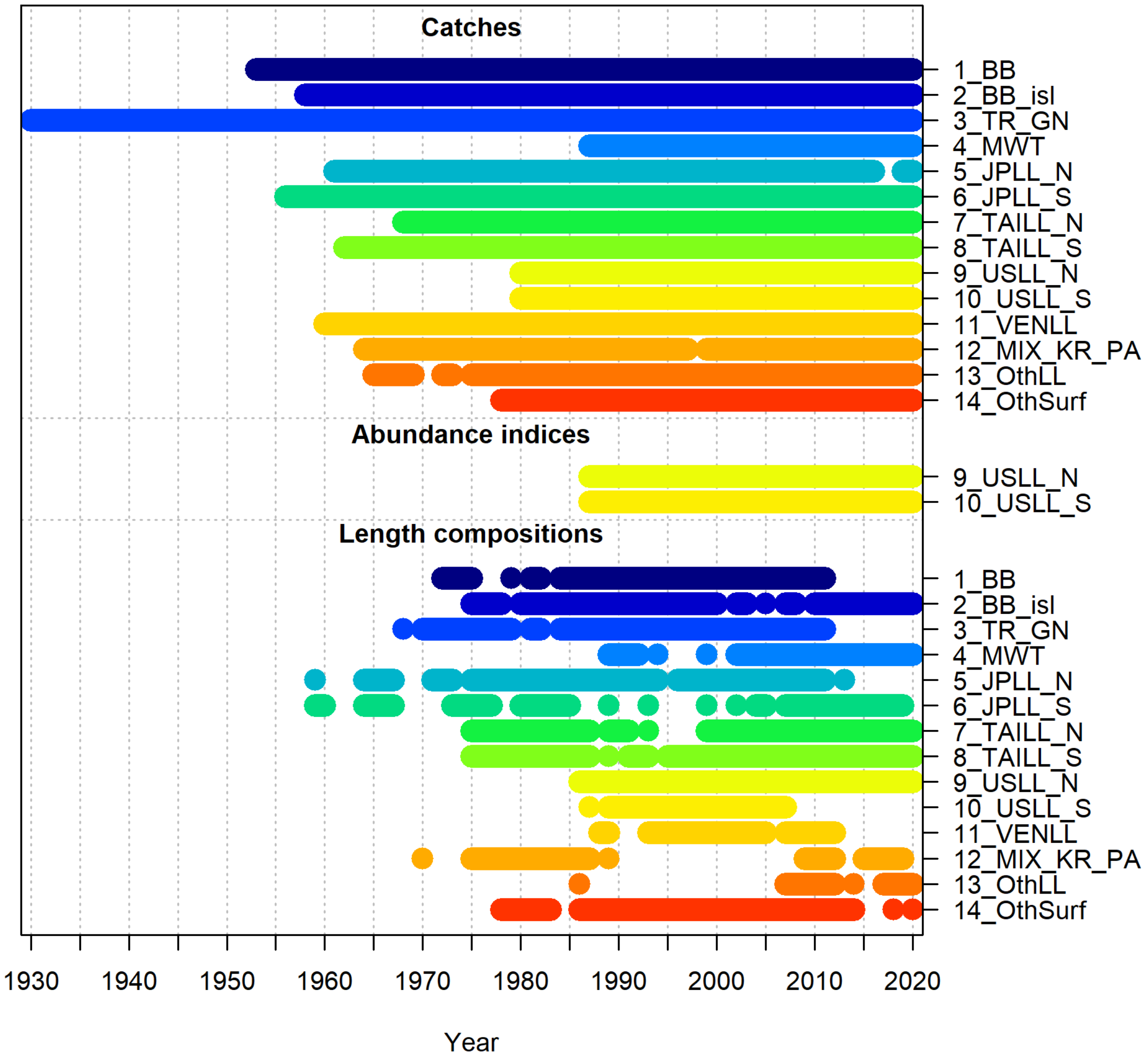

Figure 1. Catch, abundance indices and length composition data used in this preliminary configuration of Stock Synthesis.

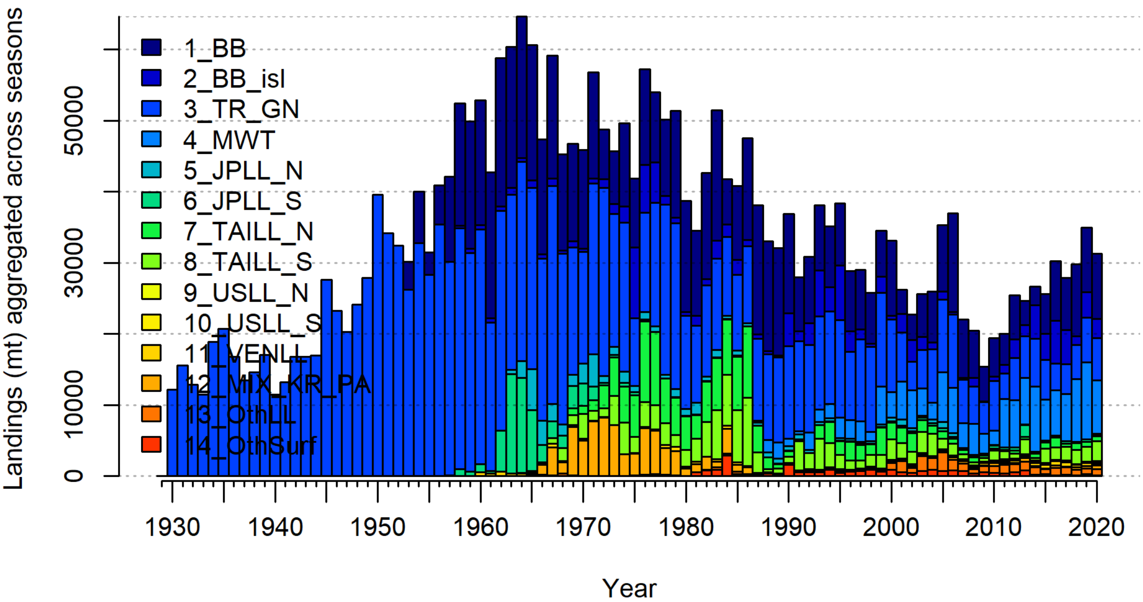

Figure 2. Total annual catch of North Atlantic albacore by main gear types from 1930 to 2021.

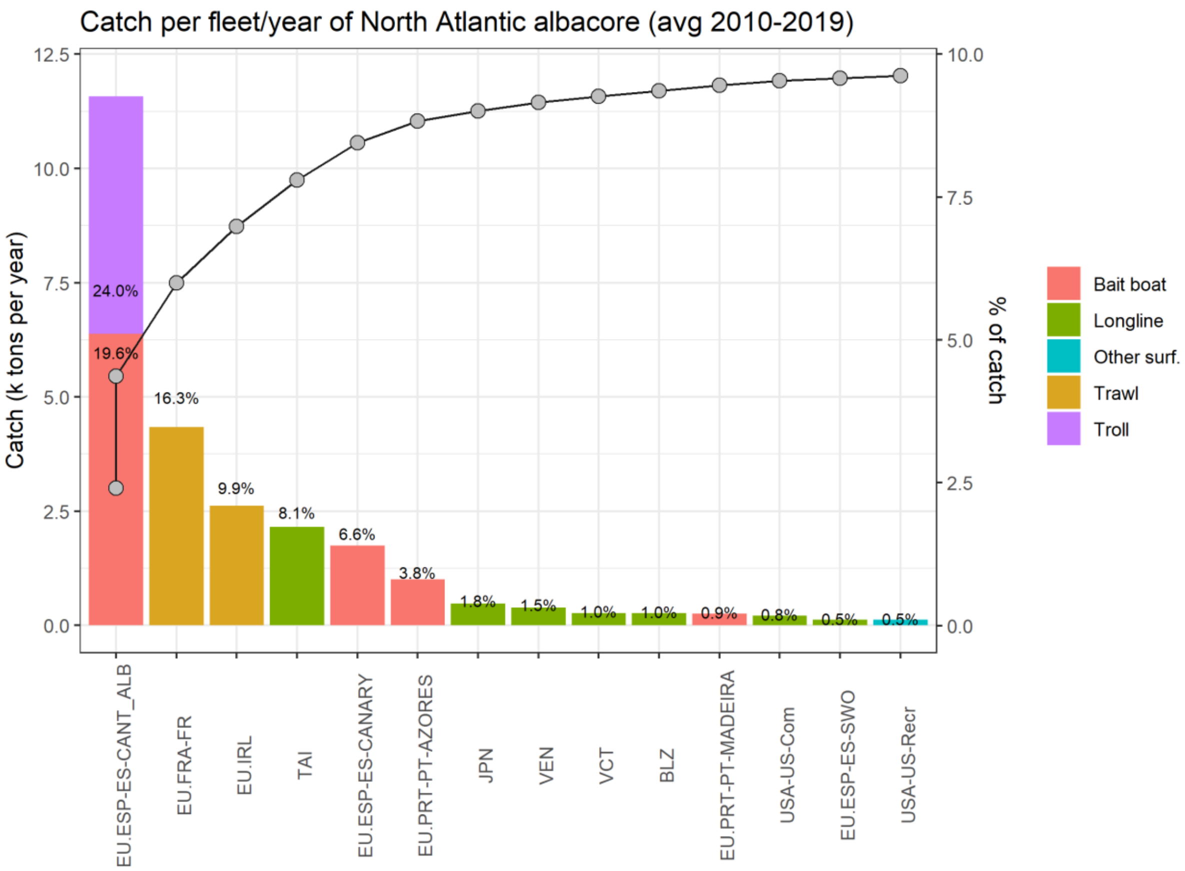

Figure 3. Main fleets and gears that represent 96% of the total catch from the 2010-2019 period, according to catch (Task 1).

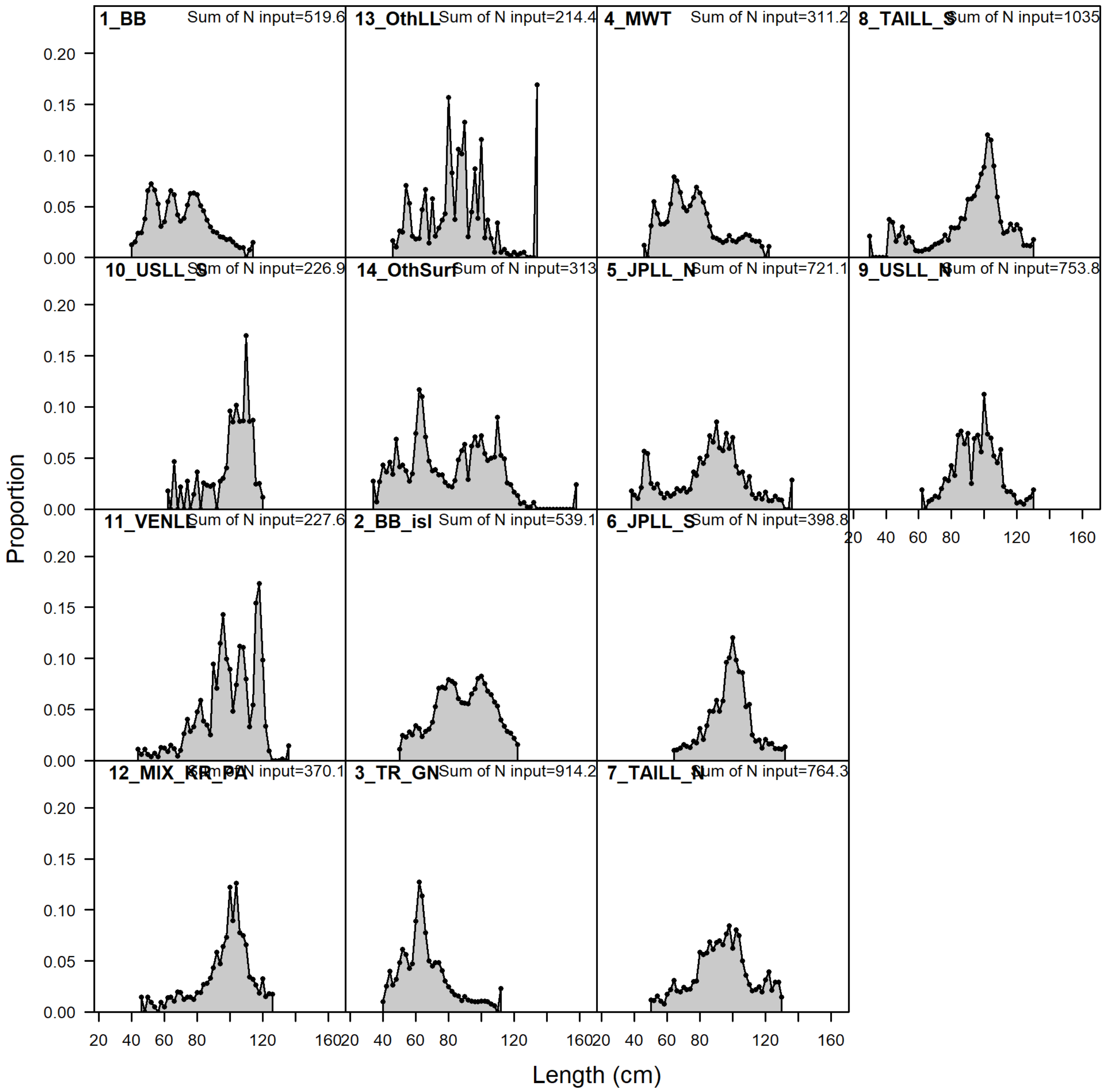

Figure 4. Length composition data aggregated across time by fleet.

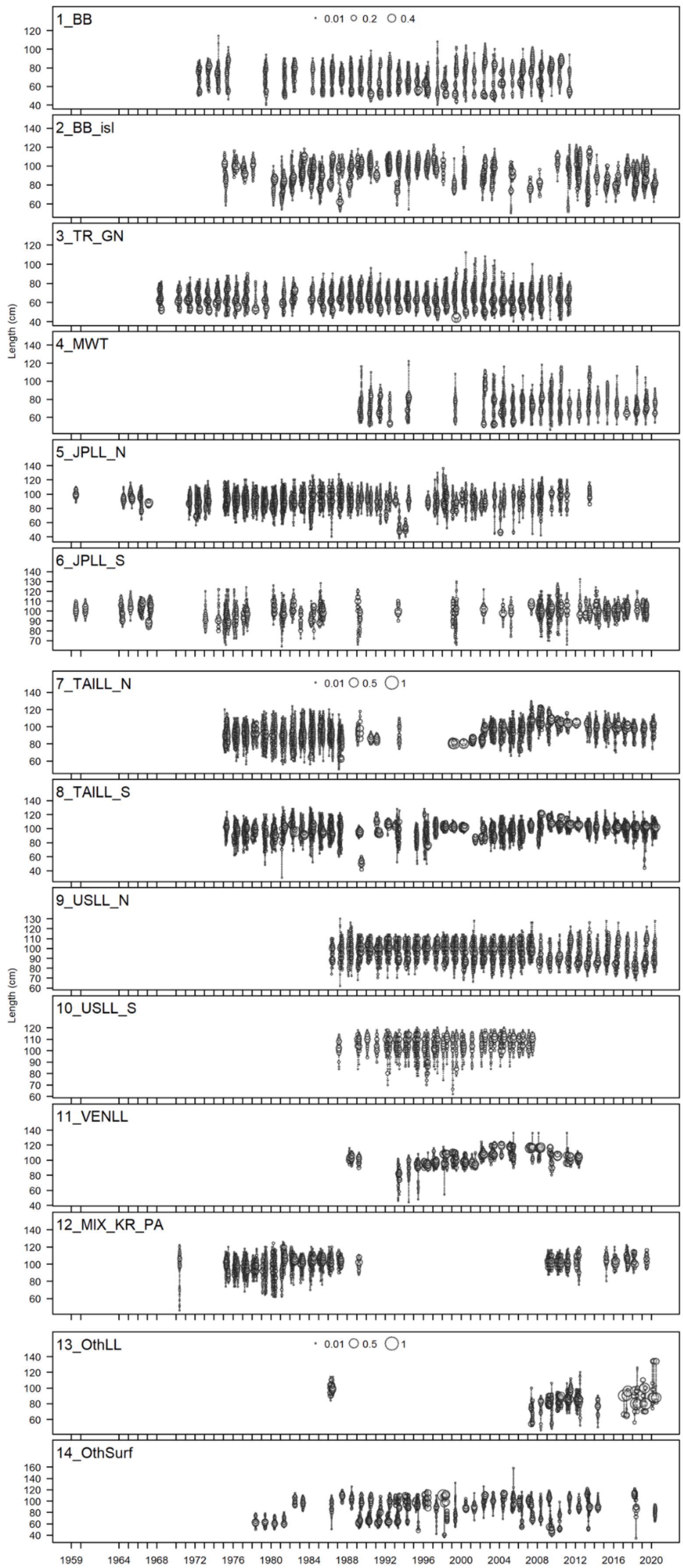

Figure 5. Length composition data series comparing across fleets.

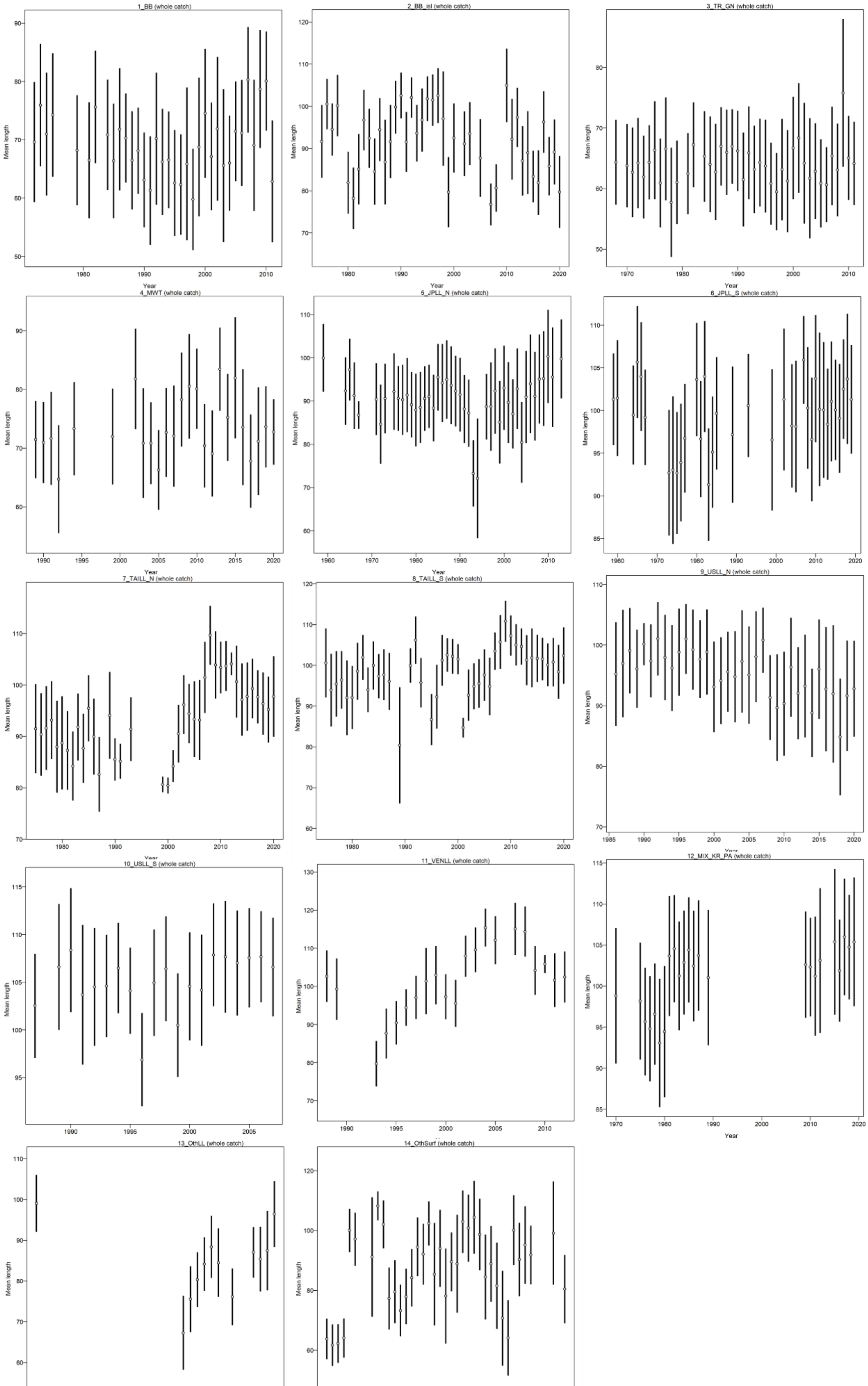

Figure 6. Mean length for the fleets considered in this Stock Synthesis configuration with 95% confidence intervals based on current sample sizes.

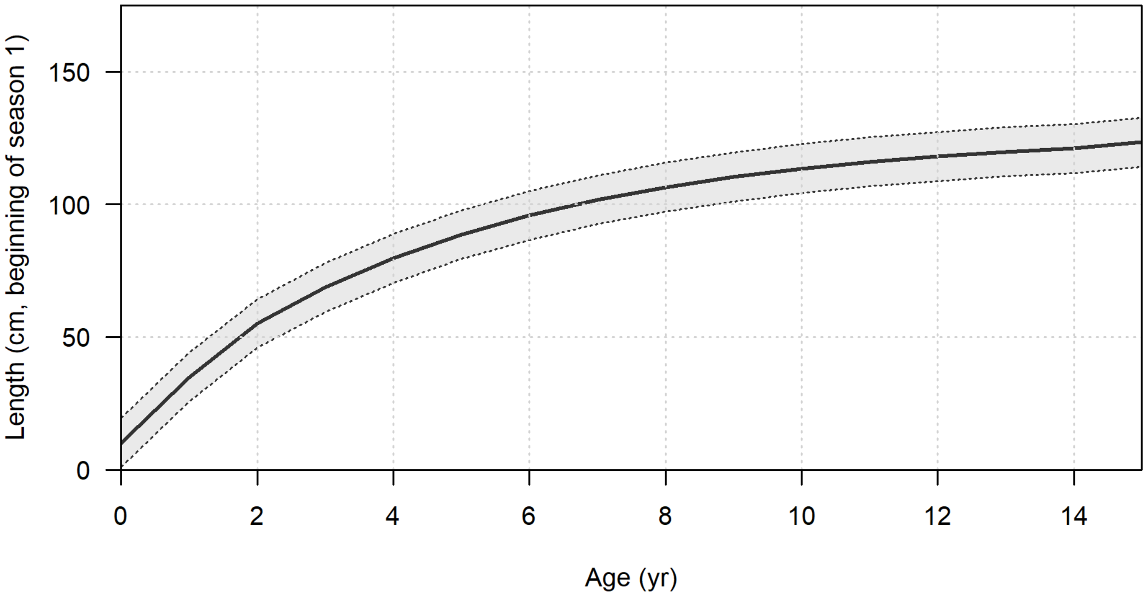

Figure 7. Length at age in the beginning of the year. Shared area indicates 95% distribution of length at age around estimated growth curve.

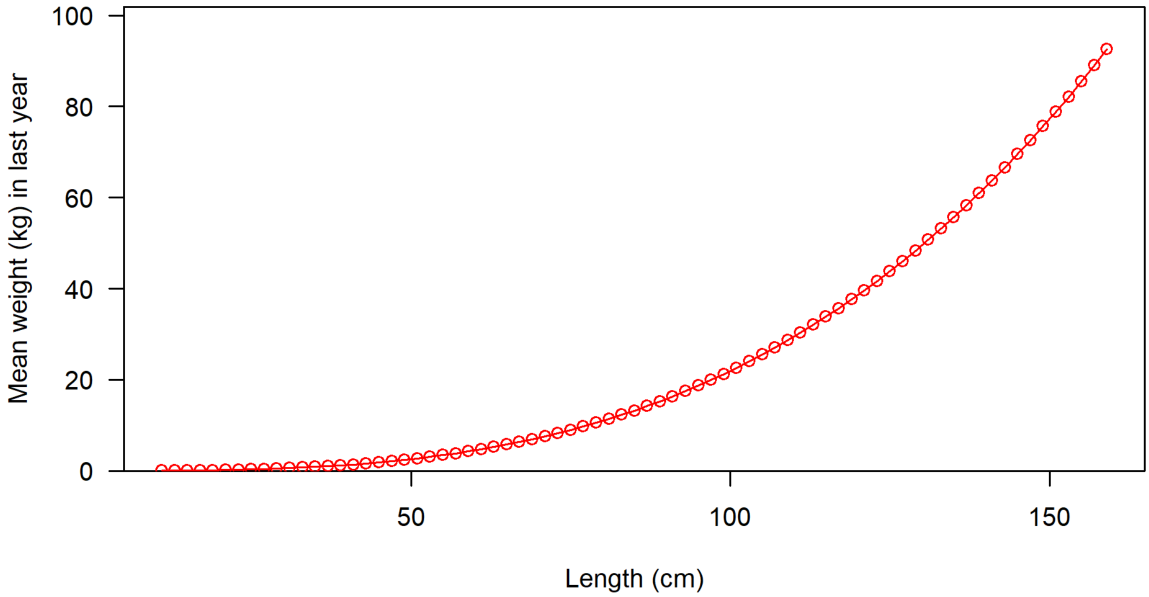

Figure 8. Weight-length relationship.

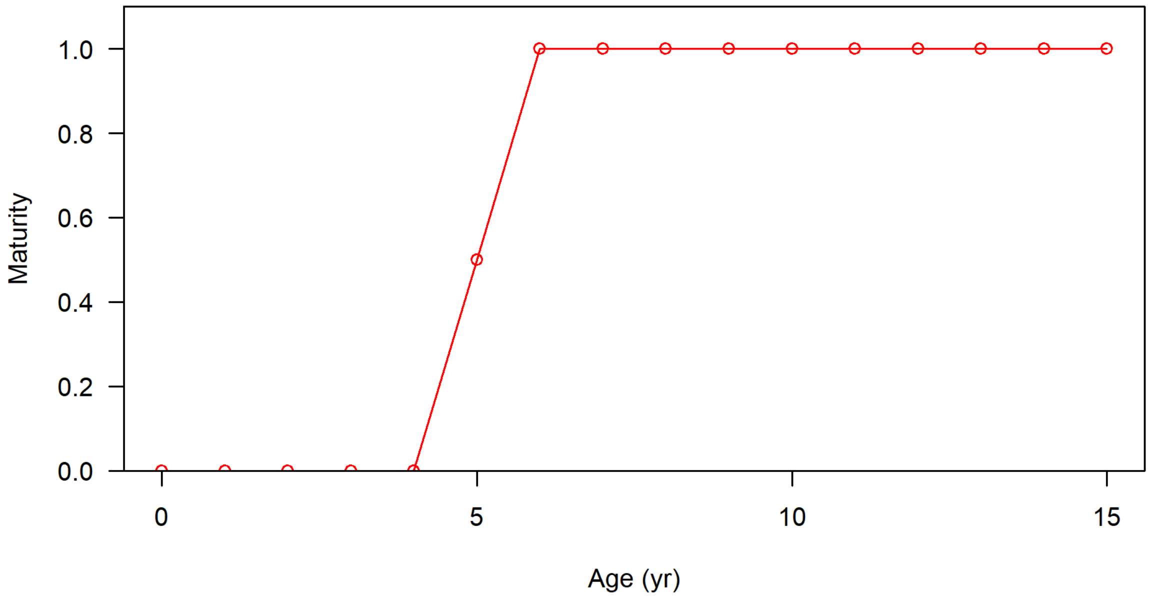

Figure 9. Maturity at age for North Atlantic albacore.

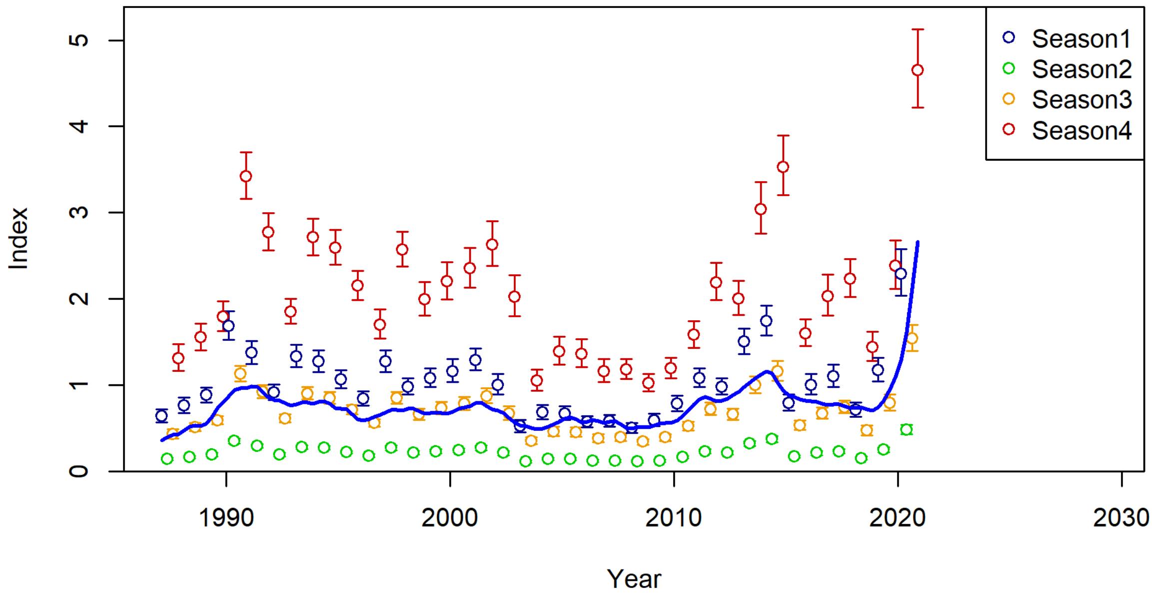

Figure 10. Fit to the index data for 9_USLL_North.

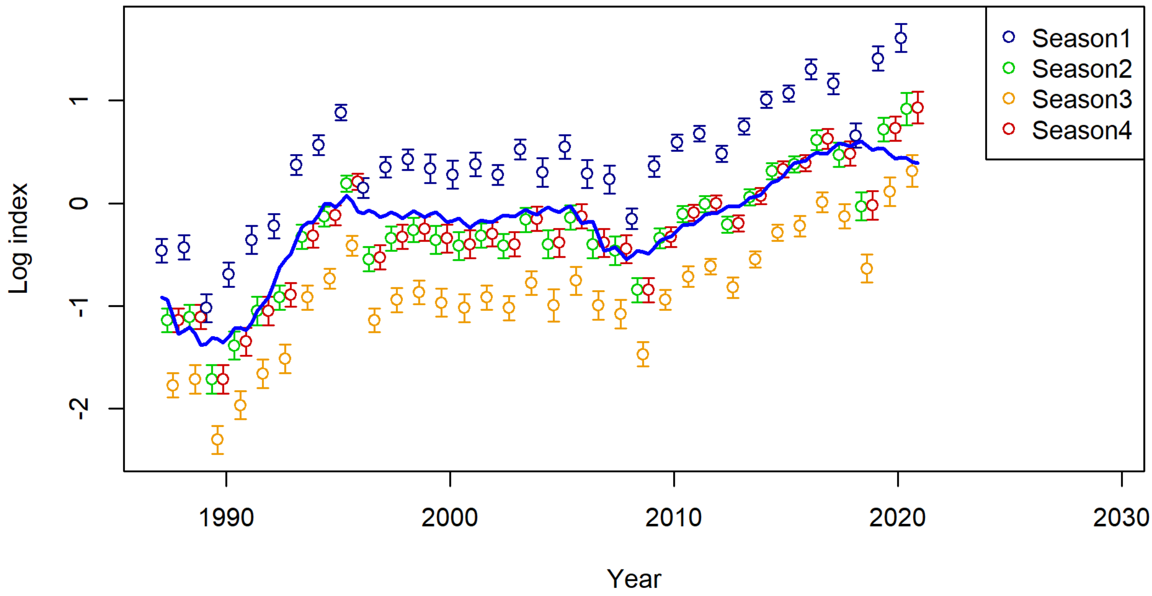

Figure 11. Fit to the index data for 10_USLL_South.

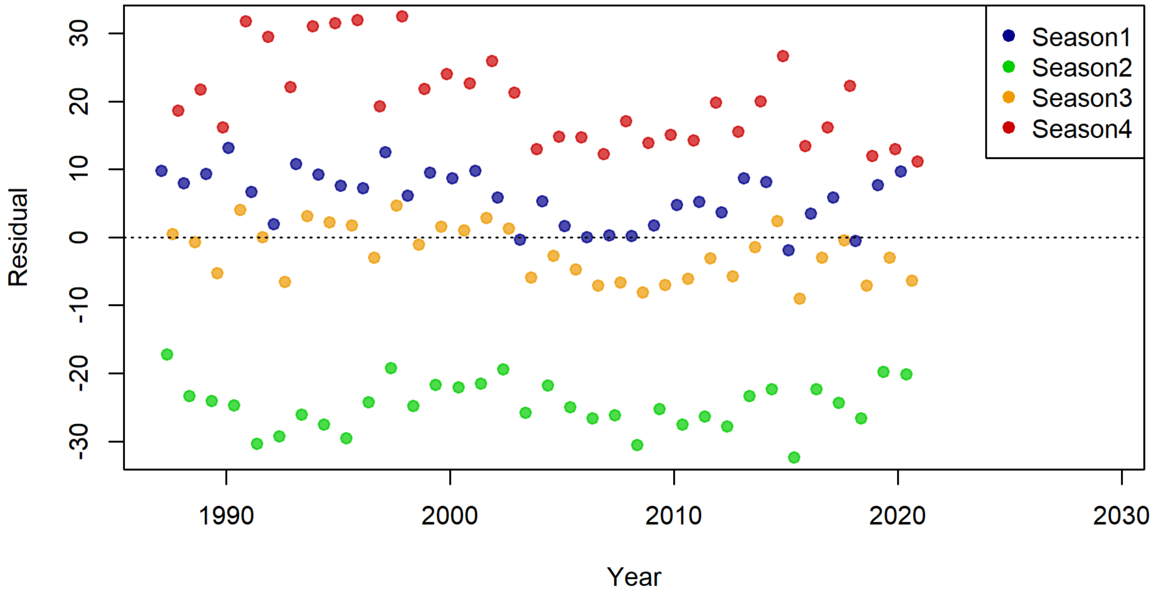

Figure 12. Residuals of fit to index 9_US_LL_North. Values are (log(Obs)-log(Exp))/SE where SE is the total standard error including any estimated additional uncertainty.

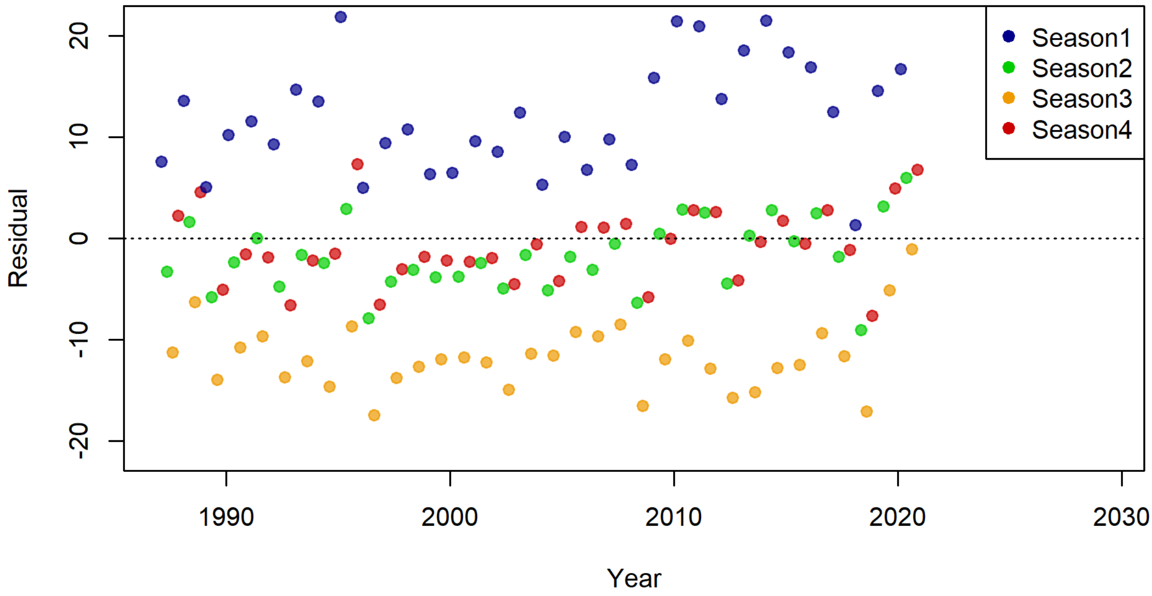

Figure 13. Residuals of fit to index 10_US_LL_South. Values are (log(Obs)-log(Exp))/SE where SE is the total standard error including any estimated additional uncertainty.

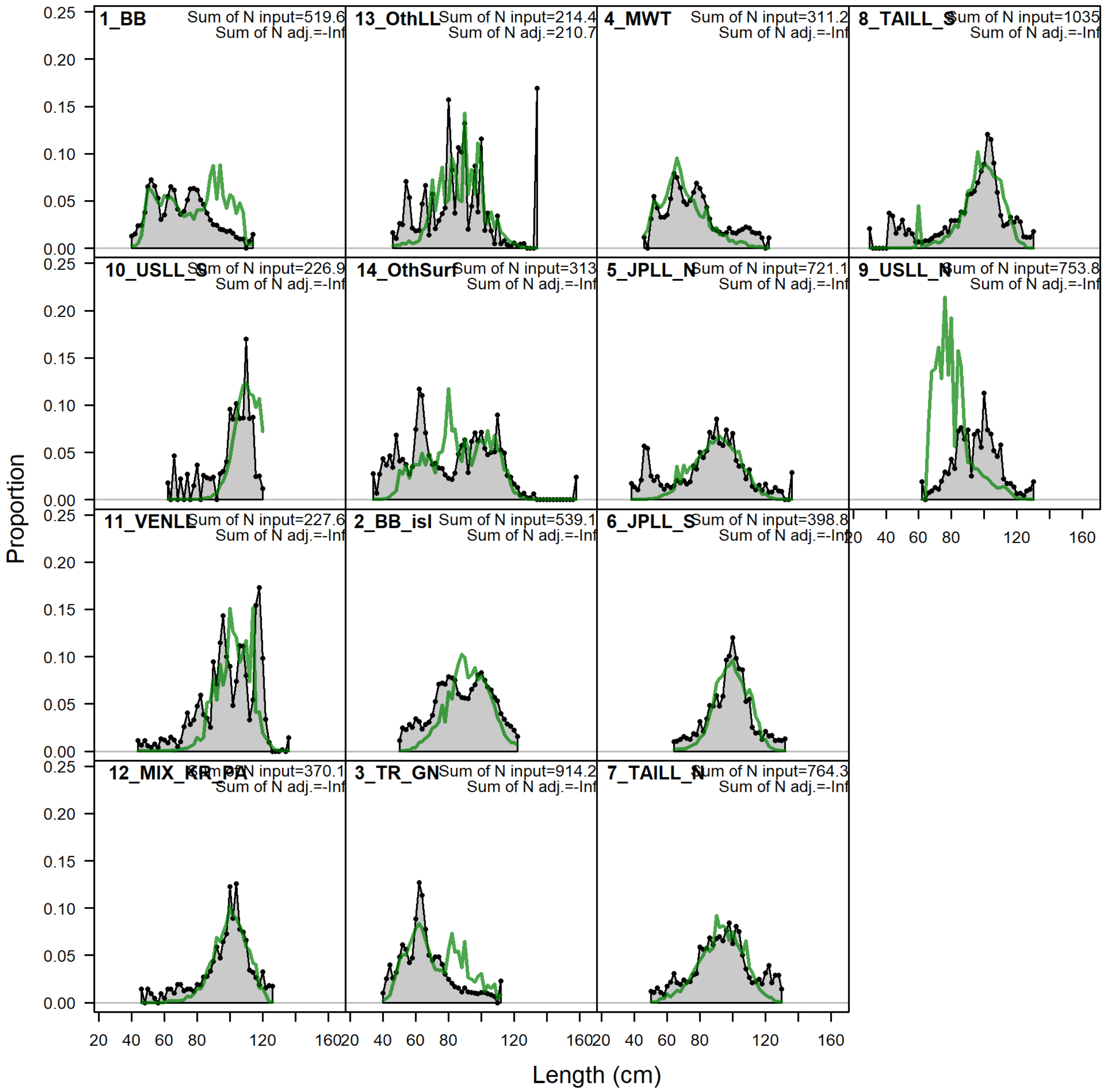

Figure 14. Length comps, aggregated across time by fleet. Observations (gray) vs estimated (green).

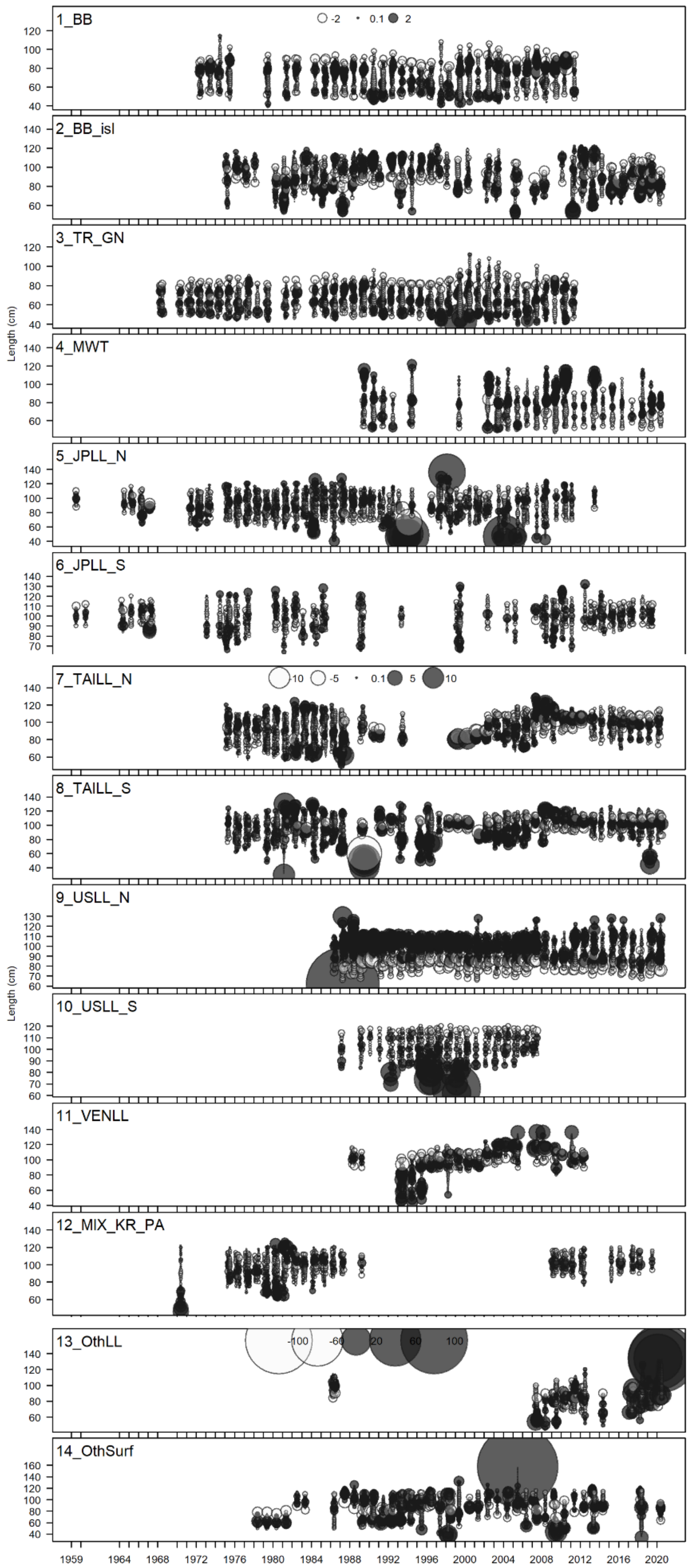

Figure 15. Pearson residuals, comparing across fleets. Closed bubbles are positive residuals (observed>expected) and open bubbles are negative residuals (observed<expected).

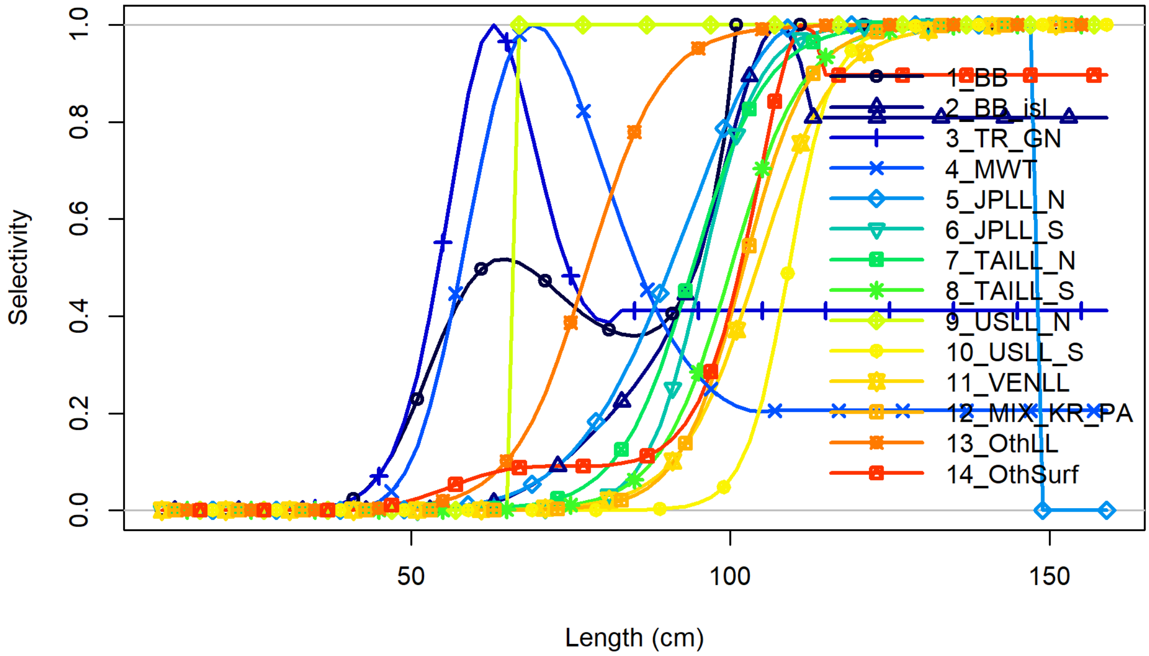

Figure 16. Selectivity at length for the fleets considered.

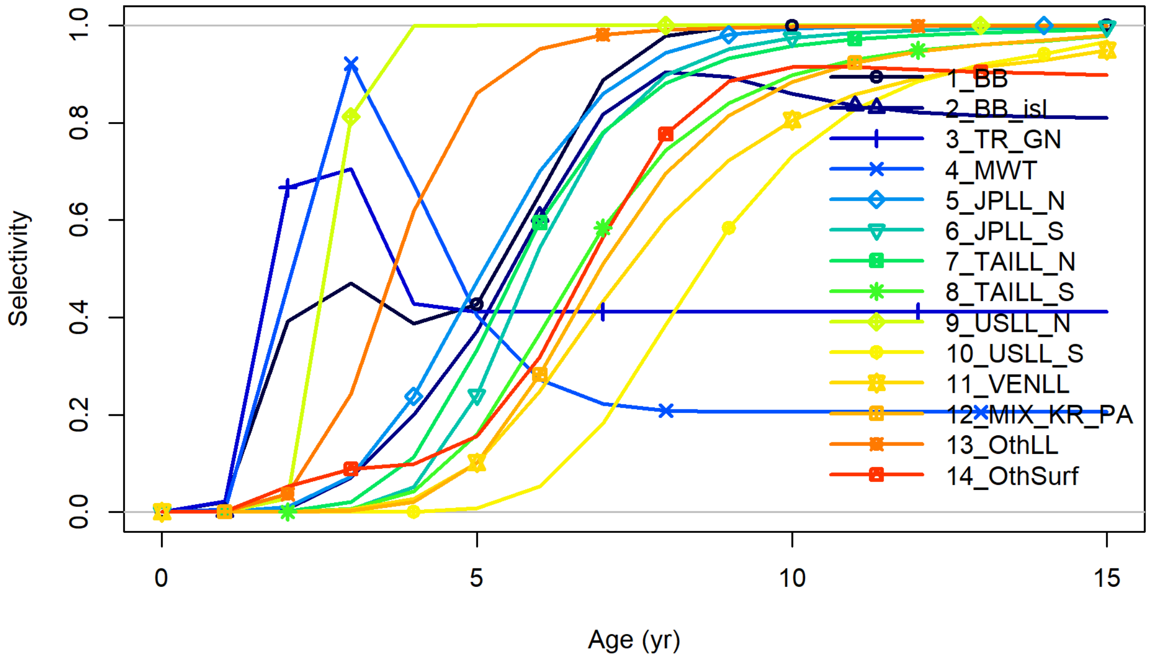

Figure 17. Selectivity at age for the fleets considered.

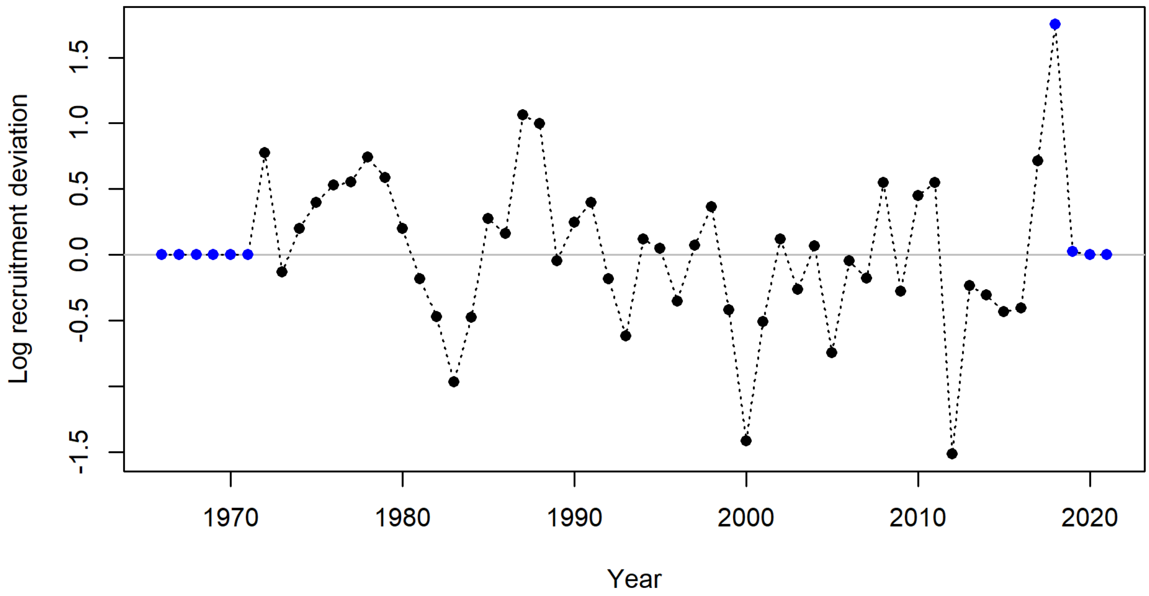

Figure 18. Estimated recruitment deviates.

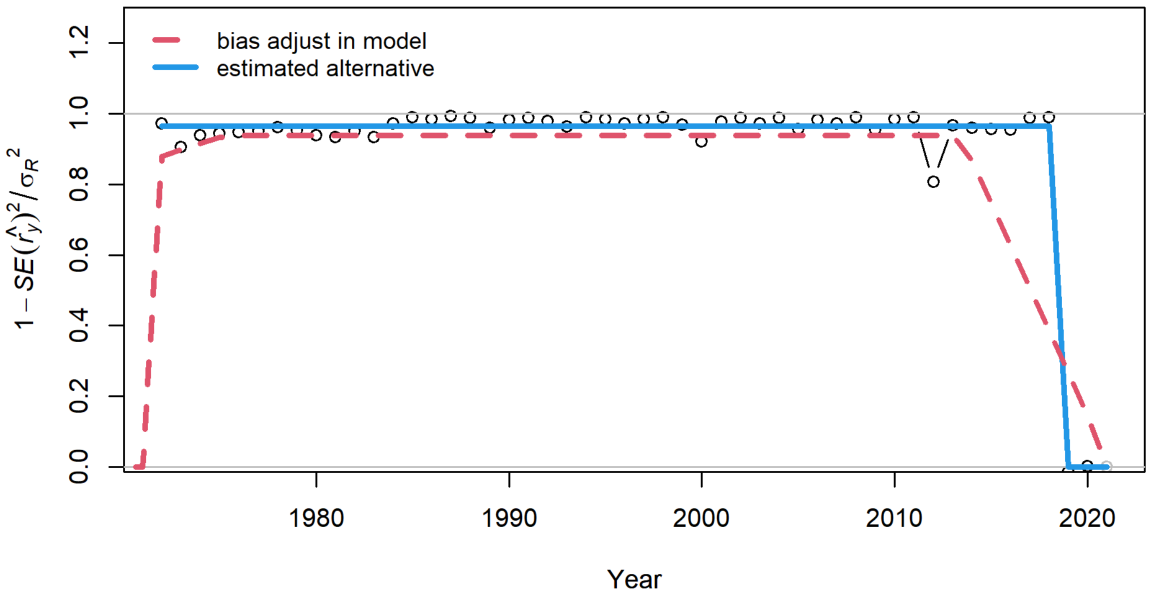

Figure 19. Red line shows current settings for bias adjustment specified in control file. Blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations (which may or may not be an improvement.

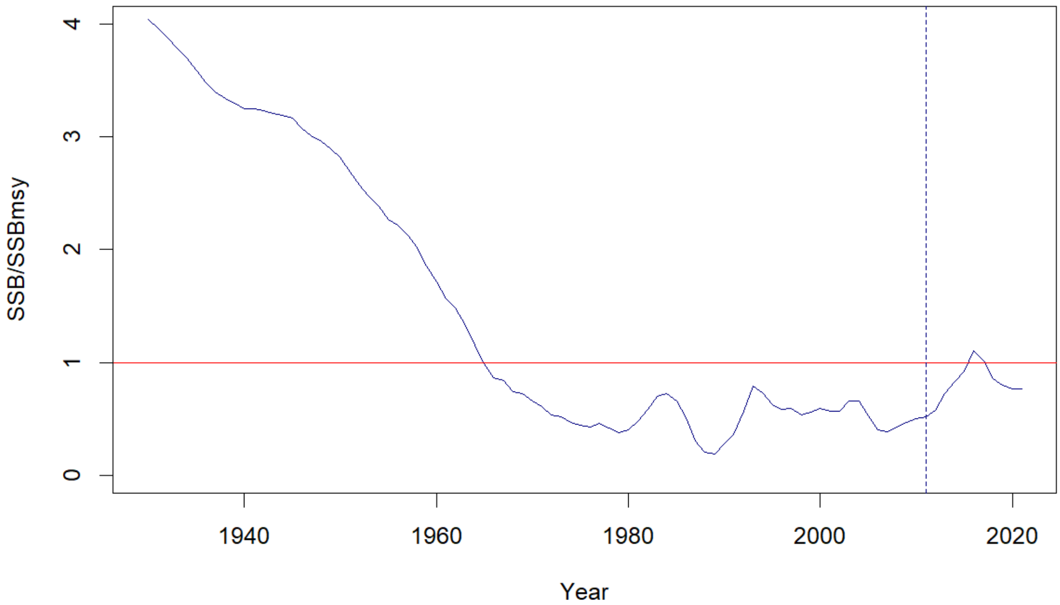

Figure 10. Spawning biomass (SSB) trend as estimated in the SS3 model configuration (preliminary), with a dashed line in the terminal year of the 2013 stock assessment.

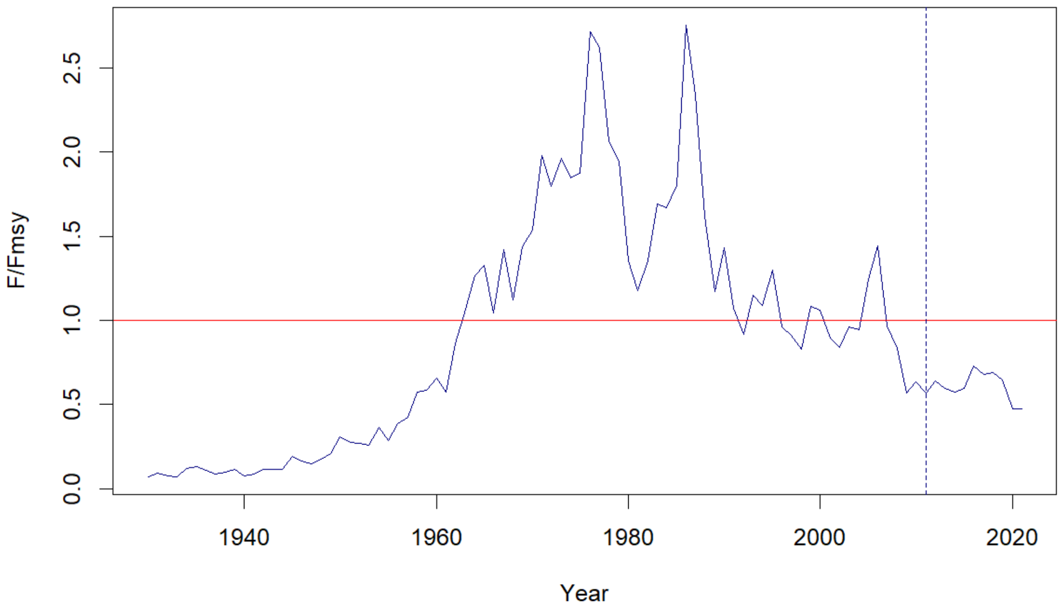

Figure 11. Relative fishing mortality (F/F_{MSY}) trend as estimated in the SS3 model configuration (preliminary) with a dashed line in the terminal year of the 2013 stock assessment.

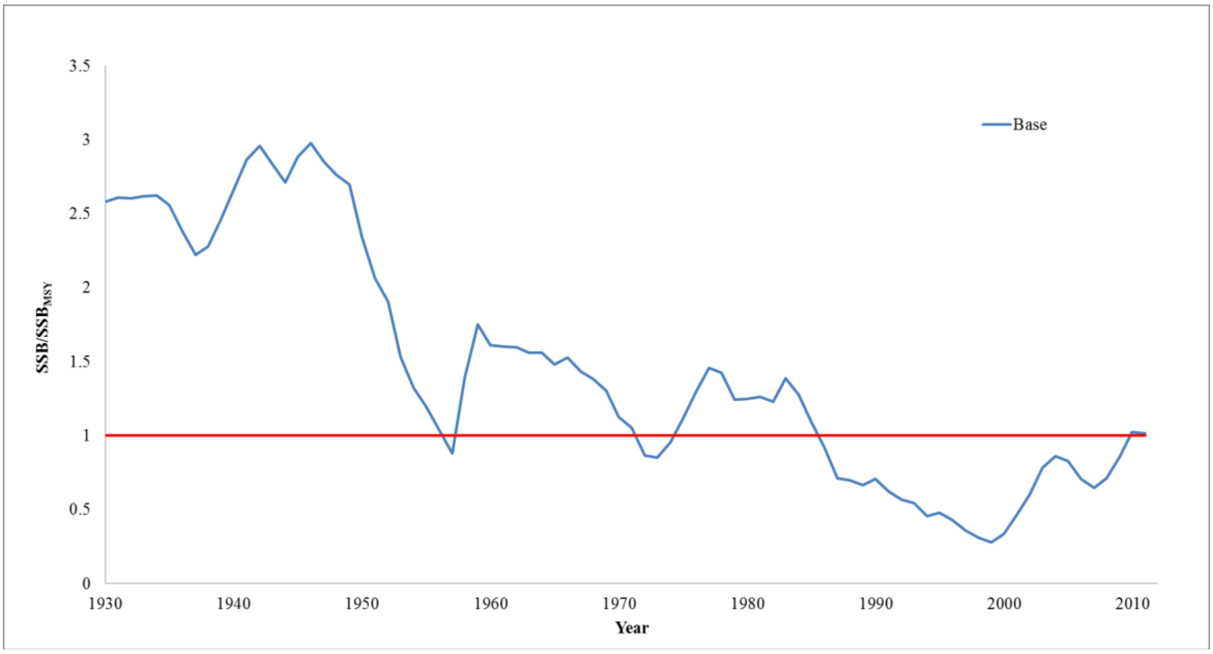

Figure 12. Model estimated relative SSB trajectory over time for the base case run of the 2013 stock assessment using MFCL.

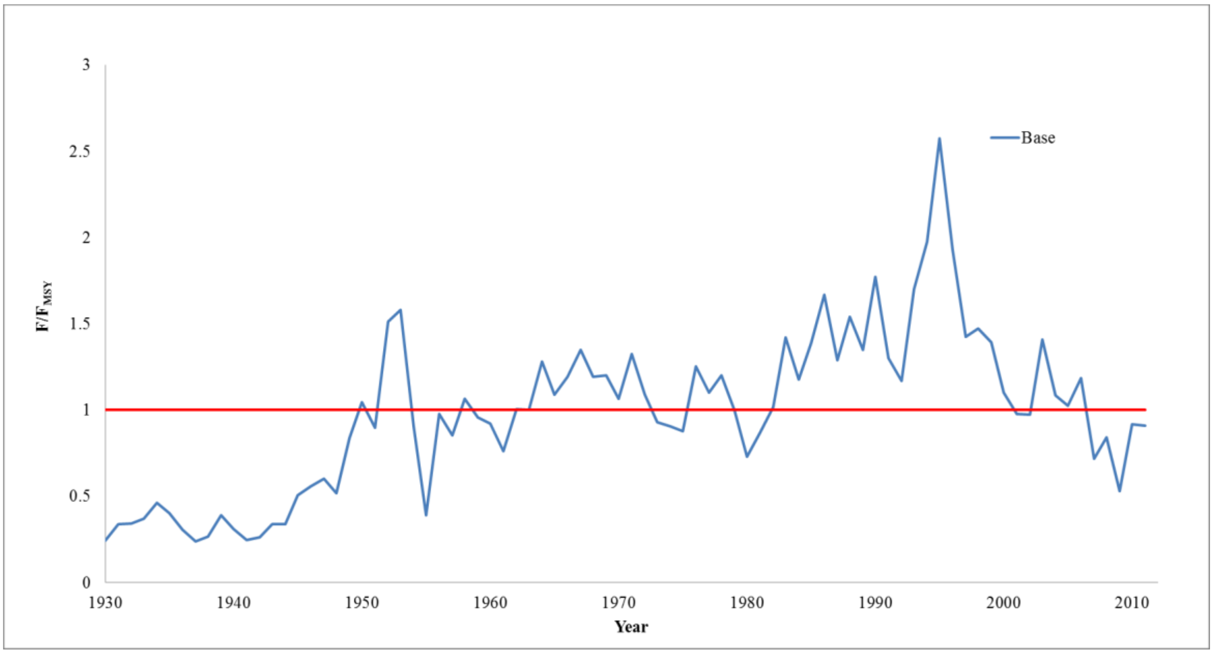

Figure 13. Relative fishing mortality (F/F_{MSY}) for the base case of the 2013 stock assessment.

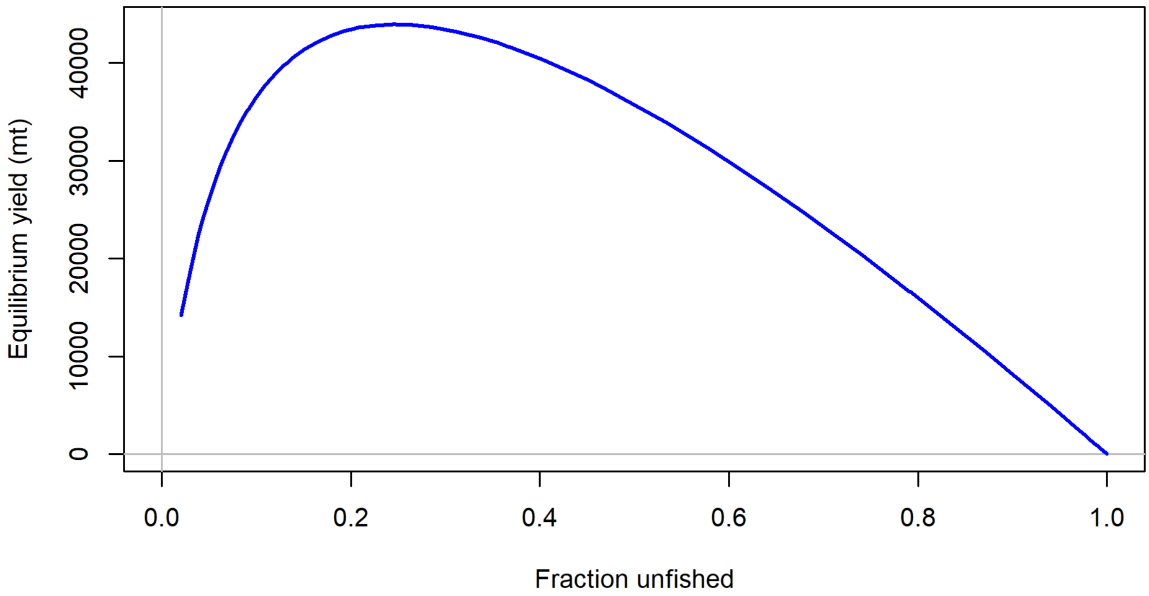

Figure 14. Equilibrium yield curve from the preliminary fits to the SS3 model.

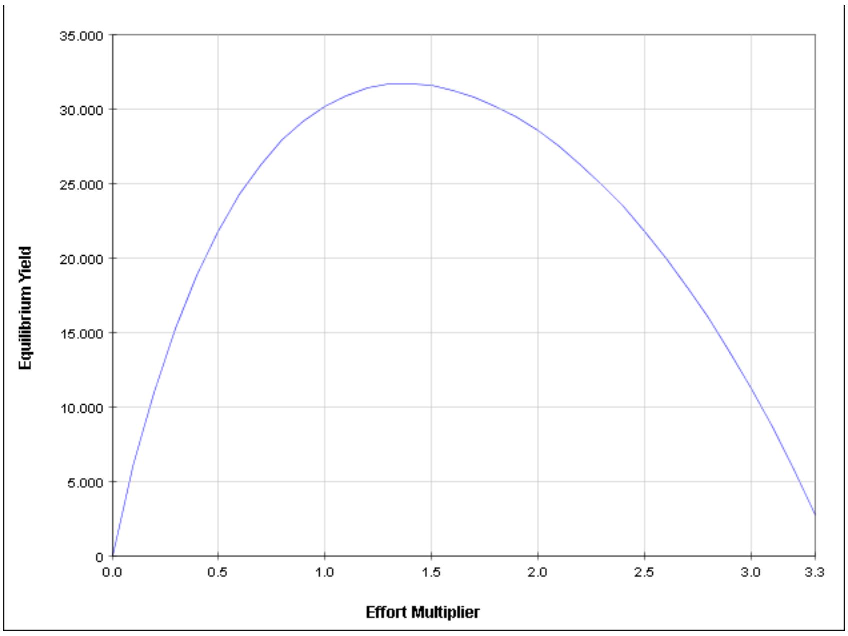

Figure 15. Equilibrium yield curve for the base case of the 2013 stock assessment.