REPORT OF THE 2013 BLUEFIN MEETING ON BIOLOGICAL PARAMETERS REVIEW *(Tenerife, Spain – May 7 to 13, 2013)*

1. Opening, adoption of the Agenda and meeting arrangements

The Meeting was held at the Centro Oceanografico de Canarias of the Instituto Español de Oceanografía (IEO), in Tenerife from May 7 to 13. Dr. Josu Santiago, SCRS Chair, opened the meeting and welcomed participants.

Drs. Clay Porch (USA) and Jean-Marc Fromentin (EC-France), BFT Rapporteurs for the western and eastern stocks, respectively co-chaired the meeting. Drs. Porch and Fromentin welcomed meeting participants ("the Group") and proceeded to review the Agenda, which was adopted without changes **(Appendix 1)**.

A List of Participants is attached as **Appendix 2** and the List of Documents presented at the meeting is attached as **Appendix 3**.

The following participants served as Rapporteurs for various sections of the report:

Section	*Rapporteurs*
1, 7	P. Pallarés
2.1	J.M. Ortiz de Urbina, P. Pallarés
2.2	A. Fonteneau
3.1	J. Walters, A. Kimoto
3.2	E. Rodríguez-Marín, J. Neilson
3.3	G. Díaz, M. Lutcavage
3.4	A. Fonteneau
3.5	D. Secor
5	C. Porch, J.M. Fromentin
6	JM Fromentin, L. Kell

2. Review of biological data used for Atlantic bluefin tuna assessment

2.1 Revision of the Task II data recovered by GBYP from 2010 to 2012: quality controls and analyses

The Atlantic-wide research programme on bluefin tuna (GBYP), among several objectives, has the duty to identify and recover any possible source of data not already included in the ICCAT bluefin tuna data catalogue. A considerable amount of both historical and recent data sets concerning most of the gears and several fishing grounds was recovered during the three first phases of the GBYP programme. A general overview of the various data sets recovered is reported in document SCRS/2013/073. Since 2011 the SCRS has been regularly informed on the activities conducted under GBYP, including data recovery (**Table 1**).

Tables 2 - 5 show the catalog of bluefin data existing in the ICCAT datas bases and the updated catalog of data recovered under the GBYP for the Eastern Atlantic and Mediterranean bluefin with indication of the type of data recovered by flag, gear and year.

Data validation

Fine quality control for incorporating the data in the ICCAT data base was accomplished by individually cross-checking all data, at first against the existing data sets in the ICCAT bluefin tuna data base to test for any potential duplication and to detect outliers.

The Secretariat carried out a detailed overview of all data recovered as well as a comparison-validation of the size data recovered under the GBYP research programme. Detailed results are presented in document SCRS/2012/116. Briefly, the approach for validation was to compare ICCAT size data and GBYP size data by including a factor *Dataset source* (ICCAT, GBYP) in a GLM model that predicted mean size of size frequencies samples. The GLM model also included the factors year, season, gear and flag. The idea behind the method was that mean size is primarily determined by gear, season and flag, the source of the data having a negligible effect. GLM results are shown in tables 4 and 5 of SCRS/2012/116. Although factor *Data source* was statistically significant, mainly due to the large number of observations, leverage plots showed that this factor had minimum or no-leverage on the predicted model in comparison to other factors like *season* and *year*.

Further analyses and potential problems

In order to further analyze new data series provided by GBYP, three main components were identified: i) farm size data provided by the CPCs, ICCAT Bluefin Regional Observer Programme and GBYP; ii) Task II size data and Task II Catch and effort data.

Size data from farms

Size data collected in Italian and Maltese farms for the period 2003-2007 were recovered under the GBYP. Those data were analysed together with other farms' size data from different sources (see section 2.2).

Task II size data

Table 3 shows size data recovered under the GBYP. Data recovered have been validated by the secretariat.

Task II catch and effort data

Table 3 shows catch and effort data recovered under the GBYP. **Table 6** shows more detailed information on task II data recovered under GBYP. The main identified problems were; discrepancies in the fishing effort units between the recovered series and those currently in ICCAT database; overlapping amongst new series provided under GBYP and overlapping amongst the new series provided by GBYP and those already in the ICCAT database

Actions and timetable

For the Task II size data the Group considered that the methods used to validate those data have been appropriate and agreed to incorporate these data to the ICCAT data bases.

As regards Task II catch and effort series that fill gaps in ICCAT current data base, once the quality checking is passed, be incorporated in the ICCAT data base

Regarding Task II catch and effort series recovered under the GBYP that overlap (see **Table 5**), scientists from the involved CPCs will work in collaboration with the Secretariat in order to solve the problem. Those corrections will be submitted to the next BFT Species Group for approval by the SCRS.

Regarding Task II catch and effort series that overlap with those already in ICCAT database, scientists from the involved CPCs will work in collaboration with the Secretariat in order to solve the problem. Those corrections will be submitted to the next BFT Species Group for approval by the SCRS.

2.2 Overview of other new information on bluefin tuna biology collected from other programmes, including farming data, market and auction data

The data collected by observers in the farms since 2003 were not used so far by the SCRS to establish the catch at size of BFT caught by Mediterranean PS because of the difficulty to estimate conversion factors due to growth in farms (ICCAT 2007, 2009). However, when the French PS log books have been widely used to estimate the PS CAS, these results were clearly widely questionable, as it was concluded by Fromentin 2004: "The information provided by the EU log-books …… remains too imprecise and lacks validation to allow the computation of a size frequency table ».

On the opposite, it appears that since 2003 large numbers of BFT have been well measured by scientific observers and national technicians in the farms since 2003 offering a good potential to estimate a much more realistic CAS. This work can be done independently of the changes in condition factors in the farms, and solely working on measurements of BFT sizes sampled at their killing in the farms. Two documents (SCRS/2013/076 and SCRS/2013/083) analysed these size data from the farms.

The numbers of yearly size samples that are now available to estimate the catch at size are given in **Table 7** (most of the 2012 samples are not yet available). This table shows well the importance of the size sampling done in the farms during the last 10 years, with more than 140.000 tunas sampled for size in the farms during the period (measured in straight fork length, curved fork length or straight first dorsal fin length). Taking into account the total BFT catches of PS used in the last assessment, an average 16% of these PS catches has been sampled in the farms: a low but still significant percentage lower than 10% during the 2003-2006 period, and a very high coverage rate between 10 and 40% of the catch sampled during the 2007-2012 period.

Time spent in cages is well known for some fishes, for which the size at catching can be estimated assuming that they have followed a typical growth pattern (for instance Cort's 1991 growth curve) in the farms. This working hypothesis is probably realistic: when the growth in weight appears to be very fast in the farms, the growth in length should not be widely different from the basic growth, at least in most farms where tunas are kept during less than 1 year. For many of these fish the fishing dates are probably available in the data bases and they should be recovered. At the moment the fishing dates remain unknown for a large proportion of the harvested tunas, at least in the files that are available today. However, if the fishing dates cannot be identified, they can easily be estimated, simply assuming that these tunas have been caught at the average fishing date around June 1st. This assumption would be fully acceptable since 2009, as the PS fishing season was limited to one month between the 15th of May and the 15th of June. This average date will be more questionable before 2007 because the fishing season was much larger (mid May to mid July) and catches were not mandatory registered with their origin; in this case the average catching period should be estimated based on the fishing dates of the other tunas harvested in each farm during this fishing season.

The average sizes sampled in the farms during recent years are shown by **Figure 1**.

The estimation of the sizes at catching would need detailed and complex calculations (as the ones envisaged in SCRS/2013/076). As a first guess of the corresponding sizes of BFT at fishing dates, it has been assumed that all the sampled tunas have been kept in the cages during an average duration of 5 months in the farms (an average period often observed in the farms, outside the Croatian farms that are keeping their small BFT during much longer periods).

Figure 2 shows the comparison of the average size distributions at harvesting and catching time estimated under this hypothesis and the average PS catch at size presently assumed for the period 2003-2012. This figure shows that the profile of these 2 vectors of catch at size are widely different: when the bimodal size structure sampled each year in the farms appears to be quite realistic and typical of BFT sizes caught in the Mediterranean, the shape and profile of the CAS used by SCRS appear to be widely questionable for a multiyear CAS average. Furthermore, it should be noted that the average weight estimated from farm samples at the fishing dates is 123 kg, i.e. much larger than the 63 kg obtained from the CAS currently used. This could be due to the fact that the French PS catches are not representative of the Mediterranean PS, or to other factors (for instance the method used to estimate the CAS or/and to a bias in the sizes estimated in the French log books).

It was also noted by the WG that the historical catch at size sampled on PS by Arena during the eighties are very similar to the CAS sampled today in the farms (see **Figure 3**): showing the same bimodal catch at size, by in equal proportion of the 2 mode when in recent years catches of the large size BFT are much lower (at least in the present preliminary analysis).

Based on these results, the WG concluded that the sizes of BFT sampled in the farms are potentially much more realistic than the CAS previously estimated by SCRS, even if the present results are still widely provisional and solely indicative.

The WG also noted that these results may be in disagreement with the total yearly catches of these farmed tunas, that have been declared by fishing countries (without a real knowledge of the real weight of these catches). It is recommended that the sizes of BFT sampled in the farms should be extrapolated, after their correction at the fishing dates, in 2 different ways:

(1) as before to the yearly catches estimated and declared of each country;

(2) but also based on the total numbers of BFT that have been identified in the ICCAT certificates and in the commercial data (Japanese imports). This extrapolation of the sampled size in the farm to the total numbers of individual sold to international markets (Japan and others) should allow estimating alternate and potentially more realistic figures of yearly catches of Mediterranean BFT. This work should be done in close collaboration with the expert team working in the analysis of BFT trade data. This work will also

need to have a full access to the file on BFT Japanese imports (Bluefin Tuna Trade and Market Data) that will be fully validated by ICCAT & GBYP.

The WG recommended that GBYP should make well before its next full assessment of the BFT stock, a full validation, analysis and extrapolation of the farm samples. This work is necessary to estimate the total catches and total catch at size of Mediterranean PS fisheries. This work is described in the Appendix 4. It was estimated that this work would require a full time work of 3 months by an expert in fishery & data bases, who will be working in close cooperation with the ICCAT secretariat and BFT scientists.

Based on this overview of the catch at size presently used by SCRS and of alternate CAS based on farm sampling, the Group concluded that:

(1) The PS CAS estimated by the SCRS and used in the last assessments are not fully adequate, because of the lack of field samples, and they should be abandoned by SCRS.

(2) Size data collected in the farms since 2003 (or 2005 as the 2003 and 2004 size sampling are relatively low and geographically limited) offer a good way, to estimate realistic catch as size of BFT caught by PS in the Mediterranean. : these sizes data from the farms are already showing that the catch at size used by SCRS are catches of medium size BFT, in a size range between 70 & 110 cm (i.e. less than 30kg), would have been overestimated, when the catches of large BFT over 2 meters (over 150kg) would have been widely underestimated.

(3) Sizes data collected by observers at harvesting in the farms should be carefully processed and extrapolated in order to estimate more realistic CAS of farmed BFT. . Extrapolation should be made to the most realistic estimates of yearly total catches in number (cf annex 1).

(4) This new data processing would possibly allow estimating new series of yearly total catches that could be different from today TASK1, and probably higher in weight, than the present catches, because of the higher average weight of these average sizes.

(5) There is no doubt already that this new CAS that will be estimated for the period 2003-2013 will be quite inconsistent with the CAS estimated today for earlier years. This inconsistency in the 2 CAS before and after 2003 will probably introduce serious problems in the stock assessment, as none of the stock assessment models will be able to cope with the major change in the CAS and CAA table after 2002. This potential problem should be well studied by SCRS, and possibly leading to a revised CAS for the years before 2003; for instance assuming an improved CAS that would be consistent with farm sizes since 2003. This work should be done in close collaboration with the expert team working in the analysis of BFT trade data.

Trade data

During the 2012 bluefin stock assessment meeting several documents were presented looking at the use of eastern bluefin trade statistics and ICCAT documentation to back-calculate catches and size distribution of the catch. The information used in some of the documents was provided to the Secretariat to be used by the SCRS. This information contained individual bluefin trade statistics for the period 2001-2012. The Group identified several potential problems in the methods used in the estimations which should be solved before the use of these data by the SCRS. The Group considered that the SCRS needs a team of experts to conduct studies aimed to provide methods to obtain unbiased catches and catch at size estimates.

This work will be conducted under a specific contract in Phase 4 of the GBYP.

The Group recognized the need of incorporating data recovered under the GBYP and other sources to the ICCAT data bases in order to make them available for future analyses on the bluefin eastern Atlantic and Mediterranean stock. The Group agreed that the final decisions should be taken by the bluefin species group during the 2013 species group meeting and then submitted to the Sub-Committee on Statistics and the SCRS for approval.

3. Review of main biological parameters used for Atlantic bluefin tuna assessment

3.1 Size conversions: length to weight, curved fork-length to straight fork-length

The original length-weight relationships for Eastern (Rey and Cort, *unpubl*,; Arena 1980) and Western Bluefin (Parrack and Phares 1979) tuna have not been updated for many years. Since these original relationships were determined, a substantial amount of new information has been made available to reevaluate these relationships. New L-W relationships have been estimated by Rodrigues-Marin et al (2013) from a large compilation of recent length-weight information. In addition, the GBYP program has obtained thousands of historical records which should permit a reevaluation of these relationships with a comprehensive set of length weight measurements and associated covariates (gear, month, area, etc).

We employ a mixed model approach where we account for variability in certain factors such as gear, year and processing technique of a vessel so that these factors can be accounted for within the model while not biasing overall relationship. We minimize the potential spurious influence of these nuisance variables by estimating them as random effects and integrating them out of the overall model. While fish condition may vary over time or even between different gear types or processing units, for this paper we are interested exclusively in the average LW relationship, while accounting for only the most critical covariates.

The primary objective of this analysis is to provide updated LW relationships useful for stock assessment modeling. This task represents a compromise between capturing the biological realism of seasonal and spatial variability in condition and hence having many LW relationships and modeling practicality where multiple LW relationships substantially complicate modeling.

3.1.1 Databases and methods used in the analysis

For both stocks numerous databases were available. The group decided to use only lengths and weights that were actually measured and not estimated values. Lengths were provided in several different formats but the primary format used in the East was Straight Fork Length (SFL) and in the West was Curved fork length (CFL). For the East, only SFL measurements were used. For the West CFL were converted into SFL using methods described below. Weights were recorded in either round weight (RWT), gilled and gutted weight (GGWT), gutted weight (GWT) or gilled, gutted and tailed weight (GGTW). Gutted weights were extremely rare and these measurements were removed. For modeling either RWT, GGWT or GGTW were used and a model term estimated depending upon which weight unit was the original measurement.

3.1.1.1 Eastern stock

For the eastern stock the following databases were available at the meeting.

GBYP data

The GBYP recovered a considerable amount of historical and recent data sets for use in BFT biometric relationships and analysis for most of the gears and fishing grounds. The data retrieved, covering the years from 1903 to 2010, and from 1512 to 2009 for tuna traps were used to update the BFT L-W regression. Relevant data from the GBYP was provided for this workshop after being cross-checked against the ICCAT BFT data base and individually quality checked. Outliers were excluded. A publication, providing a general overview of the various data sets available from the GBYP was presented in this meeting through SCRS/2013/073.

Tunisia and Malta data

A data set on the length and weight from a total of 170 wild BFT specimens caught by purse seiners in summer 2012 was also used in the analysis, together with L-W data provided by Malta for fish caught by Maltese Longliners during the reproductive period for this species (May-July) during 2005,2006,2007 and 2012. A total of 1970 L-W records were provided from the Maltese Longline fishery targeting this species. Additional information from Maltese longliners were also made available for years 2008-2011 through the work carried out by Rodriguez-Marin et al (2013) referred to in section 3.1.1.5.

Japanese LL

Length (straight fork length) and weight (processed and round) information collected by scientific observers through Japan's observer program between 2000 and 2011 were also included in the L-W regression analysis. The work carried out for the collection of this information was presented through document SCRS/2013/075. A total of 13,121 L-W records were made available for the Eastern stock analysis from this fishery.

Moroccan traps

Data from Moroccan traps was also presented to the group for inclusion. These measurements consisted of 178 fish measured in curved fork length.

Rodriguez-Marin et al.

A length-weight dataset covering wide seasonal and geographical areas of the North East Atlantic and Mediterranean from extensive sampling of several Atlantic bluefin tuna fisheries over 14 years was also utilized. The dataset provided 54,549 L-W records by geographical area and month. Work carried out in the collection of this data was presented through document SCRS/2013/079.

Arena et a l(1980)

Present L-W relationships for the Western and Eastern Mediterranean are based on Arena's (unpublished) L-W function which is used in East Atlantic and Mediterranean ABFT stock assessments for specimens greater than 100 cm SFL (ICCAT 2012). For the first time the Arena et.al (1980) publication was made available during this meeting providing the raw L-W data set to work with. L-W data by Arena et al, were collected during the reproductive period (May-July) over 20 years from the fishing grounds of the Southern Tyrrhenian Sea from purse seines and a single trap. Individual length/weight data remain unavailable (and probably lost), but mean lengths (SFL) and weights (in whole wt) could have been retrieved from Arena et. al (1980) and were used for comparison but not in model fitting.

3.1.1.2. Western stock

For the Western stock several databases were available at the meeting. Due to the short time some databases could not be obtained during the meeting and efforts will be made to acquire additional data after the meeting that could be used in the regressions.

Canadian data

Data collected onboard and onshore from the Canadian fishery were obtained. A dataset of 7855 L-W observations were made available. Lengths were measured as curved fork lengths but some concerns existed over some outliers.

Japanese longline observer data

The same dataset was described above for the Japansese longline was available for West of 45^{o}W.

Mexico longline observer data

Data collected by observers on Mexican longline vessels was provided according to methods described in SCRS/2012/193. These data comprise 755 records. At the time of the meeting it could not be determined which measurement for length and weight was taken so the data could not be incorporated in the master dataset.

United States longline observer program data

A dataset of 521 L-W observations were made available. 509 lengths were measured as curved fork lengths while 12 were in straight fork lengths. This data is collected by observers onboard US pelagic longline vessels or when the fish are landed.

Data provided by Golet and Lutcavage from US fishery

This data is collected from the US recreational and commercial fishery.

United States historical data

Data used in the original Parrack and Phares (1979) dataset apparently came from 3545 fish collected by the United States national scientists during 1974-1977. It may be possible to obtain the original dataset but this would require further inquiry after the meeting.

United States dealer records

Data may exist within United States dealer records. Given the very short timeframe of the meeting it was not possible to acquire this data within the short timeframe of the meeting and it will be available at a later date.

ICCAT tagging database

Released fish in ICCAT tagging database was examined for use for length-weight information but the very few numbers of records where length and weight were measured (~547) and the variability in which length was measured make the data an unlikely source of useful length-weight observations.

3.1.1.3 Data excluded

Some of the data available were excluded because they don't follow the criteria of quality defined by the group. Data excluded were the following:

- ✓ Data from Straits of Sicily traps were excluded for the years 1994,1995-
- ✓ Length measurements where the length type was not recorded (804 fish)
- ✓ Potential outlier records from the model fitting. Outliers were identified using the Fulton's condition factor (**Figure 4**). This condition factor is calculated as follows:

$$K= 100*(wt(grams)/length^3)$$

- ✓ Values less than 1 and greater than 2.8 (**Figure 5**) following the logic of Cort et al (in press) but allowing for a wider spread of observations. For this analysis all weights were converted to RWT using the following relationships between gilled, gutted and tailed (GGTW) and gutted weight (GWT):

  RWT=1.13 x GWT; mainly for Straights of Sicily from ICCAT conversion factors for Mediterranean

  RWT=1.16 x GGTW ; (SCRS/2013/075)

These initial conversions were done so that similar K values were obtained for excluding outliers but all modeling was performed with the original type of measurement.

Spatial partitioning of the data was initially left at the finest resolution of the datasets and consisted of areas. Temporal partitioning of the data was done by month, initially. Further exploratory analysis was conducted to condense spatial and temporal areas.

3.1.1.4 Conversion from CFL to SFL for Western data

As most of the Western data was collected in CFL but the Japanese longline data that cover some essential spatial areas was collected in SFL, a decision was made to convert CFL measures to SFL using the equation established by Parrack et al.(1979) in the western Atlantic:

SFL = 0.955 CFL (Parrack et al., 1979)

This equation is similar to the equation for the central Mediterranean presented in document SCRS/2013/065, SFL = 0.968 CFL). Note that the equations estimated Salz et al (2007, SFL = 0.9728 CFL) could also be considered.

3.1.1.5. Creating a master dataset

Essential to this exercise is the creation of a master dataset with common factors for analysis. Data fields for this master dataset are shown in Appendix 5 and example data lines are shown in Appendix 6. Initially all data fields were input at the finest available scale of resolution, i.e., if vessel code, area and sampler was available these were input. When not available, a data field was coded as ‘NA’.

3.1.2 Modeling

3.1.2.1. Exploratory analysis

Exploratory analyses were performed by conducting a PCA on the parameters of the $wt=a*length^b$ relationship, month and area to determine whether there was a month and area effect on the model coefficients. Four initial areas were explored in the PCA: ATL, WMED, CMED and EMED.

A similar analysis was conducted within the mixed model where it was initially estimated with 14 separate areas and 12 months. Model parameter estimates were explored to determine if areas or months could be condensed into homogenous groups. Areas for which the 95% percentiles for the parameter estimates overlapped were condensed to provide a more parsimonious set of regression equations.

3.1.2.2. Model construction and factors

Due to variability among processors in the way that a fish is processed to obtain gutted or gilled, gutted and tailed weights, we created an additional variable to capture variability in processing. This additional variable called ‘processing unit’ was created which constituted the individual vessel for the Japanese longline datasets and for the remaining datasets a single value was assigned to all observations (64) where a fish was landed in gutted weight. The remaining observations were measured in round weight and were assigned to another processing unit category.

Regression modeling methods followed the mixed modeling approach presented in document SCRS/2013/075 and used the MCMCglmm package (Hadfield, 2010) in R 2.15.3. Model fitting, model selection and MCMC thinning methods were similar to that presented in document SCRS/2013/075. Deviance Information Criterion (DIC) was used for model selection decisions, except as noted.

The initial models evaluated are shown below:

Model A (same *b,* different intercepts)

MCMCglmm(log(weight)~log(SFL)+as.factor(month)+as.factor(area)+as.factor(wcode),random=~*rnd*, family="gaussian",",nitt=15000,burnin=5000,thin=10,data=yfin)

Fixed factors: month,area,wcode(0:round weight,2:gilled,gutted,and tailed,3:gilled weight)

Random factors (*rnd*) : paste(*year, gear, processing unit);* such that the random factor is the combination of year, gear and processing unit.

Condensed to only 2 areas and 3 seasons:

Model B (condensed, same *b,* different intercepts)

MCMCglmm(log(weight)~log(SFL)+ as.factor(CondensedArea) +as.factor(Season) as.factor(wcode), random=~*rnd*, family="gaussian", ",nitt=15000,burnin=5000,thin=10,data=yfin)

Model C (condensed no season, same *b,* different intercepts)

MCMCglmm(log(weight)~log(SFL)+ as.factor(CondensedArea) + as.factor(wcode),random=~*rnd*, family="gaussian",",nitt=15000,burnin=5000,thin=10,data=yfin)

After condensing the model to only 2 areas and 3 seasons, interactions were tested (which estimates separate *a* and *b* parameters) with a model in the form of:

Model D (condensed, separate *a* and *b*)

MCMCglmm(log(weight)~log(SFL)+as.factor(CondensedArea) + as.factor(wcode) + log(SFL)*as.factor (CondensedArea),random=~*rnd*,family="gaussian",",nitt=15000,burnin=5000,thin=10,data=yfin)

Model E (Atlantic, separate, separate *a* and *b*, no seasonal affect)

MCMCglmm(log(weight)~log(SFL)+ as.factor(wcode) , random=~*rnd*, family="gaussian", ",nitt=15000,burnin=5000,thin=10,data=yfin)

Model F (Med, separate *a* and *b*, no seasonal affect)

MCMCglmm(log(weight)~log(SFL)+ as.factor(wcode) , random=~*rnd*, family="gaussian", ",nitt=15000,burnin=5000,thin=10,data=yfin)

3.1.3 Results

3.1.3.1 Data filtering and exclusions

The initial datasets for available to the group consisted of 117536 L-W observations for the East and 22129 observations for the West (**Tables 8** and **9**). After careful consideration of western dataset the group decided not to proceed with modeling the data until some key datasets could be obtained and a large number of outliers could be error-checked by national scientists.

After applying condition factor based exclusions (- 218 observations) using only SFL observations (-3695 observations) and removing the Arena average weight at size data (-1658) resulted in a total of 110498 remaining LW pairs (**Table 10**).

3.1.3.2. Exploratory analysis

Exploratory analyses were conducted using principal components analysis to evaluate the most influential factors on the estimated parameters. The PCA indicated that both month and area co-varied along the same component, indicating that month and area served as similar proxies for length at weight but that area partitioned the greatest variability in the length-weight relationships (**Figure 6**). This indicates that the likely strongest effects on *a* and *b* parameters would likely be due to area and that the monthly affect, while present was not as strong as the area affect. **Figures 7** and **8** show length-weight relationships by month and year.

3.1.3.3. Model results

Initial model fit

Initial parameter estimates for month from Model A indicated that there were differences in condition by month. Upper (green line) and lower (red lines) represent 95 percentiles of the MCMC estimates for the parameters. The blue line and the error bars represent the median +/- 1 standard error. The estimates show evidence of three potentially distinct ‘seasons (**Figure 9**); a ‘pre-spawn season’, months Feb-Jun; a post-spawn season (July-August) and a fat season (September-December) to capture the main temporal variation in the LW relationship.

Initial parameter estimates for area effect from Model A indicate that the further models could be condensed into homogenous areas (**Figure 10**).

On the basis of overlapping parameter confidence intervals initially two areas were considered: Atlantic and Western Med (ATL_WMED) and Eastern and Central Med (ECMED). This would condense ATL_ATL, ATL_BB, ATL_Portugal, CATL_CATL, WMED and WMED_Sardinia into the ATL_WMED and CMED_IO, CMED_Southern Med, CMED_SS (Sicily), CMED_TY, EMED_Antalya, EMED_Levant, EMED_N Aegean into the ECMED. Subsequently, the areas were revised based upon expert opinion to Atlantic Only and Mediterranean only which involved moving the Western Med samples to the Med group.

Condensed models

We compared the Deviance information criterion DIC between seasonal and non-seasonal condensed model Model B vs Model C. While the seasonal effect was significant, the confidence intervals for the seasonal models overlap (**Figure 11**) indicating that there was very little statistical difference between the seasons. In addition, there was a negligible difference in weight at length between seasons. For the largest size of fish observed (300 cm SFL) the weight at size would be 439, 447 and 457 kg at in the post-spawn, base and fat season, respectively, which would represent a difference of +/-2% from the base season. Within the range of the much of the data the absolute difference was much less but the percentage remained approximately 2% from the post-spawn to the fat season. Hence, as these differences represent such a minor amount we dropped season from the remaining models.

Interactions

To estimate separate *a* and *b* parameters it was necessary to estimate and interaction between area and SLF (Model D). This model provided a significantly improved fit over the model with single *b* and separate intercepts indicating that separate *a* and *b* parameters should be estimated. An additional complication arose when we obtained very divergent (from the ATL_WMED and non-sensible estimates for the Eastern and Central Med (ECMED) because of many missing vessel codes in the random effects. As an expedient solution to this problem the group decided to simply split the data into two areas and estimate separate models.

Final models and parameter estimation performance

The final models were constructed for the Atlantic (ATL) and for the Mediterranean (MED) separately without season factors (**Table 11**). Parameter estimation performance was evaluated by looking at traceplots of the 6 estimated parameters for the final models (**Figure 12**). These estimated parameters were: intercept (*a*), log(length) or the *b* coefficient and 2 weight code parameters. The traceplots and histograms indicated that most parameters converged to a relatively symmetric and tight distribution a central tendency.

The final models, with no seasonal effects, but only area effect showed no difference between the East Atlantic and Mediterranean, but some differences with historic relationships used by the SCRS (**Figure 13**).

3.1.3 Discussion

The Group updated LW relationships for Eastern Atlantic and Mediterranean Bluefin tuna and developed a modeling methodology for updating the Western LW relationships when information becomes available. For EBFT the Group estimated two separate regressions, one for the Atlantic (ATL) and one for the Mediterranean (MED). However the relationships and the parameter estimates were so similar that it might be desirable to have a single relationship.

The results of this analysis should probably be considered preliminary as the similarity of the ATL and MED models begs the question that they should simply be combined into a single model. Given the timeframe of the meeting and the substantial data processing required this additional model run could not be done at the meeting and could be presented as a working group product at the 2013 species group meeting. In addition it is likely that data for the Western stock will be available soon which will allow for the development of LW relationships for this stock.

These LW relationships should be applicable to wild fish at the time of capture as care was made to exclude farmed fish from the analysis. The two-area models represent the major source of identified variability in the LW regression, albeit tiny and maybe minor, while accounting for random variability in time, gear and processing method. While season was a significant factor in the models, we decided not to recommend seasonal models as the seasonal differences were very minor after accounting for areas. If a researcher desires greater spatial or temporal detail, Rodriguez-Marin et al (2013) provide a suite of separate spatial and temporal models with a more detailed consideration of spatial and temporal patterns.

Compared with other LW models for EBFT, the ATL and MED models are very similar to comparable models from the Rodriguez-Marin et al (2013) and Rey and Cort (*unpublished*) (**Figures 13** and **14**). Both models are substantially different from the Arena (1980) and the Parrack and Phares (1979) West Atlantic models which indicate substantially higher weight at length. These differences are substantial but possible may be explained by the relatively smaller and more localized samples used in Arena and Parrack and Phares (1979). Given that the current analysis as well as that of Rodriguez-Marin et al (2013) contains substantial new and more spatially and temporally comprehensive information and that they both estimate similar LW relationships, it is likely that these estimates better represent the population length-weight relationships.

3.2 Age conversions: growth curve, ageing data, ALK tables.

Current Status of Direct Age Determination Programs

The estimation of age and growth of a species is a key parameter to describe its life history and essential for its assessment. There are several approaches to estimate growth, the most frequent being: direct observation or tagging, analysis of length-frequency data and interpretation of calcified structures. Atlantic bluefin growth has been obtained from the three methods, but the growth curves that are currently used in the ICCAT assessment of this species are based on a combination of the latter two methods, length frequency analyses and direct ageing (Cort, 1991; Restrepo et al., 2010). The tagging method is one of the more reliable approaches to obtain age and growth information given good information at size at release and recapture, but up until now it has often been discounted for this species because the scarcity of larger specimens does not allow the estimation of a reliable asymptotic length. However, SCRS 2013/093 and SCRS/2013/078 develop a case that the existing tagging data could be examined further, and help inform further growth studies. The Group expressed some concern over the number and reliability of recapture information for fish of larger size.

Direct ageing of the catches through age-length-keys (ALKs) is a common method that has been widely used in many regional fisheries management organizations dealing with pelagic and ground fish species. In contrast, in ICCAT species assessments average annual growth curves are used to convert catch at size into the catch at age matrices (CAAs) instead of applying ALKs. The reasons for this procedure were mainly due to the difficulty in sampling of this species, the time consumed for developing annual ALKs and the need for validated direct ageing. However, the SCRS and national scientists have invested considerable resources into direct age determinations for both the eastern and western stocks, and the results to date and future work priorities are summarized here.

Various calcified structures have been used for age estimation of ABFT, including scales, vertebrae, otoliths, and dorsal fin spines (Rooker et al., 2007). Of all these structures, the latter two are those which have provided more reliable results (Rodriguez-Marin et al., 2007). Otoliths represent an advantage for ABFT direct ageing in relation to fin spines because all ages can be interpreted since there is no nucleus vascularization; conversely, dorsal fin spines (referred to later as spines) are easier to collect and prepare than otoliths (Rodriguez-Marin et al., 2007). Of the two structures, only age determinations from otoliths have been validated to date (Neilson and Campana, 2008), and the validations were completed for only the largest size category. The Group also noted that interpretations of ages from otoliths during the first 5 to 6 years of life is often problematic, but such structures are comparatively easy to count in spines. On the other hand, after age 7, counts of annuli from otoliths can be made with good precision. The Group noted that the most robust age assignments might be made by combining ages determined from both hard parts.

Comparing the “state of the art” for direct age determinations in the east and west, there are well-established protocols for spine age determinations that have been use for many years now (Rodriguez-Marin et al., 2012; Luque et al. submitted). In contrast, otolith-based production ageing from western laboratories is not as advanced, and workers are now establishing reference collections, otolith exchanges, and finalizing protocols. However, good progress is being made, and as reported in SCRS 2013/084, participants in a recent workshop with experience in quality control procedures in large age production laboratories indicated that a 10% Average Percent Error was commonly implemented for species like Atlantic bluefin tuna (e.g., king mackerel) that are somewhat difficult to age. With improved standardization and experience, workshop participants thought that a mean APE <5% was attainable, a level suggested by Campana (2001) as a common threshold level for production ageing laboratories.

Regarding the status of such collections for the West a collection is being developed by UMCES (SCRS/2013/084) and international partners. In the East, the IEO has been taking a leading role in developing reference collections for spines and vertebrae. These tools should be finalized as appropriate and shared with other laboratories interested in contributing to this work.

The GBYP direct ageing contribution included more than 1050 aged calcified structures (SCRS 2013/80). This document presents direct ageing results of Atlantic bluefin tuna based on otoliths and fin spines sampled in the N E Atlantic and Mediterranean Sea, with the aim of estimating the age of the catch of the eastern stock of this species. Asymptotic lengths and growth coefficients obtained from ALKs derived from both structures did not present significant differences and inter-reader precision within each structure was found to be high.

Another paper based on paired structures from the same specimens coming from GBYP and other Spanish, Canadian and US research programs, SCRS/2013/081, was presented.

This paper explored the potential value of bomb radiocarbon for validating age interpretations in ABFT available spine samples from 1984 and age estimates from paired structures were compared to examine the relative bias of spine readings in relation to otoliths. Spines contained radiocarbon at concentrations consistent with expectations. The comparison of otoliths and spines age interpretations coming from the same specimen showed a good fit to a linear relationship between both age estimations up to 10 years, and from this age it is observed that the spine age interpretations are lower than that of the corresponding otoliths. However, authors recognized that these results were preliminary since the sample size for the radiocarbon assay was small and otolith preparation and age interpretation criterion are still been reviewed. It was suggested a combination of otoliths and spine readings from the same specimen to produce a complementary and corroborating experience.

Table 12 contains a catalog of hard parts over the recent period 2010-2013, corresponding to the period of enhanced biological associated with the GBYP in the eastern Atlantic and Mediterranean and complementary national sampling programs developed by Spain in the east Atlantic and the USA and Canada in the west Atlantic. The information presented in the table is abstracted from SCRS/2013/094, SCRS/2013/050, SCRS/2013/080 and from other information provided by national scientists. There are also well-sampled historical collections of otoliths in various research institutions like the ones in NOAA (USA) from the mid 70s, in FOC (Canada) from 1970 to 1990 and spines collections in the IEO (Spain) from 1975 to 1990.

Available Age-length Keys, and comparisons of Resulting CAA with Previous Assessment

The Group developed age-length keys (ALKs) using GBYP data (i.e. spines and otoliths from E-ATL BFT) and age-length pairs from otoliths of W-ATL BFT. Although samples were available from 2009-2013, the majority of samples were from 2010 and 2011. For the purposes of this analysis, all years were combined to develop ALKs for E-ATL and W-ATL BFT. Age composition was estimated using these empirical ALKs to determine the effect of using ALKs to develop age composition rather than the age-slicing routine used to construct VPA inputs for the 2012 base models.

For W-ATL BFT, two ALKs were developed. One used only otolith observations from BFT caught in the W-ATL Northeastern U.S. and North Carolina fisheries (**Figure 15**). The second used all available age-length pairs from the W-ATL and the E-ATL (**Figure 16**).

Figures 17 and **18** compare the raised catch-at-size with the samples of otoliths and spines respectively, for the E-ATL BFT. In both figures the first panels show the length frequency distribution of the population, the second the numbers at each age (represented by the different colors) for each length group and the third panel the proportions at age. **Figures 17** and **18** allows the sampling intensity of hard parts across the length frequency distribution of the catch to be compared.

Figures 19 and **20** show the numbers sampled at each age as a “growth curve” for otoliths and spines respectively. **Figure 19** and **20** allows the overlap by length of the age classes to be compared, i.e. the greater the overlap the higher will be the uncertainty in age estimates.

Figure 21 contrast the estimates of numbers at age for “age-slicing” and using an age-length-key based on otoliths and spines. **Figure 21** compares the estimates of proportions at age. These results are preliminary and are intended to be a starting point for comparing the current assessment based on VPA using age slicing with statistical catch-at-age models, rather than drawing any quantitative conclusions.

The Group noted the differences in the reconstruction of the catch at age derived from preliminary age length keys developed for both the east and west. Missing ages at youngest ages caused problems in the west, and missing values in the oldest ages caused difficulties for the east. Use of modeling techniques such as stock synthesis could account for incomplete ALKs. However, it was noted that the ALKs provided here were preliminary, particularly for the west. As more ages become available and ALKs become more complete, more reliable catches at age should result. It was noted that with additional information at older ages, plus group problems may become less apparent.

Appropriate Scale for Aggregating Age-length Information

When considering the appropriate scale for construction of age-length keys, it is important to understand factors that could potentially influence bluefin tuna growth, and consider the literature on tuna growth broadly. For example, growth rate is shown to be a sexually dimorphic trait for several species (Atlantic bluefin tuna, southern bluefin tuna, and Pacific bigeye tuna), although the fastest-growing sex differs. Regional growth rate differences have been described and are often substantial among different management units (for example for albacore). Environmental factors have been shown to affect growth rate (see, for example, the response of Pacific bigeye tuna to El Nino and La Nina events). Considering temporal variation, there is limited information on interannual variation, although Rodriguez-Marin et al. (2009) found that cohorts of bluefin tuna can be more easily detected and followed when annual age length keys were used. Growth rates have also been found to change on a decadal time scale (southern bluefin tuna, Polacheck et al. 2004), and may be a density-dependent response to a decrease in population size.

Simulation studies can offer a means to evaluate the sensitivity of age-length keys to potential sources of bias, and to consider levels of sampling required to achieve certain levels of precision.

Comparisons among Growth Curves

The Group discussed the data that were used to derive the currently adopted growth curves for western and eastern stocks of Atlantic bluefin tuna (Cort, 1991 and Restrepo et al., 2010). It was agreed to include a detailed description of time frame and data used for both curves. Both curves are based mostly on length frequency and calcified structures that were sampled during the 70s and 80s. The updated western Atlantic bluefin tuna growth curve from Restrepo et al. (2010) is based in age information over a long time period. In this last paper two types of data were used: otolith-based age readings with the size frequency distributions of small (ages 1–3) caught by purse seiners in the 1970s. Otoliths, used in this updated growth function, were mostly collected from the western Atlantic management unit in late 1990s and 2000s but principally the giant ABFT category were collected during 1970s and 1980s. Both extremes of the updated western growth function are based on samples collected many decades ago. The same potential issue is noted for the eastern growth curve (Cort, 1991), this curve is also based in two types of data: spine age readings from tuna caught by traps in 1984 and length frequency distributions of juveniles (ages 1-5) tuna caught by bait boats from 1975 to 1984.

The methodological approach to fit the eastern growth curve from Cort (1991) was also described. This author fitted the data to the von Bertalanffy growth model by applying the Ford&Walford method, obtaining slightly different growth parameters from the recalculated ones that were obtained during the Working Group meeting from the referenced data (mean lengths at age) by minimising the sum of squared residuals (**Table 13**).

Currently adopted growth curves for east and west Atlantic bluefin tuna stocks were compared with curves derived from available calcified structures data sets by Kimura's (1980) Likelihood Ratio test (**Table 13**) . The test was conducted using equivalent age ranges as recommended by Haddon (2001). The corresponding newly estimated parameters were tested with those from other authors, which were recalculated from the referenced data (mean lengths at age) by minimising the sum of squared residuals. West otolith data sets were not included in the analysis because those age estimations were preliminary and there are relatively few available ages at lack of sampling in both extremes of the age range. It was noted that the statistical procedures used here compared the mean lengths at age, but a more appropriate use might be to treat the individual observations.

Results from **Table 13** showed that growth parameters estimations and the significance of these comparisons are sensitive to the following factors: age range compared, the use of fractional ages and the number of samples and years used in the analysis. In general using fractional ages and calcified structures data sets with numerous age estimations by age and covering wide age ranges produces growth curves which were not significantly different with the ones currently adopted by ICCAT.

The Group agreed that comparisons presented were useful and interesting. It was noted that the comparatively high estimates of $L_{infinity}$ obtained from the GBYP data set became closer to previously published estimates as more years of information were added, probably reflecting the addition of larger, older fish, which are in relatively low numbers in the current samples.

3.3 Reproduction: sex ratio, maturity, fecundity and spawning

3.3.1 Age at maturity

The Group agreed to adopt the following definitions:

Maturity – histological status of gonads and/or expression of hormone level ratios that indicate a shift from those expressed in young fish.

Spawning - The expression of eggs or sperm into the water column for the purpose of reproduction.

Age of first reproduction/spawning – the youngest age in at which individuals in the population exhibit spawning.

Earliest age at maturity – the youngest age at which individuals in the population exhibit development of gonads and/or expression of hormone level ratios that indicate a shift from those expressed in young fish.

Age to 50% maturity – the age class for which the majority of fish in the population exhibit development of gonads and/or expression of hormone level ratios that indicate a shift from those expressed in young fish.

Age to 50% spawning - the age class for which 50% of fish in the population exhibit spawning.

Age to 100% spawning – The age class at which all fish in the population exhibit spawning.

The Group discussed the pros and cons of some of the techniques currently in use in maturity studies. Histological techniques are useful to identify spawning fish. But, they can't be used to identify mature fish when they are outside their spawning cycle. In contrast, endocrine studies can unambiguously identify fish that are sexually mature, but they can't identify whether a mature fish has spawned or will spawn in the current season (Heinisch et al. submitted). Ideally, some combination of these two techniques along with gonadal somatic indices should be used for maturity/spawning studies. The Group also recommended that a set of standard techniques be agreed upon and be used simultaneously for both stocks to facilitate the comparison of results from both sides of the Atlantic (Knapp et al. submitted). In addition, the Group recommended that studies aimed at developing techniques (e.g., histological markers) that would allow the identification of past spawning activity be pursued.

The Group discussed the current state of knowledge and the factors that could affect the estimation of maturity and spawning at age for both stocks. Among the most important ones is that historically, samples collected to estimate maturity were obtained only from the spawning grounds (i.e., Gulf of Mexico and Mediterranean Sea). As previously discussed by SCRS, samples to estimate maturity should be collected from all portions of the population and not be limited to the spawning grounds. Some maturity studies were conducted for the Western stock using samples obtained outside the Gulf of Mexico (e.g., Goldstein et al. 2007). However, this is not the case for the Eastern Atlantic and Mediterranean stock in recent years/decades and, therefore, the Group recommended that samples of E-BFT outside the Mediterranean be obtained during the spawning season to conduct maturity studies.

Eastern Atlantic and Mediterranean stock

In the case of the Eastern Atlantic and Mediterranean stock, the Group identified other potential sources of bias that can affect the estimation of maturity at age. For example, BFT scientists hypothesize on the basis of electronic tagging that the Mediterranean Sea may have a "resident"[1] population composed of both mature and immature fish in addition to a transient population of mature fish that migrate from the Atlantic into the Mediterranean to spawn. When sampling only on the spawning grounds during the spawning season samples of fully mature fish from the transient population and samples from the resident population with mature and immature fish are combined. This can produce a biased estimate of age at maturity (i.e., increase proportion of mature fish at certain age classes that do not reflect the true proportion in the population).

[1] The interpretation of "resident" bluefin tunas in the Mediterranean Sea (tunas staying more than one year within the Mediterranean) is provided by Di Natale *et al*., 2005 - Bluefin tuna (*Thunnus thynnus* L.) line fisheries in the Italian seas. Old and recent data. ICCAT Coll. Vol. Sci. Pap., 58(4), 2005: 1285-1295.

The GSI can change very quickly in the Mediterranean Sea. Scientists from the IEO (EC-Spain) observed that females kept in traps can go from very low GSI values to high values within a 2 weeks period or less. Similarly, the transition from high to low GSI can also happen quickly (Medina et al. 2002, Goldstein et al. 2007). This particular characteristic makes conducting spawning studies a difficult endeavor. Because a high proportion of the samples collected for maturity studies were obtained during the purse seine or the trap fishing season, the duration of the fishing season can influence the results of the studies. The duration of the fishing season has changed during the past several years and currently is restricted to just one month. As a result, many spawning events that occur outside the purse seine and the trap fishing area and season are being missed or going undetected. This difficulty is exacerbated by the rapid change in GSI explained above where fish could have spawned or are getting ready to spawn, but the physiological stages associated with spawning go undetected.

Another source of bias discussed by the Group is the lack or low number of samples from some known spawning grounds in the Mediterranean Sea. More specifically, the spawning areas in North Africa / Eastern Mediterranean waters have been under sampled for maturity studies, especially in recent years. Scientists from the IEO (EC-Spain) analyzed a small sample (n=21) of female BFT caught by traps in Libyan waters. All analyzed females were of age 3 and 4 and all were fully mature (Tawill et al. 2002). However, this sampling regime also suffers from the potential biases outlined above when sampling only on the spawning grounds during the spawning season.

Currently for the assessment of the Eastern stock, the SCRS assumes a 50% of the population spawns at age 4 and 100% for age 5 and older. This assumption is based on a large body of literature that has shown that mature fish as young as age 3 can be found in the Mediterranean Sea as well as fish sampled within a wide range of spawning areas were 100% mature at age 4 (e.g. Mather et al. 1995, Piccinetti et al. 2012). However, considering some of the potential biases described above, the current assumptions used by the SCRS could be revised particularly taking into consideration that the proportion of fish among the total population that spawn at each age remains uncertain. The Group discussed that CAS data from particular fisheries could be explored as a proxy for the proportion of fish in each age class that spawn. However, there could be multiple maturity schedules according to population structure. Furthermore, this also implies that all spawning grounds are known, while potential spawning areas outside the Mediterranean Sea were suspected by de Buen, 1925 and 1926 and by Mather *et al*., 1995. Taking advantage of the special characteristics of the trap fishery in the area of the Strait of Gibraltar (which is aimed at catching migrating spawners using a non-selective gear), scientists from the IEO (EC-Spain) conducted a preliminary analysis to estimate age of 50% spawning using a size structured catch-curve analysis approach. The samples were collected in May in the trap of Barbate (close to the Strait of Gibraltar, along the Atlantic coast of Spain), so just before the spawning season. The preliminary results placed the age to 50% spawning around 6 yr after estimating age from length using the growth curve developed by Cort (1991) for this migratory component of the Eastern Atlantic stock. Although the approach utilized was simple and used a number of assumptions, the obtained results were considered to be plausible and supported the concern that the age of 50% spawning of the Eastern stock might have been underestimated. . Some participants pointed out the discrepancy between this recent sampling and those obtained by Rodriguez Roda (1967) in the same trap and over several years and expressed concern that the current age of 50% maturity for the Eastern Atlantic and Mediterranean stock is questioned based on these results. The Group recommended that size structured catch-curve analyses or CAS analyses be conducted on other spawning aggregations within the Mediterranean Sea as a tool to better estimate the proportion of spawning fish at age.

Western Atlantic stock

The known spawning areas for bluefin tuna in the Western Atlantic comprise the Gulf of Mexico, Straits of Florida and the Northern Caribbean Sea (Mather et al. 1995; McGowan and Richards 1989, Muhling et al., unpublished data). Unlike for the Mediterranean Sea, bluefin tuna are not found in the western spawning areas year round (Mather et al. 1995). Pelagic longline catch data and electronic tracking data show bluefin tuna in the Gulf of Mexico from November to June, with peak residency in March through May (Block et al. 2005, Galuardi et al., 2006). Currently and for stock assessment purposes, the SCRS assumes age of 100% spawning for western Atlantic bluefin tuna to be age 9 based on the findings of Baglin (1982) and the growth curve developed by Restrepo et al. (2010).

Schirripa (2011) reviewed the available literature on the eastern and western stocks' maturity schedules and potential explanations for the differences between the two. Studies of both direct (i.e.., histology) and indirect (inferred from catch statistics) evidence of spawning were included. Based on histology, maturity estimates for the eastern stock ranged widely, from 50% maturity at 97.5 cm FL and 100% maturity at 130 cm FL to 50% maturity at 140 cm and 100% maturity at >150 cm. Similarly, maturity estimates for the western stock varied widely, from 95.5 cm FL to age 10. Criticisms of the studies were also discussed. The paper also discussed research that found hormonal evidence of maturity for eastern fish as small as 110 cm FL. Two studies that used catch statistics on the Gulf of Mexico spawning ground to evaluate the age of spawning of western bluefin tuna were also reviewed. The author concluded that the reported differences in eastern and western maturity schedules are not implausible, given the geographic, environmental and genetic separation of the two stocks

Analysis of size distribution of fish caught on pelagic longlines in the Gulf of Mexico as well as movement rates of electronically tracked fish has been used to estimate the proportion of fish in each age class that migrate to the Gulf of Mexico, presumably to spawn. There was general consensus among the Group that all fish found in the Gulf of Mexico traveled there for the purpose of spawning, and could therefore be considered spawning adults.

Examining distribution of catch at age from U.S. and Japanese longliners in the Gulf of Mexico, Diaz and Turner (2007) estimated the proportion of spawning bluefin tuna in each age class, with the assumption that there is not significant spawning outside the known spawning region. Diaz (2011) updated the previous analysis for the U.S. pelagic longline catch data alone using the updated growth curve for the Western Atlantic stock of bluefin tuna developed by Restrepo et al. (2010) and concluded that less than 1% of fish in the sample taken from the Gulf of Mexico were less than age 8 and that the age at which the majority of fish in the population spawned was 15.8 years. It was noted that the Japanese longline data from before 1980 contained a larger number of smaller fish (Diaz and Turner 2007) than did the U.S. longline dataset used by Diaz (2011). A possible reason for this is that the U.S. longline fleet is restricted from fishing in Mexican territorial waters, where smaller bluefin tuna have been observed in the catch of Mexican longline vessels targeting yellowfin tuna (Ramirez-Lopez and Abad, 2012). If size segregation exists within the Gulf of Mexico, the Japanese longline fleet, which was not excluded from the Mexican EEZ, may have encountered smaller fish than the U.S. fleet. The Group recommended that the estimates of the proportion of spawning fish in each age class be updated using the Japanese and Mexican longline catch data, and the growth curve developed by Restrepo et al. (2010), as using only the U.S. catch data could underestimate the proportion of spawning bluefin tuna in the youngest age classes. It was also noted that LL is a selective gear towards the larger sizes.

The electronic tagging data of Block et al. (SCRS/2013/091) was also used to calculate the number of tagged fish by age class that were located either within or outside the Gulf of Mexico. Age was assigned at tagging based on length (Restrepo et al. 2010) and fish were "aged" according to time at liberty. According to the growth model for western bluefin tuna developed by Restrepo et al. (2010), the youngest fish observed that entered the Gulf of Mexico was age 10 (Block et al. 2005, Teo et al. 2007). Monthly plots showed that May was the month with the highest number of tracked bluefin tuna present in the Gulf of Mexico. The total distribution of all tracked fish revealed that only a small percentage of 10 year old fish entered the Gulf (0% for November through April, 2.5% in May, 6% in June). For May, the ages at which the majority of fish were found in the Gulf were ages >16 (66% for ages 17 and 19, 80% for age 18 and 100% for ages 20-23). When looking at percentage of tracked fish found in the Gulf of Mexico over all months, the earliest age for which more than 50% of tagged fish was observed to be in the Gulf of Mexico was age 15 (55%) and the earliest age for which all fish were observed to have been in the Gulf of Mexico was age 22. Although the dataset was much smaller, the results obtained from the tagging data corresponded well with those reported by Diaz (2011) for Gulf of Mexico catch records.

In separate psat tagging studies for adult bluefin released from the Gulf of Maine and Southwest Nova Scotia, Canada, 2001-2010, (e.g., Wilson et al. 2005, Sibert et al. 2006, Galuardi et al. 2010), less than half of the individuals > 185 cm CFL retaining tags through the presumed spawning period in the northern Gulf of Mexico entered the Gulf. Those that did (n= 22) entered in Nov (1), Dec-Jan (6), Feb-March (12), Ap-June (3) (Lutcavage et al., SCRS/2012/157).

The Group also discussed the possibility that mature fish skip spawning. Although the sample size was limited, using tagging data Teo et al. (2007) and Block et al. (2005) did not find evidence that Western Atlantic BFT fish might skip spawning. Although the Group agreed that the results of the mentioned studies cannot be considered as conclusive evidence that fish do not skip spawning, there was a general agreement that skipped spawning might be more common in the younger age classes (Rideout et al.,2006; Goldstein et al., 2007). Based on somatic condition of large blefin tuna (e.g., 185 cm CLF) leaving NW Atlantic feeding grounds (e.g., Estrada et al. 2005, Goldstein et al. 2007, Golet et al. 2007), reproduction profiles in other tunas (Schaeffer et al., 19XX) and bluefin tuna life history modeling (Chapman et al. 2011), skipped spawning is predicted to be less likely to occur in larger fish, at least, based on energetic status (Heinisch et al. *submitted*).

Evidence from dispersal patterns of tagged bluefin tuna released from New England and Canadian foraging grounds (n=126 , 150-185 cm CFL) with PSATS showed that most of the individuals retaining tags until the following April-June (20/36) did not enter the Gulf of Mexico. Consistent with historical observations (e.g,, Mather et al.,1995), and based on spatial and environmental information, the authors predicted that some BFT may spawn elsewhere, possibly in late winter or spring, near the Gulf Stream margin, (Lutcavage et al., (SCRS/12/157; and in prep).. Dispersal patterns exhibited by sexually mature BFT are consistent with life history models predicting that smaller/younger fish should reproduce in areas closer to foraging grounds than larger individuals (Chapman et al. 2011), similar to patterns documented for Pacific bluefin tuna (Itoh et al. 2006).

Knapp et al. (submitted) used stereological analysis of ovarian tissue to identify similarities and differences in spawning frequency, fecundity, and spawning periodicity of fish sampled from the Gulf of Mexico and the Mediterranean Sea. Atlantic bluefin tuna sampled on eastern and western spawning areas exhibited the same spawning duration (three months), but that spawning in the northern Gulf of Mexico occurred one month earlier than in most of the Mediterranean Sea. Sampled BFT showed a lower spawning frequency in the Gulf of Mexico than in the Mediterranean Sea (<50% and 60%, respectively), while fecundity (59 eggs g^{-1}) was consistent with fish sampled in the Mediterranean Sea (48.22 eggs g^{-1}).

Heinisch et al. (submitted) used histological and endocrine analyses to investigate the sexual maturation status in 93 ABFT (134-292 cm curved fork length, CFL) sampled on NW Atlantic foraging grounds off New England and Nova Scotia and in seventeen young of the year (YOY) off Virginia. There was a lack of physiological differences among small andlarge BFT. Partially spent testes and lipid stage oocytes were found in BFT of all sizes >134 cm CFL, indicating that spawning during the previous or the next reproduction season was possible. The ratio of follicle stimulating hormone (FSH) over luteinizing hormone (LH) ratios detected in BFT >134 cm CFL (<0.4), are similar to Mediterranean spawners, indicating that western BFT considerably smaller than the current assumed size at first maturity (≥185 cm CFL), are likely mature. Heinisch et al. (submitted) also found further evidence for asynchronous reproduction behavior in "giant" females BFT (221–292 cm CFL) landed off Nova Scotia in September-October, where pituitary LH secretion could be the outcome of a recent spawning event. This is the first study to integrate endocrine and histological approaches to define maturity in western BFT sampled off the spawning grounds beyond the known spawning season. Combined results from endocrine analysis and histology results do not match the spawning schedules currently assumed for western BFT.

While it cannot be ruled out that additional spawning areas exist outside of those already identified in the Western Atlantic, catch at age data and electronic tracking data do not support the notion that the majority of the population of bluefin tuna spawn in the Gulf of Mexico before age 15. However, The results presented by Heinisch et al. (submitted), that indicated that fish as young as 5 yr old are sexually mature, suggest that these younger fish: 1) spawn in unknown areas outside the Gulf of Mexico, or 2) although they are sexually mature they do not spawn until reaching older ages.

Fecundity

For stock assessment purposes, having information on the average per capita number of eggs produced by each age class is of utmost importance. Ideally, this is estimated as the product of batch fecundity (average number of eggs produced when a fish spawns) and batch frequency (average number of times a fish spawns). If spawning frequency does not change with the age, then one can substitute percent of fish spawning at age for spawning frequency at age. Similarly, if batch fecundity is proportional to total weight, then one can substitute weight at age for batch fecundity at age. The product of percent of fish spawning and weight at age is then a measure of the *relative* per capita number of eggs produced by each age class, which when multiplied by the number of fish in each age class is usually referred to as the spawning biomass.

For the Eastern stock, Aranda et al. (2012) showed an exponential relationship between ovarian volume and length with a value for the parameter a = 0.0009 and an exponent value b = 2.9586 (which in turn corresponds to a linear relationship with weight) and they also concluded that ovarian volume and fecundity are linearly related (potential fecundity = 1920.4 x ovarian volume – 0.59 $X10^{-6}$). Aranda's et al. study (2012) was conducted with a relatively small sample size (n=49) collected over 3 years and not all the data seems to fit the relationship well. Medina et al. (2002), also for the Eastern stock, provided information on the number of oocytes per gram of body mass for different development stages and estimated batch fecundity for females spawning in the Balearics to be 92.8 oocytes per body gram. Extensive studies on fecundity and correlation between body weight and length and gonads were conducted in the past, over larger samples (Rodriguez Roda, 1967). For Western bluefin tuna, Baglin (1982) reported on estimates of number of eggs by (estimated) weight and by length but a fecundity function was not estimated from the data (see Table below). The Group recognized the importance of identifying proper fecundity functions to reduce assessment uncertainties and biases. Furthermore, the Group discussed that wrong assumptions on stock fecundity can have a higher impact on assessment results than underestimating/overestimating age of maturity by 1-2 years. The Group agreed that, given the current state of knowledge on fecundity, a linear relationship between fecundity and weight seems to be an appropriate assumption for stock assessment purposes. But, given the potential impact of using the wrong fecundity assumptions, the Group also recommended that more fecundity studies be conducted to confirm if a linear relationship between fecundity and weight (as it is currently assumed to be by SCRS) is a correct assumption or if new functions should be adopted for use in future stock assessments.

Body length (cm)	Estimated body weight (kg)	Dry weight of eggs (g)	Gono-somatic index (%)	Estimated no. of eggs >0.46 mm diameter (millions)	Estimated no. of eggs >0.32 mm diameter (millions)
205	156	1,260	5.3	13.6	32.7
222	[1]188	696	2.1	16.7	22.7
229	217	1,202	3.1	24.2	46.4
229	217	2,177	5.0	55.5	96.0
229	217	1,481	2.8	33.9	64.4
231	224	1,330	4.4	26.8	41.1
236	[1]197	1,329	3.2	28.4	40.3
236	[1]189	1,404	3.2	29.6	44.7
238	246	1,788	4.1	39.0	63.9
238	246	1,703	4.2	40.1	64.5
238	246	1,796	3.8	34.4	61.7
241	254	1,483	3.4	29.8	62.4
241	254	2,436	4.8	48.0	84.9
241	[1]247	1,560	3.9	33.0	44.0
244	263	1,750	3.6	25.2	56.7
244	263	1,452	3.4	23.2	42.1
244	263	2,121	5.0	49.3	93.3
252	289	2,770	4.7	39.6	94.6
254	298	1,942	2.9	41.6	76.0
—	307	1,681	2.5	32.0	59.2
256	307	1,950	2.6	42.2	79.5
257	[1]232	1,200	2.9	24.3	33.8
257	309	750	1.9	16.2	26.2
259	316	2,750	4.2	32.6	76.9
259	316	2,500	4.4	48.8	80.6
261	[1]272	1,488	2.6	31.4	42.3
262	[1]324	2,593	4.5	57.6	81.6
269	[1]284	1,950	4.6	40.6	74.8
$\bar{X}$ 243	255	1,734	3.7	34.2	60.3
SE 2.78	8.37	102.79	0.18	2.15	4.04

[1]Actual weight determined.

Length, weight, and gonadal data for 28 female western Atlantic bluefin tuna from the Gulf of Mexico and the Florida Straits collected during April, May, and June 1967, 1968, 1974, 1975, 1976, and 1978. The mean and standard error of the mean are given at the bottom of the columns. Table taken from Baglin (1982).

Sex ratios

Document SCRS/2013/083 reported on sex ratios estimated from data collected by BFT farms in the Mediterranean Sea that have been submitted to the Secretariat since 2008. This document showed that although there seems to be some variability on the sex ratio by size, the differences were non-significant and a 1:1 sex ratio can be assumed. The results presented seem to contradict those presented by Aranda et al. (2012) that showed significantly divergences from the 1:1 sex ratio at different size ranges. However, a closer examination of the results from both studies showed that document SCRS/2013/083 highlighted divergences, albeit non-significant, in the 1:1 sex ratio in size ranges that were very similar to those where Aranda et al. (2012) found their significant differences. For the western Atlantic stock information on sex ratios is not widely available. However, Beerkircher et al. (2009) reported that slightly more females (60%) than males were observed in the catches of spawning BFT by the U.S. pelagic longline fleet operating in the Northern Gulf of Mexico. Baglin (1982) also estimated some sex ratios by month and size categories and found some significant divergences from a 1:1 sex ratio. However, Baglin (1982) did not provide detailed information on the size ranges at which those discrepancies occurred.

3.4 Natural mortality

The WG examined the conclusion of document SCRS /2013/077 discussing the values of the natural mortality rate at age (M) that could be used in future BFT stock assessments. While natural mortality is clearly a parameter of paramount importance in most tuna stock assessments, it remains today one of the least well-estimated parameters in most tuna fishery models. In the case of Atlantic BFT, it can be noted concerning this parameter that the levels and trends of age specific natural mortality used by SCRS during recent years have been widely different in the Eastern & Western Atlantic, as shown by **Figure 22**.

It appears that there are little or no scientific justification to explain why such a migratory stock, that is showing very similar growth curves in the Eastern & Western Atlantic, would show such large differences in the natural mortality east & West of the quite artificial 45°W line. It was further noted by the WG that the assumption of constant M with age had long been regarded as biologically implausible, but was retained in assessments of the western stock to maintain a consistent basis for monitoring its recovery under the rebuilding plan.

It was concluded by the WG that future stock assessment analysis of BFT should be based on a common best vector of M at age used in the entire Atlantic. Earlier work suggested that the available tag and recovery data were insufficient to estimate the level of Mi, however additional data from recent conventional and electronic tagging studies may make this possible. This prospect of data analysis should be carefully studied.

Four indirect series of natural mortality at age (Mi) were examined and discussed by the WG (**Figure 23**):

1) SBT Mi, as the one presently assumed in the Eastern Atlantic (SCRS/1998/022)
2) Mi estimated by the Lorenzen 1996 method
3) Mi estimated by the Gislason et al 2010 method
4) Mi estimated by the Watanabe method (Chen & Watanabe 1989)

The differences in the levels and trends of the Mi vectors estimated by the Gislason and Lorenzen or Watanabe methods are easily noticed, but the uncertainties in the results of each method appear to be quite limited under the presently accepted very similar growth curves accepted in the Western (Restrepo) and Eastern Atlantic (Cort).

All these vectors of Mi show a declining trend towards their lower asymptotic levels of natural M suffered by the adults at levels close to 0.075 (Lorenzen & Gislason) or 0.10 (SBT and Watanabe Mi). None of these 4 Mi displays an increasing trend after 1st spawning, as it has been often assumed various stock assessment of tropical tunas (yellowfin & bigeye). It should also be noted that, while the levels of natural mortality estimated for the adults are very similar for these 4 vectors of Mi, they are quite different for the juveniles. The estimates of M at age 0 to 2 by the Gislason method are much higher than the levels estimated by the 3 other sources. It can be noted that these high levels of M at age 0 estimated by the Gislason method are in agreement with the preliminary estimate of1.6 for M0 that has been estimated by Japanese tagging on Pacific BFT. (Iwata et al 2012).

The current stock assessment method VPA assumes a plus group of 10. However, recoveries of tagged bluefin have been observed after more than 10 years and there is no doubt that bluefin individuals can live to much older ages (e.g. Secor, SCRS/2008/084; Fromentin and Fonteneau 2001). As populations recover, the dynamics of the plus group will have an increasingly important effect on the assumed productivity of the stock, estimates of reference points and stock projections used in the Kobe advice framework. For example: do processes such as natural mortality at age increase Chen and Watanabe (1989), or slowly decrease with age (Lorenzen, 1996).

It was envisaged by the WG that the hypothesis of Natural mortality increasing for old bluefin, as in Chen & Watanabe 1989, for instance due to the large energy invested in spawning (per & post spawning migration, gonad maturation) and to a biological senescence of old fishes due to ageing and the cumulative negative factors faced by older bluefin (increased parasites, accidental hooks, accumulated injuries in fins due to fisheries, increased distances travelled in migrations, etc).

It was recommended by the WG that this potential increase of natural mortality of older BFT should be studied in future GBYP work.

The basic uncertainties in the diferent M vectors investigated during the WG should be better analyzed before making a final choice to be used in the next stock assessment, for instance better taking into account the uncertainties in BFT growth and longevity.

3.5 Population structure and stock mixing: otolith microchemistry, genetics, tagging, stock-age key tables

Review of State of Knowledge

3.5.1 Mediterranean Population

Tagging and fisheries data support migratory and resident components in the Mediterranean Sea. The migratory group appears to principally originate from reproduction in the Western and Central portions of the Mediterranean. Spawners in the Eastern Mediterranean Sea likely constitute a separate sub-population that may have had connections to the historical Black Sea population.

3.5.1.1 Migratory Component

Young Migrants

Some age-0 and age-1 juveniles depart the Western Mediterranean Sea (e.g., Balearic region) and use waters off Morocco in winter and then move to North Atlantic nursery areas (e.g., Bay of Biscay) during summer.

Based on similar oceanography, environmental conditions, and production, the shelf waters off Morocco and Northeast Atlantic provide equivalent habitats for foraging age-0 and age-1 juveniles.

Older Migrants

From age 2, some minor fraction of migratory juveniles enters Western stock management units, but the dominant fraction occupies the Northeast Atlantic Ocean (Rooker et al. 2008; Busawon et al. 2013) and recent data obtained under the GBYP.

Adults (age 4+) are intercepted on spawning migrations from the North Atlantic to the Mediterranean Sea in historical trap fisheries. Very strong seasonal cycle of entrance (April to May) and departure (late June-July) from the Mediterranean are observed in the historical trap data and correspond to the period of known spawning. Trap data also shows strong cycles in abundance at both decadal and centennial scales (Ravier and Fromentin 2001).

Electronic tagging supports spawning migrations into the Mediterranean from regions throughout the North Atlantic. Adults of this migratory group principally occupy the Western Mediterranean Sea, presumably to spawn. Electronic tagging shows little evidence of this migratory component in the Eastern Mediterranean Sea.

Historical information (Norwegian hooks) indicate incidence of a North Atlantic migratory component in spawning areas of the Western and Central Mediterranean (Sella 1929; Genovese 1959). Natural tags (cookie cutter shark bites) also support incidence in this region by the migratory component.

Range

The migratory component occurs throughout North Atlantic, Canadian and US waters. There is no evidence of this component within the Gulf of Mexico. Historical analysis suggests that the Brazilian component was not connected with Mediterranean population (Fromentin et al. submitted).

3.5.1.2 Resident Components

Residency within the Mediterranean Sea

Genetics and electronic tagging support two dominant resident components in the Western-Central region and Eastern region of the Mediterranean Sea, but natal homing or spawning fidelity to specific spawning regions remains undocumented.

Resident behavior by Mediterranean bluefin tuna is supported by their incidence in small scale fisheries, such as the hand line fishery (Di Natale *et al*., 2005), throughout the year.

Electronic tagging suggests seasonal homing to foraging areas that could underlay lifetime residency within the Mediterranean Sea.

Sub-populations within the Mediterranean Sea

Whether sub-population structure underlies residency in the Mediterranean Sea remains unknown.

Spawner size and spawn dates vary between Western, Central, and Eastern Mediterranean Sea but these do not show separation that would be consistent with sub-population differentiation. Spawner sizes are often mixed in the same spawning aggregation.

Age-0 and age-1 juveniles are distributed throughout the Mediterranean Sea, but show patchy distribution. The largest area of age-0 juvenile concentration occurs in the Central Mediterranean Sea; smaller concentrations occur elsewhere in Eastern and Western Mediterranean Sea. Age-0 concentrations show evidence of being discrete through genetics and otolith chemistry (Rooker et al. 2003).

Hypotheses specific to resident components in the Mediterranean Sea

Juveniles show discrete spatial ranges within the Mediterranean Sea, which underlay possible population structure.

Eastern Mediterranean Sea might have harbored the spawning habitat for the historical Black Sea population. Recolonization of the Black Sea would depend on bluefin tuna originating from the Eastern Mediterranean Sea.

The Black Sea may have supported reproduction and a separate sub-population (Mather et al. 1995). Adults have been captured during the last part of the spawning season in the Black and Azov Seas (McKenzie and Patrizio 2012), but conditions may be too cold for egg and larval survival.

3.5.2 Gulf of Mexico Population

Evidence for a separate western population of Atlantic bluefin include incidence of larvae, a size structure that indicates a very different age at maturation than the Mediterranean population, and conventional tagging (Fromentin and Powers 2005). Electronic tagging, otolith microchemistry, natural tracer studies, and genetics strongly support the premise of a Western Atlantic population, which is discrete from the Mediterranean population (Carlsson et al 2007; Boustany et al 2008; Rooker et al. 2008). However, similar to the Mediterranean population, the Gulf of Mexico population could include separate components with unique spawning and migration behaviors.

3.5.2.1 Separation from the Mediterranean population

Natural markers, genetics, and differing size structure of spawners are all consistent with view of separate spawning populations between Gulf of Mexico and Mediterranean Sea. Mediterranean and Gulf of Mexico spawners show very high levels of natal homing (>90%) to these broad centers of origin (Rooker et al. 2013; Secor et al. 2013a).

Tagging and fisheries data support the premise that the Gulf of Mexico is a unique spawning habitat. PSAT tags mostly show individual occupancy of ~2 mo., with bluefin occurring from November through June. Early winter entry by some fish could suggest a protracted spawning season or a separate migratory component (e.g. Eastern

v. Western Gulf of Mexico contingents). Catch records also show incidence of Atlantic bluefin tuna during winter months.

The significance of early season spawning should be investigated further through larval surveys and habitat suitability modeling.

No electronically-tagged adult has visited both the Gulf of Mexico and the Mediterranean Sea.

3.5.2.2 Separate sub-populations:

Recently documented catches of bluefin tuna in the southwestern Gulf of Mexico include a greater proportion of small fish (110-180 cm CFL) than has been observed in the Northern Gulf of Mexico (Ramirez and Abad 2013). Further study is required, but this could suggest a component with unique migration and/or different spawning behaviors.

3.5.2.3 Range

In efforts to document movements of Gulf of Mexio-origin fish, individuals have been assigned to the Gulf of Mexico population based on whether they were tagged in the Gulf of Mexico or later visited the Gulf of Mexico after being tagged elsewhere (Block et al. 2005; Walli et al. 2009). Such fish move into Northwest, Central Atlantic, and Northeast Atlantic. The predominate destination for Gulf of Mexico fish is the Northwest Atlantic. A few fish from Northwest Atlantic (Canada) show evidence of moving seasonally towards the Northeast Atlantic.

Historical analysis of long-line and oceanographic data suggests that some contingents of fish could have migrated between Gulf of Mexico and Brazil and subsequently disappeared because of oceanographic change and possible overfishing (Fromentin et al., submitted).

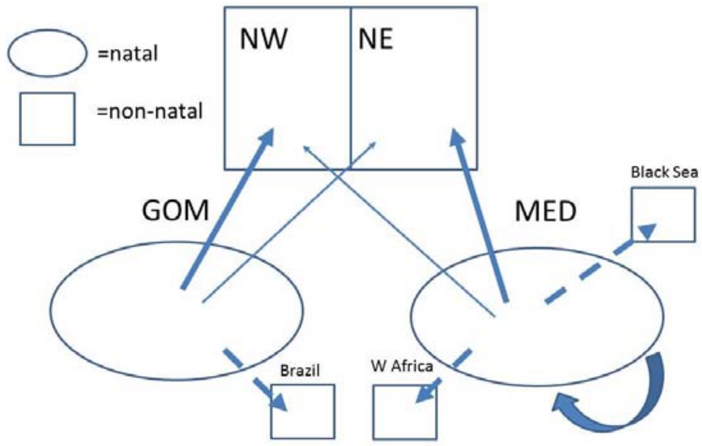
3.5.3 Other population Structures

Pacific bluefin tuna show an interesting population structure that could be considered an alternative population structure for Gulf of Mexico and Mediterranean populations. Pacific bluefin tuna spawn across latitudes (Taiwan to Sea of Japan) with small spawners showing increased propensity to use the Sea of Japan and larger ones using more southern spawning locations (Itoh 2006). Some have suggested that a similar structure could be applied in the Western Atlantic.

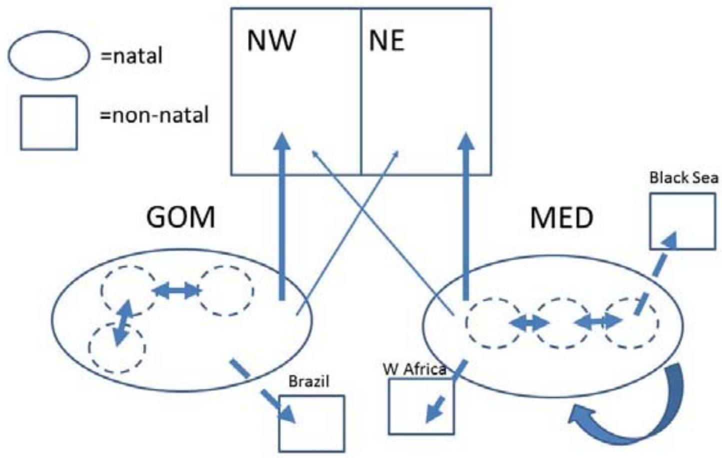
Concepts of Population Structure – Diagrams

Scientists have proposed a range of population structures for Atlantic bluefin tuna. The diagrams below show population structures that depend on self-reproducing entities (populations and sub-populations) and groups with similar lifetime migration behaviors, which do not necessarily depend on reproductive isolation (contingents). These population structures are not exhaustive: for instance, one could conceive of combinations of sub-populations and contingents within the same structure. The intent here is to provide principal population structures and challenge them with existing data.

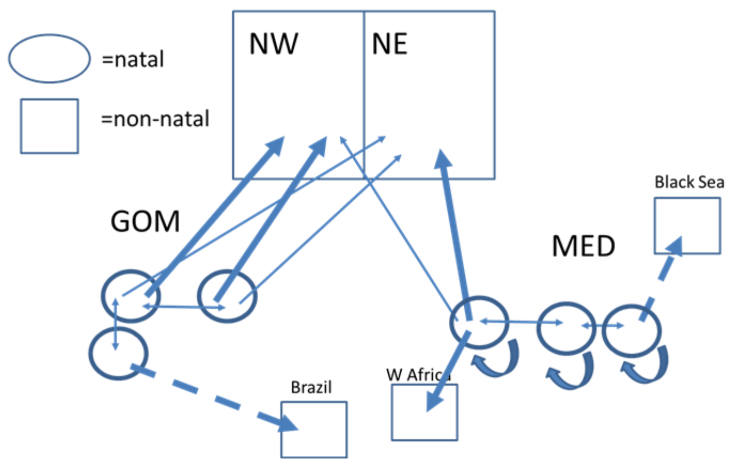
Two Population Model with No Sub-populations



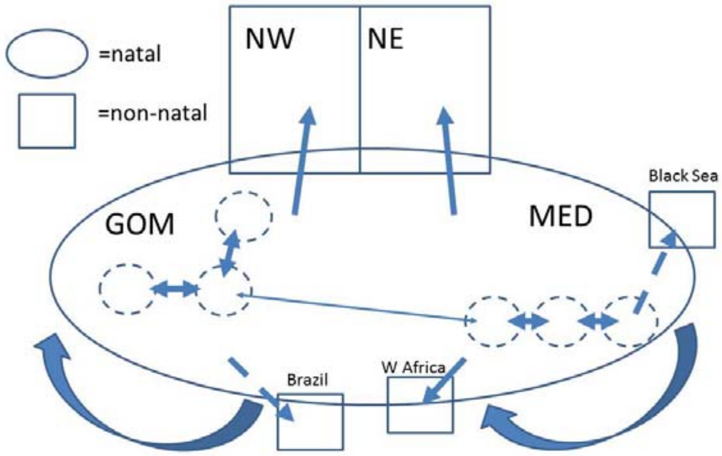
Two Population Model with Contingents



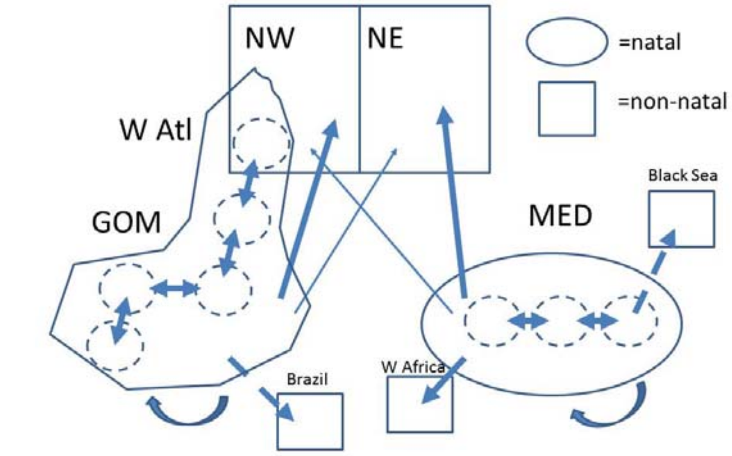
Metapopulation Model



Panmictic Population with Some Patchiness



Extended W. Atl. Two Population Model w Contingents



Approaches for Evaluating Population Structure

Approaches that address population structure include molecular markers, otolith chemistry, contaminants, "natural tags," and electronic tags. Movements and mixing are most precisely evaluated through tagging data, but natural tags can also convey information on regional movements. Tracers of population structure, principally genetic and otolith chemistry approaches, vary substantially in how past spatial historypopulation structure is represented.

Molecular Approaches

In the past 15 years, several molecular techniques have been exploited in an effort to elucidate a more accurate depiction of Thunnus thynnus population structure and dynamics in line with the results developed by electronic tagging campaigns and traditional ecological knowledge. The sophistication and resolution of these techniques is evolving and recent results are showing great potential for adding clarity to this elusive issue that has interfered with the optimal management of the species (**Table 14)**.

The earliest evidence of differentiation between Atlantic and Mediterranean populations came from Alvarado Bremer et al. (1999), who genotyped Atlantic bluefin tuna (ABFT) using the mitochondrial DNA control region (mtDNA CR); although, the effectiveness of this marker was called into question when a later study was unable to differentiate samples collected from multiple years (Ely et al. 2002). Subsequent studies utilizing allozyme analysis failed to distinguish populations (Ely et al. 2002; Pujolar 2003). Differentiation of populations within the Mediterranean was first revealed using molecular markers in 2004, when Carlsson et al. genotyped a collection of young-of-the-year ABFT using the mtDNA CR and microsatellites. Since then, various studies have both supported population differentiation of the Gulf of Mexico and the Mediterranean (Carlsson et al. 2005; Boustany et al. 2008) as well as within the Mediterranean (Carlsson et al. 2005; Riccioni et al. 2010); albeit with rather low FST values when compared to other marine species (Waples 1998). Conversely, other studies have failed to reveal the same population structuring using the same molecular techniques (Alvarado Bremer et al. 2005; Viñas et al. 2011). Albaina et al. (2013) are the first to characterize population structure between the western Atlantic and the East Atlantic/Mediterranean using single nucleotide polymorphisms (SNPs); a relatively novel marker showing much potential for efficiency, affordability and capacity. The 17 SNPs used in their study produced the most significant evidence for differentiation of populations to date. However, due to the limited number of samples used in their study it is necessary that its potential for population assignment is sufficiently validated before large scale applications are conducted. (See Appendix X for detailed records of all previous ABFT genetic analyses).

Currently, within the ICCAT-GBYP project a panel of SNPs is being developed via Reduced Representation Sequencing and Genotyping (RRSG) a Next Generation Sequencing (NGS) technology. The ultimate goal of this endeavor is to resolve population structure of ABFT and to develop a SNP panel capable of population assignment that can be utilized by the various qualified parties within ICCAT. This will have direct applicability to stock assessments as well as commercial traceability. In the future, individual SNPs could be assigned to genes associated with selective pressures, thereby highlighting functional differences between populations or contingents of ABFT. Thus SNPs derived from this project may also reveal information concerning the influence of environmental factors on survivalship of recruits within the same population.

The preliminary data analyses carried out in GBYP-Phase 3 on a total of 555 ABFT individuals, focused mainly on larvae and young-of-the-year samples from spawning sites, revealed a limited number high performance SNPs capable of identifying and differentiating at least three ABFT spawning populations (GOM, WMED, EMED), which are genetically clustered and temporally stable. Current GBYP genetics work is focused on completing the analysis of 1332 samples from throughout the species range already sequenced as well as validation of a reduced panel of SNPs (48-192 plex). Due to the complexity and quantity of the RRSG-generated genomic data obtained for the ABFT (i.e. a genomic data-poor non-model fish exhibiting a complex and partially unresolved ecology and biology), various additional analyses are required to fine tune SNP selection/validation for traceability and management purposes, in order to provide sound scientific findings to support ICCAT ABFT management actions in the near future. Within the GBYP framework, results from SNP panel genotyping and population structure analysis are expected during 2013 and 2014 calendar years. Therefore it is reasonable to expect that data developed during this large scale and comprehensive project will be available for stock assessment activities in 2015.

Otolith Stable Isotopes

Otolith stable isotope tracers represent physical environments experienced by young bluefin tuna. Stable differences occur between principal nursery systems for Atlantic bluefin tuna in measured isotopes, consistent differences reflected in >10 years of juvenile samples (Secor et al. 2013 b,c). Baseline samples of juvenile bluefin tuna from either nursery system show overlap but are sufficiently distinct to permit classification of unknown samples to nursery (natal) areas. An important assumption is that juveniles do not undertake transoceanic migrations during their first year of life. This approach has been developed in several peer-reviewed papers and cross-laboratory training to EU, Canadian, and U.S. scientists now allows production-level processing of otoliths to support stock structure analysis. The approach requires more labor (otolith removal and processing) and analytical costs on a per-sample basis than molecular approaches such as the use of SNPs, but is now in an application phase. It expected that prior to the 2015 assessment, mixing level estimates isotopes will be available for principal Atlantic tuna fisheries based on analysis of >4000 otoliths (see **Table 15**).

Contaminant tags

Contaminant tags function as a “diet tag” conveying information on recent trophic and growth history. Organochlorine ratios (trans-nonachlor/PCB 153, cis-nonachlor/PCB 187; Dickhut et al., 2009) are a particularly effective way of utilizing regional differences in contaminant sources to evaluate movements, but the approach requires that regional baselines are established. Particularly large differences exist between the Western North Atlantic and Mediterranean organochlorine ratios to allow recent migrants to be detected between these two regions. For young fish movements or lack of movements (residency) have conformed to expectations of trans-oceanic migrations by age 2-3 fish (Dickhut et al., 2009). Operationally, this is the most expensive of the reviewed approaches, but provides unique information related to recent (~≤1 year) movement histories. Currently the approach can provide critical corroboration of results from other approaches such as genetics or otolith stable isotopes. Future developments could allow organochlorine ratios to be applied to age-specific movements between broad ocean regions, although regional signals are likely forced by seasonal and inter-annual climate and oceanographic forcing

Electronic Tags

Electronic tracking technologies (e.g. archival tags, acoustic tags, satellite tags) have been utilized within many studies (Lutcavage et al. 1999, Block et al. 2001, Block et al. 2005, Teo et al. 2005, De Metrio et al. 2005, Boustany et al. 2008, Walli et al. 2009, Stokesbury et al. 2007, 2001, Wilson et al. 2005, Wilson et al. 2009, Lawson et al. 2010, Galuardi et al. 2010, Fromentin 2010, Galuardi et al. 2012) throughout the Eastern and Western Atlantic, Gulf of Mexico, and Mediterranean to examine bluefin temporal and spatial dynamics (Fromentin and Powers, 2005). Many of these findings have been enhanced through the integration of genetic analyses (Boustany et al., 2008), otolith microchemistry (Rooker et al. 2008), and fisheries data (Diaz et al. 2006) to infer population structure and to advance the development of spatially structured stock assessment models (Taylor et al. 2011). Electronic tracking with archival tags has revealed repeated migrations by multiple individuals to spawning habitats within the Gulf of Mexico and the Mediterranean Sea, indicating spawning fidelity (Block et al. 2005) and individual migrations into both regions have not been observed. The tracking data supports a multiple of population structure hypothesis in the Atlantic and adjacent seas, with distinct spawning populations within the Mediterranean Sea and the Gulf of Mexico. Genetics data from tagged fish also supports the multiple-population hypothesis (see Molecular Approaches above). Additional tagging data will further elucidate the ‘border’ between these populations. Recent Mediterranean Sea tracking data presented since 2009 and during this meeting by G. Quilez-Badia et al. and JM Fromentin indicate a high level of residency in the Western Basin, with some movement into the Central Basin (see also Medina et al. 2011; Tudela et al. 2010; Fromentin 2010, Quilez-Badia et al. 2013), but no connection (thus far from tracking data) to the Eastern Basin. . Unexpected movements in the central-eastern Atlantic during the spawning season have been also detected by GBYP tagging activities (Quilez-Badia *et al*. 2013). More tag deployments within specific regions of the Gulf of Mexico (NE, NW, SW areas) will further refine knowledge about intra-Gulf bluefin movements and behaviors and substantiate ongoing genetics research to elucidate population structure.

4. Incorporation of data collected and/or recovered into the ICCAT databases

The procedure to follow to incorporate new available information on fishery statistics to the ICCAT data bases is under item 2.1.

5. Recommendations

Research Recommendations

Task II and biological data

- The Group recommends to check and to validate all farms data as indicated in the report and then to introduce these data in the CAS of the Mediterranean BFT, so that this considerable source of information can be used in the 2015 stock assessment.

- In order to better understand the potential biases and uncertainty associated with the CAA, the group continues to recommend further analyses on the methodology used to compute CAA. A simulation framework including the sampling process and a range of alternative methods to convert CAS into CAA is suggested. This simulation framework can be integrated into the MSE framework in the future, and would allow better identifying and ranking the different sources of uncertainty (sampling vs. modeling) with respect to the management advice.

- The Group recommends continuing the analysis of VMS data to get a better estimates of the spatial and temporal variations in the fishing effort of the main fleets and to obtain an index of abundance of the Mediterranean PS fleet through state-space modeling. For that purpose, the Group also recommends that VMS data be provided at the highest temporal resolution (1 hour or less) possible.

Size conversions

- The Group recommends using updated size conversion algorithms that are based on more recent and more extensive datasets for the 2015 stock assessment.

Age conversions:Recommendations for Future Work

- The Group noted that there are continuing problems in obtaining calcified structures and (especially otoliths) samples in certain markets, as there is resistance to physically damaging the valuable fish during the sampling process. One method to overcome this is to launch an education campaign among buyers and processers that promotes the concept that a sampled fish has contributed to science and conservation efforts. A program such as this was initiated for southern bluefin tuna, and has been successful (Anon. 2002). The Group also noted that after consideration of minimum sample sizes required for construction of age-length keys, the SCRS should consider requesting the Commission to include minimum sampling levels for hard parts in the next management recommendation that is adopted.

- The Group discussed the importance of hard part reference collections. Such collections can be an invaluable tool for quality control and training purposes, and are routinely used by labs conducting age determinations (Jerald 1983, Kimura and Anderl 2005, Campana 2001). It was also noted that additional institutions have stated their intent to contribute age determinations, but they wish to ensure that their interpretations are consistent with those already developed by SCRS scientists. The Group recommends the provision of a common reference collection to assist institutions with such efforts.

- The Group recommends the development of conventions for production age determination. Examples include the number of agers involved with interpretations, birth date assumptions, use of fractional ages based on either month or multiple ages, use of precision thresholds for excluding interpretations.

- Given the observation that both otoliths and spines contribute useful information to age interpretations, the SCRS could develop an approach for age assignment using both otoliths and spines, possibly weighting the contribution of the two hard parts by the variance of the mean age at length, or by the readers' relative confidence in the age determination.

- In advance of the 2015 assessment, a compilation of available hard parts and age determinations (**Table 12**) should be circulated to labs participating in age and growth studies, with a request to review and update. A completed version of this table would be a useful aid to planning sampling efforts.

- Given the intent of the SCRS to develop assessment approaches that are more reliant on age-structured information, continued investment in biological sampling and age and growth remains a high priority.

- It is recommended that methods be developed for disaggregating eastern fish from the western catch at age.

- The Group recommends further analyses of tag-recovery data for estimating growth and variability in growth among individuals and through time.

- In preparation for the next stock assessment, the Group recommends an analysis of the tradeoffs between combining ALKs over several years to accommodate under-represented size classes (particularly larger fish) and annual ALKs (which better capture variations in year-class strength).

- In order to better understand the potential biases and uncertainty associated with the CAA used in stock assessment, the group recommends further analyses on the methodology used to compute CAA. A simulation framework including the sampling process and a range of alternative methods to convert CAS into CAA is suggested. This simulation framework can be integrated into the MSE framework in the future (e.g. as an observation error model) and would allow to better identify and rank the different sources of uncertainty (sampling vs. modeling) with respect to the management advice. It will also help specify processes in statistical catch-at-age models

Reproduction

- The Group recommends to revise the current maturity schedules assumed for stock assessment for both the eastern and western stocks, using the spawning ogives, and to determine a comprehensive maturity ogive for the western Atlantic.

- The Group recommends to conduct sampling for reproductive samples (e.g., histology, GSI, FSI, etc) and larval samples for western Atlantic bluefin across their range, especially in areas not well sampled, such as pelagic Atlantic (i.e., longline regions), from late Feb. through July in order to examine whether bluefin reproduction occurs in the Atlantic beyond the Gulf of Mexico.

- The Group recommends examining the utility of using data from other larval sampling programs (eg MARMAP) to test for the presence of larval bluefin tuna in areas outside the currently identified spawning areas.

- The Group recommends agreeing upon a set of standard histological and endocrine techniques to be used simultaneously for both stocks to facilitate the comparison of maturation schedules on both sides of the Atlantic and to develop methods (e.g., histological markers) that will allow the identification of past spawning activity.

- The Group recommends obtaining samples of E-BFT outside the Mediterranean during the spawning season to conduct maturity studies and to use size structured catch-curve approaches and CAS analyses to explore spawning schedules for different fisheries in the Mediterranean Sea.

- The Group recommends updating the Diaz (2011) estimate of the proportion of spawning fish in each age class in the Gulf of Mexico using the Japanese and Mexican longline catch data, and the Restrepo et al. (2011) western BFT growth curve.

- The Group recommends conducting more fecundity studies to confirm if a linear relationship between fecundity and weight is a correct assumption or if new functions should be adopted for use in future stock assessments. Attempt to secure the Medina et al. (2002, 2007) dataset to incorporate in this effort.

Natural Mortality

- The Group recommends using alternative natural mortality vectors for both the Eastern and Western stocks for the 2015 stock assessment. This vector should be the same for all Atlantic BFT stocks. Further investigations need to be made, according to incoming data (such as tagging). The M vector estimated from Lorenzen (1996)'s method is recommended as being the best working hypothesis, but estimates based on the Gislason et al (2010)'s hypothesis should also be considered.

- Active and explicit biological investigations on BFT natural mortality should be recommended and preferably included in the GBYP in order to better estimate the BFT natural mortality at age (for instance analyzing the tagging/recovery data) or to study the potential ageing & senescence of BFT.

Population structure and mixing

- Given that a more complex population Structure than currently assumed is likely, the Group recommends to start to test the effects of such a structure on the scientific advice during the 2015 stock assessment.

- The 2015 assessment is planned to be a milestone for the SCRS, as it is anticipated that significant new information concerning stock mixing will be available, and new modeling approaches incorporating mixing will be undertaken. The Group highlighted data that will be available from molecular and otolith stable isotopes (**Tables 14** and **15**). However efforts to assemble similar information on electronic and conventional tags was far more complex due the greater number of investigators involved, the lead role of academic and NGO groups have played, and diverse objectives for these studies. To help inform the process, the Group recommends that once the modeling requirements for the 2015 assessment are established, that a call for electronic and conventional tagging data be issued to all parties conducting such research on Atlantic bluefin tuna. In the case of electronic tagging, and to avoid concerns that sharing such data might compromise publication possibilities, the Call should identify that the data requested include:

1) the date, location, and size of all tags released during the study
2) the date, location, and size (or age) of all recoveries during the study
3) where applicable, the duration of time spent within a X by X degree square
4) where applicable, the stock of origin as deduced by genetics or otolith microchemistry

6. Other matters

6.1 Revision of other available data (e.g., VMS)

The ICCAT VMS system for the Eastern bluefin tuna fleet has been fully operational since 2008. A preliminary analysis of the 2010-2011 VMS information concluded that it is possible to estimate a probability of effective fishing effort given an identification of the main gear-fleet by vessel (SCRS/2012/125). The analyses and review of the VMS data indicated that given the main gear, there are identifiable differences in the variables of vessel speed, time at sea and overall fishing behavior between the longline, pole and line and purse seine fleets. These variables can be used to identify fishing trips and estimate effective fishing effort. It has been recommended that validation be done with auxiliary information such logbooks or reports from observers at board. Furthermore, it has been recommended, in the case of bluefin tuna to link individual vessel operations with the bluefin catch documentation (BCD) files to associate individual fishing effort and the associated catch and size distribution of the catch.

6.2 Proposal for the development of an operating model for use in MSE

The GBYP Steering Committee (SC) reviewed in its 2013 December meeting a multi-year workplan, including objectives, time lines and deliverables, for the modeling work. As part of this work plan the SC recommended that a group be formed under the SCRS to help develop an operating model. This group should work in advance to this meeting and should present the results at a 3 day GBYP meeting to be held after this meeting with the objective of developing specifications for the operating model.

For different reasons the preparatory work was not made in advance to the meeting and consequently the three days meeting will be used to conduct the preparatory work. Hence, the work on the Operating Model design would now be conducted in advance of the Boston BFT SCRS meeting with the participation of BFT SCRS scientists.

7. Adoption of the report and closure

The report was adopted.

The Chairman thanked the participants for their hard work.

The meeting was adjourned.

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Table 1. SCRS documents relating GBYP data (Inventory.xlsx, in the sharepoint)

DocN	Subject
SCRS/2011/015	Trap fisheries
SCRS/2011/036	Tap fisheries iconography
SCRS/2011/037	Trap fisheries
SCRS/2011/038	Trap fisheries
SCRS/2011/039	Trap fisheries data
SCRS/2011/110	Population structure
SCRS/2011/152	Historical distribution, arctic ocean
SCRS/2011/166	GBYP coordination
SCRS/2012/029	Catch curve analysis
SCRS/2012/030	Length based indicator
SCRS/2012/038	Historical growth data
SCRS/2012/116	Size frequency samples
SCRS/2012/125	VMS, effort
SCRS/2012/139	GBYP coordination
SCRS/2012/140	Aerial survey
SCRS/2012/141	Catch, size, historical data
SCRS/2012/142	South Atlantic
SCRS/2012/143	Pop-up tagging
SCRS/2012/149	Reproduction
SCRS/2012/186	Projections
SCRS/2013/073	Catch, size, historical data
SCRS/2012/083	Catch, size, historical data

Table 2 Eastern Atlantic bluefin catalog of data existing in the ICCAT data bases.

Bluefin East_Atlantic Stock unit

Species	Stock	Status	FlagName	GearGrp	Values	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	2011	Rank
					Year	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	2011	
					NC	19,272	23,087	31,616	30,287	28,142	33,381	22,522	27,478	26,475	19,238	19,145	21,253	23,763	9,030	10,284	10,861	9,331	10,564	4,686	5,768	5,972	4,761	4,733	4,687	6,071	9,971	5,120	6,921	5,799	4,767	4,211	3,259	6,702	8,152	7,395	4,807	4,687	4,456	6,951	5,433	6,040	6,556	7,619	9,367	6,930	9,650	12,663	13,539	11,376	9,628	10,528	10,086	10,347	7,362	7,410	9,036	7,535	8,037	7,645	6,684	4,379	3,984	
					Ztop10	18129.92	21363.26	28881.8	29120.04	26484.54	31064.56	21475.475	25447.57	25852.14	17409.77	18609.8	20779.96	23393.29	8854.05	10237.05	10807.75	9297.73	10507.88	4483.01	5567.675	5700.31	4557.78	4605.475	4624.48	5830.66	9640.744	5012.358	6389.619	5133	3614.035	4024.883	3107.444	6492.107	7863.835	7086.75	4497.753	4174.172	4013.448	6445.613	4998.42	5732.611	6197.215	6594.69	8136.862	5982.772	8640.259	10862.4	11165.04	9596.25	7843.642	8563.299	8584.38	9283.217	6674.77	6742.032	8084.271	5903.592	7430.749	7311.217	6327.905	4172.287	3788.059	
					%Ztop10	94%	93%	91%	96%	94%	93%	95%	93%	98%	90%	97%	98%	98%	98%	100%	100%	100%	99%	96%	97%	95%	96%	97%	99%	96%	97%	98%	92%	89%	76%	96%	95%	97%	96%	96%	94%	89%	90%	93%	92%	95%	95%	87%	87%	86%	90%	86%	82%	84%	81%	81%	85%	90%	91%	91%	89%	78%	92%	96%	95%	95%	95%	
BFT	ATE	CP	EU.España	TP	t1	6764	4508	4858	7750	6397	7242	7744	9200	8000	4800	5700	4700	4700	1800	2500	3200	1400	3000	1100	1900	1500	600	250	504	13	448	490	339	450	600	700	787	1916	1862	2271	1630	891	939	2389	1174	1911	1040	1271	1244	1136	941	1207	2723	1525	2005	1416.324	1239.9	1548.4	749.82	862.44	880.45	819.755	1348.322	1194.255	1209.166	887.375	901.908	1
BFT	ATE	CP	EU.España	TP	t2																																																															1
BFT	ATE	CP	Norway	PS	t1	2199.92	6728.26	14751.8	10217.04	12144.54	13393.56	5313.475	6436.565	3860.14	3240.77	4214.8	8552.96	8730.29	167.05	1461.045	2505.75	999.73	2014.88	753.01	841.675	470.31	652.78	430.475	421.48	868.66	988	529	764	221	60	282	161	50	1	243		31													5													2
BFT	ATE	CP	Norway	PS	t2																																																															2
BFT	ATE	CP	EU.España	BB	t1	996	1086	1424	1192	979	1417	1338	1604	1526	1021	645	546	572	635	676	1199	1723	945	1084	1292	2285	2375	2292	2602	1635	1923.448	1418.747	2207.32	2813.812	1748.845	1215.411	952.351	650.634	1419.374	1679.811	1620.532	1113.781	1229.781	1427.892	1663.549	1313.932	996.564	768.562	3281.199	1694.243	2386.396	4594.554	2939.917	2016.605	1216.842	1728.579	2167.937	2410.372	1239.39	1735.316	2011.98	1065.132	1902.813	1726.906	1197.419	641.434	562.408	3
BFT	ATE	CP	EU.España	BB	t2																																																															3
BFT	ATE	CP	Japan	LL	t1								33	2	56	481	204	2484	1618	582	404	50	100	13	2	21	157	240	44	2195	2900	1973	1594	577	630	880	515	2573	2609	1514	420	739	900	1169	838	1464	2981	3350	2484	2075	3971	3341	2905	3195	2690	2895	2425	2536	2695	2015	2598	1896	1612	2350.58	1903.978	1155.286	1088.824	4
BFT	ATE	CP	Japan	LL	t2																																																															4
BFT	ATE	CP	Maroc	TP	t1							3347	5784	7961	5378	3714	1377	3648	2318	2256	1882	1601	1331	635	59	286	63	122	1	7			222			6	72	393	94				166	101	235	304	323	482	94	387	494	210	699	1240	1615	852	1540	2330	1670	1305	1098	1518	1744	2417	1909	1348	1055	5
BFT	ATE	CP	Maroc	TP	t2																																																																5
BFT	ATE	CP	EU.France	BB	t1	1869	2893	2362	2364	3451	3031	1453	1550	1303	2031	553	907	965	543	400	621	1624	860	390	534	732	680	740	540	522	692	267	592	723	275	260	153	150	400	566	380	272	533	479	306	367	448	372	164	66	181	310	134	282	270	91.1	105	150	130	47	50.224	127.61	67.487	62.15	83.094			6
BFT	ATE	CP	EU.France	BB	t2																																																															6
BFT	ATE	CP	Maroc	PS	t1									2539		2286	2994	1628	1419	2059	906	1778	2048	453	678	406	30	531	512	590	2624	331	662	36	206	155	105	600	187	127	86	122				54	46	462	24	213	458	323	828	692	709	660	150	884	490	855	871	179						7
BFT	ATE	CP	Maroc	PS	t2																																																															7
BFT	ATE	CP	Maroc	UN	t1	4800	4800	3400	4900	2300	4800																																																									8
BFT	ATE	CP	Maroc	UN	t2																																																															8
BFT	ATE	CP	EU.Portugal	TP	t1	1501	1348	2086	2697	1213	1181	2280	840	661	883	1016	1499	666	354	303	90	122	209	55	261																										1	15	19	45	2	40.1	15.4	16.9	27	17.654	9.451	24.562	22.6	24.39	46.192	57.098	179.919	9
BFT	ATE	CP	EU.Portugal	TP	t2																																																															9
BFT	ATE	CP	EU.España	TR	t1																										65.296	3.611	9.299	312.188	94.19	526.472	362.093	159.473	1291.461	685.939	361.221	839.391	310.667	745.721	712.871	299.679	203.651	277.128	552.663	304.529	491.863	372.841	376.12	225.645	93.8	192.196	151.143	67.545	38.56	111.622	195.39	124.919	0.404	0.599				10
BFT	ATE	CP	EU.España	TR	t2																																																															10
BFT	ATE	CP	EU.Denmark	UN	t1	817.722	1267.11	2112.534	800.28	897.75	1126.548	464.778	614.574	226.746	792.072	48.222	147.744	155.952	3.078	44.118	23.444	2	15	8	1	1	2	1	3	1	2	1	3	0.348	1	2	1	0.37	0.13	0.013	37	0.002	0.015	1		0.13	0.013		37		0.002	0.015		1														11
BFT	ATE	CP	EU.Denmark	UN	t2																																																														11
BFT	ATE	CP	EU.Germany	UN	t1	230	235	305.748	314.982	664.848	1095.768	569.43	1319.436	389.88	1002.402	445.284	293.436	199.044																																																		12
BFT	ATE	CP	EU.Germany	UN	t2																																																															12
BFT	ATE	CP	EU.France	TW	t1																																							100	22	101	70	441	436	224	400		57	259	247	393.8	456	599	518.1	26		730.879	500.895	179.83	295.168	121.702	28.421	13
BFT	ATE	CP	EU.France	TW	t2																																																															13
BFT	ATE	CP	EU.España	HL	t1																												300	450	998	38	70	12															162	28	33	125.593	61.2	62.5	109.04	87.232	11.31	4.238	10.41	6.283	1.977	20.938	18.937	14
BFT	ATE	CP	EU.España	HL	t2																																																															14
BFT	ATE	CP	Libya	LL	t1																																											312				576	477	511	450							47						15
BFT	ATE	CP	Libya	LL	t2																																																															15
BFT	ATE	NCC	Chinese Taipei	LL	t1																			138	114	46	12	2	1	12	5	3	2		3	5	6	16	2	3	15.6	196.8	20.4		109.2				6	20	8	61	226	350	222	144	304	158			10	4						16
BFT	ATE	NCC	Chinese Taipei	LL	t2																																																															16
BFT	ATE	CP	EU.Portugal	LL	t1																																										99	4	4	8		97	246	18	403.6	397.6	383.4	160.149	32.785	1.27	62.928	71.186	5.602	12.028	5.476			17
BFT	ATE	CP	EU.Portugal	LL	t2																																																															17
BFT	ATE	CP	EU.Portugal	BB	t1																									191	303	24	14	56.191	10	24.364	17.116	30.64	53	15.3	3	28	58	29.1	1	12		0.1	1.931	219.375	34	80	447	251.862	5.2	1.979	2.157	6.7	1.464	7.79	6.14	0.215	1.09					18
BFT	ATE	CP	EU.Portugal	BB	t2																																																															18
BFT	ATE	CP	EU.France	GN	t1																																							145	31	42	47	74	497	21	144	253	3	72	71	56.6	68	6										19
BFT	ATE	CP	EU.France	GN	t2																																																															19
BFT	ATE	CP	Panama	LL	t1																								3			69	208	156	14	117	48	12		17	22	11	4							1	19	550	255		1													20
BFT	ATE	CP	Panama	LL	t2																																																														20
BFT	ATE	CP	EU.France	UN	t1																																								101					25			75							263	818	188.545		5.447		18.861		21
BFT	ATE	CP	EU.France	UN	t2																																																															21
BFT	ATE	CP	EU.Sweden	UN	t1	94	222	316	52	95	94	12	96	6	34	42	13	15								4	3				2	8	2	2			1		1								1																					22
BFT	ATE	CP	EU.Sweden	UN	t2																																																															22
BFT	ATE	NCO	NEI (Flag related)	LL	t1																																										85	144	223	68	189	71	208	66														23
BFT	ATE	NCO	NEI (Flag related)	LL	t2																																																															23
BFT	ATE	CP	China P.R.	LL	t1																																																	85	103	79.6	68.1	39.1	19.3	41	23.695	42	72	119	41.7	38.22	35.929	24
BFT	ATE	CP	China P.R.	LL	t2																																																															24
BFT	ATE	CP	Maroc	SU	t1																																		84	44			255	202	147																							25
BFT	ATE	CP	Maroc	SU	t2																																																															25
BFT	ATE	CP	Korea Rep.	LL	t1																							19	43	36	15	3	2		1				3		77									4	205	92	203			5.573	0.5		0.081	3.151		1						26
BFT	ATE	CP	Korea Rep.	LL	t2																																																															26
BFT	ATE	CP	Norway	LL	t1												19				30	31	41	57	85	207	85																																									27
BFT	ATE	CP	Norway	LL	t2																																																															27
BFT	ATE	CP	Libya	PS	t1																																																			486.5												28
BFT	ATE	CP	Libya	PS	t2																																																															28
BFT	ATE	CP	EU.España	LL	t1																										3				100		6	104	12	7	16	20			15	32	32							5	8.414	3.3	3.8	0.4	1.24	3.911	2.55	18.464	14.035	9.569				29
BFT	ATE	CP	EU.España	LL	t2																																																															29
BFT	ATE	CP	EU.France	PS	t1																																																							223		152.8						30
BFT	ATE	CP	EU.France	PS	t2																																																															30
BFT	ATE	CP	EU.Portugal	SU	t1																																	10	47	16	25	41	102	18	0.2	14	18	34	19	12	0.1			8	0.1	1.2	2.8	2.7						0.017	1.283	0.075	0.334	31
BFT	ATE	CP	EU.Portugal	SU	t2																																																															31
BFT	ATE	CP	EU.España	SU	t1														173																			15	2	158		12																										32
BFT	ATE	CP	EU.España	SU	t2																																																															32
BFT	ATE	CP	Guinée Conakry	UN	t1																																													330																		33
BFT	ATE	CP	Guinée Conakry	UN	t2																																																															33
BFT	ATE	CP	Maroc	LL	t1																																																						2	8	16	273	1.242					34
BFT	ATE	CP	Maroc	LL	t2																																																															34
BFT	ATE	NCO	Faroe Islands	LL	t1																																																	67	104	118												35
BFT	ATE	NCO	Faroe Islands	LL	t2																																																															35
BFT	ATE	CP	EU.France	TR	t1																								11											36	110	76							2																0.021	0.36	0.401	36
BFT	ATE	CP	EU.France	TR	t2																																																															36
BFT	ATE	CP	Sierra Leone	LL	t1																																																			92.62	118.344											37
BFT	ATE	CP	Sierra Leone	LL	t2																																																															37
BFT	ATE	CP	EU.Portugal	PS	t1																																		74	3		123.2								0.02									0.014			0.694			0.437	0.624		38
BFT	ATE	CP	EU.Portugal	PS	t2																																																															38
BFT	ATE	CP	EU.Poland	UN	t1																						100	100																																								39
BFT	ATE	CP	EU.Poland	UN	t2																																																															39
BFT	ATE	CP	Maroc	GN	t1																																									31	3	6	4	13	10	13		34	30	28	17	11										39
BFT	ATE	CP	Maroc	GN	t2																																																															39
BFT	ATE	CP	EU.France	LL	t1																																											7												2		95.154	0.631		8.926		32.193	41
BFT	ATE	CP	EU.France	LL	t2																																																															41
BFT	ATE	CP	EU.Ireland	TW	t1																																																	16	49.86	20	6.34	15	3	1.476	0.95	2.323	0.484	0.873	1.045	2.15	4.39	42
BFT	ATE	CP	EU.Ireland	TW	t2																																																															42
BFT	ATE	NCO	NEI (ETRO)	UN	t1																																			6	3	4		5	6	74	4																					43
BFT	ATE	NCO	NEI (ETRO)	UN	t2																																																															43
BFT	ATE	CP	EU.France	HL	t1																																																													4.115	73.503	44
BFT	ATE	CP	EU.France	HL	t2																																																															44
BFT	ATE	CP	EU.Portugal	HL	t1																														25				0.4		0.839	1.162	2.808	1	2	1																						45
BFT	ATE	CP	EU.Portugal	HL	t2																																																															45
BFT	ATE	CP	Iceland	LL	t1																																																	1	27			1.133										46
BFT	ATE	CP	Iceland	LL	t2																																																															46
BFT	ATE	CP	EU.Germany	TW	t1																					14	1	6	2					1	1		2																															47
BFT	ATE	CP	EU.Germany	TW	t2																																																															47
BFT	ATE	CP	EU.España	UN	t1																																											2		2					3	7.937	9.1											48
BFT	ATE	CP	EU.España	UN	t2																																																															48
BFT	ATE	CP	EU.Ireland	LL	t1																																																14	2	0.96													49
BFT	ATE	CP	EU.Ireland	LL	t2																																																															49
BFT	ATE	CP	Panama	PS	t1																																																		12													50
BFT	ATE	CP	Panama	PS	t2																																																															50
BFT	ATE	CP	Cape Verde	BB	t1																																		10	1																												51
BFT	ATE	CP	Cape Verde	BB	t2																																																															51
BFT	ATE	CP	EU.United Kingdom	LL	t1																																																0.401		10													52
BFT	ATE	CP	EU.United Kingdom	LL	t2																																																															52
BFT	ATE	CP	EU.Portugal	TW	t1																																															7																53
BFT	ATE	CP	EU.Portugal	TW	t2																																																															53
BFT	ATE	CP	EU.España	GN	t1																																			2				4																								54
BFT	ATE	CP	EU.España	GN	t2																																																															54
BFT	ATE	CP	EU.Ireland	GN	t1																																																	3	1.2	0.4	1.23											55
BFT	ATE	CP	EU.Ireland	GN	t2																																																															55
BFT	ATE	CP	EU.Greece	TR	t1																																	5																														56
BFT	ATE	CP	EU.Greece	TR	t2																																																															56
BFT	ATE	CP	U.S.A.	PS	t1																																	5																														56
BFT	ATE	CP	U.S.A.	PS	t2																																																															56
BFT	ATE	CP	EU.United Kingdom	TW	t1																																																	1	2	0.42			0.27			0.003			0.561			58
BFT	ATE	CP	EU.United Kingdom	TW	t2																																																															58
BFT	ATE	CP	Iceland	TW	t1																																																	1													2.062	59
BFT	ATE	CP	Iceland	TW	t2																																																															59
BFT	ATE	CP	Japan	BB	t1															3																																																60
BFT	ATE	CP	Japan	BB	t2																																																																60
BFT	ATE	CP	EU.Ireland	TR	t1																																																			2							0.16					61
BFT	ATE	CP	EU.Ireland	TR	t2																																																			a							a					61
BFT	ATE	NCO	Seychelles	LL	t1																																																					1.635										62
BFT	ATE	NCO	Seychelles	LL	t2																																																					-1										62
BFT	ATE	CP	EU.United Kingdom	GN	t1																																														1	0.146	0.341		0.067													63
BFT	ATE	CP	EU.United Kingdom	GN	t2																																														-1	-1	a		-1													63
BFT	ATE	CP	Norway	TW	t1																																																												0.3				64
BFT	ATE	CP	Norway	TW	t2																																																												ab				64
BFT	ATE	CP	EU.Portugal	UN	t1																																													0.23																		65
BFT	ATE	CP	EU.Portugal	UN	t2																																													a																		65
BFT	ATE	CP	EU.United Kingdom	TN	t1																																																											0.012				66
BFT	ATE	CP	EU.United Kingdom	TN	t2																																																											-1				66

Table 3 Eastern Atlantic bluefin catalog of data recovered under GBYP (F: Fishing operation (only catch); CE: Catch and effort; S: Size; F + S : catch + size; CE + S: CE + size.

Bluefin East_Atlantic Stock unit

Year	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
NC	19,272	23,087	31,616	30,287	28,142	33,381	22,522	27,478	26,475	19,238	19,145	21,253	23,763	9,030	10,284	10,861	9,331	10,564	4,686	5,768	5,972
Ztop10	18129.92	21363.26	28881.8	29120.04	26484.54	31064.56	21475.475	25447.57	25852.14	17409.77	18609.8	20779.96	23393.29	8854.05	10237.05	10807.75	9297.73	10507.88	4483.01	5567.675	5700.31
%Ztop10	94%	93%	91%	96%	94%	93%	95%	93%	98%	90%	97%	98%	98%	98%	100%	100%	100%	99%	96%	97%	95%

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
NC	4,761	4,733	4,687	6,071	9,971	5,120	6,921	5,799	4,767	4,211	3,259	6,702	8,152	7,395	4,807	4,687	4,456	6,951	5,433	6,040
Ztop10	4557.78	4605.475	4624.48	5830.66	9640.744	5012.358	6389.619	5133	3614.035	4024.883	3107.444	6492.107	7863.835	7086.75	4497.753	4174.172	4013.448	6445.613	4998.42	5732.611
%Ztop10	96%	97%	99%	96%	97%	98%	92%	89%	76%	96%	95%	97%	96%	96%	94%	89%	90%	93%	92%	95%

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
NC	6,556	7,619	9,367	6,930	9,650	12,663	13,539	11,376	9,628	10,528	10,086	10,347	7,362	7,410	9,036	7,535	8,037	7,645	6,684	4,379	3,984
Ztop10	6197.215	6594.69	8136.862	5982.772	8640.259	10862.4	11165.04	9596.25	7843.642	8563.299	8584.38	9283.217	6674.77	6742.032	8084.271	5903.592	7430.749	7311.217	6327.905	4172.287	3788.059
%Ztop10	95%	87%	87%	86%	90%	86%	82%	84%	81%	81%	85%	90%	91%	91%	89%	78%	92%	96%	95%	95%	95%

Yes GBYP	Species	Stock	Status	FlagName	GearGrp	Values	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	2011	Rank
1	BFT	ATE	CP	EU.España	TP	t1	6764	4508	4858	7750	6397	7242	7744	9200	8000	4800	5700	4700	4700	1800	2500	3200	1400	3000	1100	1900	1500	600	250	504	13	448	490	339	450	600	700	787	1916	1862	2271	1630	891	939	2389	1174	1911	1040	1271	1244	1136	941	1207	2723	1525	2005	1416.324	1239.9	1548.4	749.82	862.44	880.45	819.755	1348.322	1194.255	1209.166	887.375	901.908	1
1	BFT	ATE	CP	EU.España	TP	t2																																																															1
1	BFT	ATE		EU.España	TP	GBYP		F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F					
1	BFT	ATE	CP	Norway	PS	t1	2199.92	6728.26	14751.8	10217.04	12144.54	13393.56	5313.475	6436.565	3860.14	3240.77	4214.8	8552.96	8730.29	167.05	1461.045	2505.75	999.73	2014.88	753.01	841.675	470.31	652.78	430.475	421.48	868.66	988	529	764	221	60	282	161	50	1	243		31													5													2
1	BFT	ATE	CP	Norway	PS	t2																																																													2
1	BFT	ATE		Norway	PS	GBYP	S	S	S	S	S																																																									

Table 4 Mediterranean bluefin catalog of data existing in the ICCAT data bases.

Bluefin East_Med Stock unit

Year	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
NC	5,597	5,708	5,354	7,042	6,710	6,232	4,900	6,838	6,395	5,454	4,815	5,614	4,794	6,460	6,295	5,997	5,326	8,744	7,933	8,690	4,694	6,195	5,954	6,051	13,056	11,241	17,073	11,797	8,846	7,456	10,039
Ztop10	3857	3609	2945	4771	4198	3690	3379	4392	4541	3311	2554	2895	2499	2860	3313	2299	3521	5668	6080	6953	3354	5114	5479	5412	12520	10778	16386	11110	8247	6819	9151
%Ztop10	69%	63%	55%	68%	63%	59%	69%	64%	71%	61%	53%	52%	52%	44%	53%	38%	66%	65%	77%	80%	71%	83%	92%	89%	96%	96%	96%	94%	93%	91%	91%

Year	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	2011	2012
NC	10,515	15,706	13,650	17,032	17,203	14,560	13,764	17,167	15,628	17,207	19,872	24,230	24,901	39,810	37,640	38,144	33,616	28,342	22,828	23,238	24,519	23,424	23,801	23,971	26,810	23,154	26,479	16,205	13,066	6,949	5,790	133
Ztop10	9091	13377	11715	11525	12520	9967	9407	11717	9838	11539	13356	17978	19689	26449	24293	26583	24525	21118	14443	15923.57	16902.1	17387.2	16992.2	16826.95	20273.6	18507.85	20415.34	10643.3	9793.028	4451.182	4216.653	0
%Ztop10	86%	85%	86%	68%	73%	68%	68%	68%	63%	67%	67%	74%	79%	66%	65%	70%	73%	75%	63%	69%	69%	74%	71%	70%	76%	80%	77%	66%	75%	64%	73%	0%

Species	Stock	Status	FlagName	GearGrp	Values	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
BFT	MED	CP	EU.France	PS	t1																	1000	1500	2500	1500	1100	2200	1100	1400	1800	1600	3800	3182	1566	1527	1701
BFT	MED	CP	EU.France	PS	t2																															
BFT	MED	CP	EU.Italy	PS	t1			722	476	592	555	366	239	217	164	116	349	332	1256	990	301	630	1088	691	1828	1203	1336	2783	2700	6000	6270	9607	5431	4663	3705	6120
BFT	MED	CP	EU.Italy	PS	t2																															
BFT	MED	CP	Turkey	PS	t1																															
BFT	MED	CP	Turkey	PS	t2																															
BFT	MED	CP	EU.Italy	TP	t1	2200	1978	1044	2007	1752	1589	1560	2571	2736	1823	1229	1423	1280	1227	1652	1264	945	1949	1739	1324	961	1044	835	367	739	713	650	698	210	195	152
BFT	MED	CP	EU.Italy	TP	t2																															

Species	Stock	Status	FlagName	GearGrp	Values	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	2011	2012	Rank
BFT	MED	CP	EU.France	PS	t1	2300	4818	3600	3570	5400	3460	4300	5750	4404	4663	4570	7346	6965	11803	9494	8547	7701	6800	5907	6779.6	6119	5810	5549.4	6339	8328.4	7437.598	9543.488	2536.428	2917.963	1545.691	677.638		1
BFT	MED	CP	EU.France	PS	t2																																	1
BFT	MED	CP	EU.Italy	PS	t1	5704	6442	5552	5382	4522	4789	2579	2229	2345	2651	2652	3846	4162	4654	3613	7060	7068	3334	1859	2801.114	3255.828	3245.517	3848.7	3751.6	3960.93	4006.145	4310.851	1853.514	2339.383		752.155		2
BFT	MED	CP	EU.Italy	PS	t2																																	2
BFT	MED	CP	Turkey	PS	t1					41	69	972	1343	1707	2059	2459	2817	3084	3466	4219	4616	5093	5899	1200	1070	2100	2300	3300	1075	990	806	918	879.165	665.445	409.377	527.532		3
BFT	MED	CP	Turkey	PS	t2																																	3
BFT	MED	CP	EU.Italy	TP	t1	209	155	284	327	295	293	310	301	301	279	263	364	199	182	241	297	154	419	308	352.524	426.55	364.122	144.819	118.7	69.43	125.315	93.054	148.562	143.94	280.835	164.747		4
BFT	MED	CP	EU.Italy	TP	t2																																	4

Table 5 Mediterranean bluefin catalog of data recovered under GBYP (F: Fishing operation (only catch); CE: Catch and effort; S: Size; F + S : catch + size; CE + S: CE + size.

Bluefin East_Med Stock unit

Year	NC	Ztop10	%Ztop10
1950	5,597	3857	69%
1951	5,708	3609	63%
1952	5,354	2945	55%
1953	7,042	4771	68%
1954	6,710	4198	63%
1955	6,232	3690	59%
1956	4,900	3379	69%
1957	6,838	4392	64%
1958	6,395	4541	71%
1959	5,454	3311	61%
1960	4,815	2554	53%
1961	5,614	2895	52%
1962	4,794	2499	52%
1963	6,460	2860	44%
1964	6,295	3313	53%
1965	5,997	2299	38%
1966	5,326	3521	66%
1967	8,744	5668	65%
1968	7,933	6080	77%
1969	8,690	6953	80%
1970	4,694	3354	71%
1971	6,195	5114	83%
1972	5,954	5479	92%
1973	6,051	5412	89%
1974	13,056	12520	96%
1975	11,241	10778	96%
1976	17,073	16386	96%
1977	11,797	11110	94%
1978	8,846	8247	93%
1979	7,456	6819	91%
1980	10,039	9151	91%
1981	10,515	9091	86%
1982	15,706	13377	85%
1983	13,650	11715	86%
1984	17,032	11525	68%
1985	17,203	12520	73%
1986	14,560	9967	68%
1987	13,764	9407	68%
1988	17,167	11717	68%
1989	15,628	9838	63%
1990	17,207	11539	67%
1991	19,872	13356	67%
1992	24,230	17978	74%
1993	24,901	19689	79%
1994	39,810	26449	66%
1995	37,640	24293	65%
1996	38,144	26583	70%
1997	33,616	24525	73%
1998	28,342	21118	75%
1999	22,828	14443	63%
2000	23,238	15923.57	69%
2001	24,519	16902.1	69%
2002	23,424	17387.2	74%
2003	23,801	16992.2	71%
2004	23,971	16826.95	70%
2005	26,810	20273.6	76%
2006	23,154	18507.85	80%
2007	26,479	20415.34	77%
2008	16,205	10643.3	66%
2009	13,066	9793.028	75%
2010	6,949	4451.182	64%
2011	5,790	4216.653	73%
2012	133	0	0%

Year	BFT MED CP EU.France PS t1	1 BFT MED CP EU.Italy PS t1
1950		
1951		
1952		722
1953		476
1954		592
1955		555
1956		366
1957		239
1958		217
1959		164
1960		116
1961		349
1962		332
1963		1256
1964		990
1965		301
1966	1000	630
1967	1500	1088
1968	2500	691
1969	1500	1828
1970	1100	1203
1971	2200	1336
1972	1100	2783
1973	1400	2700
1974	1800	6000
1975	1600	6270
1976	3800	9607
1977	3182	5431
1978	1566	4663
1979	1527	3705
1980	1701	6120
1981	2300	5704
1982	4818	6442
1983	3600	5552
1984	3570	5382
1985	5400	4522
1986	3460	4789
1987	4300	2579
1988	5750	2229
1989	4404	2345
1990	4663	2651
1991	4570	2652
1992	7346	3846
1993	6965	4162
1994	11803	4654
1995	9494	3613
1996	8547	7060
1997	7701	7068
1998	6800	3334
1999	5907	1859
2000	6779.6	2801.114
2001	6119	3255.828
2002	5810	3245.517
2003	5549.4	3848.7
2004	6339	3751.6
2005	8328.4	3960.93
2006	7437.598	4006.145
2007	9543.488	4310.851
2008	2536.428	1853.514
2009	2917.963	2339.383
2010	1545.691	
2011	677.638	752.155
2012		
Rank	1	2

Table 6 Number of fishing operations recovered under the GBYP by flag, gear and fishing ground.

FlagVess	Gear	FishingGroundg	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2010
MAR	HL	Gibraltar Strait										341	1551	
EU.ESP	BB	Bay of Biscay					17	23224	12022	4473	653	305		
		Senegal												3
	BB&TR	Bay of Biscay				11364	15466	6760	5942	1716	1100			
	TR	Bay of Biscay	9	10	96	155	140							
EU.ITA	GN	Tyrrhenian Sea										119	409	
	HL	Tyrrhenian Sea										66	24	
	HP	Tyrrhenian Sea								22	38	76	44	
	LL	Ionian sea											3	
		Strait of Sicily										204	998	233
		Tyrrhenian Sea										2	7	
	PS	Strait of Sicily											55	
		Tyrrhenian Sea										68	119	

Table 7 Yearly numbers of BFT measured at killing in the farms, estimated total weight of this sample at catching (assuming for all tunas a farming duration of 5 months) and corresponding average weight estimated at catching.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
Total number of tunas sampled for size in farms	630	2156	5132	7841	37864	32483	26555	13898	16465	698	143722
Weight of sampled catches (at fishing date)	81	335	976	1405	3600	2988	3179	1357	1760	75	15756
Average Weight of sampled catches in kg (at fishing dates)	129	156	190	179	95	92	120	98	107	108	110
% of PS catches weight sampled	0,5	1,8	4,3	7,0	15,7	23,6	27,9	27,2	40,8		16,0

Table 8. Eastern Atlantic L-W data

	SFL	CFL
GBYP	42658	0
Tunisia and Malta	170	6849
Japan LL	13121	0
Moroccan Trap	0	178
Rodriguez-Marin et al. 2013	54549	11
New Malta	0	1969
Arena	1658*	0
Grand totals	110498	7038

* not used in model fitting

Table 9. Western Atlantic L-W data

Dataset	1: straight fork length	2: curved fork length	Total
CAN_marifs		7855	7855
US GOLET and Lutcavage		488	488
USPLLOBS	509	12	521
CAN_GSL		8288	8777
Mexico LL			755
ICCAT Tagging			547
JLL	3186		3186
US dealer			*
Grand Total	3695	16643	22129

* identified as existing but not available for the meeting

Table 10. Data exclusions

	Number of outliers (for SFL data)	Exclusions	Totals
GBYP	48		48
Tunisia and Malta	0		0
Japan LL	93		93
Moroccan Trap	0		0
Rodriguez-Marin et al. 2013	77		77
New Malta	0		0
Arena		1658*	1658
Grand totals	218	1658	110498

* not used in model fitting

Table 11. Final parameter estimates for L-W models

	intercept	slope
MED	-10.162271	2.857753
ATL	-10.139701	2.855380

Table 12. Ctalog of hard parts over the recent period 2010-2013.

West							Sanpled			
Stock	**Country**	**Year**	**Agency**	**Area Sampled**	**# Fish sampled**	**Contact**	**Otoliths**	**Spines**	**Vertebrae**	**Size range (CFL,cm)**
West Atl.	USA	2010	NOAA	West Atlantic	160	R. Allman	26	149	18	
West Atl.	USA	2011	NOAA	West Atlantic	262	R. Allman	75	196	65	
West Atl.	USA	2010	NOAA	West Atlantic	32	R. Allman	13	29	27	
West Atl.	USA	2011	NOAA	West Atlantic	234	R. Allman	218	217	212	
West Atl.	USA	2012	NOAA	West Atlantic	235	R. Allman	220	206	185	
West Atl.	USA	2011	UMCES	West Atlantic	135	D. Secor	135			
West Atl.	USA	2012	UMCES	West Atlantic	157	D. Secor	157			
West Atl.	USA	2013	UMCES	West Atlantic	114	D. Secor	114			
West Atl.	USA	2010	GMRI	West Atlantic	412	W. Golet	337	213		
West Atl.	USA	2011	GMRI	West Atlantic	494	W. Golet	459	165		
West Atl.	USA	2012	GMRI	West Atlantic	582	W. Golet	558	199		
West Atl.	Canada	2010	DFO	Newfoundland	8	D. Busawon	8			251-302
West Atl.	Canada	2010	DFO	Maritimes	72	D. Busawon	72			180-305
West Atl.	Canada	2011	DFO	Maritimes	119	D. Busawon	119	8		127-300
West Atl.	Canada	2011	DFO	Gulf of St. Law	190	D. Busawon	190			186-309
West Atl.	Canada	2012	DFO	Gulf of St. Law	187	D. Busawon	187	6		174-308
West Atl.	Canada	2012	DFO	Maritimes	107	D. Busawon	107	13		127-285
East							Sampled and/or aged			
Stock	**Country**	**Year**	**Agency**	**Area Sampled**	**# Fish sampled**	**Contact**	**Otolith**	**Spine**	**Vertebrae**	**Size range (SFL, cm)**
E. Atl + Med	EC-Spain	2010	IEO	Bay Biscay, Str. Gibralt. W Med	319	E. Rguez-Marin	62	319	23	27-257
E. Atl + Med	Consortium	2011	GBYP	NE Atl & Mediterranean	1900*	GBYP coordinator	426	468		21-284
E. Atl + Med	EC-Spain	2011	IEO	Bay Biscay, Str. Gibralt. W Med	137	E. Rguez-Marin	24	232	30	27-215
E. Atl + Med	Consortium	2012	GBYP	NE Atl & Mediterranean	2800*	GBYP coordinator	99	65		60-263
E. Atl + Med	EC-Spain	2012	IEO	Bay Biscay, Str. Gibralt. W Med	75	E. Rguez-Marin	25	50		102-205

* Samples from GBYP were use for stock structure and direct ageing analysis

Table 13. Estimated parameters of the von Bertalanffy growth model and growth curve comparisons.. Likelihood ratio test, n. s.: not significant, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Age range compared	Data source	L∞	k	to	Likelihood Ratio test L∞ *p*	k *p*	to *p*	Age material	Data	Years	Fraction. ages
1–15	Restrepo et al. (2010)	314.7	0.089	-1.13	***	n.s.	n.s.	L distrib. & otoliths	Estim L at	1970-2000s	no
	Cort (1991). Recalculated	334.3	0.084	-1.17				L distrib. & spines	Obs. L at Age	1975-1986	no
0–13	GBYP Otoliths ALK (Rguez-Marin et al., 2013)	392.5	0.06	-1.65	n.s.	n.s.	*	Otoliths	Obs. L at Age	2011-12	no
	GBYP Spines ALK (Rguez-Marin et al., 2013)	380.2	0.07	-1.18				Spines	Obs. L at Age	2011-12	no
0–13	GBYP Otoliths ALK (Rguez-Marin et al., 2013)	387.7	0.07	-1.53	n.s.	n.s.	*	Otoliths	Obs. L at Age	2011-12	yes
	GBYP Spines ALK (Rguez-Marin et al., 2013)	370.9	0.08	-1.02				Spines	Obs. L at Age	2011-12	yes
0–13	GBYP Otoliths ALK (Rguez-Marin et al., 2013)	392.5	0.065	-1.65	**	**	**	Otoliths	Obs. L at Age	2011-12	no
	Restrepo et al. (2010)	314.6	0.089	-1.13				L distrib. & otoliths	Estim L at	1970-2000s	no
0–13	GBYP Otoliths ALK (Rguez-Marin et al., 2013)	387.7	0.066	-1.53	**	*	*	Otoliths	Obs. L at Age	2011-12	yes
	Restrepo et al. (2010)	314.6	0.089	-1.13				L distrib. & otoliths	Estim L at	1970-2000s	no
0–13	GBYP Otoliths & 2010 IEO Traps	397.4	0.064	-1.56	**	**	*	Otoliths	Obs. L at Age	2010-12	yes
	Restrepo et al. (2010)	314.6	0.089	-1.13				L distrib. & otoliths	Estim L at	1970-2000s	no
0–13	GBYP Spines ALK (Rguez-Marin et al., 2013)	370.9	0.078	-1.02	*	n.s.	n.s.	Spines	Obs. L at Age	2011-12	yes
	Restrepo et al. (2010)	314.6	0.089	-1.13				L distrib. & otoliths	Estim L at	1970-2000s	no
0–13	GBYP Spines & 2010 IEO Traps	383.7	0.074	-1.07	**	n.s.	n.s.	Spines	Obs. L at Age	2010-12	yes
	Restrepo et al. (2010)	314.6	0.089	-1.13				L distrib. & otoliths	Estim L at	1970-2000s	no
0–17	GBYP Spines & 1990-2010 IEO All gears	328.7	0.096	-0.85	n.s.	n.s.	*	Spines	Obs. L at Age	1990-2012	yes
	Restrepo et al. (2010)	314.7	0.089	-1.13				L distrib. & otoliths	Estim L at	1970-2000s	no
1–13	GBYP Spines ALK (Rguez-Marin et al., 2013)	376.6	0.076	-1.09	n.s.	n.s.	n.s.	Spines	Obs. L at Age	2011-12	yes
	Cort (1991). Recalculated	336.2	0.083	-1.19				L distrib. & spines	Obs. L at Age	1975-1986	no
1–13	GBYP Spines & 2010 IEO Traps	393.6	0.07	-1.17	n.s.	n.s.	n.s.	Spines	Obs. L at Age	2010-12	yes
	Cort (1991). Recalculated	336.2	0.083	-1.19				L distrib. & spines	Obs. L at Age	1975-1986	no
1–15	GBYP Spines & 1990-2010 IEO All gears	335.6	0.093	-0.86	n.s.	n.s.	n.s.	Spines	Obs. L at Age	1990-2012	yes
	Cort (1991). Recalculated	334.3	0.084	-1.17				L distrib. & spines	Obs. L at Age	1975-1986	no

Table 14. ICCAT State-of-the-Art Genetic Summary

Year	Marker	Sample size	Result	Reference
1999	mtDNA CR	Mediterranean Sea and western Atlantic Ocean (Total n=140) Sardinia (18) Ionian (36) Turkey (12)	Allele frequency revealed no differentiation within Mediterranean (P=0.3721). Allele frequencies revealed differentiation of pooled MED and W. Atlantic (P=0.0428)	Alvarado-Bremer JR, Naseri I, Ely B (1999) A provisional study of northern bluefin tuna populations. Collect Vol Sci Pap ICCAT 49:127–129
2002	mtDNA CR	MED 1990 (31) MED 1992 (32) MED 1993 (37) MED 1998 (38) Atlantic Large 1994 (34) Atlantic Small 1994 (38)	No differentiation	Ely B, Stoner DS, Bremer A.J, Dean JM, Addis P, Cau A and Quattro JM (2002) Analyses of nuclear ldhA gene and mtDNA control region sequences of Atlantic northern bluefin tuna populations. Marine Biotechnology 4: 583-588.
2002	*ldhA* nuclear gene	MED 1990 (31) MED 1992 (32) MED 1993 (37) MED 1998 (38) Atlantic Large 1994 (34) Atlantic Small 1994 (38)	Differentiation of MED 1998 and all other strata No other differentiation of other strata combinations	Ely B, Stoner DS, Bremer A.J, Dean JM, Addis P, Cau A and Quattro JM (2002) Analyses of nuclear ldhA gene and mtDNA control region sequences of Atlantic northern bluefin tuna populations. Marine Biotechnology 4: 583-588.
2003	37 allozyme loci	NW Atlantic 1996 (39) NE Atlantic 1994 (49) WMED (601) CMED (133)	No differentiation within MED No differentiation of E Atlantic and MED Significant allele frequency differences for *SOD-1* enzyme between pooled E Atlantic/MED and pooled W Atlantic	Pujolar JM, Roldán MI and Pla C (2003) Genetic analysis of tuna populations, *Thunnus thynnus thynnus* and *T. alalunga*. Marine Biology 143: 613-621.
2004	9 microsatellites	Young of the Year only Balearic 1998 (74) Balearic 1999 (60) Tyrrhenian 1998 (28) Tyrrhenian 1999 (33) Tyrrhenian 2002 (63) Ionian 1998 (9) Ionian 1999 (16)	No temporal differentiation within WMED (F_{SC} = −0.0013, P = 0.735) No differentiation within Balearic and Tyrrhenian (F_{CT} = 0.0013, P = 0.196) No temporal differentiation within Baleriac, Tyrrhenian and Ionian (F_{SC} = −0.0020, P = 0.883) Differentiation of Balearic, Tyrrhenian and Ionian Sea (F_{CT} = 0.0032, P =0.019) No differentiation of temporally pooled Balearic and Tyrrhenian (F_{ST}=0.0007, P=0.226)	Carlsson J, McDowell JR, Diaz-Jaimes P, Carlsson JEL, Boles SB, Gold JR and Graves J E (2004) Microsatellite and mitochondrial DNA analyses of Atlantic bluefin tuna (*Thunnus thynnus thynnus*) population structure in the Mediterranean Sea. Molecular Ecology 13: 3345-3356.

			No differentiation of temporally pooled Balearic and Ionian (F_{ST}=0.0046, P = 0.103) Differentiation of temporally pooled Ionian and Tyrrhenian (F_{ST}=0.0087, P=0.015) Differentiation of temporally pooled Balearic, Ionian and Tyrrhenian (F_{ST}=0.0023, P = 0.038).	
2004	mtDNA CR (868bp)	Young of the Year only Balearic (24) Ionian (23) Tyrrhenian (22)	Differentiation of Ionian, Balearic and Tyrrhenian (Φ_{ST}= 0.0239, P = 0.0314) No differentiatioan of Balearic and Ionian Seas (Φ_{ST}=0.0085, P=0.250) No differentiation of Balearic and Tyrrhenian Seas (Φ_{ST}= 0.0270, P=0.053) Differentiation of Ionian and Tyrrhenian Seas (Φ_{ST}=0.0366, P = 0.030)	Carlsson J, McDowell JR, Diaz-Jaimes P, Carlsson JEL, Boles SB, Gold JR and Graves J E (2004) Microsatellite and mitochondrial DNA analyses of Atlantic bluefin tuna (*Thunnus thynnus thynnus*) population structure in the Mediterranean Sea. Molecular Ecology 13: 3345-3356.
2005	mtDNA CR (450bp)	n=607 W Atlantic (50) E Atlantic (24) Mediterranean (Gulf of Mersin, Aegean Sea, Ionian Sea, Libyan coast, Tyrrhenian Sea, Tunisian coast, Ligurian Sea, Gulf of Valencia) (323) *Augmented by samples from Ely et al. (2002)	No differentiation of Atlantic and MED (Φ_{ST} = 0.002, P = 0.245)	Alvarado Bremer JR, Viñas J, Mejuto J, Ely B and Pla C (2005). Comparative phylogeography of Atlantic bluefin tuna and swordfish: the combined effects of vicariance, secondary contact, introgression, and population expansion on the regional phylogenies of two highly migratory pelagic fishes. Molecular phylogenetics and evolution 36: 169-187.
2006	8 microsatellites	n = 800 Iceland EEZ	Differentiation of pooled early season (1999+2002) and pooled late season ABFT (1999+2002) (F_{ct}=0.00154, P= 0.000) No differentiation between alternative temporal or spatial combinations	Carlsson J, McDowell JR, Carlsson, JEL, Ólafsdóttir D and Graves JE (2006) Genetic heterogeneity of Atlantic bluefin tuna caught in the eastern North Atlantic Ocean south of Iceland. ICES Journal of Marine Science 63: 1111e1117
2007	8 microsatellites	Gulf of Mexico Larvae 2003 (40) WMED YOY 1998-2002 (255) EMED YOY 1998-2002 (25)	Global differentiation (F_{ST} = 0.0059, P = 0.0005) Differentiation of WMED and GOM (F_{ST} = 0.0048, P = 0.0260)	Carlsson J, McDowell JR, Carlsson, J.E and Graves JE (2007) Genetic identity of YOY bluefin tuna from the eastern and

			Differentiation of WMED and EMED (F_{ST} = 0.0067, P = 0.0279) Differentiation of GOM and EMED (F_{ST} = 0.0117, P = 0.0236)	western Atlantic spawning areas. Journal of Heredity 98: 23-28.
2007	mtDNA CR	Gulf of Mexico Larvae 2003 (40) WMED YOY 1998-2002 (255) EMED YOY 1998-2002 (25)	Global differentiation (Φ_{ST} = 0.0129, P = 0.0139) Differentiation of WMED and GOM (Φ_{ST} = 0.0104, P = 0.0359) Differentiation of WMED and EMED (Φ_{ST} = 0.0174, P = 0.0482) No difference of GOM and EMED (Φ_{ST} = 0.0134, P = 0.1105)	Carlsson J, McDowell JR, Carlsson, J.E and Graves JE (2007) Genetic identity of YOY bluefin tuna from the eastern and western Atlantic spawning areas. Journal of Heredity 98: 23-28.
2008	mtDNA CR	n=170 Gulf of Mexico 1995-2005 (61) WMED 1997-2004 (47) EMED 1997-2003 (62) Range of size classes	Differentiation of GOM and MED (Φ_{ST} = 0.01116, P = 0.03029) No significant differentiation of GOM and WMED (Φ_{ST}= 0.01223, P = 0.06554) No significant differentiation of GOM and EMED (Φ_{ST}= 0.00699, P = 0.12019) No significant differentiation of WMED and EMED (Φ_{ST} = -0.00419, P = 0.6504)	Boustany AM, Reeb CA and Block BA (2008). Mitochondrial DNA and electronic tracking reveal population structure of Atlantic bluefin tuna (*Thunnus thynnus*). Marine Biology 156: 13-24.
2010	8 microsatellites	Adriatic 2003-2005 (73) S. Tyrrhenian 2007 (39) Ligurian 1999-2000 (36) SW Sardinia 2005 (29) Algeria 2006 (39) Alboran 2005 (40) Historical Adriatic 1926-1927 (69) Historical Tyrrhenian 1911 (39)	Global F_{ST} contemporary (F_{ST} = 0.014, P < 0.0001) Differentiation of historical samples (F_{ST} = 0.020, P < 0.0001) Differentiation among all pairwise comparisons except contemporary populations of Algeria and S Tyrrhenian, Ligurian and SW Sardinia, and Adriatic and Ligurian.	Riccioni G, Landi M, Ferrara G, Milano I, Cariani A, Zane L, Sella M, Barbujani G and Tinti F (2010) Spatio-temporal population structuring and genetic diversity retention in depleted Atlantic bluefin tuna of the Mediterranean Sea. Proceedings of theNational Academy of Sciences of the United States of America 107: 2102–2107.
2011	7 microsatellites	EMED - Turkey 2008 (48) WMED - Balearics 2008 (48)	No differentiation of EMED and WMED (F_{ST} = 0.002, P = 0.2)	Viñas J, Gordoa A, Fernández-Cebrián R, Pla C, Vahdet Ü and Araguas RM (2011) Facts and uncertainties about the genetic population structure of Atlantic bluefin tuna (*Thunnus thynnus*) in the Mediterranean. Implications for fishery

				management. Reviews in Fish Biology and Fisheries, 21: 527-541.
2011	mtDNA CR	EMED - Turkey 2008 (48) WMED - Balearics 2008 (48) *Augmented by samples from Ely *et al.* (2002) and Bremmer *et al.* (2005) Total MED of known origin = 516 (1990-2010)	No global differentiation (Φ_{ST} = -0.004, P = 0.618) No differentiation of EMED and WMED (n = 426) (Φ_{ST} = 0.002, P = 0.135) No temporal differentiation across all 516 samples (Φ_{ST} = 0.004, P =0.111)	Viñas J, Gordoa A, Fernández-Cebrián R, Pla C, Vahdet Ü and Araguas RM (2011) Facts and uncertainties about the genetic population structure of Atlantic bluefin tuna (*Thunnus thynnus*) in the Mediterranean. Implications for fishery management. Reviews in Fish Biology and Fisheries, 21: 527-541.
2013	17 SNPs	n=107 Bay of Biscay (46) Balearic Sea (46) NW Atlantic (Virginia) (15)	Differentiation of NW Atlantic, Bay of Biscay and Mediterranean Sea F_{ST} = 0.029±0.024, P < 0.05 H_e = 0.272 ± 0.178 F_{IS} = 0.096 ± 0.133 BB–NWA: F_{ST} = 0.120±0.091, P < 0.01 MED–NWA: F_{ST} =0.116±0.078, P < 0.01 BB-MED: F_{ST} = 0.004±0.007, P>0.01	Albaina A, Iriondo M, Velado I, Laconcha U, Zarraonaindia I, Arrizabalaga H, Pardo MA, Lutcavage M, Grant WS and Estonba A (2013) Single nucleotide polymorphism discovery in albacore and Atlantic bluefin tuna provides insights into worldwide population structure. Animal Genetics. doi: 10.1111/age.12051

Table 15. Completed or ongoing analysis on Atlantic bluefin tuna population assignment based on otolith stable isotopes. Periods of collection are separated between recent (2009-2014) and historical (<2008). Age estimate indicates the fraction of the otolith sample aged; yes=100% of the sample was used for age estimates.

Collection years	Region	Otolith Analyses (N)	FL/CFL range (cm)	Age Estimate	PIs/Group
		Completed Analyses			
Recent					
2011-2012	Gulf St. Lawrence	191	186-313 CFL	yes	J. Neilson/DFO
2011-2012	Canadian Maritimes	151	127-300	yes	J. Neilson/DFO
2011-2012	St. Margaret's Bay	17	175-277	yes	J. Neilson/DFO
2010-2011	US Atlantic-MD_MA	247	70-160	yes	NMFS/D. Secor
2010-2011	US Atlantic-MA	74	175-275	yes	NMFS
2011-2012	US Atlantic-NC	218	120-220	yes	D. Secor
1999-2011	Gulf of Mexico	183	>180	yes	NMFS
2010-2011	Central North Atlantic	177	121-236 FL	0%	TAMU/AZTI (GBYP)
2011	Morocco	32	207-257	0%	TAMU/AZTI (GBYP)
2009-2011	Bay of Biscay	262	55-182	24%	TAMU/AZTI (GBYP)
2011	Strait of Gibraltar	190	161-278	94%	TAMU/AZTI (GBYP)
2011	Balearics	39	82-305	59%	TAMU/AZTI (GBYP)
2011	Malta	82	112-261	34%	TAMU/AZTI (GBYP)
2011	Sardinia	20	123-247	70%	TAMU/AZTI (GBYP)
2011	Adriatic Sea	47	105-127	23%	TAMU/AZTI (GBYP)
2011	Levantine Sea	48	174-282	27%	TAMU/AZTI (GBYP)
Subtotal		1978			
Historical					
1975-1977	Gulf of St. Lawrence	10	247-297	yes	J. Neilson/DFO
1975-2007	Gulf of St. Lawrence	269	>180	yes	J. Neilson/DFO
1978	Gulf of Mexico	60	>180	yes	NMFS
2003-2007	Mediterranean Sea	131	School/Med/Large	yes	J. Rooker/D. Secor
1996-2002	US Atlantic	225	School/Med/Large	yes	J. Rooker/D. Secor
Subtotal		695			

Ongoing Analyses

Recent					
2013	US Atlantic-NC	115	Med/large	in progress	D. Secor
2012-2013	US Atlantic-MD-MA	300	School/Med	in progress	NMFS
2012-2013	US Atlantic-MA	50	Large/Giant	in progress	NMFS
2013	Gulf of St. Lawrence	100	Large/Giant	in progress	DFO
2013	Canadian Maritimes	100	Large/Giant	in progress	DFO
2012-2013	Central North Atlantic	100	Large	no	TAMU/AZTI (GBYP)
2012-2013	Morocco	100	Large	no	TAMU/AZTI (GBYP)
2012-2013	Bay of Biscay	100	Juvenile	no	TAMU/AZTI (GBYP)
2010	Newfoundland	8	251-302	in progress	J. Neilson/DFO
2010	Canadian Maritimes	72	180-305	in progress	J. Neilson/DFO
2011	Canadian Maritimes	119	127-300	in progress	J. Neilson/DFO
2011	Gulf of St. Lawrence	190	186-309	in progress	J. Neilson/DFO
2012	Gulf of St. Lawrence	187	174-308	in progress	J. Neilson/DFO
2012	Canadian Maritimes	107	127-285	in progress	J. Neilson/DFO
2010	Gulf of Maine and Georges Bank	*337*	112-284	completed	W. Golet/Umaine/ GMRI; M. Lutcavage/ Umass Amherst LPRC-NMFS
2011	Gulf of Maine and Georges Bank	*459*	83-293	in progress	W. Golet/Umaine/ GMRI; M. Lutcavage/ Umass Amherst LPRC-NMFS
2012	Gulf of Maine and Georges Bank	*558*	91-307	in progress	W. Golet/Umaine/ GMRI; M. Lutcavage/ Umass Amherst LPRC-NMFS
Subtotal		3002			
Historical					
1974-1978	US Atlantic	100	Large/Giant	in progress	D. Secor
1974-1978	US Atlantic	100	School/Med	in progress	D. Secor
1974-1978	Gulf of Mexico	100	Large/Giant	in progress	D. Secor
1995-2001	US Atlantic	50	School/Med	in progress	D. Secor
1995-2001	US Atlantic	39	Large/Giant	in progress	D. Secor
Subtotal		389			

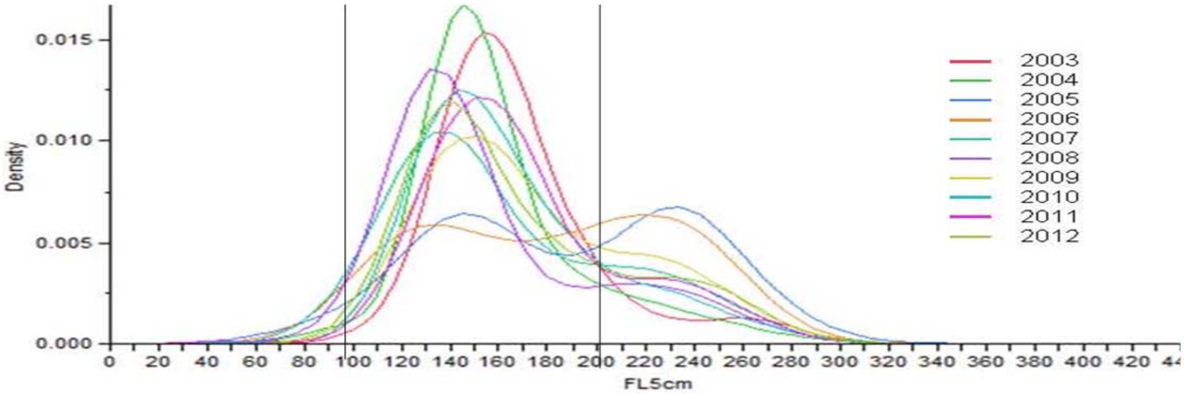


Figure 1 Yearly frequency of BFT sizes sampled at harvesting by observers in the farms during the period 2003-2012 (SCRS/2013/083).

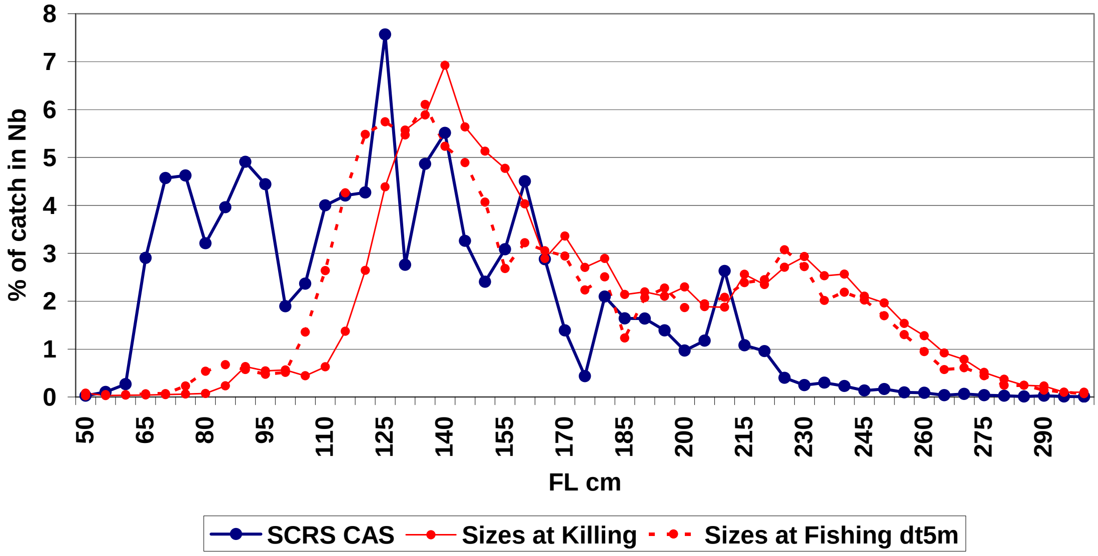


Figure 2 Average sizes sampled at harvesting and estimated at the fishing dates, compared to average Catch at size used by SCRS, period 2003-2011.

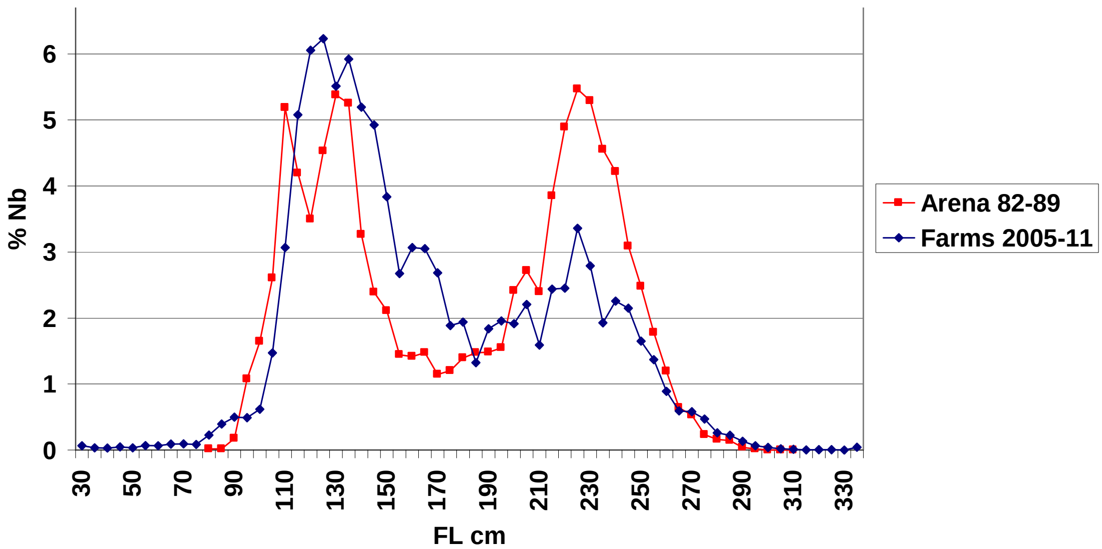


Figure 3 Average catch at size sampled by Arena during the 1982-1989 period (1560 tunas sampled) and in farms period 2005-2011.

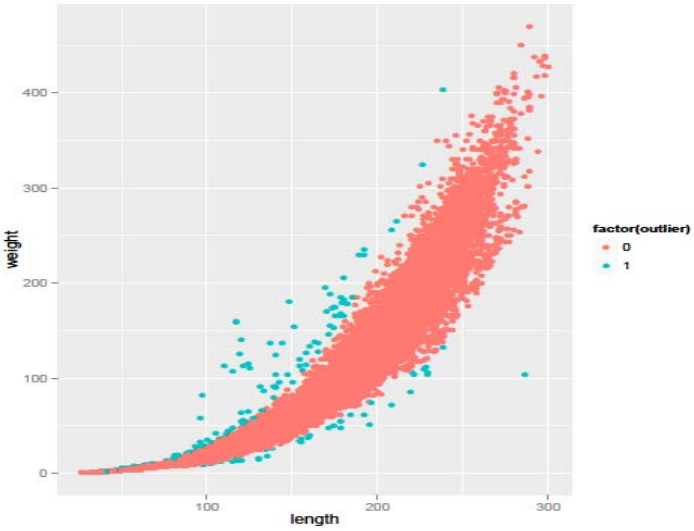


Figure 4 Results of applying Fulton's K factor values between 1 and 2.8 (K=100*wt(grams)/SFL^3) to the dataset of length-weight observations.

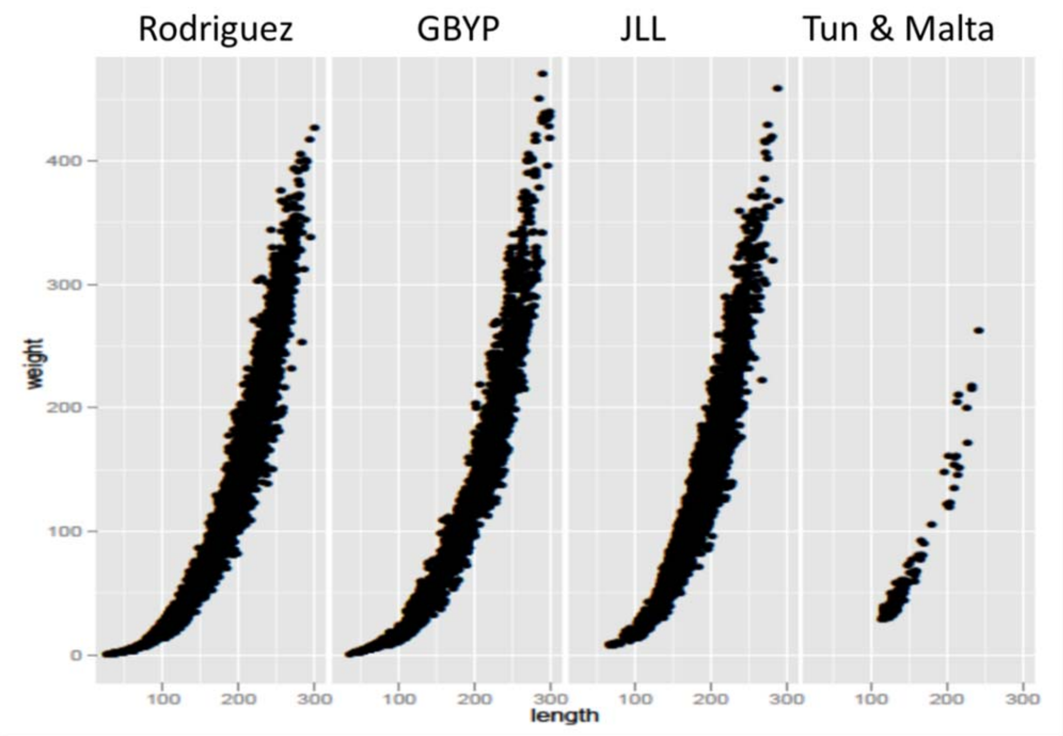


Figure 5 Plot of data by sources after applying the K filter.

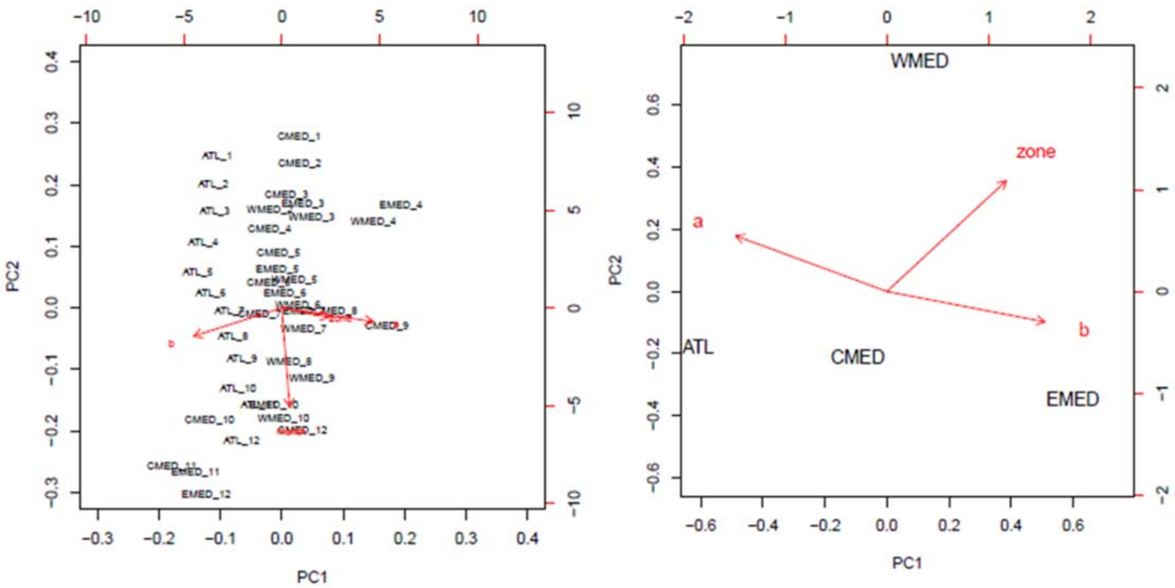


Figure 6 PCA analysis of initial estimates of *a* and *b* parameters from L-W relationship indicating that the spatial differences tend to be more important than temporal differences.

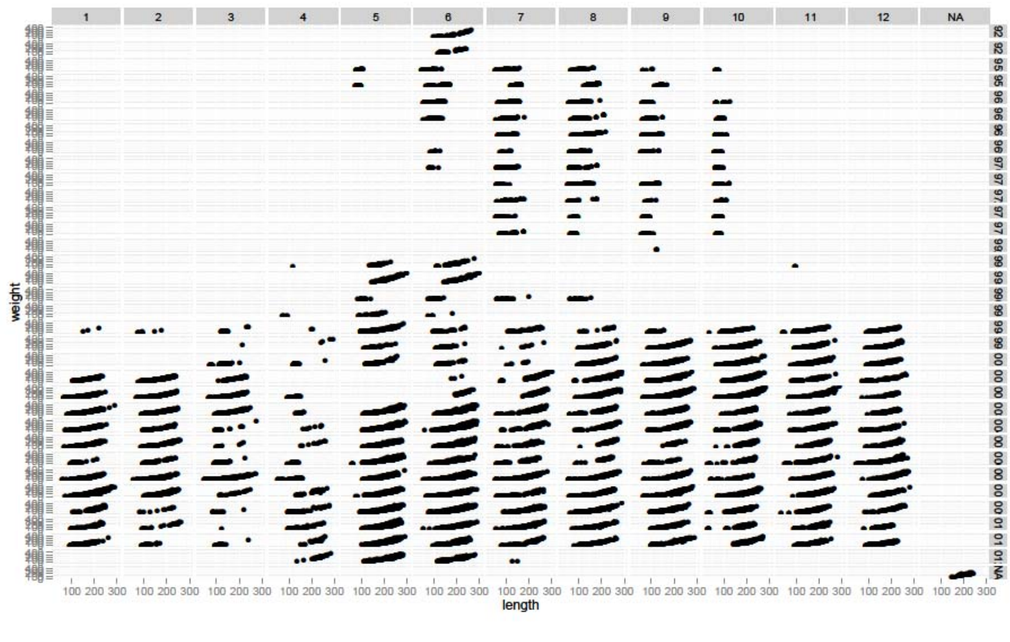


Figure 7 Plot of the Eastern LW data by year and month.

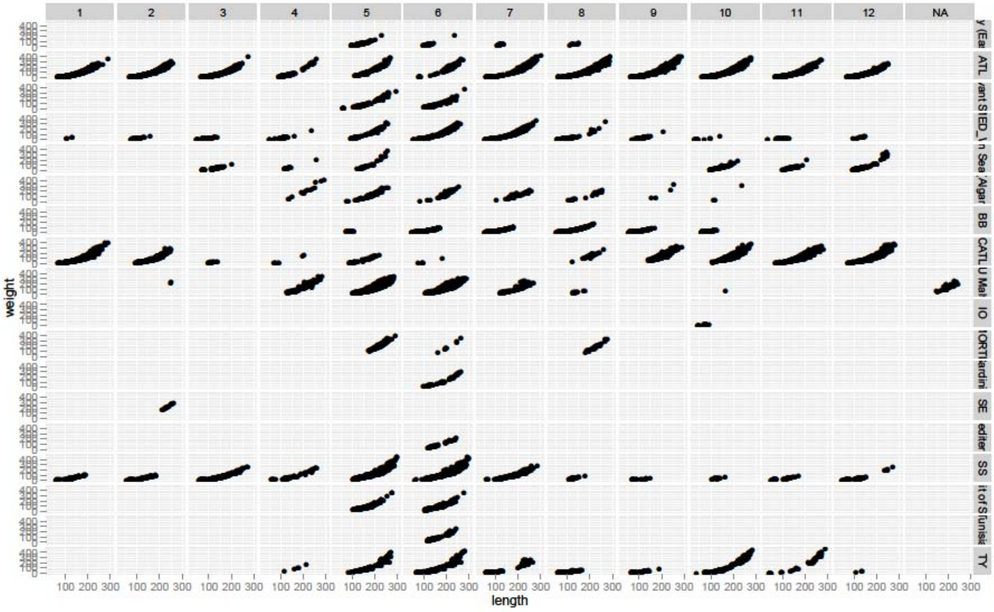


Figure 8 Eastern L-W data by month and area.

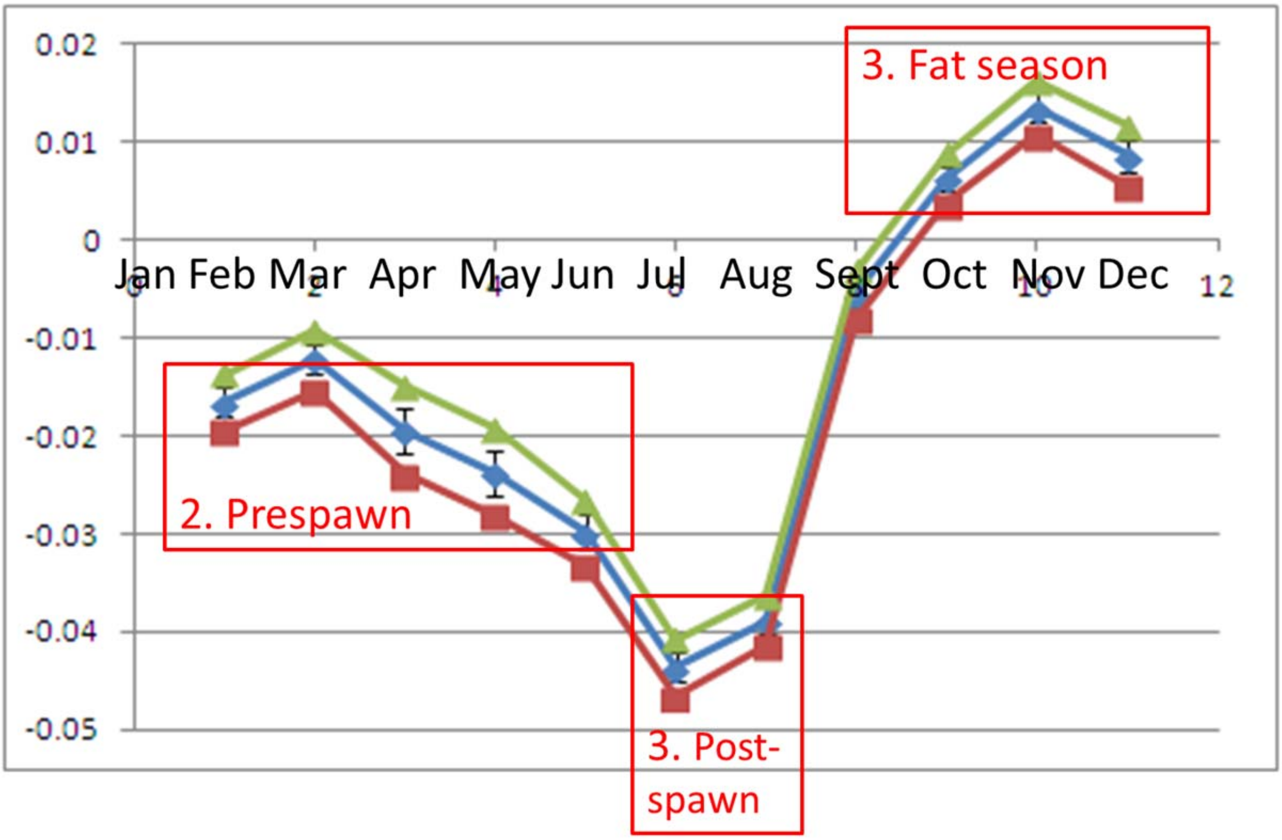


Figure 9 Initisal parameter estimates for month indicating that there are poten. Upper (green line) and lower (red lines) represent 95 percentiles of the MCMC estimates for the parameters. The blue line and the error bars represent the median +/- 1 standard error. The estimates show evidence of three potentially distinct ‘seasons’.

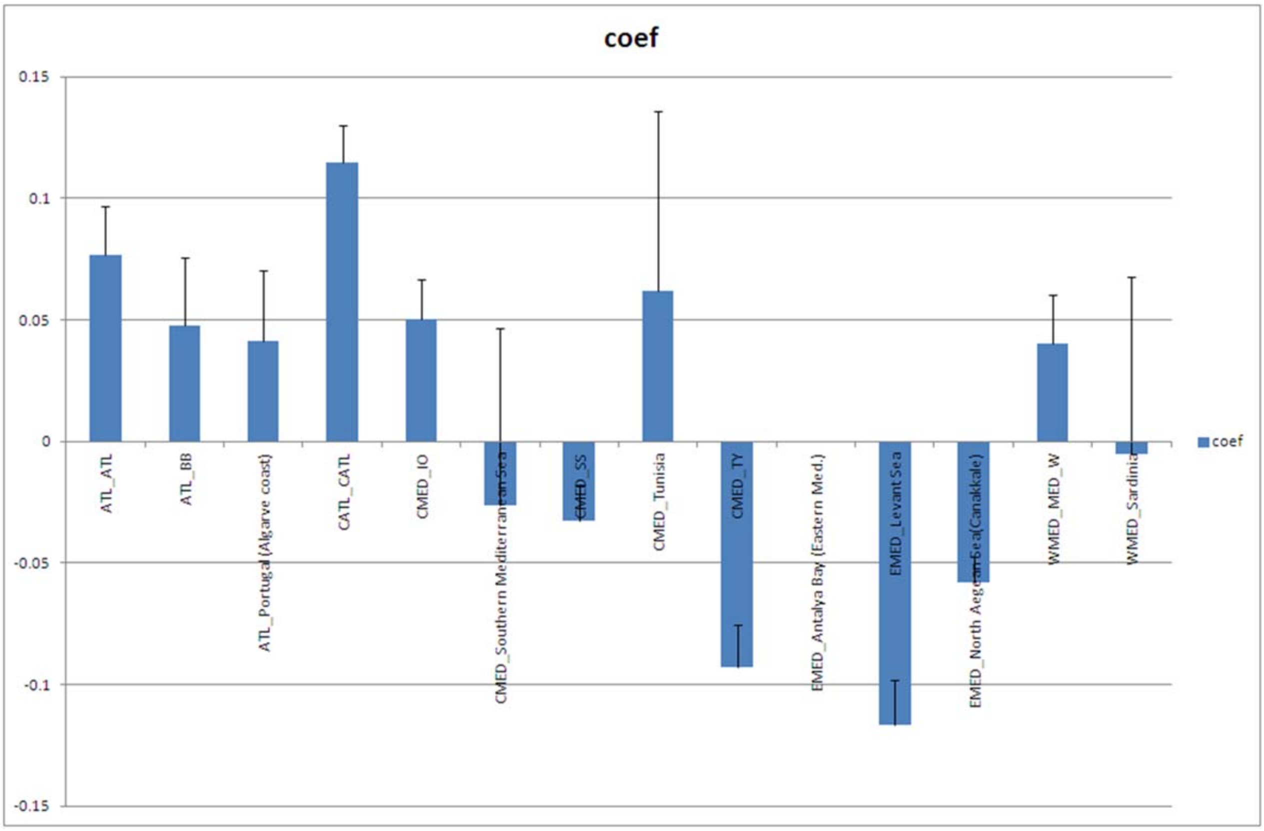


Figure 10 Coefficients (+/- 1SE) for the area effect from the initial model (A) to evaluate condensing the models to homogenous areas.

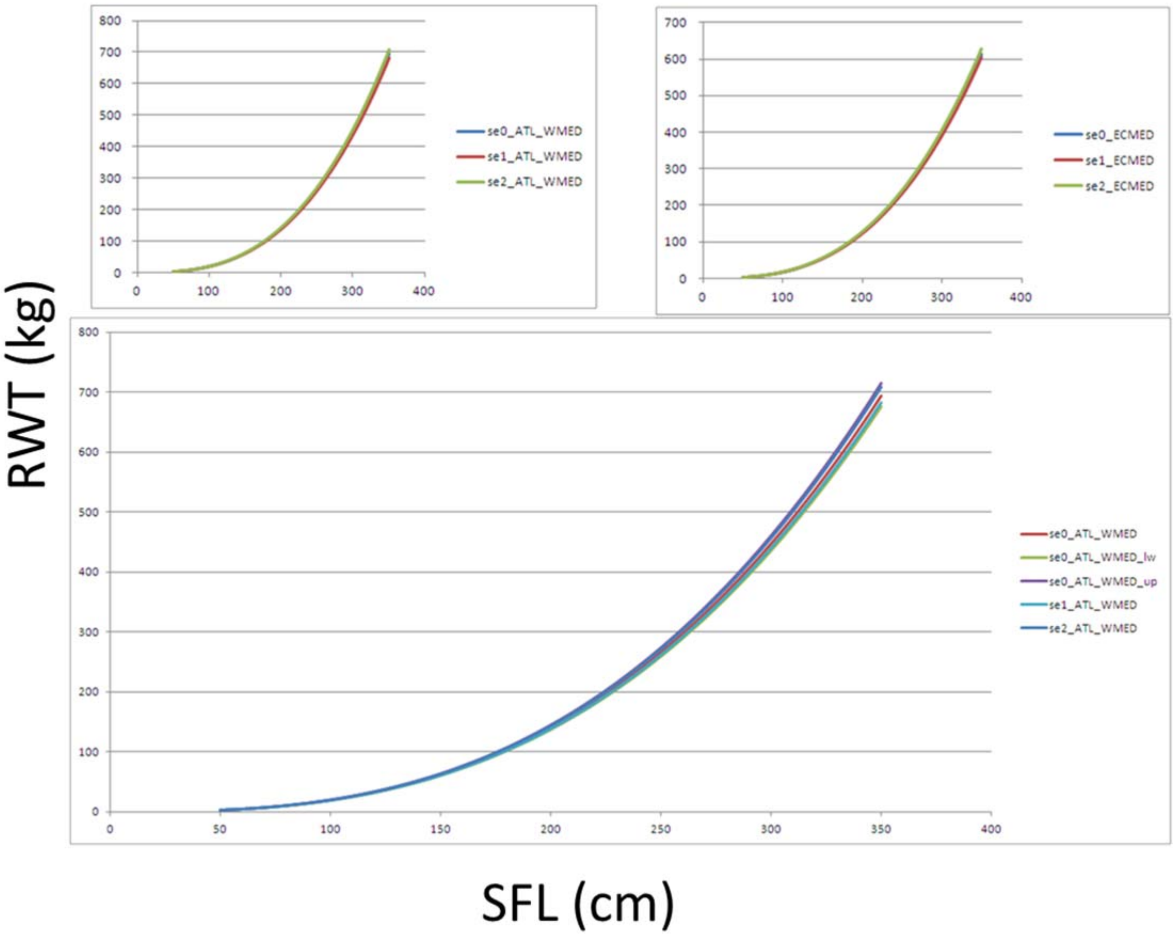
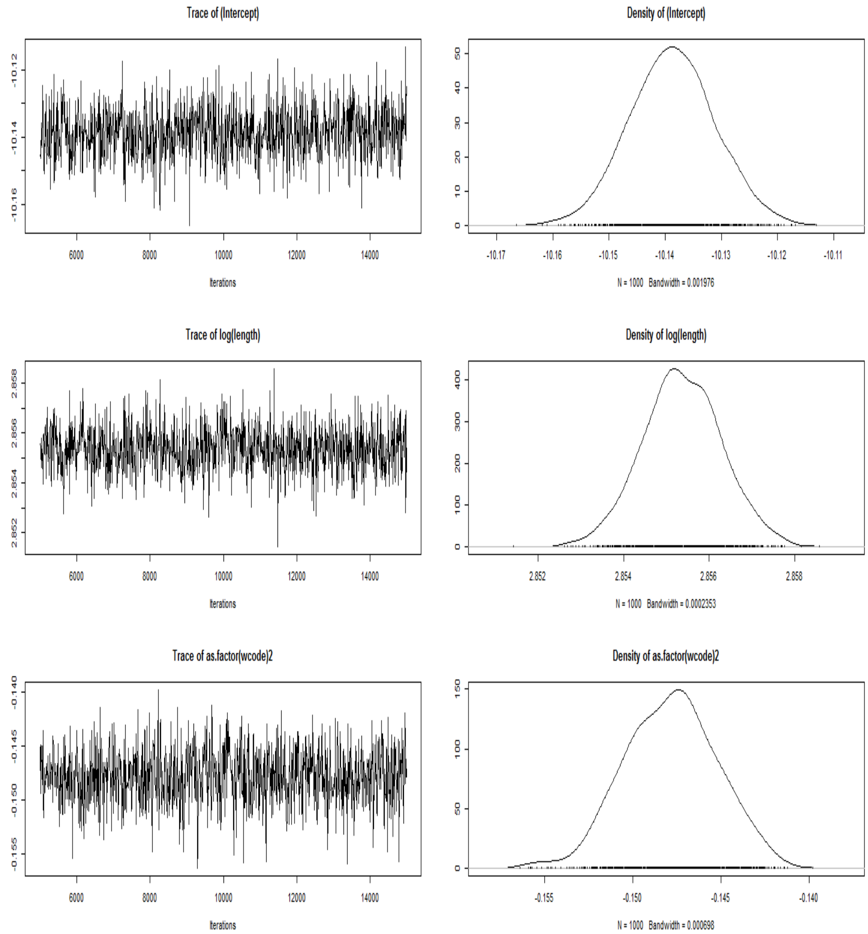


Figure 11 Model-estimated L-W relationships for condensed (3) seasons showing very small differences. Seasonal estimates fall within the CI of other estimates from Model .

a) Atlantic by Model E



b) Med by Model F

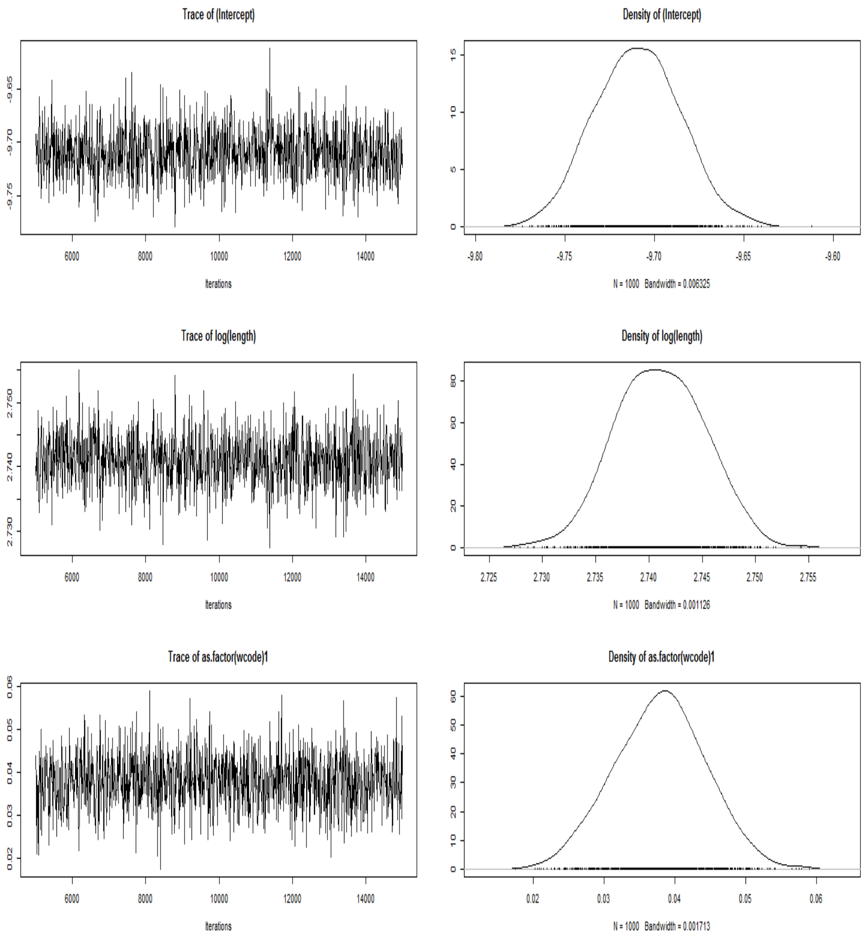


Figure 12 Parameter estimates and convergence considerations for the final models; a) Atlantic by Model E, and b) Med by Model F.

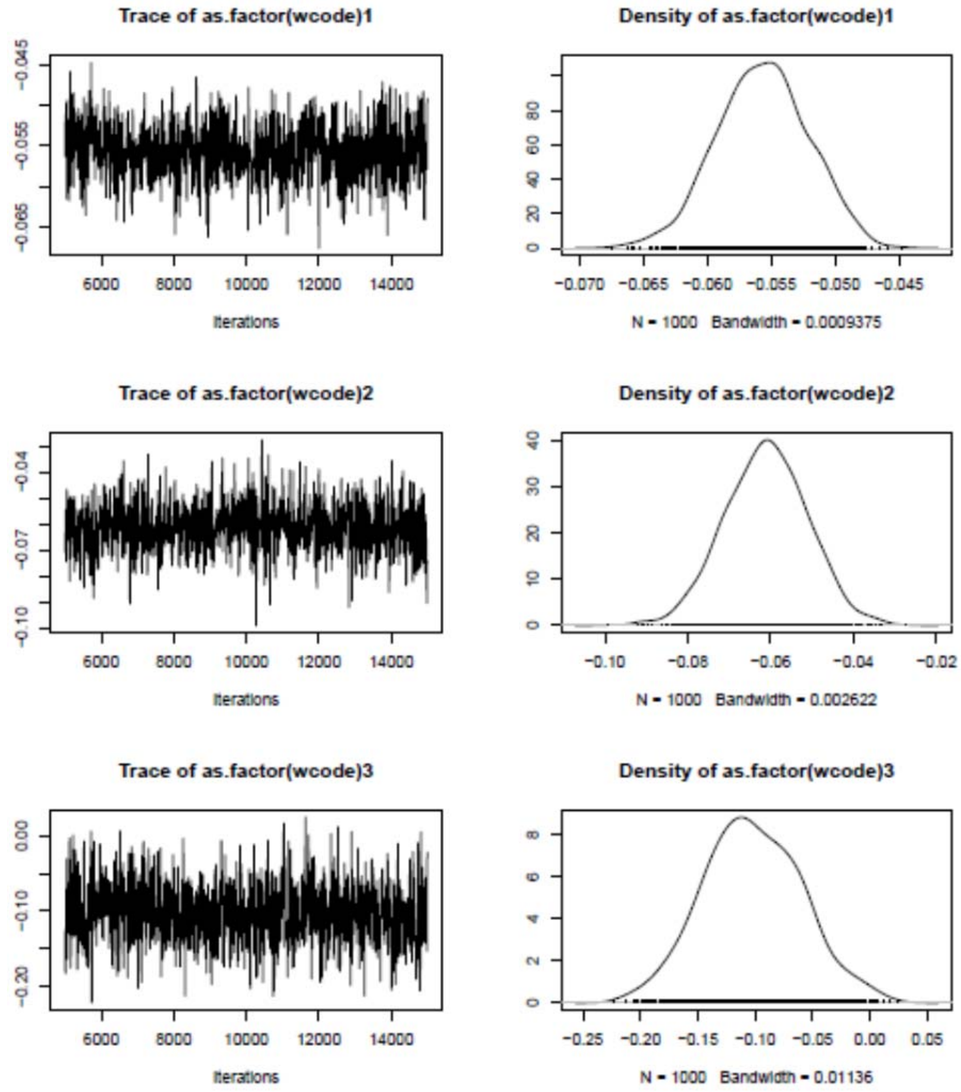


Figure 12 continued.

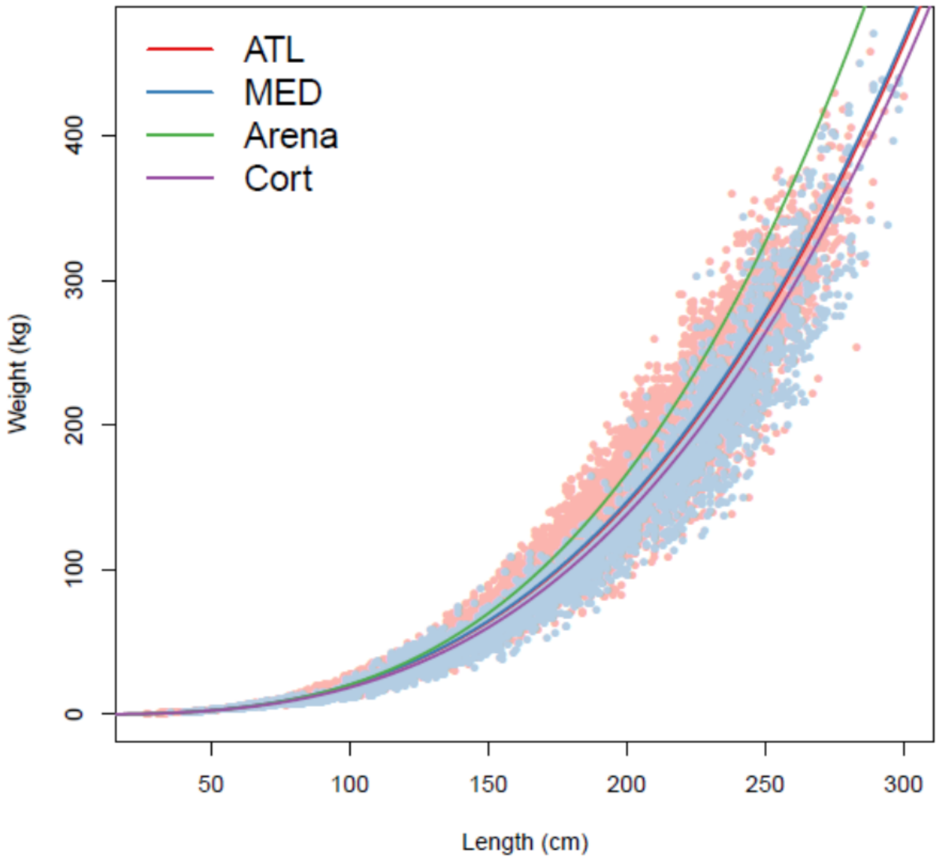


Figure 13 Final models from this analysis overlaid on raw data with other LW models and the average weight at length from the Arena (1980) paper and Rey and Cort relationships.

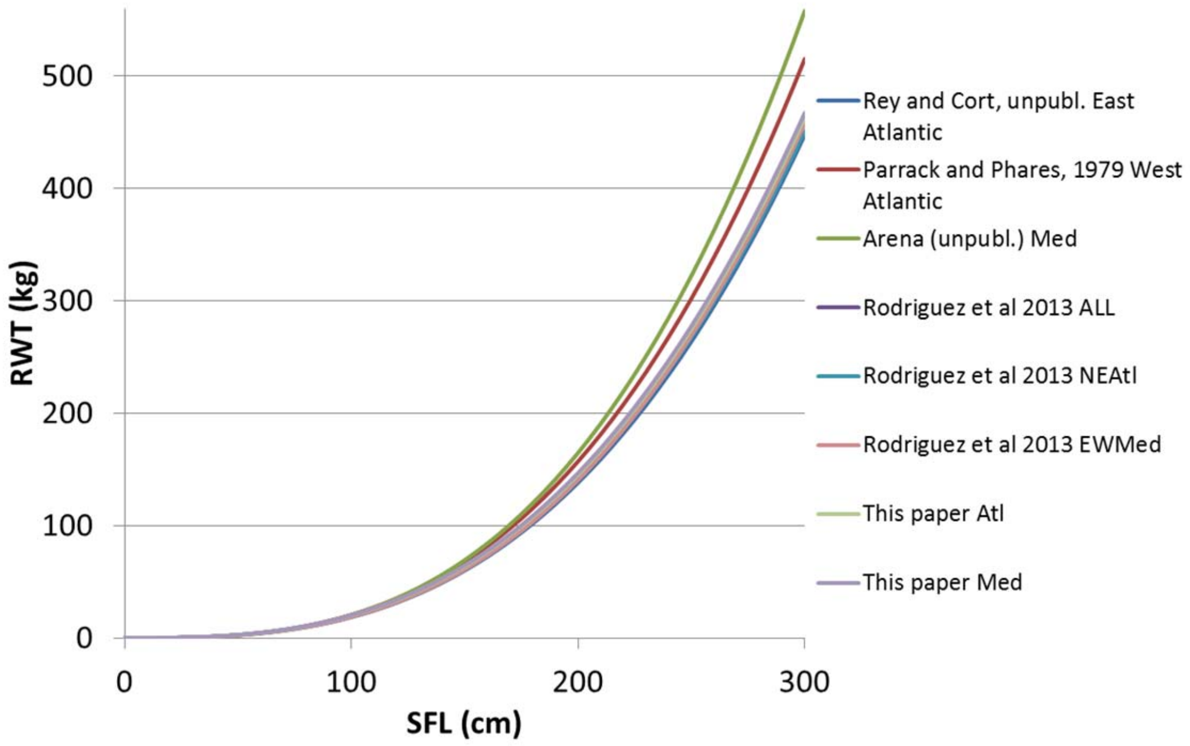


Figure 14 Comparison of LW models existing for the Eastern Atlantic and Mediterranean Bluefin tuna stock.

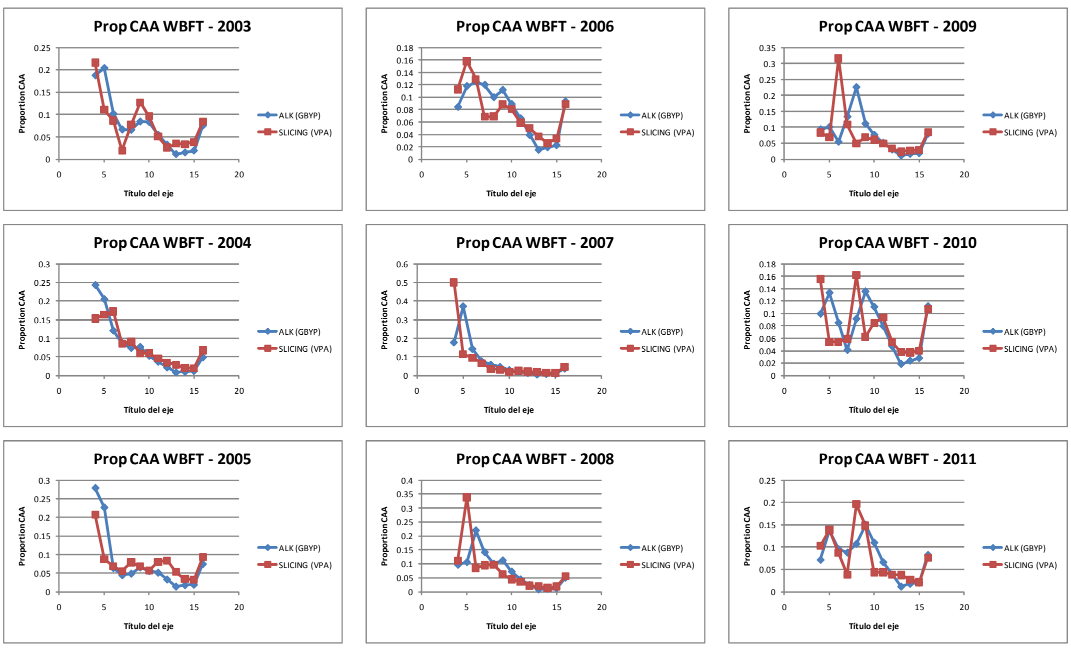


Figure 15 Comparison of the estimated proportion at age of W-ATL BFT using the age-slicing routine (red squares) applied to the VPA base model, and the PRELIMINARY age-length key (ALK) developed for GBYP (blue diamonds). For this comparison, only available age-length samples from the W-ATL were used to produce the ALK

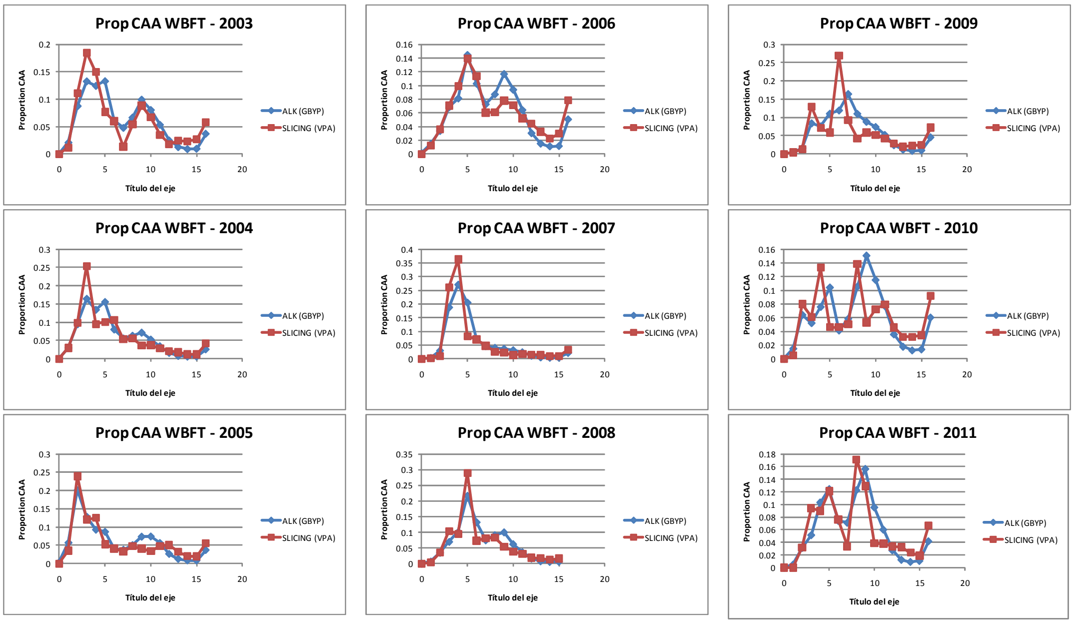


Figure 16 Comparison of the estimated proportion at age of W-ATL BFT using the age-slicing routine (red squares) applied to the VPA base model, and the PRELIMINARY age-length key (ALK) developed for GBYP (blue diamonds). For this comparison, all available age-length samples were combined to produce a single ALK (i.e. E-ATL otoliths, E-ATL spines and W-ATL otoltihs).

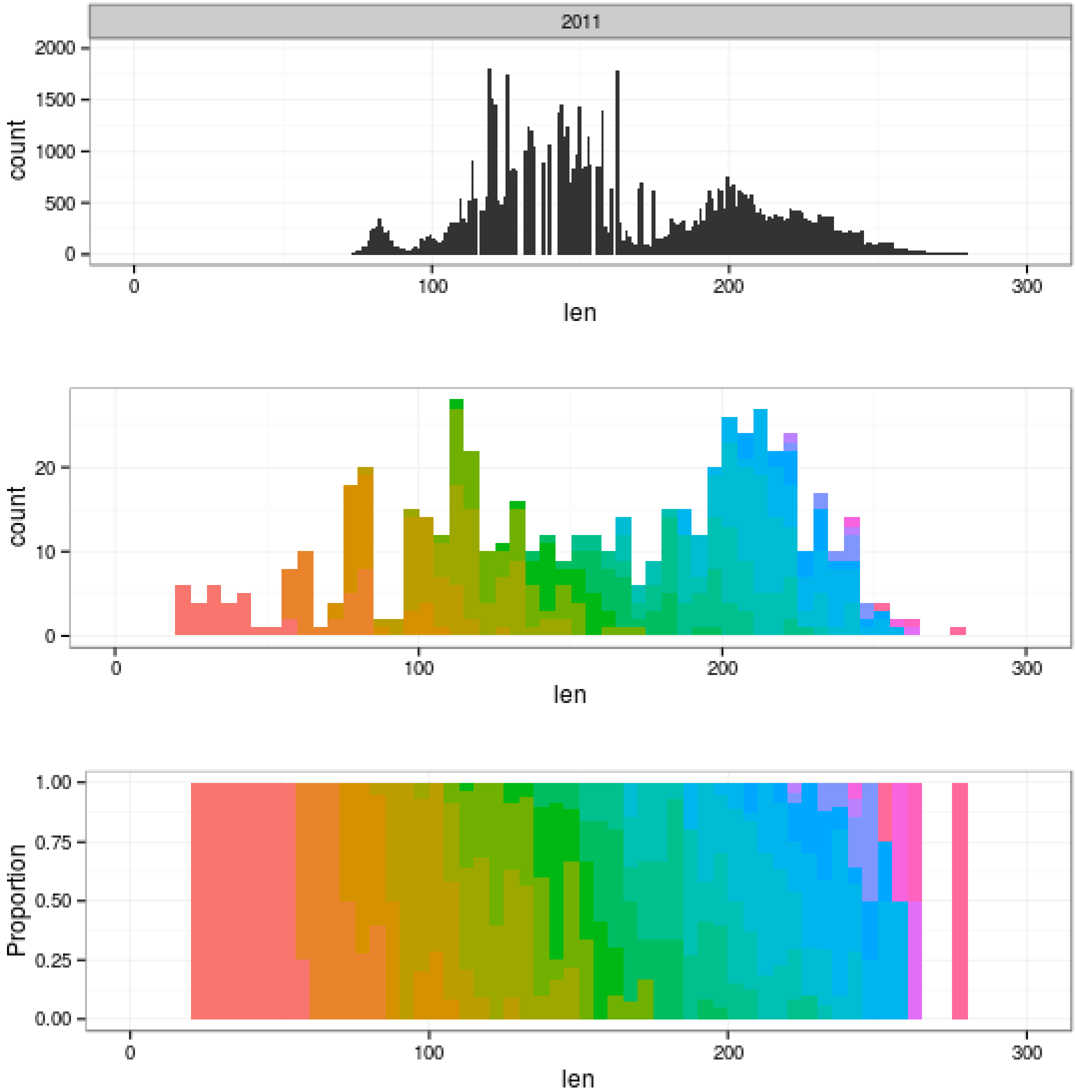


Figure 17 A comparison of the raised catch-at-size with otolith samples. The first panels show the length frequency distribution of the population, the second the numbers at each age (represented by the different colors) for each length group and the third panel the proportions at age.

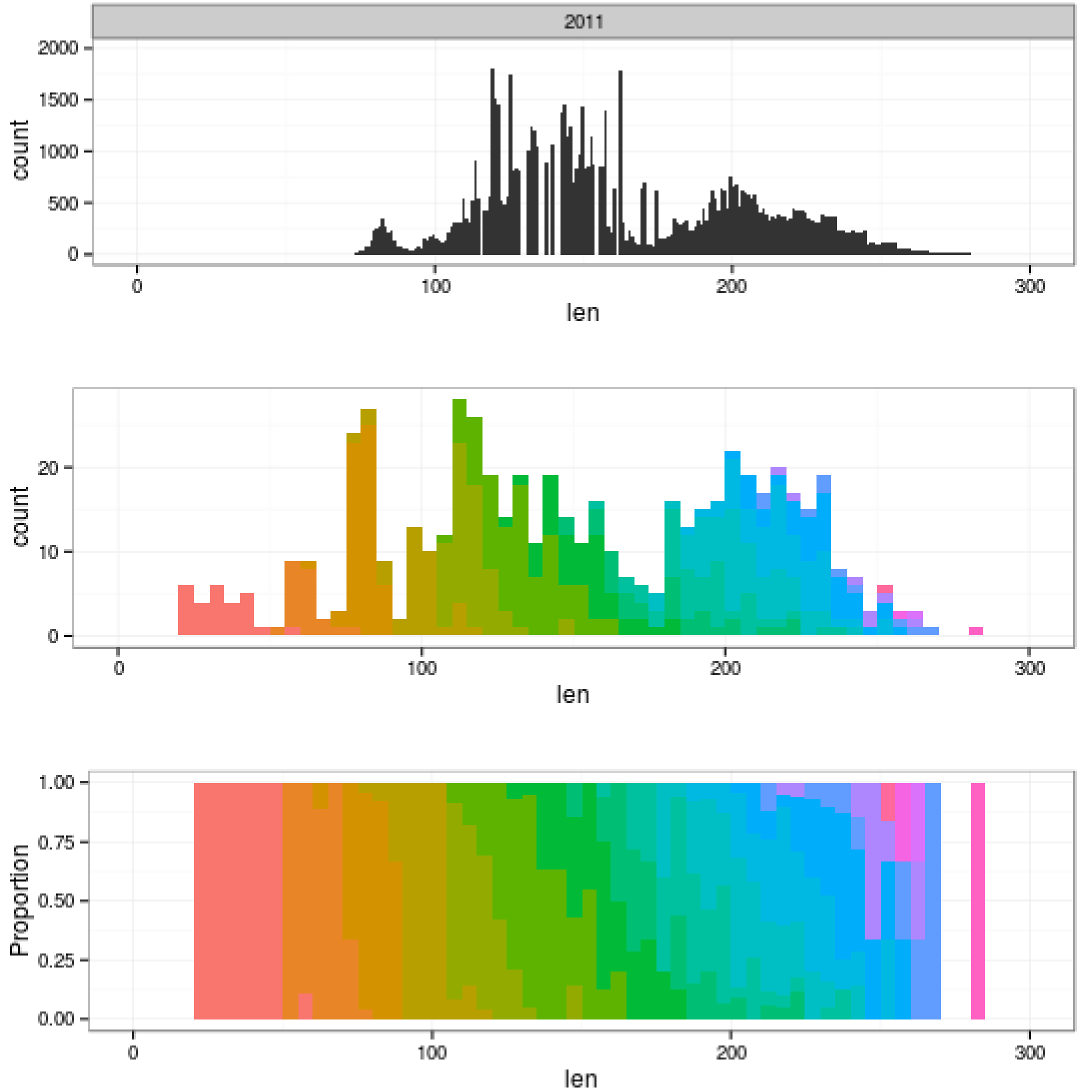


Figure 18 A comparison of the raised catch-at-size with spine samples. The first panels show the length frequency distribution of the population, the second the numbers at each age (represented by the different colors) for each length group and the third panel the proportions at age.

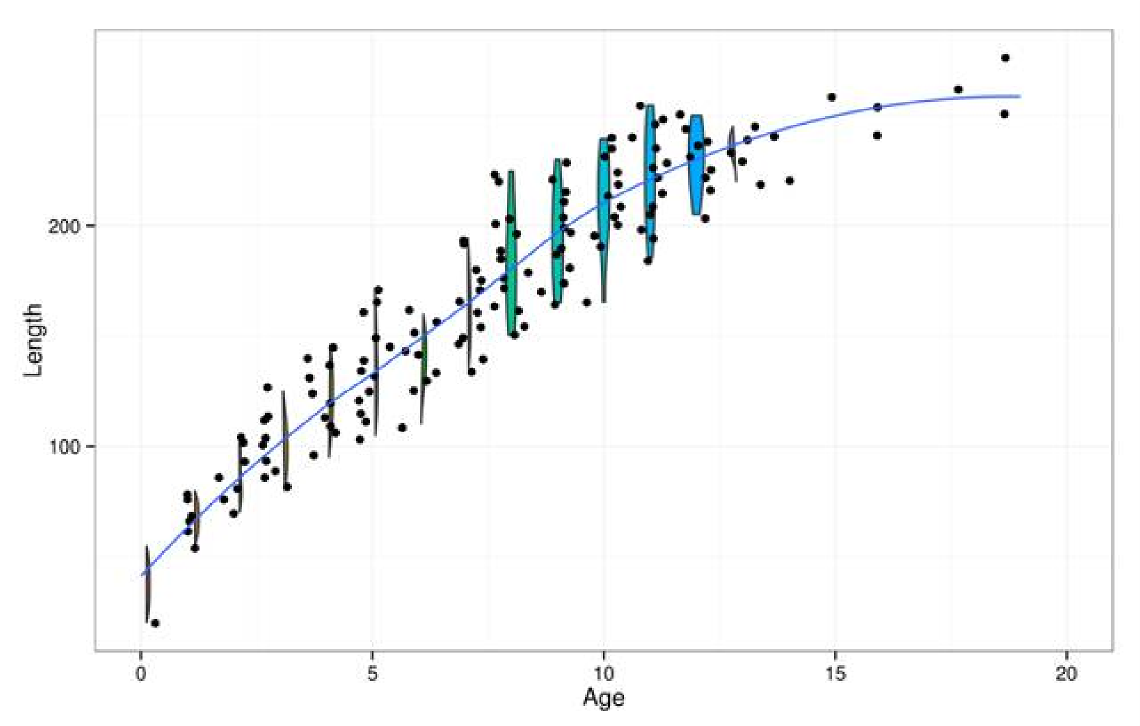


Figure 19 Numbers sampled at each age as a "growth curve" for otoliths

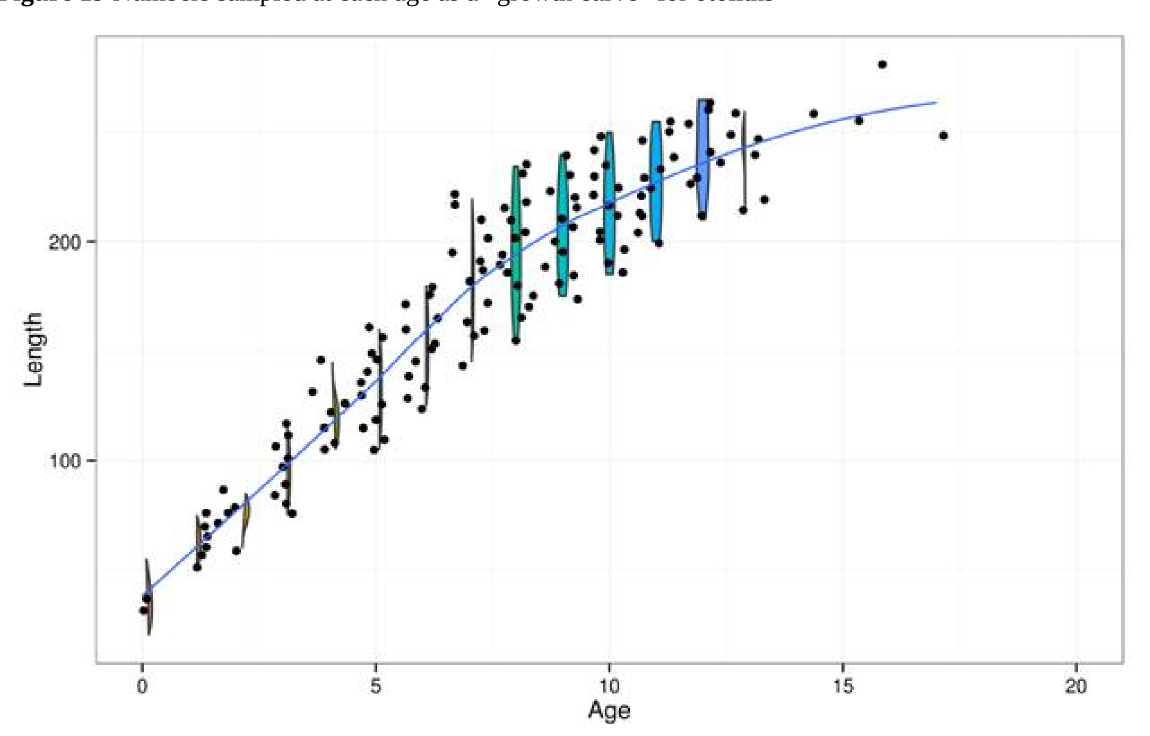


Figure 20 Numbers sampled at each age as a "growth curve" for spines.

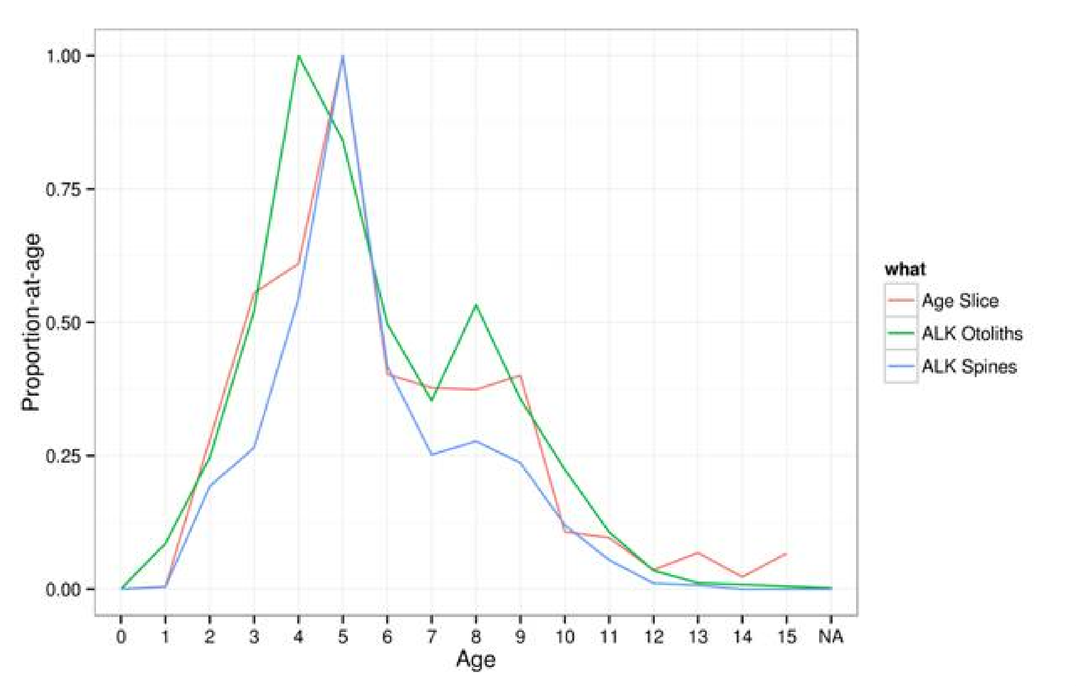


Figure 21 A comparison of estimates of numbers at age for "age-slicing" and using an age-length-key based on otoliths and spin

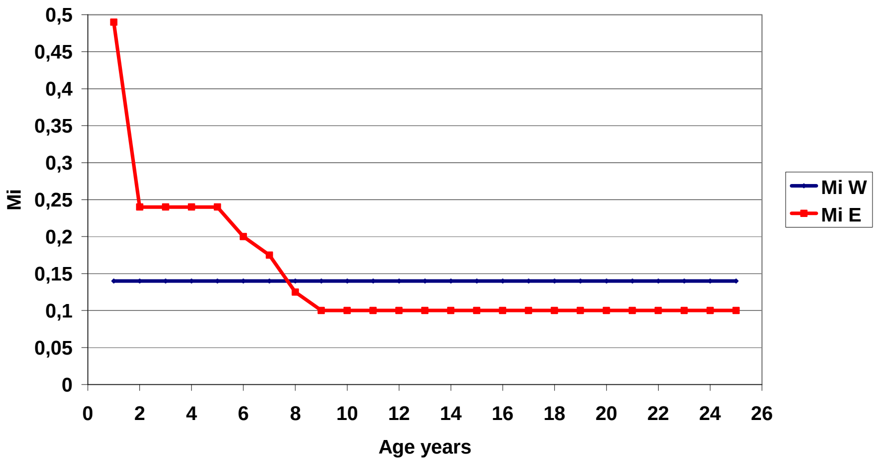


Figure 22 Natural mortality presently assumed for the eastern and western Atlantic Bluefin

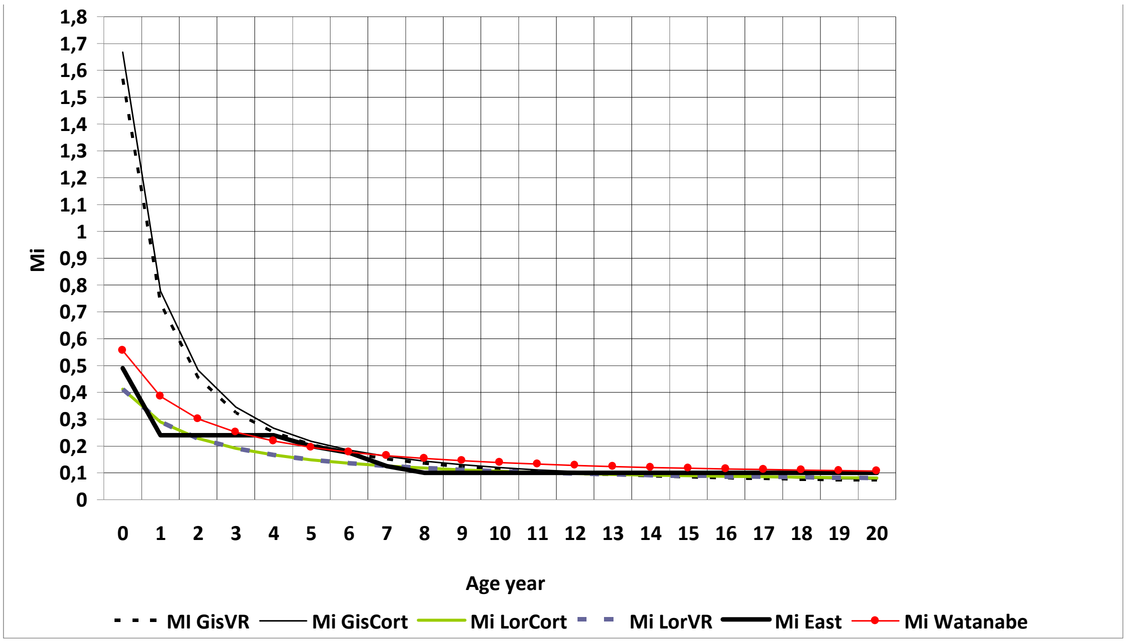


Figure 23 Potential Natural mortality at age that could be used for future stock assessment of BFT in the Atlantic: SBT Mi (MiEast), and Mi estimated by the Gislason 2010 (Gis) and by the Lorenzen 2000 (Lor) method for the Cort growth (cort) and the Restrepo 2009 growth (VR), and by the Chen & Watanabe 1989 method.

Appendix 1

AGENDA

1. Opening
2. Revision of biological data used for Atlantic bluefin tuna assessment
   2.1 Revision of the Task II data recovered by GBYP from 2010 to 2012: quality controls and analyses
   2.2 Overview of other new information on bluefin tuna biology collected from other programmes, including farming data, market and auction data
3. Revision of main biological parameters used for Atlantic bluefin tuna assessment
   3.1 Size conversions: length to weight, curved fork-length to fork-length, etc.
   3.2 Age conversions: growth curve, ageing data, ALK tables.
   3.3 Reproduction: sex ratio, maturity, fecundity and spawning
   3.4 Natural mortality
   3.5 Population structure and stock mixing: otolith microchemistry, genetics, tagging, stock-age key tables
4. Incorporation of data collected and/or recovered into the ICCAT databases
5. Recommendations
6. Other matters
   6.1 Revision of other available data (e.g., VMS)
   6.2 Proposal for the development of an operating model for use in MSE
7. Adoption of the report and closure.

Appendix 2

LIST OF PARTICIPANTS

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

CONTRACTING PARTIES

Algerie
Labidi, Naciba
Ministère de la Pêches et des Ressources Halieutiques, Rue des Quatre Canons, 1600 Alger
Tel: +213 21 43 3033, Fax: +213 21 43 3048, E-Mail: sdvd@mpeche.gov.dz; naciba.labidi@gmail.com

Canada
Neilson, John D.
Head, Large Pelagic and Pollock Projects, Population Ecology Section, Fisheries and Oceans Canada, St. Andrews Biological Station, 531 Brandy Cove Road, St. Andrews New Brunswick E5B 2L9
Tel: +1 506 529 5913, Fax: +1 506 529 5862, E-Mail: john.neilson@dfo-mpo.gc.ca

European Union
Arrizabalaga, Haritz
AZTI - Tecnalia /Itsas Ikerketa Saila, Herrera Kaia Portualde z/g, 20110 Pasaia Gipuzkoa, ESPAÑA
Tel: +34 94 657 40 00, Fax: +34 94 300 48 01, E-Mail: harri@azti.es

Bonhommeau, Sylvain
IFREMER - Dept. Recherche Halieutique, , B.P. 171 - Bd. Jean Monnet, 34200 Séte , FRANCIA
Tel: +33 4 9957 3266, Fax: +33 4 9957 3295, E-Mail: sylvain.bonhommeau@ifremer.fr

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

Fromentin, Jean Marc
IFREMER - Dpt. Recherche Halieutique, , BP 171 - Bd. Jean Monnet, 34203 Sète Cedex , FRANCIA
Tel: +33 4 99 57 32 32, Fax: +33 4 99 57 32 95, E-Mail: jean.marc.fromentin@ifremer.fr

Macías, Ángel David
Ministerio de Economía y Competitividad, Instituto Español de Oceanografía, C.O.de Málaga, Puerto pesquero s/n, 29640 Fuengirola Málaga, ESPAÑA
Tel: +34 952 197 124, Fax: +34 952 463 808, E-Mail: david.macias@ma.ieo.es

Ortiz de Urbina, Jose María
Ministerio de Economía y Competitividad, Instituto Español de Oceanografía, C.O de Málaga, Puerto Pesquero s/n, 29640 Fuengirola Málaga, ESPAÑA
Tel: +34 952 197 124, Fax: +34 952 463 808, E-Mail: urbina@ma.ieo.es

Puncher, Gregory Neils
Laboratory of Genetics & Genomics of Marine Resources and Environment, Dept. Biological, Geological & Environmental Sciences, University of Bologna, Via S. Alberto 163, 48123 Ravenna (Italy)
Tel: +39(0)544/937311 Fax: +39(0)544937411, E-mail: Gregory Neils Puncher <gregoryneil.puncher2@unibo.it>

Rodríguez-Marín, Enrique
Ministerio de Economía y Competitividad, Instituto Español de Oceanografía, C.O. de Santander, Promontorio de San Martín s/n, 39004 Santander Cantabria, ESPAÑA
Tel: +34 942 291 716, Fax: +34 942 27 50 72, E-Mail: rodriguez.marin@st.ieo.es

Japan

Itoh, omoyuki
Chief, Temperate Tuna Group, Tuna and SkipjackBluefin Tuna Resources Division, National Research Institute of Far Seas Fisheries, 5-7-1 Orido Shimizu-ku, Shizuoka-City, Shizuoka 424-8633
Tel: +81 543 36 6036, Fax: +81 543 35 9642, E-Mail: itou@fra.affrc.go.jp

Kimoto, Ai
Researcher, Temperate Tuna Group, Tuna and SkipjackBluefin Tuna Resources Division, National Research Institute of Far Seas Fisheries, 5-7-1 Orido Shimizu-ku, Shizuoka-City, Shizuoka 424-8633
Tel: +81 543 36 6036, Fax: +81 543 35 9642, E-Mail: aikimoto@affrc.go.jp

Maroc

Baibat, Sid Ahmed
Centre de Recherche Halieutique de Laayoune

Tunisie

Zarrad, Rafik
Institut National des Sciences et Technologies de la Mer, BP 138 Mahdia 5199
Tel: +216 73688604, Fax: +216 73688602, E-Mail: rafik.zarrad@instm.rnrt.tn

United States

Boustany, Andre M.
Duke University, Nicholas School of the Environment Box 90328, Durham NC 27708, ESTADOS UNIDOS
Tel: +1 831 402 1364, Fax: E-Mail: andre.boustany@duke.edu

Cass-Calay, Shannon
NOAA Fisheries, Southeast Fisheries Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami Florida 33149
Tel: +1 305 361 4231, Fax: +1 305 361 4562, E-Mail: shannon.calay@noaa.gov

Díaz, Guillermo
NOAA-Fisheries, Southeast Fisheries Science Center, 1315 East-West Highway # 13562, Silver Spring Maryland 20910
Tel: +1 301 713 2363, Fax: +1 301 713 1875, E-Mail: guillermo.diaz@noaa.gov

Lutcavage, Molly
Director, Large Pelagics Research Center, University of Massachusetts, 108 East Main Street, Gloucester MA 01930
Tel: +1978 283 0368, Fax: +1 978 283 0297, E-Mail: mlutcavage@eco.umass.edu

Porch, Clarence E.
Chief, Sustainable Fisheries Division, Southeast Fisheries Science Center, National Marine Fisheries Service, 75 Virginia Beach Drive, Miami Florida 33149
Tel: +1 305 361 4232, Fax: +1 305 361 4219, E-Mail: clay.porch@noaa.gov

Secor, David
University of Maryland Center for Environmental Science, P.O. Box 38, MD Solomons 20688
Tel: +1410 326 7229, Fax: +1 410 326 7210, E-Mail: secor@cbl.umces.edu

Walter, John
NOAA Fisheries, Southeast Fisheries Center, Sustainable Fisheries Division, 75 Virginia Beach Drive, Miami Florida 33149
Tel: +305 365 4114, Fax: +1 305 361 4562, E-Mail: john.f.walter@noaa.gov

Wozniak, Andrew
Virginia Institute of Marine Science, College of William and Mary, P.O. Box 1346, Gloucester Point VA 23062,
Tel: +1 757 683 3996, Fax: E-Mail: wozniak@vims.edu

OBSERVERS - Non-governmental Organizations

Pew Environment Group

Miller, Shana
Pew Charitable Trusts,901 E Street, NW, Washington, DC 20004, ESTADOS UNIDOS
Tel: +1 631 671 1530, Fax:E-Mail: smiller-consultant@pewtrusts.org

WWF Mediterranean Programme Office

Quílez Badia, Gemma
WWF Mediterranean Programme Office, c/ Carrer Canuda, 37 3er,, 08002 Barcelona Barcelona , ESPAÑA
Tel: +34 93 305 6252, Fax: +34 93 278 8030, E-Mail: gquilez@atw-wwf.org

****

ICCAT SECRETARIAT

C/ Corazón de María, 8 - 6 Planta, 28002 Madrid, ESPAÑA
Tel: + 34 91 416 5600, Fax: +34 91 415 2612, E-Mail: info@iccat.int

Pallarés, Pilar
Kell, Laurence
Ortiz, Mauricio
Di Natale, Antonio
Idrissi, M'Hamed

Appendix 3

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Appendix 4

Data processing & extrapolation of tuna sizes sampled in the farms

This data processing should necessarily incorporate the following elements:

1) Full use of all size sampling data collected in Mediterranean farms since 2003, independently of their sources: National, GBYP samples or MRAG sampling since 2010. The work should simply try to eliminate all duplicate samples.

2) All sizes data that have been obtained in predorsal and in round length should be used and converted to straight FL; the round length conversion should be done on a revised conversion parameter, as the today 5% of decreasing size appears to be much too low for large & fat tunas from the farms.

3) GBYP should ASAP obtain this improved conversion factor between round and straight length at killing in the farms (for medium and large BFT).

4) Fishing dates of all measured fishes should be recovered as much as possible: this basic information has net been identified in recent sampling files, but it should be recovered when possible, for instance with connection various sources of information and files.

5) Sizes at fishing dates should be estimated assuming that each fish has been growing following the typical growth curve proposed by Cort. This calculation is trivial for all tunas killed & fished at known dates. When fishing dates are missing, they will be assumed, based on the average fishing dates of the year (using external information, for instance ICCAT certificates) or simply assuming a fishing date on June 1st .

6) Catch at size should necessarily be extrapolated with a geographical stratification of the farms and of the fishing location of the fished tunas, for instance Eastern & Western Medit, and Croatian farms. These Croatian farms should be treated separately because of their peculiar sizes and durations in the farming process.

7) The sizes at fishing dates of the BFT sampled in the farms should be extrapolated to their total CAS in 2 different ways: (1) as before to the yearly catches of Mediterranean PS declared by each country, and (2) also based on the total numbers of BFT that have been identified in the ICCAT certificates and in the commercial data (Bluefin Tuna Trade and Market Data).

Appendix 5

Description of variables for creation of master datasets.

DATA SETTING: year,month,gear,area,vescode,port,sampler,length,lcode,weight,wcode,ew
###gear code, enter name of gear code, i.e. enter "HL", "PS" or "LL"

1:BB
2:BB&TR
3:GN
4:HL
5:HP
6:LL
7:PS
8:TP
9:TR

#area, enter name of fishing area at finest level of detail (NAFO unit, US area, etc)

1:Central Atlantic
2: Emed_Ionian
3. Tunisia
etc, ...

#port (enter name of landing port, - when not available code as NA

1: on board
2:

#vescode (often not available - when not available code as NA)

#some identifier for a unique vessel

#sampler (enter name of sampler- when not available code as NA)

1: scientific observer number

#length in cm

1:straight fork length
2:curved fork length
3: dressed length

#weight in kg
0:round weight
1: gilled and gutted
2: gilled, gutted and tailed
3: gutted wt

#ew e=east of 45W, w=west of 45W
1:east
2:west

#dataset (US dealer, Malta , Japan longline, GBYP, etc)

Appendix 6

Example of master dataset fields

year	month	gear	area	vescode	port	sampler	length	lcode	weight	wcode	ew	dataset
2004	4	LL	GOM	NA	NA	NA	252	1	241.76	1	2	USPLLOBS
2004	4	LL	GOM	NA	NA	NA	271	1	280.32	1	2	USPLLOBS
2006	4	LL	MAB	NA	NA	NA	241	1	202.76	1	2	USPLLOBS
2006	4	LL	GOM	NA	NA	NA	258	1	289.85	1	2	USPLLOBS
1960_1980	567	TRAP_PS	CMED	NA	NA	1	45	1	1.60	0	1	Arena
1960_1981	567	TRAP_PS	CMED	NA	NA	1	46	1	1.80	0	1	Arena
1960_1987	567	TRAP_PS	CMED	NA	NA	1	49	1	2.20	0	1	Arena
1960_1988	567	TRAP_PS	CMED	NA	NA	1	50	1	2.50	0	1	Arena
2005	5	LL	CMED	NA	NA	1	158	2	66.00	1	1	Malta
2005	5	LL	CMED	NA	NA	1	195	2	187.00	1	1	Malta
2005	5	LL	CMED	NA	NA	1	210	2	158.00	1	1	Malta