SCRS/2015/169 Collect. Vol. Sci. Pap. ICCAT, 72(7): 1694-1714 (2016)

UPDATED STANDARDIZED BLUEFIN TUNA CPUE INDEX OF THE BAY OF BISCAY BAITBOAT FISHERY (1952-2014)

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SUMMARY

In the BFT stock assessment conducted in 2010, the final advice on stock status was based on two ADAPT runs which basically differed on which baitboat index was considered (age specific up until 2007, or age aggregated up until 2009, respectively). The uncertainties derived from the potential effect of the BFT Recovery Plan on the behaviour of the BB fleet in the Bay of Biscay prevented to update the age specific baitboat CPUE index. In 2012, a long term age-aggregated index, from 1952 to 2007, based on trip information; and a new age-aggregated index for the most recent period, 2000-2011, based on a fine scale database that incorporates daily logbooks, trip and VMS information, were produced. The effects of regulations on the CPUE were described and considered in the analysis, as well as technological and environmental variables. Both indices showed similar trends in the overlapped timeframe. These indices were used in the 2012 and 2014 stock assessments, and are updated here until 2014.

RÉSUMÉ

Dans l'évaluation du stock de thon rouge réalisée en 2010, l'avis final sur l'état du stock se fondait sur deux scénarios ADAPT qui différaient dans le fond en fonction de l'indice des canneurs qui était pris en compte (spécifique à l'âge jusqu'en 2007 ou regroupé par âge jusqu'en 2009, respectivement). Les incertitudes entourant l'effet que le programme de rétablissement du thon rouge pourrait avoir sur le comportement de la flottille de canneurs dans le golfe de Gascogne ont empêché d'actualiser l'indice spécifique à l'âge de la CPUE des canneurs. On a élaboré en 2012 un indice agrégé par âge couvrant une longue période (1952 à 2007), reposant sur des informations des sorties et un nouvel indice agrégé par âge portant sur la période plus récente, de 2000 à 2011, reposant sur une base de données à fine échelle qui incluent les données des carnets de pêche quotidiens, les données des sorties et de VMS. Les effets des réglementations sur la CPUE ont été décrits et pris en compte dans l'analyse ainsi que les variables technologiques et environnementales. Les deux indices présentaient des tendances semblables pendant la période de chevauchement. Ces indices ont été utilisés dans les évaluations de stocks de 2012 et 2014 et ils sont mis à jour dans le présent document jusqu'en 2014.

RESUMEN

En la evaluación de stock de atún rojo llevada a cabo en 2010, el asesoramiento final sobre el estado del stock se basó en dos ensayos de ADAPT que básicamente diferían en el índice de cebo vivo que se consideraba (específico de la edad hasta 2007 o agregado por edad hasta 2009, respectivamente). Las incertidumbres derivadas del posible efecto del Plan de recuperación para el atún rojo en el comportamiento de la flota de cebo vivo en el golfo de Vizcaya impidieron actualizar el índice de la CPUE de cebo vivo específico de la edad. En 2012, se elaboró un índice para un largo periodo agregado por edad, para el periodo 1952-2007, basado en información de mareas y un nuevo índice agregado por edad para el periodo más reciente, 2000-2011, basado en una base de datos de escala fina que incorporaba datos de cuadernos de pesca diarios, así como información de mareas y de VMS. Se describían y consideraban en los análisis los efectos de las reglamentaciones en la CPUE, así como las variables tecnológicas y medioambientales. Ambos índices mostraban tendencias similares en el periodo de solapamiento. Estos índices se utilizaron en las evaluaciones de stock de 2012 y 2014 y aquí se actualizan hasta 2014.

KEYWORDS

Bluefin tuna, Bay of Biscay, Baitboat, Catch and effort
CPUE standardization, Delta-lognormal model, Generalized Linear Mixed Model

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1. Introduction

Tuna fishing activity in the Bay of Biscay and adjacent areas starts annually in late spring just after the finalization of the anchovy season with purse seine. Basque fishermen target albacore using trollers and baitboats and bluefin tuna with baitboats. Bigeye and skipjack may also appear occasionally in the catches. The bluefin tuna fishery has traditionally taken place in the south-eastern area of the Bay of Biscay from June to October. Most of the catches are composed by juveniles (1-4 years) and are usually concentrated in a very limited area (south of 45°30'N and west of 4°W) where the fleet operates and occasionally combines this activity with albacore fishing. When targeting albacore the fleet spreads over wider areas (**Figure 1**).

Hondarribia is the main bluefin tuna fishing port in the Bay of Biscay. Vessels based in this port have been responsible for more than 90% of the bluefin tuna catches obtained by the Spanish fleet in the Bay of Biscay during the last six decades (**Figure 2**). This major presence has been reduced during the last fifteen years due to several reasons, especially because of the anchovy fishery crisis starting in mid-1990s that peaked during its closure (2005-2009) and the entry into force of the BFT Recovery Plan [Rec. 06-05]. The anchovy crisis caused baitboats from other ports to start targeting bluefin tuna in late spring, before the albacore fishery (their traditional activity) started in summer.

The BB technique was introduced in Hondarribia in 1948 following pioneer initiatives in the neighbour port of Saint Jean de Luz (France). Prior to that year, annual catch of bluefin made by the Hondarribia fleet was around 200-500 t; after the introduction of BB fishing the average catch increased significantly to around 1,000 t in the 1950s, declined to around 500 t in the 1960s and increased again and remained relatively stable around 1,000-1,200 t until mid-1990s. After 1995 catches increased showing high year-to-year variations. Finally, since 2008 a strict quota system has been put in place together with a dynamic framework of allocation with equal sharing opportunities that was voluntarily adopted by the fleet in order to maximize profit by spreading landings along the fishing season (**Figure 3**). In 2012 the BB Spanish fleet sold partially the assigned annual quota and fished 134 t; and in 2013 and 2014 they sold the full annual quota.

Few CPUE indices are available to assess the status of East Atlantic and Mediterranean Bluefin tuna (Anon 2011a). The Japanese longline, the Spanish-Moroccan traps and the historical Norwegian purse seine index are used for adults, and the Spanish baitboat CPUE is the only available index for juveniles. In 2010, a standardized historical (1952-1972) baitboat index (Santiago *et al*., 2011) was used for the first years, and both an age specific index (Rodríguez Marin *et al.*, 2011) and an age aggregated index (1973-2009, updated from García *et al.* 2007, Anon 2011a) for the latest period.

The historical baitboat index (Santiago *et al.*, 2011) was presented in the 2010 data preparatory meeting (Anon, 2011b), which also included information on fleet characteristics and technological improvements introduced during the time series, and interviews with fishermen that allowed a better understanding of the dynamics of the fishery at that time. For the recent period, the age specific CPUE index was not updated because regulations were believed to affect the fishing strategy. Given the lack of a standardized baitboat index for the last two years in the assessment (2008- 2009), during the 2010 BFT SA session (Anon., 2011a) it was requested to standardize the alternative age-aggregated catch rate series of the baitboat fishery targeting bluefin tuna in the Bay of Biscay (García *et al.* 2007). The main difference with respect to the age disaggregated standardized index used for VPA tuning of ages 2 and 3 in the 2008 assessment is that it only included boats from Hondarribia (excluding those from Getaria, which were larger and more prone to target albacore). Furthermore, effort was measured as days at sea (instead of days at sea targeting bluefin), which is believed to be less affected by recent regulations that might have modified, to a certain extent, the behaviour of the fleet (specially targeting issues; Rodríguez Marin *et al*, 2011).

The 2010 BFT SA group recommended trying to include technological and environmental factors in the standardization, as well as to try to overcome the potential effects of the recent regulations. The final advice on stock status was based on ADAPT runs 13 and 15, which basically differed on which baitboat index was considered (age specific up until 2007, or age aggregated up until 2009, respectively).

Santiago *et al.* (2012) produced a unique long term index, based on trip information, merging the previous "historical" (1952 onwards) index (Santiago *et al*., 2011) and the "recent" (1970 onwards) age aggregated index (García *et al.* 2007, Anon., 2011a) into a single index (1952-2007). Moreover, the authors presented a new recent index (2000-2011) based on a fine scale database that incorporates daily logbooks, trip and VMS information. Technological and environmental variables were also considered in the analyses.

The 2012 BFT assessment used these age aggregated indices to calibrate the VPA. For the continuity run (Run 2), the Group decided to split the baitboat index in three series: Spanish bait boat_1 (1952-1962, ages 5-6), Spanish bait boat_2 (1963-2006, ages 2-3) and Spanish bait boat_3 (2007-2011, ages 3-6, Anon., 2013). The first two series correspond to the trip based long term index, and the third series to the fine scale data based recent index. These indices were also used in the 2014 assessment.

In this working document we present the analyses carried out to create the two indices and we update the most recent index up to 2014 incorporating daily records from the Basque-French baitboats that operate in the same area and season as the Basque-Spanish fleet.

2. Data and methods

Two different periods have been considered in the present analysis, according to the entry into force of the BFT Recovery Plan. A first period of 55 years (1952-2007) in which there have not been relevant changes in the performance of the fleet of Hondarribia, apart from the different technological improvements introduced. And a second period of 15 years (2000-2014), period with some convulsions in the activity derived from the Bay of Biscay anchovy fishery closure, the adaptation of the BB fleet to the BFT Recovery Plan and the recent sale of the annual fishing quota. Due to the different approaches that have been followed in the analysis of both series, an overlap period (2000-2007) was considered for comparative purposes.

For the first period 1952-2007, only BB vessels from Hondarribia were selected since these boats have systematically sampled bluefin tuna abundance in the Bay of Biscay along the time series, and avoiding subjective decisions about the target species for specific trips of boats from other ports, that may introduce substantial variability in the system. This selection allowed working on a trip by trip basis with 52,897 trips corresponding to 194 vessels.

As for the second period, 2000-2014, all BB vessels available were considered irrespective of their port of origin. And due to the variations in the behaviour and composition of the fleet, especially after 2007, it was necessary to work the information in detail on a daily basis. In this way, the number of daily observations amounted to 29,362 coming from 56 vessels (33 from Hondarribia, 16 from Getaria, 1 from Orio and 6 from Saint Jean de Luz, Hendaye and Capbreton).

2.1 Description of the data sources

- *1952-2007*

Daily landings per vessel for the period 1952-2007 were obtained from the Official Registry Books of the fishermen association of Hondarribia “Hondarribiko Done Pedro Itsas Gizonen Kofradia”. The Registry included information of date of landing, vessel name, tuna species, quantity sold (kg) and price. Information corresponding to vessels from other fishing ports (not regular vessels) was excluded and only records of baitboat vessels from Hondarribia fishing for tuna were considered. These records include mostly trips targeting bluefin, but also some trips with combined bluefin and albacore catch, and a few (8%) trips with purely albacore landings, predominantly during the last decade.

Effort, measured in number of fishing days, was generally estimated subtracting the dates of arrival and departure of each trip. Some assumptions were made based on the knowledge of the fishery. Several interviews with old fishermen were carried out to obtain information from the evolution of the activity during the period analysed, with special emphasis on those patterns that might facilitate a proper estimation of the effort associated to landings by trip. For the initial period of the series, 1952-1968, the duration of the trip was set to 1, since they had no freezing system and not enough capacity for longer trips; this limitation is also applied to <20 GRT vessels for the complete period. From 1969 and onwards, freezing systems improved and the capacity of the fleet started to increase, which allowed for a progressive increase in distance to the fishing grounds. In this period, the effort was estimated as the number of days between successive landings minus one, except if landings occurred in consecutive days. The rules followed by the fleet of Hondarribia regarding local festivities (need to be in port between prefixed dates around the festivities) were also taken into account at the time of estimating the effort.

The method used for estimating fishing effort does not allow estimating effort for the first trip of a boat in a given year, so these trips were discarded. Typically, a bluefin tuna trip during the recent decades does rarely exceed a week. However, because albacore targeted trips are considered in the database, trips durations up until 20 days are included.

In order to select the boats with largest experience, a subset of vessels with at least 7 years of bluefin tuna records were kept for the analysis. After applying this selection criterion, the total number of records compiled represents 44,938 trips conducted by 141 different vessels during 56 years.

Because of low and irregular number of observations in the start and end of the fishing season, observations in May and June, and those in October and November were combined (**Table 1**).

In order to consider targeting effects in the analysis, a "target" variable was defined with 3 levels, depending of the weight proportion of bluefin tuna in the landings of each fishing trip: "ALB" if the proportion of BFT was ≤0.25, "Mix" if it was >0.25 and ≤0.75, and "BFT" if >0.75.

Information on vessel characteristics was also made available from the Fishermen Association and official fleet registers, and included vessel name, tonnage (GRT), power (HP), total length (m) and year of construction. The technological characteristics of the vessels (number of colour echosounders, monochrome sonars, colour sonars, radio direction finders, navigation radars, GPS and plotters) were obtained through personal interviews to skippers and vessel owners.

Long term meteorological and oceanographic data were also collected for the whole 1952-2007 period. On the one hand, daily wind speed and direction at 45ºN 2.5ºW was obtained from NCEP NOAA[4]. These were used to calculate the average upwelling induced at the French coast (following Borja et al., 2008) during five days prior to each landing. A positive index indicates an upwelling event, while a negative index represents downwelling. Thus, the upwelling variable was categorized into negative, positive and very positive values (defined as >700 m3/km2). The inclusion of this upwelling variable was justified because week upwellings positively affect anchovy recruitment (Borja et al., 2008), which is one of the most preferred prey for juvenile bluefin tuna in this feeding area (Logan et al 2011, Goñi et al, unpublished data) and could increase the availability of bluefin in the fishing area. On the other side, upwelling events associated with shallower mixed layer depths could also affect the vertical availability of bluefin tuna to the surface layers, thus increasing catchability to surface gears like baitboat.

Several interviews with fishermen were carried out to obtain information from the evolution of the activity during the period analyzed, with special emphasis on those patterns that might facilitate a proper estimation of the effort associated to daily landings (García et al., 2007; Santiago et al., 2011). As regards technological evolution of the fleet, 24 skippers were interviewed about when different devices were acquired. All skippers were also asked about their opinion about the influence of the different technological devices on the catch rates.

In an attempt to quantify the effect of the devices identified by the skippers, a subset of the 1952-2007 dataset with the boats that had information "with" and "without" such technological devices was used. A categorical variable (e.g. "Sonar") with two levels ("with" and "without") was added as fixed effect to the final model selected to standardize the historical time series. The ratio between the expected CPUE with and without the technological device was used to test whether it had a positive effect (as expected) or not.

- *2000-2014*

Three different sources of information of the fleet activity were available for this period: logbooks, catch landings and satellite-based Vessel Monitoring System (VMS).

- Logbooks. Skippers of all European Community vessels over 10m length are required to record the retained catch weights (in kg) by species in logbooks on a daily basis. Logbooks available for the present study comprise:
    - 28,772 daily observations from 50 BB vessels that caught 11,564 t of bluefin and 27,358 t of albacore, representing 71% and 42% of the total catch made by the BB Spanish-Basque fleet of each species respectively in the period 2000-2011.

[4] http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml

- 667 daily observations from 6 vessels that caught 1051 t of bluefin and 38 t of albacore, representing 96% and 26% of the total catch made by the BB French-Basque fleet of each species respectively in the period 2001-2013.

- Catch landings. Catch landings were obtained from the sales notes collected from fish auctions and compiled by the Department of Agriculture and Fisheries of the Basque Government and AZTI. They contain per vessel data on sales per species in weight (kg) and value by date and port. This information was used to correct the estimated catches annotated in the logbooks by the skippers. This was done distributing the total landings of the trip among its fishing days proportionally to the skippers' value provided in the mandatory logbooks.

- VMS. Since January 2000 all European fishing vessels exceeding 24m in overall length (15m from 2005) have been required to use VMS and to transmit their position at least every two hours. For the purpose of this study the Spanish Ministry of Agriculture, Food and Environment has provided 958,000 records of VMS data from the BB Spanish-Basque fleet for the period 2000-2011. VMS data are collected on a different temporal scale (2 hours) to the logbook data (24 hours) which creates a problem for linking the two datasets. For this reason the VMS data for each vessel was averaged on a daily basis, using records between 8:00 and 20:00 hours (BB fishing takes place only during daylight hours).

After the adjustment with catch landings DB, data from logbooks provided detailed information on positive daily catches by vessel. VMS information was used to characterize the activity of the Spanish-Basque fleet to identify the BFT targeting fishing days; VMS information was not used in the case of the French-Basque fleet because they continuously target BFT. As for the former, we characterize the effort of each fishing day (positive and with no catch) into three categories: targeting BFT, targeting ALB and Other Activities (bait searching, bait fishing, stay in port …) according to the vessel position, the characteristics of the trip and based on fishery knowledge. The general criteria used were: a) assign targeting ALB when position north of 47ºN or west of 7ºW; b) Other Activities when south of 43º40'N (bait fishing or at port) or the French continental shelf (bait fishing); c) targeting BFT when BFT catches > 75% tuna catches in the trip; d) targeting ALB when ALB catches > 75% tuna catches in the trip; e) targeting ALB once the BFT quota (dynamic framework of allocation adopted by the fleet) is achieved.

The different restrictions applied to the fishery, after the entry into force of the BFT Recovery Plan, have been taken into account in the characterization of effort after 2007. The following official restrictions have affected the dynamics of the BB BFT fishery in the Bay of Biscay: Size limits [<6.4 kg (2003) and <8 kg (2008)], closed fishing seasons [15 Nov-15 May (2007) and 15 Oct-15 Jun (2009)], quota [1,406 t (2008), 931 t (2009), 550 t (2010), 525 t (2011)]. Moreover there have been agreements at the level of Fishermen Associations that have guided the activity of the fleet for the period 2008-2013; the agreed decisions are summarized in **Figure 3** and basically involved the fixation of periodic individual quotas with the aim of keeping prices as high as possible, as well as quota sells in the last two years.

The restrictions have clearly affected the fishing strategy of the BB fleet from 2008 onwards, making it more difficult to conduct a homogeneous analysis on the long time series based on trips. However, a daily basis approach appears feasible to isolate the BFT activity from the general fishing activity of the fleet. And the analysis of logbook and VMS data on a daily basis, in conjunction with the framework of the various individual quota arrangements, has allowed the identification of those days that vessels were supposed to be targeting BFT and therefore the estimation of BFT CPUE daily values by vessel.

There are other aspects resulting from the change in the fishing strategy of the fleet that should be bear in mind when considering the CPUE series derived in the present analysis. The increase of the negative skewness of the log (BFT) annual distributions due to the incidence of the individual quota limits after 2007; and changes in selectivity towards bigger fishes mainly driven by market requirements in a context of reduced allowable catches (**Figure 4**).

Other variables that were compiled for the CPUE standardization analysis included fleet characteristics (as for the period 1952-2007) and oceanographic variables (2000-2011). These were monthly values of 5 m–below sea level potential temperature[5] and mixed layer depth[6] extracted from the LDEO/IRI Data Library (**Figures 5a-b**). These two oceanographic variables were selected because they reflect in some extent the thermal structure of the waters which is important for understanding the vertical distribution of bluefin tuna and their availability to the

[5] http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.EMC/.CMB/.GODAS/.monthly/.BelowSeaLevel/.POT
[6] http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCEP/.EMC/.CMB/.GODAS/.monthly/.ocean_mixed_layer_bot/

BB gear. BFT CPUE geolocations existing for the 2000-2011 were superimposed on the 0.33x1 degree grid of both variables. Approximately 25% of the 28,774 daily records (5,604) lacked of the associated environmental data because of absence of VMS or environmental information. Therefore the initial analysis with the full set of variables was restricted to 23,170 daily records (46 vessels) whereas the final model included the complete set of records (28,774 records, 50 vessels).

Number of vessels, number of daily CPUE observations (total, targeting BFT and BFT positives) and proportion of BFT positives for the period 2000-2014 are shown in **Table 2**. As in the 1952-2007 period, due to low and irregular number of observations in the start and end of the fishing season, observations in May and June, and those in October and November were combined (**Table 3**).

2.2 Standardization of catch rates

Catch-rate standardization is in theory the process used to remove factors other than changes in abundance of the population that can impact nominal catch rates over time. The objective is then to obtain a reliable index of relative abundance that reflects primarily changes in population abundance (Maunder and Punt, 2004). For the present study, relative abundance of bluefin was estimated by standardizing nominal catch rates from the Basque (including both the Spanish-Basque and the French-Basque) BB fleet using a Generalized Linear Mixed Modelling approach.

Because of the significant proportion of sets with zero catch of bluefin tuna [between 0.1 and 53% (1952-2007) and 8% and 41% (2000-2013) on average per year], the standardization method used a delta lognormal model distribution that can take into account zero observations (Lo *et al*., 1992; Stefansson, 1996; Ortiz and Arocha, 2004; Shono, 2008). The delta model estimates the predicted catch rates as the result of two processes; i) the probability of encounter bluefin tuna in the catch (proportion of positive catch) and, ii) the mean catch rate given that a positive catch has been realized (conditional predicted catch rate) (Lo *et al*., 1992). Then the estimated catch rates overall are the product of these two processes.

Catch rates of bluefin in the Basque BB fleet are likely affected by several factors. Maunder and Punt (2004) recommend at least considering spatial-temporal variables, factors affecting the catchability such as, gear, fishery operations, vessel type, skippers experience, target species, etc., and environmental factors that may condition the availability of the species to the catching gear. The set of potential factors that were considered in the analyses were temporal variables (month), variables related to the fleet characteristics (vessel or vessel category as defined by vessel cluster analysis considering length, tonnage, power and year of construction), target species and environmental factors (mean wind speed and average upwelling for the period 1952-2007 and monthly values of 5 m–below sea level potential temperature and mixed layer depth for the period 2000-2011). Spatial factors were not considered because BFT fishing activity is regularly concentrated in the same limited area (**Figure 1**).

One important factor that has been shown to greatly affect catch rates of target species in the BB fleet is the vessel type, particularly related to size and operational characteristics (Santiago *et al*., 2011). In one type of analysis, vessels were classified into 4 categories based on a cluster analysis that included: length, tonnage, power and year of construction. The S size category comprised boats of 10m length on average, operating mostly during the 50is and 60ies; the M size category grouped boats of 17 m on average that operated since the 50ies and up until the 90ies; the L size category grouped vessels of 26 m length on average that operated mostly after the 70ies, and the XL category grouped vessels with average length of 31 m that operated since the mid 90ies. This “Vessel Type” variable was included as factor in the models. Alternatively, it was also possible to associate each observation with a single vessel through the whole time series. The advantage of this association is that the variability within vessel groups can be further partitioned into each vessel variance, and account for possible auto-correlation between observations from the same vessel (Maunder and Punt, 2004; Punt *et al*., 2000). In practice, each group of observations from the same vessel is treated as a "repeated measurements" statistical problem (Fabrizio *et al.*, 2000). Because it is likely that the same vessel (having the same skipper) will operate similarly within and between years, will have similar catch rates (other factors being equal), thus making observations from a vessel unit auto-correlated and non-truly independent as required by the generalized linear models. In the case of the BB fleet, the auto-correlation within a vessel was evaluated. This was done by using a variance-covariance matrix model where each vessel is the subject unit (Autoregressive variance -covariance model AR1). The parameters estimated where the auto-correlation for each vessel in which observations close in time are expected to show higher correlation compared with observations far apart (Littell *et al.* 1996; Bishop, 2006). The correlation within vessel units was compared statistically against the alternative model with no correlation within the observations from the same vessel; this been the classical generalized linear model.

Statistically, a step-wise regression procedure was used to determine the set of explanatory factors and interactions that significantly explained the observed variability. For this, deviance analysis tables were created for the proportion of positive observations (e.g., positive sets/total sets), and for the positive catch rates. Final selection of explanatory factors was conditional to: a) the relative percentage of deviance explained by adding the factor in evaluation (normally factors that explained more than 4% were selected), and b) The Chi-square ($\chi 2$) significance test.

Interactions among factors were also evaluated, if an interaction was statically significant, and included the year factor in particular, it was then considered as a random interaction(s) within the final model (Rodriguez-Marin *et al*. 2003, Maunder and Punt, 2004). The auto-correlation within the vessel unit was statistically tested using the Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC) (Littell *et al.*, 1996).

Lastly, the selection of the final mixed model was based on the Akaike's Information Criterion (AIC), the Bayesian Information Criterion (BIC), and a Chi-square ($\chi 2$) test of the difference between the log-likelihood statistics of two nested model formulations (Littell *et al*., 1996). Once having a final model selected, the relative indices for the Delta model formulation were calculated as the product of the year effect least square means (LSmeans) from the binomial and the lognormal model components (Ortiz and Arocha, 2004; Punt *et al*., 2000). These LSmeans estimates use a weighted factor of the proportional observed margins in the input data to account for the non-balance characteristics of the data. The LSMeans of the lognormal positive trips component were bias corrected for the logarithm transformation using Lo *et al*., (1992) algorithms. All analyses were done using the Glimmix and Mixed procedures from the SAS© statistical computer software (SAS Institute Inc. 1997).

In the case of the most recent index, model selection was performed using data for the period 2000-2011 where all variables (including environmental variables) were available (see Santiago *et al*., 2012). The final model selected was then updated to 2013 as a contribution to the 2014 BFT stock assessment session, and again to 2014 for the 2015 BFT species group meeting.

3. Results and discussion

The following models were finally selected in Santiago 2012, and were updated till 2014 with new data. In the case of the binomial model for the period 2000-2011, the random interactions including the year variable were not used in the update because of lack of convergence:

1952-2007	Binomial	Year, Month, Vessel-T, Upwelling
	Lognormal	Year, Month, Target, Upwelling, Year*Month, Year*Target - AR1(Subject=Vessel)
2000-2011	Binomial	Year, Month, Other, Year*Month, Year*Vessel, Year*Other - AR1(Subject=Vessel)
	Lognormal	Year, Month, Vessel, Year*Month, Year*Vessel

- *1952-2007*

The results of the deviance analysis are shown in **Table 4**. The most significant explanatory factors for the binomial model on the proportion of positives included Year, Month and Vessel Type, as well as the interactions Year*Month, Year*Upwelling and Year*Vessel-Type. In order to consider the Year*Upwelling interaction, Upwelling was included as fixed factor. These interactions were considered as random interactions. However, the mixed effects model did not converge and the final model included the fixed factors Year, Month, Vessel Type and Upwelling (**Table 5**).

The most significant explanatory factors for the lognormal model on the positive records were Year, Month, Target and Vessel-Type, as well as the interactions Year*Month, Year*Target and Year*Upwelling (**Table 4**). In order to consider the Year*Upwelling interaction, Upwelling was included as fixed factor. These interactions were considered as random interactions. Based on likelihood ratio tests, the final lognormal model included the Year, Month, Target, Vessel-Type and Upwelling as fixed factors, and Year*Month and Year*Target as random interactions (**Table 5**). An alternative lognormal model formulation was tested, by replacing the Vessel-Type fixed factor by an autoregressive covariance structure, with individual vessels as subject and repetitive measurements throughout the time series (following Littell *et al*. 1996). This model formulation (AR1) was selected as the final Lognormal model (based on a lower AIC, **Table 5**).

No significant residual patterns were observed for either the lognormal or the binomial model (**Figure 6**). The standardized CPUE values show somewhat less pronounced trends (compared to the nominal CPUE values) in both the proportion of positive observations, and the magnitude of the positive observations.

The estimates of the final Delta model are provided in **Figure 7** and **Table 6**. Most of the nominal CPUE values are embedded within the confidence interval of the standardized CPUE. The standardized CPUE shows a general increasing trend over the whole time period, with more variable values after the mid 80's, with two peaks in the 90's and one in the middle 2000's. The CVs remain relatively stable (just above 40%) during the whole time series.

Different technological devices were introduced in the fleet along the time series. **Figure 8** includes a description of the temporal evolution of the fleet in terms of incorporating new technological equipment (namely GPS, Plotter, Radar, Radio Direction Finder (RDF), Colour Sonar, Monochrome Sonar, and Colour Echosounder). All the interviewed skippers agreed that the Monochrome sonar (acquired mostly during the 70's) was the device that might have most importantly affected their ability to catch bluefin tuna. However, this hypothesis could not be confirmed based on model results, since, for a subset of 6 boats that had data with and without the monochrome sonar, the expected CPUE was not higher with the monochrome sonar compared to without this equipment (**Figure 9**). Thus, we concluded that there was no evidence that the introduction of the monochrome sonar affected the CPUEs in a statistically significant way. Although the incidence of the introduction of the monochrome sonar was the reason to cut the series in the past, we have not found evidence of positive effect, so we kept a continuous series. In the future, there is a need to test the potential impact of other equipments in the catchability, possibly taking into account some learning period by the skippers in the analysis, as well as potential combined effects of different technological devices.

- *2000-2014*

The results of the deviance analysis conducted with 2000-2011 data are shown in **Table 7**. The most significant explanatory factors for the binomial model on the proportion of positives included Year, Month, Vessel, Other tuna catch (presence of ALB, BET or SKJ in the catch), and the interactions Year*Month, Year*Vessel and Year*Other. These interactions were considered as random interactions. However, the model with random interactions did not converge in 2014 and they were not used in the final model update.

The most significant explanatory factors for the lognormal model on the positive records were Year, Month and Vessel, as well as the interactions Year*Month and Year*Vessel (**Table 7**). These interactions were considered as random interactions.

Alternative formulations were tested for both model components, by replacing the fixed factor Vessel by an autoregressive covariance structure, with individual vessels as subject and repetitive measurements throughout the time series (following Littell *et al.* 1996). This model formulation (AR1) was selected as the final binomial model (based on a lower AIC, **Table 8**).

No significant residual patterns were observed for either the lognormal or the binomial model (**Figure 10**).

The estimates of the final Delta model, updated till 2014, are provided in **Figure 11** and **Table 9**. The standardized CPUE values show no clear trend; there is an upward tendency until 2005, then a decrease in 2006 followed by an increase to relatively higher levels in 2007-2008; after the decrease in 2009, years 2010 and 2011 return to higher levels again, being the value of 2011 the highest of the series. Years in 2012, 2013 and 2014 show a decreasing trend again, being the 2014 the lowest value (relative to the 2000-2014 series). Nominal CPUE values fall within the confidence intervals of the standardized CPUEs. The CVs remain relatively stable (between 28-44%) during the whole time series.

The standardized CPUE trends of the 2000-2014 and 1952-2007 analyses are very similar during the overlapping period (2000-2007), in spite of the different approaches that have been followed (**Figure 12**).

Acknowledgements

This work was supported by the Government of the Basque Country. We thank the Basque Fishermen Associations for giving access to most of the historical and present information, especially to Norberto Emezabel and Andrés Olaskoaga, President and Secretary of the San Pedro Fishermen Association of Hondarribia ("Hondarribiko Done Pedro Itsas Gizonen Kofradia"). Special thanks to José Luis Gonzalez and his group at the General Secretary of the Sea, Spanish Ministry of Agriculture, Food and Environment. We are grateful to David Milly and Kandy Belloc, director and secretary of the Cooperative Pêcheurs d'Aquitaine for giving us access to the logbooks of the baitboat vessels from Hendaye, Saint Jean de Luz / Ciboure and Capbreton. We also thank Almudena Fontán who kindly provided wind and upwelling data.

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Table 1. Number of observed trips per year and month, for the period 1952-2007.

Year	*5-6*	*7*	*8*	*9*	*10-11*
1952	1269	631	423	147	8
1953	1370	392	0	0	0
1954	1192	609	479	197	377
1955	518	487	263	194	244
1956	713	337	321	127	248
1957	1186	796	415	124	13
1958	973	600	755	311	195
1959	1416	710	585	160	33
1960	580	422	433	87	80
1961	784	463	486	228	314
1962	589	173	181	137	61
1963	268	227	162	185	24
1964	140	213	215	256	152
1965	350	343	515	185	46
1966	382	296	548	232	51
1967	153	114	386	144	17
1968	37	105	220	53	133
1969	24	91	183	67	267
1970	45	160	226	78	73
1971	7	158	259	122	173
1972	10	108	172	73	58
1973	39	137	193	79	149
1974	4	125	151	74	35
1975	12	124	134	79	110
1976	6	75	118	57	46
1977	8	91	87	92	126
1978	2	67	99	85	97
1979	8	60	124	62	90
1980	0	42	96	61	32
1981	2	70	88	79	15
1982	6	65	95	56	21
1983	0	3	67	83	147
1984	0	22	125	78	25
1985	6	139	122	60	110
1986	0	47	104	78	137
1987	1	92	101	76	53
1988	0	64	123	69	158
1989	11	119	112	67	114
1990	21	73	89	58	91
1991	0	90	103	72	65
1992	0	83	101	55	108
1993	24	128	143	84	14
1994	3	45	60	56	163
1995	12	97	107	48	203
1996	61	132	131	59	120
1997	53	127	146	85	165
1998	10	142	122	78	73
1999	16	98	93	47	2
2000	23	101	95	86	89
2001	14	131	112	25	35
2002	27	66	95	81	29
2003	23	92	61	41	27
2004	43	77	70	25	54
2005	48	108	68	80	140
2006	66	54	71	59	70
2007	35	72	90	29	42
	12,590	**10,493**	**10,923**	**5,410**	**5,522**

Table 2. Number of vessels, number of daily CPUE observations (total, targeting BFT and BFT positives) and proportion of BFT positives for the period 2000-2014.

Year	*N vessels*	*Nobs*	*Nobs Target BFT*	*Nobs BFT >0*	*% Nobs BFT >0*
2000	23	2,038	764	490	64%
2001	24	1,416	917	543	59%
2002	24	1,347	959	614	64%
2003	23	1,838	407	255	63%
2004	18	1,316	458	313	68%
2005	32	3,534	1,116	721	65%
2006	32	3,270	470	292	62%
2007	32	3,428	788	522	66%
2008	35	3,176	443	297	67%
2009	35	2,964	530	335	63%
2010	33	2,839	189	152	80%
2011	32	2,081	189	146	77%
2012	4	61	52	48	92%
2013	4	54	48	42	88%
2014	4	77	77	59	77%
	355	**29439**	**7407**	**4829**	**70%**

Table 3. Number of daily CPUE observations and BFT positives by month for the period 2000-2014.

Year	*Nº obs*	*Nº obs BFT >0*	*5-6*	*7*	*8*	*9*	*10-11*
2000	2,038	490	71	112	118	65	124
2001	1,416	543	45	266	207	15	10
2002	1,347	614	97	166	250	96	5
2003	1,838	255	51	149	42	2	11
2004	1,316	313	82	122	68	6	35
2005	3,534	721	194	154	59	108	206
2006	3,270	292	134	9	17	53	79
2007	3,428	522	241	155	97	29	
2008	3,176	297	108	66	4	34	85
2009	2,964	335	43	92	177	19	4
2010	2,839	152	10	9	63	48	22
2011	2,081	146	13	27	60	35	11
2012	61	48		17	22	6	3
2013	54	42		24	17	1	
2014	77	59		19	45	13	
	29439	**4829**	**1,089**	**1,387**	**1,246**	**530**	**595**

Table 4. Deviance tables for the binomial (top) and the lognormal (bottom) components of the Delta-lognormal model of the 1952-2007 period. Significant (p<0.05) factors and interactions explaining >4% of total deviance are highlighted.

Model factors proportion positives	***d.f.***	***Residual deviance***	***Change in deviance***	***% of total deviance***	***p***
1	1	9883.77			
Year *[1952-2007]*	55	6862.01	3021.76	36%	< 0.001
Month *[6-10]*	4	3941.77	2920.23	35%	< 0.001
Vessel-T *[S,M,L,XL]*	3	3573.35	368.42	4%	< 0.001
Upwelling [-,+,++]	2	3530.41	42.95	1%	< 0.001
Month*Upwelling	8	3482.12	48.28	1%	< 0.001
Vessel-T*Upwelling	6	3462.06	68.35	1%	< 0.001
Month*Vessel-T	12	3312.61	217.80	3%	< 0.001
Year*Vessel-T	71	3192.54	337.87	4%	< 0.001
Year*Upwelling	85	3093.96	436.44	5%	< 0.001
Year*Month	210	1487.59	2042.82	24%	< 0.001

Model factors positive catch rates values	***d.f.***	***Residual deviance***	***Change in deviance***	***% of total deviance***	***p***
1	1	111409.25			
Year *[1952-2007]*	55	95918.95	15490.30	34.8%	< 0.001
Month *[6-10]*	4	90020.11	5898.83	13.2%	< 0.001
Target *[ALB,BFT,mix]*	2	77765.24	12254.88	27.5%	< 0.001
Vessel-T *[S,M,L,XL]*	3	72372.66	5392.57	12.1%	< 0.001
Upwelling [-,+,++]	2	72280.03	92.64	0.2%	< 0.001
Target*Upwelling	4	72267.85	12.17	0.0%	0.016
Month*Upwelling	8	72199.95	80.08	0.2%	< 0.001
Vessel-T*Upwelling	6	72196.75	83.27	0.2%	< 0.001
Month*Target	8	72102.94	177.09	0.4%	< 0.001
Target*Vessel-T	6	72060.16	219.87	0.5%	< 0.001
Month*Vessel-T	12	71933.75	346.28	0.8%	< 0.001
Year*Vessel-T	70	71559.98	720.04	1.6%	< 0.001
Year*Upwelling	85	71013.06	1266.96	2.8%	< 0.001
Year*Target	108	70894.07	1385.95	3.1%	< 0.001
Year*Month	208	66851.31	5428.72	12.2%	< 0.001

Table 5. Likelihood ratio tests of alternative mixed model formulations of the proportion of positive and positive catch rates, respectively (period 1952-2007).

GLMixed Model	***-2 REM Log likelihood***	***AIC***	***BIC***	***Likelihood Ratio Test***	***Disper .***
Proportion Positives					
Year Month Vessel-T Upwelling	297742	297744	297753		1.009
Year Month Vessel-T Upwelling *Year*Month*		not convergence			
Positives catch rates					
Year Month Target Vessel-T Upwelling	140814	140816	140824		
Year Month Target Vessel-T Upwelling *Year*Month*	138401	138405	138413	2412	
Year Month Target Vessel-T Upwelling *Year*Month Year*Target*	138027	138033	138044	374	
Year Month Target Upwelling *Year*Month Year*Target AR1(Subject=Vessel ID)*	136453	136461	136476	1574	

Table 6. Nominal and standardized baitboat CPUE for the period 1952-2007. The nominal CPUE is scaled to the historical mean.

Year	N Obs	Nominal CPUE	Standard CPUE	Low IC	Upp IC	CV	Std error
1952	2478	0.35	179.22	79.36	404.72	42.5%	76.13
1953	1762	0.37	184.74	68.27	499.92	53.0%	97.95
1954	2854	0.34	226.46	102.13	502.15	41.4%	93.86
1955	1706	0.45	187.01	83.04	421.17	42.3%	79.15
1956	1746	0.52	470.53	206.07	1074.38	43.1%	202.82
1957	2534	0.63	315.05	142.98	694.18	41.1%	129.46
1958	2834	0.38	252.25	114.87	553.93	40.9%	103.17
1959	2904	0.39	506.79	229.41	1119.54	41.2%	208.99
1960	1602	0.36	485.16	214.83	1095.67	42.5%	206.10
1961	2275	0.26	327.29	147.88	724.37	41.3%	135.31
1962	1141	0.28	180.12	74.71	434.27	46.2%	83.25
1963	866	0.54	312.09	122.76	793.42	49.3%	153.89
1964	976	0.39	457.40	205.98	1015.71	41.5%	189.96
1965	1439	0.37	228.91	104.05	503.61	41.0%	93.87
1966	1509	0.34	349.10	155.59	783.26	42.1%	147.01
1967	814	0.38	345.89	156.00	766.96	41.4%	143.36
1968	548	0.63	447.00	198.77	1005.22	42.2%	188.82
1969	632	0.60	610.62	282.28	1320.90	40.1%	244.62
1970	582	0.91	594.66	260.58	1357.03	43.1%	256.13
1971	719	0.83	744.71	343.05	1616.65	40.3%	299.80
1972	421	0.94	525.63	237.49	1163.38	41.3%	217.32
1973	597	0.82	535.63	249.61	1149.38	39.6%	212.17
1974	389	0.90	245.39	105.97	568.27	43.9%	107.75
1975	459	0.62	484.22	220.06	1065.46	41.0%	198.60
1976	302	0.67	483.96	218.54	1071.74	41.4%	200.24
1977	404	0.89	547.56	250.46	1197.06	40.7%	222.59
1978	350	1.09	705.26	319.60	1556.31	41.2%	290.40
1979	344	0.72	623.01	283.95	1366.90	40.9%	254.52
1980	231	0.82	634.81	270.76	1488.35	44.6%	283.21
1981	254	0.53	510.66	227.19	1147.81	42.2%	215.57
1982	243	0.68	503.78	225.63	1124.81	41.8%	210.77
1983	300	1.17	625.14	273.14	1430.79	43.2%	270.31
1984	250	2.29	331.71	140.67	782.22	44.9%	149.09
1985	437	1.50	1125.74	514.65	2462.43	40.7%	457.98
1986	366	0.88	751.21	336.19	1678.55	41.9%	314.61
1987	323	1.21	1008.43	454.11	2239.37	41.5%	418.81
1988	414	0.98	1394.68	623.77	3118.35	41.9%	584.60
1989	423	1.04	1285.60	595.35	2776.13	40.0%	513.76
1990	332	1.29	986.51	450.94	2158.16	40.7%	401.41
1991	330	1.21	901.20	400.97	2025.50	42.2%	380.40
1992	347	0.68	695.16	306.41	1577.13	42.7%	297.12
1993	393	3.84	2093.55	962.81	4552.23	40.3%	844.74
1994	327	1.20	1007.03	450.23	2252.44	41.9%	422.32
1995	467	1.60	1235.91	566.51	2696.25	40.5%	500.97
1996	503	2.33	1739.29	807.99	3744.01	39.8%	692.00
1997	576	2.29	2246.41	1031.35	4892.97	40.4%	908.56
1998	425	1.73	879.51	400.30	1932.40	40.9%	360.00
1999	256	1.14	339.77	147.41	783.15	43.6%	148.28
2000	394	0.95	960.44	442.83	2083.07	40.2%	386.16
2001	317	2.26	704.49	299.79	1655.50	44.7%	315.22
2002	298	2.14	687.42	305.51	1546.77	42.3%	290.60
2003	244	0.54	444.91	178.40	1109.52	48.2%	214.37
2004	269	1.43	1210.46	543.27	2697.00	41.7%	504.99
2005	444	1.92	2383.57	1102.14	5154.88	40.0%	954.54
2006	320	0.70	850.09	342.03	2112.88	48.0%	407.93
2007	268	1.68	1177.62	527.12	2630.86	41.9%	493.07

Table 7. Deviance tables for the binomial (top) and the lognormal (bottom) components of the Delta-lognormal model of the 2000-2011 period. Significant (p<0.05) factors and interactions explaining >4% of total deviance are highlighted.

Model factors proportion positives	**d.f.**	**Residual deviance**	**Change in deviance**	**% of total deviance**	***p***
1	1	7065.17			
Year *[2000-2011]*	11	7005.83	59.34	4.0%	< 0.001
Month *[6-10]*	4	6942.89	62.95	4.2%	< 0.001
Vessel *[individual vessels]*	45	6840.99	101.89	6.8%	< 0.001
Other *[+/- other tuna in the catch]*	1	6626.55	214.45	14.4%	< 0.001
Depth *[thermocline, <30,30-40,40-50,>50m]*	3	6625.15	1.40	0.1%	0.705
SST *[≤18,19-20,21-22,>22ºC]*	3	6621.55	3.60	0.2%	0.308
Year*Month	40	6433.20	188.34	12.6%	< 0.001
Year*Vessel	226	6168.56	264.64	17.7%	0.039
Year*Other	11	6091.58	76.98	5.2%	< 0.001
Year*Depth	11	6063.55	28.03	1.9%	0.003
Year*SST	17	6013.20	50.35	3.4%	< 0.001
Month*Vessel	168	5839.73	173.47	11.6%	0.370
Month*Other	4	5825.62	14.11	0.9%	< 0.001
Month*Depth	0	5825.62	0.00	0.0%	-
Month*SST	6	5816.93	8.69	0.6%	0.192
Vessel*Other	42	5799.26	17.68	1.2%	1.000
Vessel*Depth	85	5719.36	79.90	5.4%	0.636
Vessel*SST	107	5576.16	143.20	9.6%	0.011
Other*Depth	3	5576.16	0.00	0.0%	1.000
Other*SST	3	5574.01	2.14	0.1%	0.543
Depth*SST	1	5573.99	0.02	0.0%	0.900

Model factors positive catch rates values	**d.f.**	**Residual deviance**	**Change in deviance**	**% of total deviance**	***p***
1	1	6992.53			
Year *[2000-2011]*	11	6826.97	165.56	6.00%	<0.001
Month *[6-10]*	4	6494.79	332.17	12.04%	<0.001
Vessel *[individual vessels]*	45	6075.90	418.89	15.18%	<0.001
Other *[+/- other tuna in the catch]*	1	6048.42	27.48	1.00%	<0.001
Depth *[thermocline, <30,30-40,40-50,>50m]*	3	6010.80	37.62	1.36%	<0.001
SST *[≤18,19-20,21-22,>22ºC]*	3	5935.12	75.68	2.74%	<0.001
Year*Month	40	5375.53	559.59	20.28%	<0.001
Year*Vessel	225	4965.47	410.06	14.86%	0.009
Year*Other	11	4909.27	56.21	2.04%	<0.001
Year*Depth	9	4861.18	48.09	1.74%	<0.001
Year*SST	17	4825.08	36.10	1.31%	0.106
Month*Vessel	166	4602.07	223.01	8.08%	0.786
Month*Other	4	4584.39	17.67	0.64%	0.017
Month*Depth	0	4584.39	0.00	0.00%	-.
Month*SST	6	4564.33	20.06	0.73%	0.034
Vessel*Other	41	4503.57	60.76	2.20%	0.460
Vessel*Depth	75	4389.03	114.54	4.15%	0.392
Vessel*SST	102	4240.40	148.63	5.39%	0.513
Other*Depth	3	4235.85	4.55	0.17%	0.378
Other*SST	3	4235.45	0.39	0.01%	0.966
Depth*SST	1	4233.18	2.27	0.08%	0.214

Table 8. Likelihood ratio tests of alternative mixed model formulations of the proportion of positive and positive catch rates, respectively (period 2000-2011).

Model	*Test*	*Binomial*	*Lognormal*
Vessel as Factor	AIC	30902.8	14201.1
	Neg2LgLike	30894.8	14195.1
Vessel AR1	AIC	29008.0	14207.2
	Neg2LgLike	29900.1	14195.1

Table 9. Nominal and standardized baitboat CPUE for the period 2000-2014. The nominal CPUE is scaled to the historical mean.

Year	*N Obs*	*Nominal CPUE*	*Standard CPUE*	*Low IC*	*Upp IC*	*CV*	*Std error*
2000	764	0.770106	1368.574	706.7118	2204.769	29.03%	397.2833
2001	917	1.201482	1090.193	552.8894	1788.289	29.99%	326.946
2002	959	1.002452	1044.222	533.0266	1701.789	29.64%	309.5443
2003	407	0.72441	1009.691	498.2203	1702.254	31.46%	317.6046
2004	458	1.22411	2078.78	1056.1	3403.935	29.90%	621.4771
2005	1116	1.089774	2187.728	1140.037	3492.504	28.55%	624.5125
2006	470	0.748626	952.4258	482.9707	1562.467	30.00%	285.6829
2007	788	1.116314	2179.982	1080.162	3660.044	31.23%	680.8743
2008	443	1.459369	2154.014	1088.602	3545.66	30.18%	649.9899
2009	530	0.763162	955.3767	481.5088	1576.937	30.32%	289.6908
2010	189	1.348535	2126.197	1064.774	3531.981	30.66%	651.9696
2011	189	1.264483	2785.474	1401.081	4606.85	30.43%	847.5804
2012	52	0.949531	2306.988	997.5753	4438.273	38.66%	891.7662
2013	48	0.842607	1569.126	614.3269	3334.153	44.25%	694.32
2014	77	0.495039	678.2874	280.5241	1364.352	41.14%	279.0603

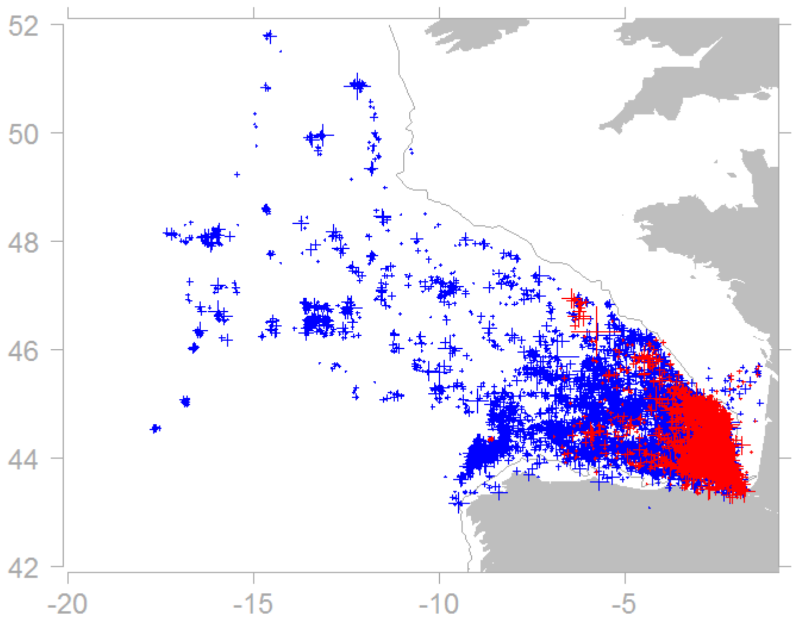


Figure 1. Spatial distribution of BFT (in red) and ALB (in blue) catches by the BB Basque fleet in the Bay of Biscay in the period 2000-2014.

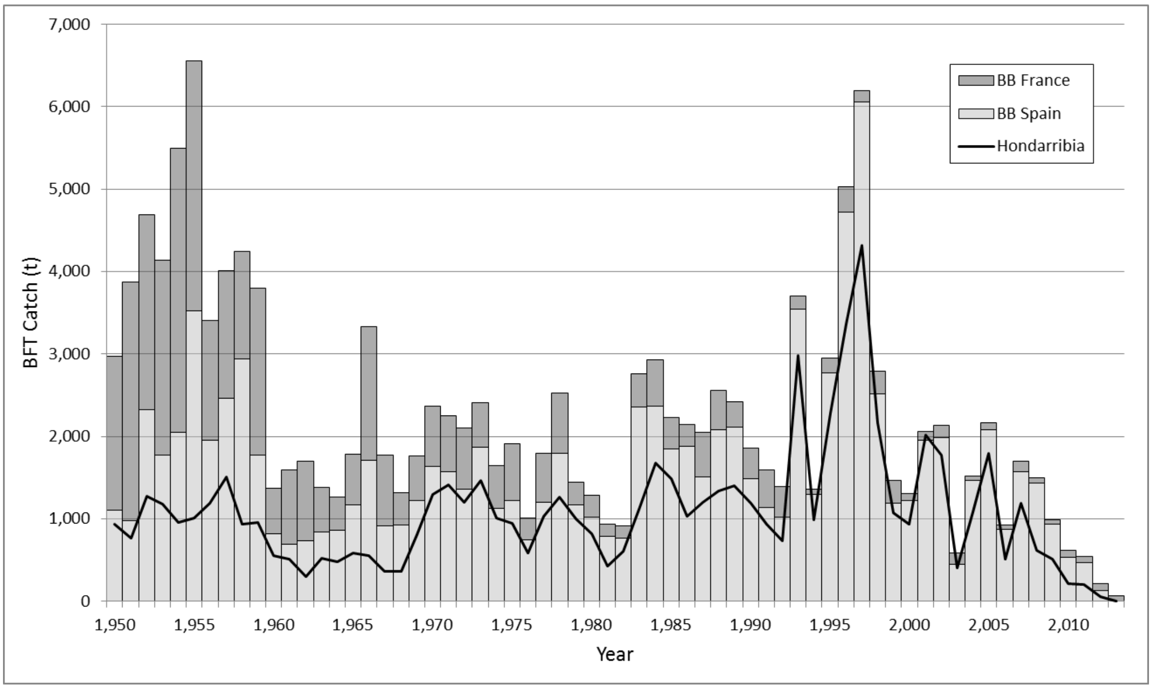


Figure 2. Historical bluefin tuna landings in Hondarribia compared to total BB catches obtained by the Spanish and French fleets in the Bay of Biscay.

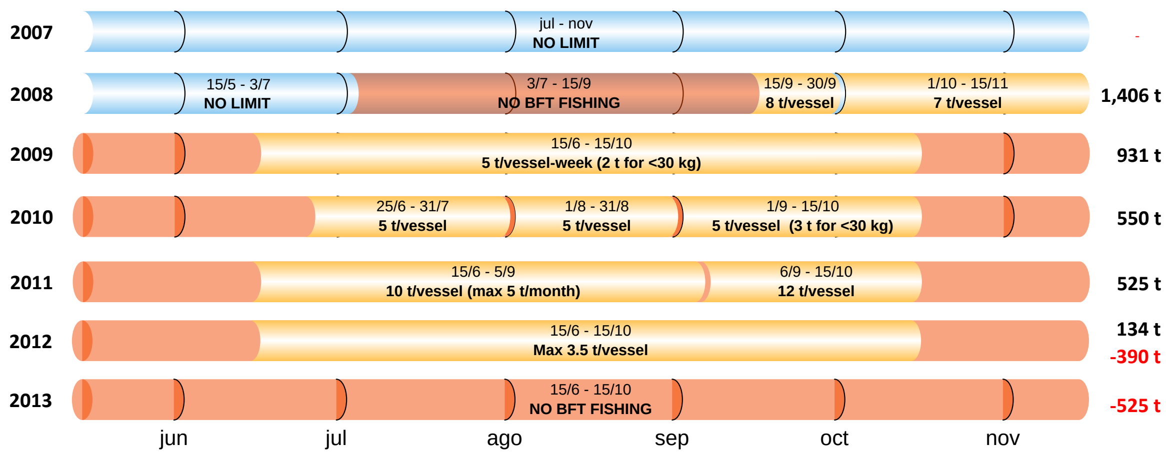


Figure 3. Scheme of the various individual quota agreements adopted by the BB Spanish fleet in the Bay of Biscay after the entry into force of the EBFT Recovery Plan [Rec. 06-05]. The quota assigned to the BB fleet is also shown in the right hand side (red figures indicate the amounts transferred to other fisheries).

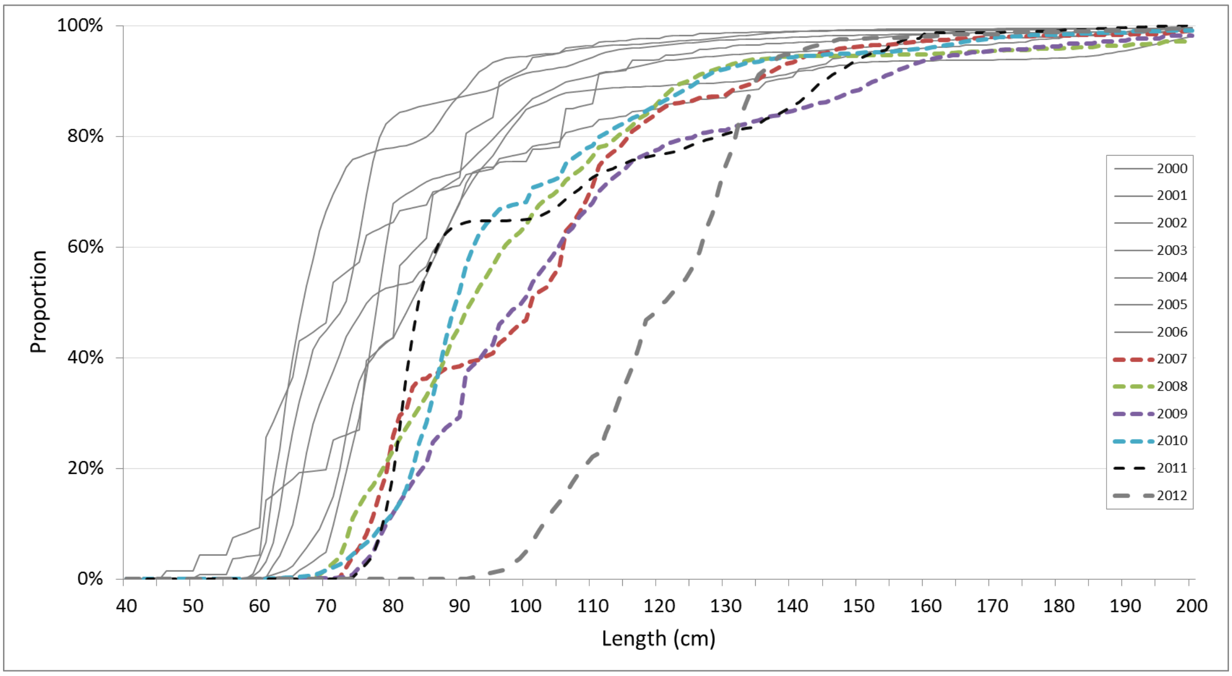
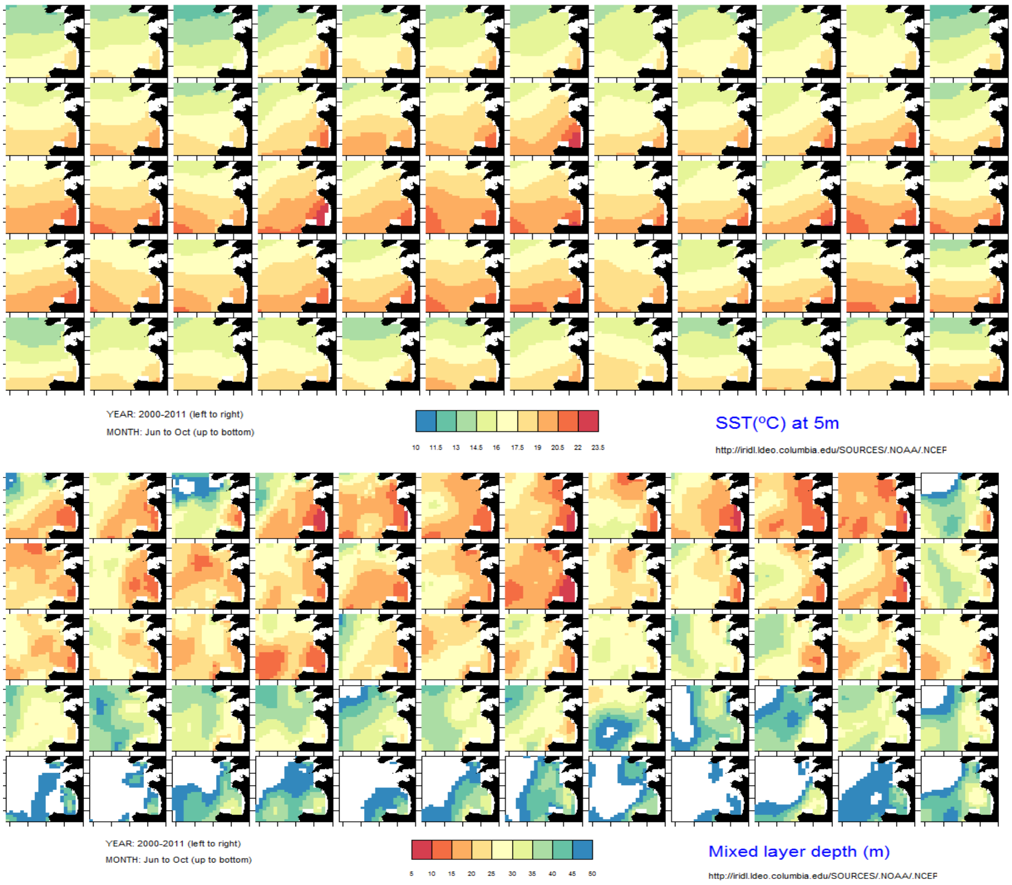


Figure 4. Comparison of cumulative length-frequency distributions of BFT captured by the BB Spanish-Basque fleet for the period 2000-2012.



Figures 5a-b. Monthly values of 5 m–below sea level potential temperature (a) and mixed layer depth (b) extracted from the LDEO/IRI Data Library. Years 2000-2011 (left to right), Months June to October (top to bottom).

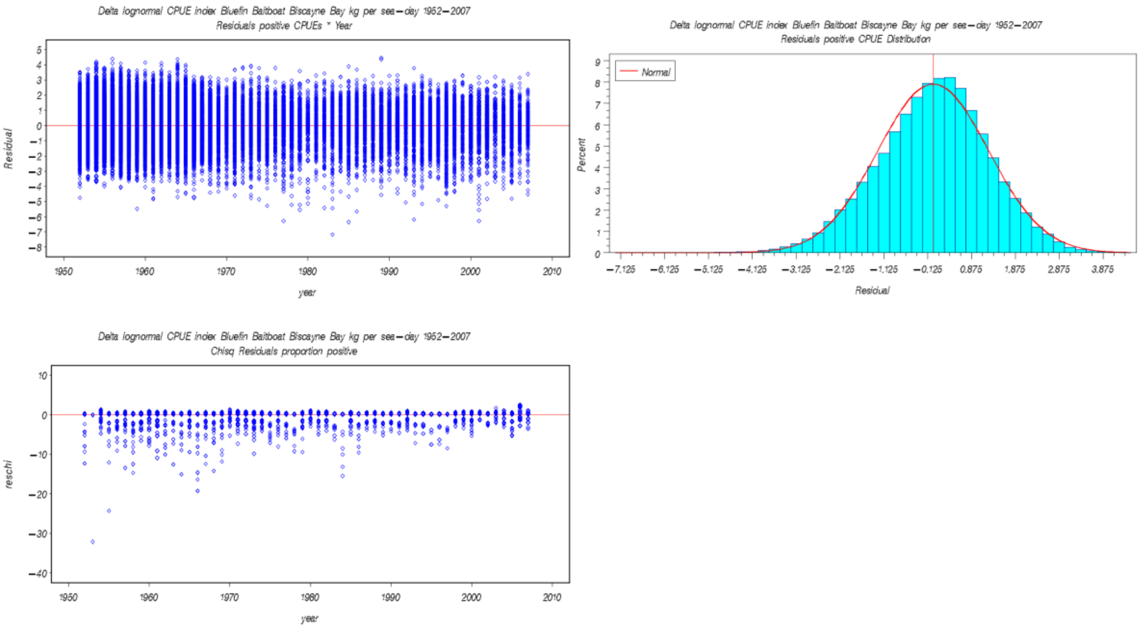


Figure 6. Diagnostics of the binomial (lower panel) and lognormal (upper panel) models selected for the period 1952-2007: residuals by year (left) and frequency distributions of the residuals (right).

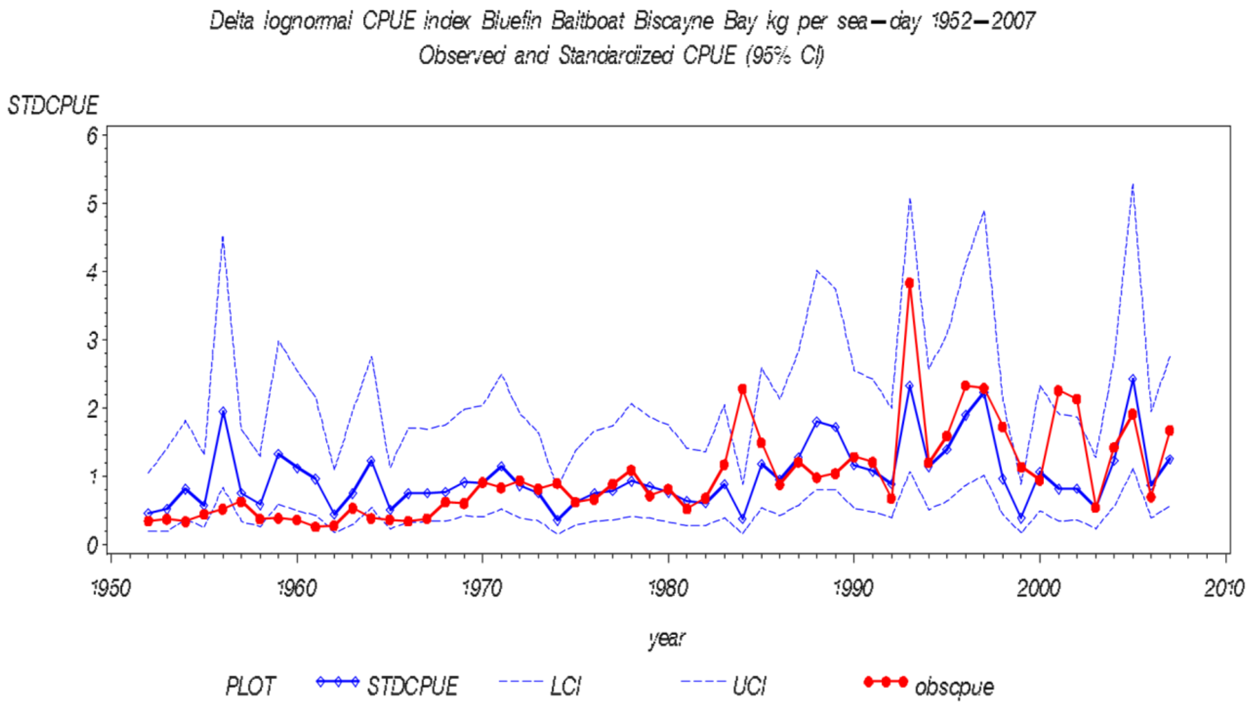


Figure 7. Time series of nominal and standardized CPUE values for the period 1952-2007, scaled to their respective means. The upper and lower confidence intervals are shown for the standardized CPUE.

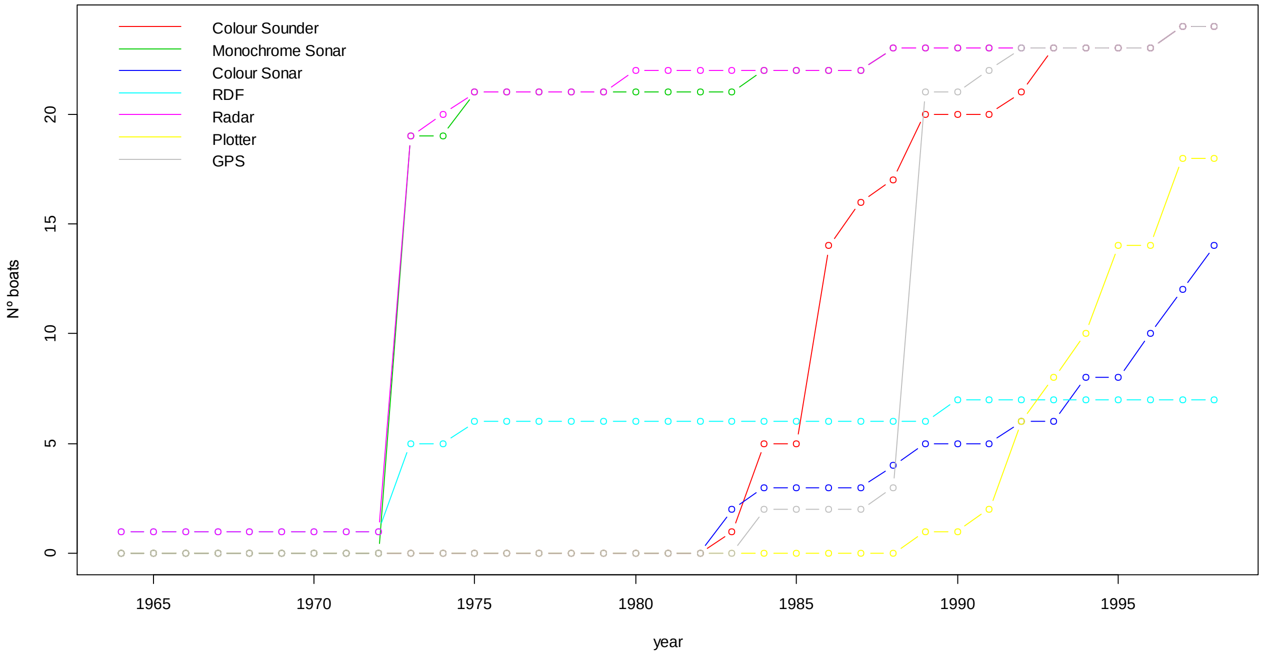


Figure 8. Description of when the baitboat fleet incorporated different technological devices, namely the GPS, plotter, radar, Radio Direction Finder (RDF), colour sonar, monochrome sonar, and colour echosounder. Data is based on a survey to 24 boat owners.

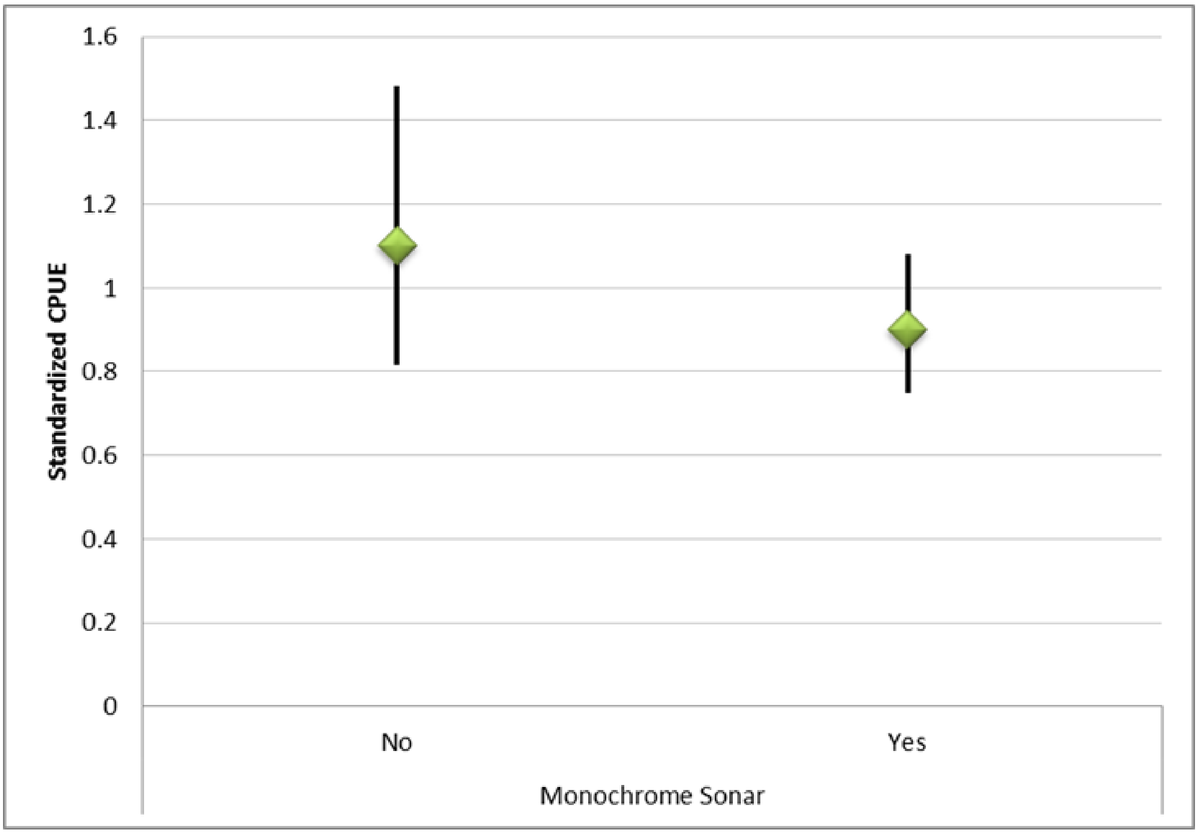


Figure 9. Expected CPUE and confidence interval for two levels of monochrome sonar (with and without).

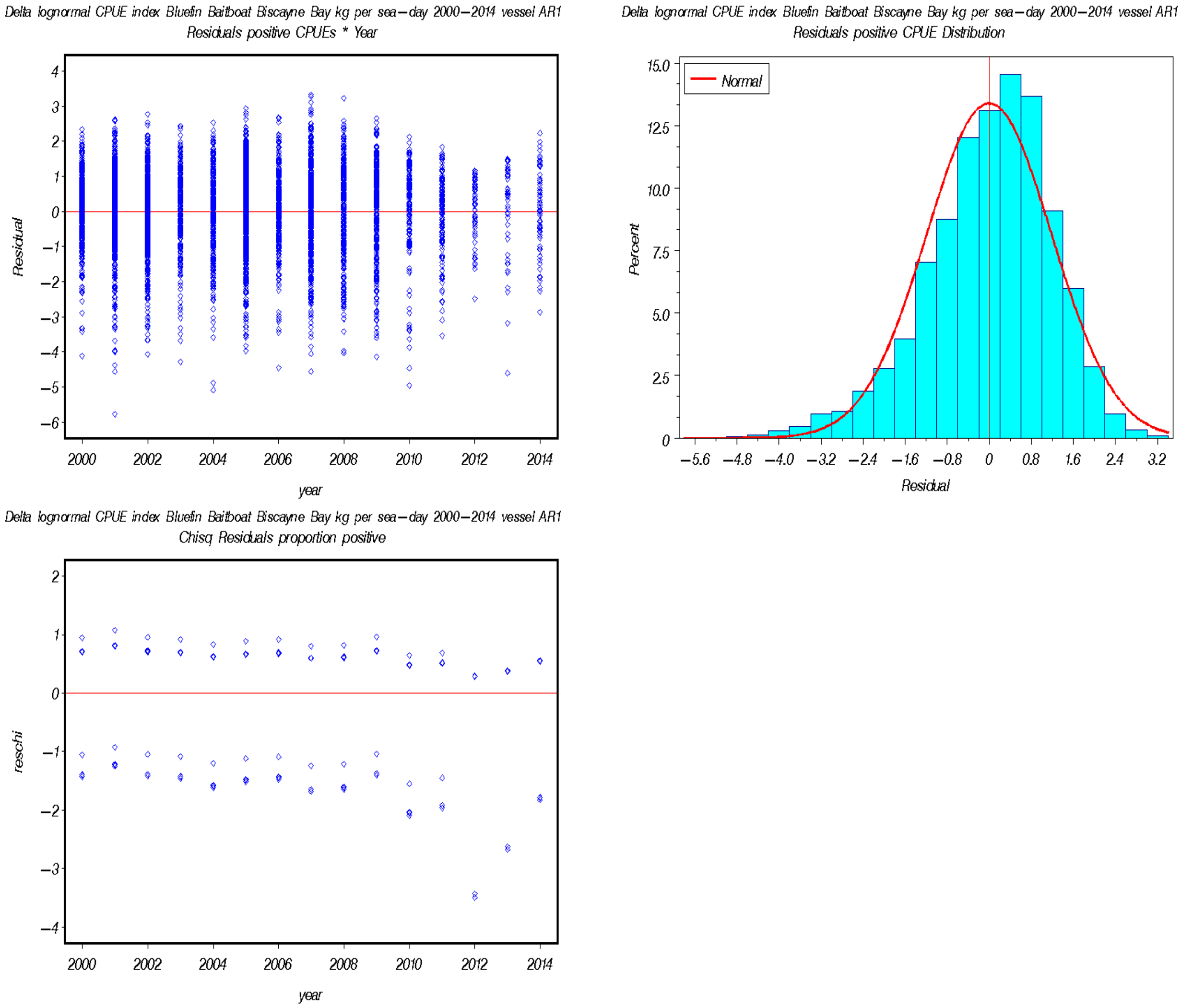


Figure 10. Diagnostics of the binomial (lower panel) and lognormal (upper panel) models selected for the period 2000-2014: residuals by year (left) and frequency distributions of the residuals (right).

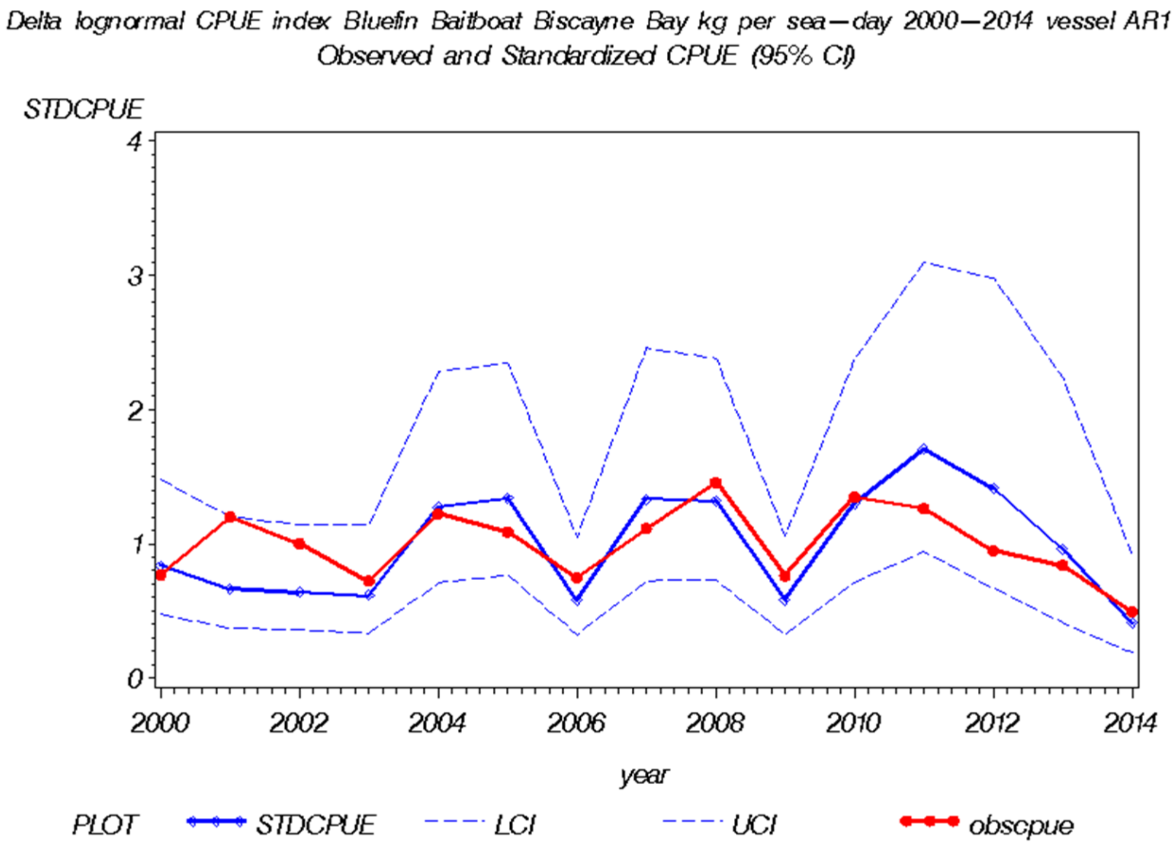


Figure 11. Time series of nominal and standardized CPUE values for the period 2000-2014. The upper and lower confidence intervals are shown for the standardized CPUE.

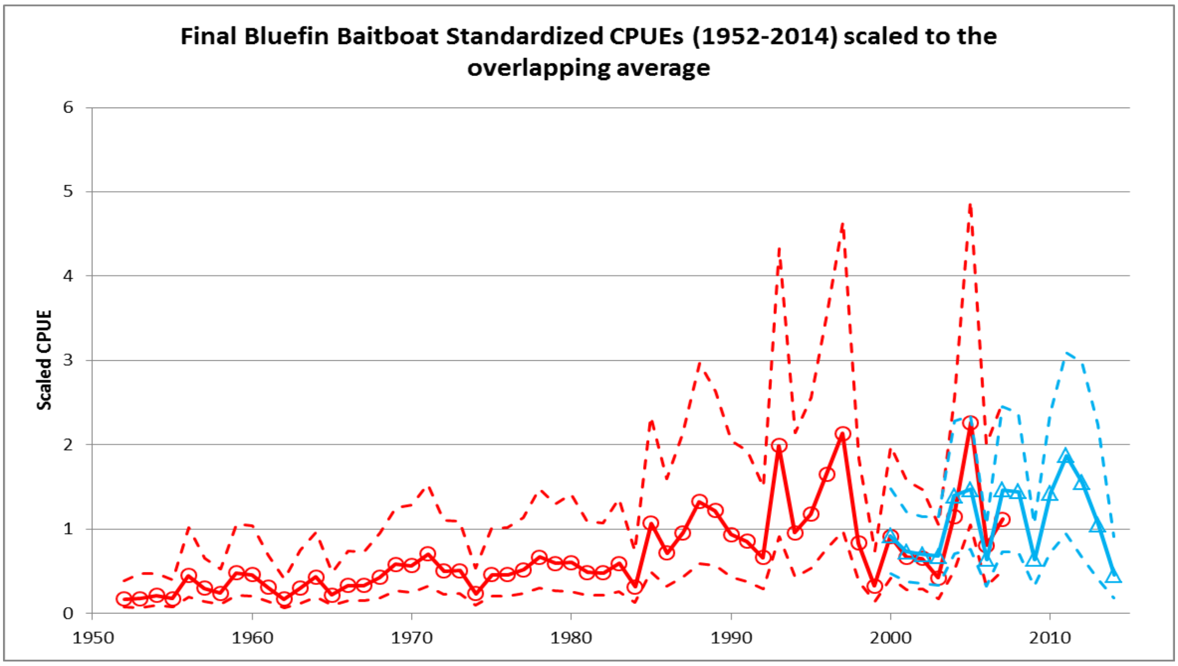


Figure 12. Final standardized CPUE series (1952-2007 and 2000-2014, respectively), scaled to the overlapping period (2000-2007).