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Stock Annex: Boarfish (*Capros aper*) in Subareas 6–8 (Celtic Seas, English Channel, and Bay of Biscay

Stock-specific documentation of standard assessment procedures used by ICES.

Stock	Boardfish
Working Group:	Working Group for Widely distributed stocks
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A. General

A1. Stock definition

The boarfish (*Capros aper*, Linnaeus) is a deep bodied, laterally compressed, pelagic shoaling species distributed from Norway to Senegal, including the Mediterranean, Azores, Canaries, Madeira and Great Meteor Seamount (Blanchard & Vandermeirsch 2005). An analysis of IBTS data suggests a continuity of distribution spanning Subareas 27.4, 6, 7 and 8 (Figure A.1.1). Isolated small occurrences appear in the North Sea in some years and an isolated landing in area 27.5.b 2 indicates spill-over into these areas (Figure A.1.2). A hiatus in distribution is apparent between Divisions 8.c and 9.a south. Boarfish are considered very rare in northern Portuguese waters but are abundant further south (Cardador & Chaves 2010) however it is unclear if this suggested hiatus represents a true stock separation. Based on these data, a single stock is considered to exist in Subareas 27.4, 5, 6, 7, 8 and the northern part of 27.9.a. This distribution is broader than the current EC TAC area: 27.6, 7, and 8.

A dedicated study on the genetic population structure of boarfish within the Northeast Atlantic and Mediterranean Sea commenced in October 2013 in order to resolve outstanding questions regarding the stock structure of boarfish and the suitability of assessment data. Novel genetic methods utilising next generation sequencing were developed to identify species-specific polymorphic microsatellite loci and to screen samples following a genotyping-by-sequencing approach (Farrell *et al.* 2015, 2016; Vartia *et al.* 2016). Results (Farrell *et al.* 2016) based on the genotyping of 839 samples at forty microsatellite loci indicated strong population structure across the distribution range of boarfish with 7-8 genetic populations identified (Figure A.1.3).

The eastern Mediterranean (MED) samples comprised a single population and were distinct from all other samples. Similarly the Azorean (AZA), Western Saharan (MOR) and Alboran (ALM) samples were distinct from all others. Of particular relevance to the assessment and management of the boarfish fishery is the identification and delineation of the population structure between southern Portuguese waters (PTN2B-PTS) and waters to the geographic north. A distinct and temporally stable mixing zone was evident in the waters around Cabo da Roca. The PTN2A sample appeared to be significantly different from all other samples however this sample was relatively small and was considered to represent a mixed sample rather than a true population.

No significant spatial or temporal population structure was found within the samples comprising the NEA population (Figure A.1.3). A statistically significant but comparatively low level of genetic differentiation was found between this population and the northern Spanish shelf/northern Portuguese samples (NSA-PTN1). However a high level of migration was revealed between these two populations and no barriers to gene flow were detected between them. Therefore for the purposes of assessment and management these areas can be considered as one unit.

Whilst the current assessment and management area constitutes the majority of the most northern population it should be extended into Northern Portuguese waters and repeated genetic monitoring of the stock in this region should be conducted to ensure the validity of this delineation. Based on analyses of IBTS data (ICES 2013) the biomass in this area is suspected to be small relative to the overall biomass in the TAC area.

A2. Fishery

Previous to the development of the fishery, boarfish was a discarded bycatch in pelagic fisheries for mackerel in Subareas 7 and 8. A study by Borges *et al.* (2008) found that boarfish may account for as much as 5% of the total catch of Dutch pelagic freezer trawlers.

The first targeting of boarfish began in 2001. Landings fluctuated between 100 and 700 t per year (Table A.2.1). In 2006 the landings began to increase considerably, and cumulative landings since 2001 are now in excess of 580 000 t. The expansion of the fishery in the mid-2000s was associated with developments in the pumping technology for boarfish catches. These changes made it easier to pump boarfish ashore. The fishery targets dense shoals of boarfish. Catches are generally free from bycatch from September to February. From March onwards a bycatch of mackerel is found in the catches. Information on the bycatch of other species in the boarfish fishery is sparse, though thought to be minimal. The fishery uses typical pelagic pair trawl nets with mesh sizes ranging from of 32 to 54 mm. Preliminary information suggests that only the smallest boarfish escape this gear. From 2001 to 2006 only Ireland participated in the fishery. In 2007 UK-Scotland also participated, landing less than 750 t. In all years the vast majority of catches have come from Subarea 7.j and 7.h (Table A.2.1 and Table A.2.2).

Since 2013, the TAC has not been caught. This is thought to be partly due to lesser availability of fishable aggregations, and partly due to economic and administrative reasons. According to the industry, fishable aggregations were not always available during the fishery. The season coincides with the mackerel and horse mackerel fisheries. Also, the Irish quota was allocated to individual boats, with non-specialist vessels receiving allocations that were not used. In 2016 Q3 and Q4 individual boat quotas have been removed in Ireland, in an attempt to allow the specialist 6-7 vessels to target the stock without 7(what the industry considers to be unnecessary) constraints. In 2015 there was a significant decrease in catches with 17 766 t reported, well under the TAC of 53 296 t. Ireland continued to be the main participant in the fishery (16 325 t).

A TAC was set for this species for the first time in 2011, covering ICES Subareas 6, 7 and 8. This TAC was set at 33 000 t. Before 2010, the fishery was unregulated. In October 2010, the European Commission notified national authorities that under the terms of Annex 1 of Regulation 850/1998, industrial fisheries for this species should not proceed with mesh sizes of less than 100 mm. In 2011, the European Parliament voted to change Regulation 850/1998 to allow fishing using mesh sizes ranging from 32 to 54 mm.

In 2011, 31 295 t were caught. Ireland continued to be the main participant (20 685 t), with Denmark taking 7 797 t and Scotland 2 813 t. Due to the 2010 net regulation and extended negotiations over quota allocations the Irish target fishery commenced in late Q3 and as such landings in Q1 and Q2 may be considered as bycatch. Twenty-nine Irish registered fishing vessels reported landings of boarfish. Only 2 Scottish vessels reported landings of boarfish, which were in Q3 and Q4. The number of Danish vessels participating in the fishery is unknown.

For 2012, ICES advised that catches of boarfish should not increase, based on precautionary considerations. As supporting information, ICES noted that it would be cautious that landings did not increase above 82 000 t, the average over the period 2008-2010, during which the stock did not appear to be overexploited. In 2012 the TAC was set at 82 000 t by the Council of the European Union.

In August 2012 the executive committee of the Pelagic RAC approved a long term management plan for boarfish. The management plan has not yet been evaluated by ICES. However, in 2013, ICES advised that Tier 1 of the plan can be considered precautionary if a Category 1 assessment is available. For 2013, ICES advised that catches of boarfish should not be more than 82,000 t. This was based on applying a harvest ratio of 12.2% (F0.1, as an FMSYproxy). For 2013, the TAC was set at 82 000 t by the Council of the European Union.

For 2014, ICES advised that, based on FMSY (0.23), catches of boarfish should not be more than 133 957t. ICES also stated that if discard rates do not change from the average of the last ten years this implies landings of 127 509t. For 2014 the TAC was set at 127 509t by the Council of the European Union. The assessment was considered to be category 1 conducted using a Bayesian-Schaefer surplus production model.

The advice given for 2015 was based on the data-limited approach and stated that catch should be no more than 53 296 t. The assessment conducted was now a category 3 assessment indicative of trends using an exploratory Bayesian Schaefer surplus production model.

For 2016, ICES advised based on the precautionary approach that catches should be no more than 42 637 t.

For 2017, ICES advised based on the precautionary approach that catches should be no more than 27 288 t. For the first time, the precautionary buffer has been applied resulting in a 36% reduction compared to the year before. The acoustic survey suggested that the stock abundance was at an historic low.

In 2017, ICES advised a 2 year quota of 21 830 t for 2018 and 2019. In 2018 the assessment appears stable and supports the choice made for a 2 year advice.

Since 2011, there has been a provision for by-catch of boarfish (also whiting, haddock and mackerel) to be taken from the western and North Sea horse mackerel EC quotas. These provisions are shown in the text table below. The effect of this is that a quantity not exceeding the value indicated of these 4 species combined may be landed legally and subtracted from quotas for horse mackerel.

Year	North.Sea.(t)	Western.(t)
2011	2 031	7 779
2012	2 148	7 829
2013	1 702	7 799
2014	1 392	5 736
2015	583	4 202
2016	760	5 443
2017	912	4191
2018	759	5053

A3. Ecosystem aspects

The ecological role and significance of boarfish in the NE Atlantic is largely unknown. However, in the south-east North Atlantic, in Portuguese waters, they are considered to have an important position in the marine food web (Lopes *et al.* 2006). The diet has been investigated in the eastern Mediterranean, Portuguese waters and at Great Meteor Seamount and consists primarily of copepods, specifically *Calanus helgolandicus*, with some mysid shrimp and euphausiids (Macpherson 1979; Fock *et al.* 2002; Lopes *et al.* 2006). This contrasted with the morphologically similar species, the slender snipefish, *Macroramphosus gracilis* and the longspine snipefish,* M. scolopax, *whose diet comprised* Temora spp.*, copepods and mysid shrimps, respectively (Lopes *et al.* 2006). Despite the obvious potential for these species to feed on fish eggs and larvae, there was no evidence to support this conclusion in Portuguese waters and they were not considered predators of commercial fishes and thus their increase in abundance was unlikely to affect recruitment of commercial fish species (Lopes *et al.* 2006). If the NE Atlantic population of boarfish is sufficiently large then there exists the possibility of competition for food with other widely distributed planktivorous species.

Both seasonal and diurnal variations were observed in the diet of boarfish in all three regions. In the eastern Mediterranean and Portuguese waters, mysids become an important component of the diet in autumn, which correlates with their increased abundance in these regions at this time (Macpherson 1979; Lopes *et al.* 2006). Fock *et al.* (2002) found that boarfish at Great Meteor Seamount fed mainly on copepods and euphausiids diurnally and on decapods nocturnally, indicating habitat dependent resource utilisation.

Boarfish appear an unlikely target of predation given their array of strong dorsal and anal fin spines and covering of ctenoid scales. However, there is evidence to suggest that they may be an important component of some species' diets. Most studies have focused in the Azores and few have mentioned the NE Atlantic, probably due to the relatively low abundance in the region until recent years. In the Azores, boarfish was found to be one of the most important prey items for tope (*Galeorhinus galeus*), thornback ray (*Raja clavata*), conger eel (*Conger conger*), forkbeard (*Phycis phycis*), bigeye tuna (*Thunnus obesus*), yellowmouth barracuda (*Sphyraena viridensis*), swordfish (*Xiphias gladius*), blackspot seabream (*Pagellus bogaraveo*), axillary seabream (P*agellus acarne*) and blacktail comber (*Serranus atricauda*) (Clarke *et al.* 1995; Morato *et al.* 1999, 2000, 2001, 2003; Arrizabalaga *et al.* 2008). Many of these species also occur in the NE Atlantic shelf waters although it is unknown whether boarfish represent a significant component of the diet in this region.

In the NE Atlantic boarfish have not previously been recorded in the diets of tope or thornback ray (Holden & Tucker 1974; Ellis *et al.* 1996). However, this does not prove that they are currently not a prey item. A study of conger eel diet in Irish waters from 1998-1999 failed to find boarfish in the diet (O\&\#39 *et al.* 2004). However, in Portuguese waters a recent study has found boarfish to be the most numerous species in the diet of conger eels (Xavier *et al.* 2010). It has been suggested that boarfish are an important component of the diet of hake (*Merluccius merluccius*), as they are sometimes caught together. However, a recent study of the diet of hake in the Celtic Sea and Bay of Biscay did not report any boarfish in the stomachs of hake caught during the 2001 EVHOE survey (Mahe *et al.* 2007).

The conspicuous presence of boarfish in the diet of so many fish species in the Azores is perhaps more related to the lack of other available food sources than to the palatability of boarfish themselves. Given the large abundance in NE Atlantic shelf waters it is likely that they would have been recorded more frequently if they were a significant and important prey item.

Boarfish are also an important component of the diet a number of sea birds in the Azores, most notably the common tern (*Sterna hirundo*, Granadeiro *et al.* (2002)) and Cory's shearwater (*Calonectris diomedea*, Granadeiro *et al.* (1998)). This is surprising given that in the Mediterranean discarded boarfish were rejected by seabirds whereas in the Azores they were actively preyed on (Oro & Ruiz 1997). Cory's shearwaters are capable of diving up to 15 m whilst the common tern is a plunge-diver and may only reach 2-3 m. It is therefore surprising that boarfish are such a significant component of their diet given that it is generally considered a deeper water fish. In the Azores boarfish shoals are sometimes driven to the surface by horse mackerel and barracuda where they are also attacked by diving sea birds (J. Hart, CW Azores, pers. comm.). Anecdotal reports from the Irish fishery indicate that boarfish are rarely found in waters shallower than 40 m. This may suggest that they are outside the range of shearwaters and gannets, the latter having a mean diving depth of 19.7±7.5 m (Brierley & Fernandes 2001). However, the upper depth range of boarfish is within maximum diving depth recorded for auks (50 m) as recorded by Barrett & Furness (1990). Given their frequency in the diets of marine and bird life in the Azores, boarfish appear to be an important component of the marine ecosystem in that region. There is currently insufficient evidence to draw similar conclusions in the NE Atlantic.

The length-frequency distribution of boarfish may be important to consider. IBTS data shows an increase in mean total length with latitude and perhaps the smaller boarfish in the southern regions are more easily preyed upon. Length-frequency data of boarfish from stomach contents studies of both fish and sea birds in the Azores indicate that the boarfish found are generally < 10 cm (Granadeiro *et al.* 1998, 2002).

B. Data

B1. Historical

In the Northeast Atlantic region boarfish have historically been characterised by apparent fluctuations in abundance. A literature review of historical sources suggests peaks in abundance in the following periods:

- 1840s to 1880s,
- 1950s,
- Mid–1980s to 1990s.

From the 1840s to 1880s large abundances were periodically observed in the western English Channel [Day *et al.* (1880); Couch (1838); cunningham_notes_1888]. Gatcombe (1879) stated that they had become an extreme nuisance in trawl fisheries. In the early 1900s boarfish were noted for their sporadic occurrence in the English Channel and were scarce or absent for many years in the area around Plymouth where they had previously been abundant (Cooper 1952). In the mid-1900s there was another apparent increase in abundance, which Cooper (1952) hypothesised was caused by a 'submarine eagre' that swept shoals of boarfish from submarine canyons in the southern edge of the Celtic Sea onto the continental shelf. It should be noted that these apparent peaks in abundance occurred during periods when fisheries and sampling were less widespread that the present day. The primary distribution area of boarfish, along the shelf edge, was rarely, if ever sampled during this time. Therefore, the observations of peaks in abundance are only related to inshore areas. There is no evidence that boarfish were not also abundant offshore throughout these periods.

Increases in abundance were observed in the Bay of Biscay, Galician continental shelf waters and the Celtic Sea between the 1980s and 2000 (Fariña *et al.* 1997; Pinnegar *et al.* 2002; Blanchard & Vandermeirsch 2005). The relative abundance in the Bay of Biscay increased from 0.3% in 1973 to 16% in 2000 resulting in boarfish becoming one of the dominant species in the fish community in this region (Blanchard & Vandermeirsch 2005).

Based on the above information the external reviewers in 2012 noted the possibility that boarfish was a deepwater species that had undergone a shoreward range extension onto the shelf in the late 1980's. They suggested that this was consistent with the large proportion of older fish in the stock and stated "If the increased abundance during the early 1990s was due to increasing recruitment on the continental shelf, then it seems unlikely that so many old fish would be observed". On this basis the reviewers made two recommendations: one was to extend the acoustic survey tracks into deeper water off shelf waters. This is already part of the standard protocol of the acoustic survey and since 2011 all westward transects extend until no boarfish shoals have been recorded for 15 nm (O'Donnell 2013). No boarfish shoals have been detected off the shelf from 2011 to 2013 and anecdotal evidence from the fishing industry also suggests that boarfish is a shelf species and does not occur off the shelf. The second recommendation was to use an integrated analysis model capable of simultaneously examining the age composition data, the catch time series, and the survey index time series to compare the movement hypothesis to the increased recruitment on the shelf hypothesis. Whilst it would be an interesting exercise this second point is deemed unnecessary as there is no evidence for boarfish being a deep water off-shelf species. It is also unclear why the reviewers considered that the increasing abundance during the early 1990's could not be due to increased recruitment on the shelf as these fish would now be in the 20+ age group and thus increased recruitment on the shelf could be the source of these fish.

Preliminary GAM modelling of the IBTS data also lends supports to the fact that boarfish are a shelf species. There is no evidence of a spread of boarfish from oceanic waters onto the shelf. Furthermore the GAM models highlight where the theories such as this likely arose. The periodic increases in abundance in the western English Channel may simply have been an incursion of boarfish from shelf waters. Such incursions are evident from the GAM model in 1999 and 2002 (Figures B.4.3.a & B.4.3.b). The reasons for these incursions are unknown but may be related to annual hydrographic conditions. They do not occur in all years and as such likely result in a perceived local increase in abundance.

B2. Commercial catch

For years prior to 2011, a proxy catch-at-age matrix was constructed using the age-length key from a combination of fisheries-independent and dependent data (Table B.2.1). Length-frequencies of commercial catches are available from 2007 onwards (Table B.2.2). Ageing is based on the method that has been validated for ages 0–7 by Hüssy *et al.* (2012). These age samples were collected mainly during 2010. The age range is similar to the published growth information presented by White *et al.* (2011).

ALKs were applied to commercial length-frequency data available for the years 2007-2017 to produce a proxy catch numbers-at-age (Figure B.2.1 and Table B.2.3). It can be seen that many older fish are still present in catches, with a high proportion in the plus group (15+) each year. The main ages in recent years are 7,8,9 and 10. There is poor cohort tracking with the same ages dominant each year. In 2015 a high proportion of age 2 boarfish can been seen. These were not picked up at age 1 in the 2014 fishery or at age 3 in 2016.

Since 2011, catch number-at-age were prepared for Irish, Danish and Scottish landings using the ALKs in Table B.2.1. The same ALK was also applied to the IBTS data (Table B.4.1) there were a number of unsampled metiers and allocations were made appropriately. Ireland is the main participant in the fishery and therefore collects the most samples. Only Irish collected samples were deemed reliable enough for length frequency and length weight analyses. The sampling intensity of commercial catches is presented in Table B.4.1.

B3. Biological data

The boarfish are classified in the order Perciformes. They are a small (max 23cm TL), thin, laterally compressed pelagic shoaling species. They have a red to orange colour and are sexually dimorphic. They are widely distributed at depths from the surface to 600m.

Kaya & Özaydin (1996) conducted a study on boarfish in the Mediterranean (Turkish waters) and estimated a maximum age of 4 years and age at maturity 2 years. These results conflicted with the results of White *et al.* (2011) who attained a maximum age of 26 years and age at maturity of 5.25 and 4.6 years for males and females respectively, based on samples from the NE Atlantic. Neither study included a validation of the ageing method used or information on methods used for maturity determination.

In 2010, a biological study of boarfish commenced based on both fishery dependent and independent samples (n = 3376). Samples were collected from ICES Divisions 27.6.a, 7.b, 7.h, 7.j and 8.a from September 2009 to December 2010 (excluding August). TL ranged from 26 to 180 mm, with one additional fish reaching 233mm. Based on 232 of these samples Hüssy *et al.* (2012) carried out an age validation study. Subsequently an ALK was produced and used for preliminary growth investigations. Farrell *et al.* (2012) also investigated the reproductive biology of the species based on 2015 of these samples. From these 2 studies the following biological background information has been gathered:

Boarfish reach a maximum age of 31 years. An ALK based on 407 age readings, from 0 to 28 years, of males and females combined was applied to a combination of length-only fishery independent and dependent data (n = 1633). The von Bertalanffy growth curve was constructed based on the typical parameterisation of the von Bertalanffy growth equation (Table B.3.1 and Figure B.3.1):

$$TL_{age} = L_{\infty} * (1 - exp(-K * (age - t_0)))$$

The growth curve and ALK were used to investigate length-at-age, age distribution and maturity at age/length. Growth is fastest in the first 2-3 years then levels off and energy is allocated to other processes such as reproduction. The age distribution (Figure B.3.2) is unimodal with a peak at 7 years (corresponding to approx. 12 cm). Length classes were continuous up to 18 cm after which only one individual fish was present in the 23 cm length class. The abundance of females peaked in the 12 cm length class, while the highest number of males was observed in the 11 cm length class.

The length and age at 50 % maturity were 9.7 cm TL and 3.5 years, respectively (Figure B.3.3). The reproductive cycle commenced between February and April and finished between October and December, when fish entered the resting phase. Oocyte development was asynchronous and all oocytes stages were present concurrently in spawning fish. There was no hiatus between pre-vitellogenic and vitellogenic oocytes. Spawning occurred in June and July with a notable peak in July (Figure B.3.4). No samples were available from August. The boarfish is a batch spawner. In September there was a generalised atresia and remaining oocytes were observed to be resorbed. Aquarium observations of spawning fish indicated that males spawned daily whilst females spawned every 2-3 days. In the controlled aquarium environment spawning lasted approximately 9 months. All indications are that the boarfish has indeterminate fecundity.

B4. Surveys

IBTS

The western IBTS data and CEFAS English Celtic Sea Groundfish Survey were investigated for their utility as abundance indices. An index of abundance was constructed from the following surveys:

- EVHOE, French Celtic Sea and Biscay Survey, (Q4) 1997 to 2015,
- IGFS, Irish Groundfish Survey, (Q4) 2003 to 2015,
- WCSGFS, West of Scotland, (Q1 and Q4) 1986 to 2015 (no Q4 survey in 2010),
- SPPGFS, Spanish Porcupine Bank Survey, (Q3) 2001 to 2015,
- SPNGFS, Spanish North Coast Survey, (Q3/Q4) 1991 to 2015,
- ECSGFS, CEFAS English Celtic Sea Groundfish Survey, (Q4) 1982 to 2003.

The time series for each survey with the exception of the CEFAS groundfish survey were updated and used in the 2018 exploratory assessment.

From the IBTS data CPUE was computed as the number of boarfish per 30 minute haul. The abundance of boarfish per year per ICES Rectangle was then calculated by summing the boarfish in a given rectangle and dividing by the total number of hauls in that rectangle. The complete area was sampled from 2003-2017. The only exception is the EVHOE survey which was incomplete in 2017 due to its vessel breakdown.

The shoaling nature of the species results in occasional large hauls. This is evidenced in the 2014 data which appears to indicate a peak in abundance. Therefore, the number of hauls sampled was compared with the number of hauls in which boarfish were caught (Figure B.4.1). The number of hauls containing boarfish increased until 2004 and since then has levelled off while the total number of hauls shows greater fluctuations. The number of hauls and thus the number of hauls containing boarfish dropped in 2017 because of the EVHOE survey failure.

The IBTS appears to give a relative index of abundance, with good resolution between periods of high and low abundance. The main centres of abundance in the survey (Figures A.1.1 & A.1.2) correspond to the main fishing grounds (Figure A.2.1). Figure B.4.2 shows the signal in abundance, increasing in the 1990s and reached a small peak in 2000. A decrease can be seen until another peak is reached in 2008. A fluctuating trend can be seen in more recent years with 2015 being the highest number of boarfish in the time series. Similar trends have been reported by (Fariña *et al.* 1997; Pinnegar *et al.* 2002; Blanchard & Vandermeirsch 2005). These authors used IBTS and other trawl survey data to show the increased abundance of the species in this area.

Anecdotal evidence from the fisheries indicates that from September to March boarfish are found on the shelf in dense shoals often in close proximity to the bottom. These shoals are particularly abundant around the banks in ICES Division 7.j in the Celtic Sea. Therefore boarfish are likely effectively sampled by the demersal gear of the IBTS despite being a pelagic species. However the shoaling nature of the species results in occasional large hauls.

The preliminary results of a GAM modelling project of the IBTS data up to 2011, including the Portuguese data, are presented to illustrate the temporal and spatial distribution of boarfish in the ICES Area. A GAM based on the probability of occurrence of boarfish in a surveyed area was developed based on presence absence data from over 13,000 individual fishing hauls in 7 groundfish surveys over a 30 year period (Figures B.4.3.a, B.4.3.b, B.4.4.a & B.4.4.b). The GAM models clearly illustrate that boarfish are distributed on the shelf and have a wide area of distribution. In recent years (2003 onwards) there has been an increase in the northerly distribution of boarfish. The depth distribution profile of boarfish within these hauls was also calculated, which shows that boarfish have a depth distribution preference of approximately 100-300m and the probability of occurrence in deeper water decreases sharply (Figures B.4.3.a & B.4.3.b). The proportion of each region over which boarfish were distributed per year was also investigated and shows an increasing trend over time (Figures B.4.4.a & B.4.4.b). This indicates that the area of spread of boarfish within the surveyed area has increased during the period.

For subsequent surplus production modelling, biomass indices were extracted from each of the IBTS surveys using a delta-lognormal model (Stefánsson 1996). Many of the surveys exhibited a large proportion of zero tows (Figure B.4.7) with occasionally very large tows, hence the decision to explicitly model the probability of a non-zero tow and the mean of the positive tows. A delta-lognormal fit comprises fitting two generalized linear models (GLMs). The first model (binomial GLM) is used to obtain the proportion of non-zero tows and is fit to the data coded as 1 or 0 if the tow contained a positive or zero CPUE, respectively. The second model is fit to the positive only CPUE data using a lognormal GLM. Both GLMs were fit using ICES rectangle and year as explanatory factor variables. Where the number of tows per rectangle was less than 5 over the entire series, they are grouped into an "others" rectangle. An index per rectangle and year is constructed, according Stefánsson (1996), by the product of the estimated probability of a positive tow times the mean of the positive tows. The station indices are aggregated by taking estimated average across all rectangles within a year. To propagate the uncertainty, all survey index analyses were conducted in a Bayesian framework using MCMC sampling in WinBUGS (Spiegelhalter *et al.* 2003).

Acoustic survey

The Boarfish Acoustic Survey (BFAS) series was initiated in July 2011 and is now in its 8th year. The 2011 survey, the first in the series, was conducted by Marine Institute scientists aboard the Irish pelagic RSW vessel FV "Felucca" with a towed body system with a calibrated 38 kHz split beam transducer (O'Donnell 2013). The survey was designed to extend the Malin Shelf Herring Acoustic Survey (MSHAS) conducted aboard the RV "Celtic Explorer" to the south, which increased the range of continuous coverage from approximately 58.5°N to 47.5°N (Figure B.4.2.1). The 2011 BFAS operated on a 24 hour basis as it was an exploratory survey and the distribution and behaviour of boarfish during this time of year were unknown prior to the survey. The combined surveys resulted in a continuous coverage over 33 days, 90 000 nmi2 and transect coverage over 4 500 nmi. 24 trawls were sampled and lengths, weights, maturity data, and otoliths of boarfish were collected. In 2011 the total biomass of boarfish in the survey area was estimated at 670 176 t. Biomass estimates of boarfish biomass by year are presented in Table B.4.2 and the spatial distribution of the echotraces attributed to boarfish in each year can be seen in Figure B.4.2.1. A significant temporal pattern can be seen along the years with a rather pronounced downward trend followed by stability at rather low levels.

The text table below explains the categories used to report estimated biomass from all BFASs. Following standard acoustic survey protocols the Total Biomass estimate includes the *'Definitely'*, *'Probably'* and *'Mixture'* categories but excludes the *'Possibly'* category.

CATEGORY	DEFINITION
Definite	Identified on the basis of captures of boarfish from the fishing trawls which were sampled directly. Based on the directly sampled schools echotraces were also characterised as definitely boarfish which appeared very similar on the echogram i.e. large marks which showed as very high intensity (red), located high in the water column(day) and as strong circular schools.
Probably	Attributed to smaller echotraces that had not been fished but which had similar characteristics to "definite" boarfish traces.
Mixture	Attributed to NASC values arising from all fish traces in which boarfish were contained, based on the presence of a proportion of boarfish in the catch or within the nearest trawl haul. Boarfish were often taken during trawling in mixed species layers during the hours of darkness.
Possibly	Attributed to small echotraces outside areas where fishing was carried out, but which had the characteristics of definite boarfish traces.

In 2012 the survey methodology was refined by switching to daylight only (04:00-00:00) surveying. This change in protocol was a result of the observation during the 2011 BFAS that boarfish shoals were observed to break up during the night (00:00-04:00) and could not be acoustically detected or quantified. The 2012 total biomass estimate was 863 446 t (O'Donnell (2013); Table B.4.4), with the increase partially attributable to the protocol change.

In July 2013 the BFAS series was continued, with the survey being conducted again aboard the FV "Felucca" (O'Donnell 2013). The survey used the same equipment and followed the same protocol as the 2012 survey and the survey track was broadly similar (Figure B.4.2.1). In total 4,295nmi (nautical miles) of cruise track was undertaken by both vessels over 53 transects relating to a total area coverage of 57,020nmi^2. Transect spacing was set at 15nmi for the Felucca and 15 and 7.5nmi for the Explorer component. Coverage extended in coastal areas from the c.50m contour to the shelf slope (250m). The survey was carried out from 04:00-00:00 each day. In 2013 thirty three hauls were carried out during the survey, 19 of which contained boarfish. A total of 1,074 boarfish echotraces were identified during the survey. Of this 98% were categorised as *'Definitely'* boarfish, 1.6% as *'Probably'* and 0.3% *'Boarfish in a mixture'*. The total estimated biomass of the survey area was 439 890 t (Table B.4.2).

As no species-specific target strength (TS) previously existed for boarfish, an industry funded project was conducted to model boarfish TS. Samples were collected during the 2011 survey and MRI scans were taken of the swim bladders from the observed size range of boarfish. 3D swimbladder dimensions of each fish sample were used as input to a KRM model. An estimated TS-L relationship of -65.98dB was derived based on model calculations. This TS was used in 2012 to produce biomass estimates for the 2012 and 2011 survey. In 2013 this TS was reviewed and revised to -66.2dB (O'Donnell 2013; Fässler *et al.* 2013). This new TS (-66.2dB) was applied to the 2013 survey data and retrospectively to the 2012 and 2011 BFAS survey data for use in the boarfish assessment.

The July 2014 BFAS again comprised acoustic and trawl data recorded from the FV "Felucca" and RV "Celtic Explorer". Temporal and spatially coverage were almost identical to 2013 and the revised TS was used in the biomass calculation. Twenty one hauls were carried out during the survey, 11 of which contained boarfish. A total of 3 160 boarfish lengths, 1 102 length/weight measurements and 397 otoliths were collected during the survey. The total estimated biomass was 187 779 t, 57% less than the 2013 BFAS estimate. Of this total estimate 71% were categorised as 'definitely' boarfish, 27% as 'probably' and 1.4% 'boarfish in a mixture'. It should be noted that the higher percentage of 'Probably' boarfish this year was mainly due to technical difficulties with the trawl gear that prevented sampling of some schools that had all the characteristics of 'Definitely' boarfish. A full breakdown of school categorisation, abundance and biomass by ICES statistical rectangle is available in O'Donnell & Nolan (2014).

The 2015 BFAS was conducted on board the FV "Felucca" (O'Donnell & Nolan 2015). Twenty hauls were carried out by the Felucca during the survey, 14 of which contained boarfish. An additional 4 carried out by the C. Explorer were used in the analysis. In total, 4,168 lengths and 1,500 length/weight measurements were taken in addition to 695 individual boarfish otoliths collected for aging. The total biomass estimate from this survey was 232 634 t. There was concern that the low estimate in 2014 could have been an outlier and it did cause some problems for the Bayesian assessment model but the 2015 acoustic biomass estimate supports the validity of the 2014 estimate.

In 2015, the 2011 survey data were reworked to exclude the data collected between 00:00 and 04:00. This allowed the inclusion of the 2011 survey estimate in the assessment.

In 2016 this survey was carried out on the RV Celtic Explorer and run in conjunction the Malin Shelf herring survey. These surveys are collectively known as the Western European Shelf Pelagic Acoustic Survey (WESPAS). The WESPAS survey in 2016 was carried out over a 42 day period beginning on the 16 June in the north (59°N) and working south to 47°N ending on 30 July. The 2016 estimate of total biomass is 69 690 t and is 70% lower than observed in 2015. Significant annual variation is a feature of the time series although an overall downward trend is evident. No strong evidence exists for removing any of the survey points from the time series.

In 2017, the WESPAS survey was carried out over a 42 day period beginning on the 06 June in the south (47°N) and working northwards to 59°N ending on 26 July. The survey direction was changed in 2017 from south to north to force containment in the southern area by aligning ourselves with the PELGAS survey. Spatial and temporal alignment has much improved with this move and the survey will be continued in this way in years to come. The 2017 estimate of biomass is almost 160 000t more than observed in 2016 (70 000t in 2016, 230 000t in 2017). This estimate more closely matches that of the 2015 (232 000t) and makes the low estimate in 2016 appear as an outlier. Containment issues were addressed with the change in survey direction adopted this year and it is hoped that this will increase the precision of the survey overall. A large proportion of the stock was observed in the southern survey area. Although more numerous than further north the acoustic density of individual schools was lower overall. More biomass was observed on the Porcupine Bank and with a wider distribution than in previous years for the same expended effort.

The 2018 estimate of biomass is 45,000t lower than observed in 2017 (230,000t in 2017, 185,000t in 2018). The low estimate in 2016 (70,000t) appears to be an outlier. Containment issues in 2016 were addressed and the survey has been conducted from south to north since 2017. The changes were implemented to increase the precision of the survey overall. Approximately 45% of the stock was observed in the southern survey area (Celtic Sea, including Celtic Sea Deep and NW Bank areas). Boarfish were found further north than in previous years.

It should be noted that the survey does not contain the stock fully, given that concentrations of boarfish are likely to be found southward of the survey area as evidenced by both IBTS data and information from the PELACUS survey on the northern Spanish Shelf (Carrera-López *et al.* 2013).

C. Assessment: data & method

A number of exploratory assessment runs for boarfish were carried out in 2013.

Model used: Bayesian Schaefer state space surplus production model (BSP, Meyer & Millar (1999)).

Model priors:

- *r ~ U(0.001,2)*
- *ln K ~ U(ln max(C), ln 10xsum C) = U(ln 144,047t, ln 4,450,407t)*
- *a ~ U(0.001, 1.0)*
- *ln qi ~ U(-16,0) (for IBTS)*
- $\frac{1}{\sigma_u^2} \sim gamma(0.001,0.001)$

Model outputs:

Posteriors

- *r* (intrinsic rate of population growth),
- *K* (carrying capacity),
- *a* (proportion of *K* in 1982),
- q_i (catchabilities, 6 IBTS and 1 acoustic survey),
- B_t (biomass states, 33 years).

Errors:

- Single biomass process error encompassing recruitment and growth variability
- Measurement errors come directly from variance of delta-lognormal indices

Prior assumptions on the parameter distributions were:

- Intrinsic rate of population growth: *r ~ U(0.001, 2)*
- Natural logarithm of the carrying capacity *ln K ~ U(ln(max(C)), ln(10.sum(C)) = U(ln(144,047t), ln(4,450,407t))*
- Proportion of carrying capacity in first year of assessment: *a ~ U(0.001, 1.0)*

- Natural logarithm of the survey-specific catchabilities $\ln(q_i) \sim U(-16, 0)$ (for IBTS only). Acoustic survey is discussed below when separate runs are described.
- Process error precision ~Gamma(0.001,0.001)

Eight initial runs were performed. The four base runs are explained in the table below

Run	qacoustic	Iacoustic,2012.(t)	Iacoustic,2013.(t)
1	Fixed at 1	Total (863,446)	Total (863,446)
2	Free (strong prior)	Total (863,446)	Total (863,446)
3	Fixed at 1	Definitely (708,019)	Definitely (708,019)
4	Free (strong prior)	Definitely (708,019)	Definitely (708,019)

$q_{acoustic}$ is the catchability of the acoustic survey, $I_{acoustic}$ is the acoustic index value used for the specified years.

Runs 1 and 3 assume that the acoustic survey surveys the entire stock and is an absolute index of abundance. Runs 2 and 4 assumes a strong prior $ln(q_{acoustic}) \sim N(1, 1/4)$ (standard deviation of 1/4), which has 95% of the density between 0.5 and 2. Given the short acoustic series (2 years) it is not possible to estimate this parameter freely (using an uninformative prior) but assuming a strong prior removes the assumption of an absolute index from the acoustic survey and will be continually updated as data accrue.

Following concerns regarding the quality of the recording of boarfish from the early part of the ECSGFS survey and the fact that the WCSGFS survey is distant from the centre of abundance and unlikely to provide an index for the complete stock, sensitivity runs were performed on Runs 1-4 that completely omitted the ECSGFS and WCSGFS surveys. These are referred to as runs 1.1, 2.1, 3.1, and 4.1 with the same settings as the corresponding runs 1 through 4 respectively with the omission of these two surveys.

Following plenary discussion of the sensitivity runs, it was decided that the final run be based on a run that includes all surveys with the omission of the first 5 years of the WCSGFS and first 9 years of the ECSGFS. The reasons for this decision was:

- It is unclear whether boarfish were consistently recorded in the early part of the ECSGFS
- The WCSGFS is thought to be at the northern extreme of the distribution and may not be an appropriate index for the whole stock.
- The SPNGFS commences in 1991 such that running the assessment from 1991 onwards includes at least three surveys without relying solely on the ECSGFS and WCSGFS.
- Surveys are internally weighted such that highly uncertain values receive lower weight.

Run 2.2 is therefore the final run. The specifications are that for run 2 with the omission of the early parts of the WCSGFS and ECSGFS, as detailed above.

Run convergence

Parameters for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1 and final run 2.2 converged with good mixing of the chains and Rhat values lower than 1.1 indicating convergence (Figures C.1, C.2 & C.3). MCMC chain autocorrelation was also low indicating good sampling of the parameter posteriors (Figures C.4 & C.5).

Diagnostic plots for these runs are provided in Figures C.6 & C.7, showing residuals about the model fit. There is relatively little difference between any of the runs in the fitting of the trawl surveys, and a fairly balanced residual pattern is in evidence. In some cases outliers are apparent, for instance in the English survey in the final year (2003). However, these points are down-weighted according to the inverse of their variance and hence to not contribute much to the model fit. For this reason, no indices were removed from the analyses. The west of Scotland IBTS survey, located at the northern extreme of the stock distribution underestimates the stock in the early period (years) and overestimates it in the recent period from all fits. This could be indicative of stock expansion into this area at higher stock sizes and suggests that this index is not representative of the whole stock. Figures C.8, C.9 & C.10 show the prior and posterior distributions of the parameters of the biomass dynamic model. The estimate of q in runs 2, 2.1, 4 and 4.1 is less than 1.0, leading to higher estimates of final stock biomass than the acoustic survey.

Trajectories of observed and expected indices are shown in Figures C.11, C.12 & C.13, along with the stock size over time and a harvest ratio (total catch divided by estimated biomass). It can be seen that runs 2, 2.1, 2.2, 4 and 4.1 lead to larger stock sizes given the non-absolute assumption on the acoustic survey catchability. Parameter estimates from the four preliminary runs (1-4), four sensitivity runs (1.1, 2.1, 3.1, 4.1) and the final run (run 2.2) are summarized in Table C.1.1. It can be seen that the precision of the estimates of stock size are higher (more certain) for the runs where q is set at 1.0 for the acoustic surveys (Runs 1, 3, 1.1, 3.1). As the acoustic survey does not span the entire range of the stock, assuming the catchability of the acoustic survey is likely incorrect, hence the decision to use a strong prior on the acoustic survey catchability. Consequently the group considers run 2.2 as the final run for the purposes of stock assessment and forecasting catch options for 2013.

2014–2018 Assessments

In 2014 the Bayesian state space surplus production model was again fit using the catch data, delta-lognormal estimated IBTS survey indices, and the acoustic survey estimates. However, the inclusion of the low 2014 acoustic biomass estimate changed the perception on the stock, which raised concerns over the sensitivity and process error of the model. The stock was moved from a category 1 assessment to a category 3 with the results of the surplus production model being used to calculate an index for the data limited stock approach.

Since 2014, the procedure used to run the model did not change. Only the length of the time series used increase yearly. Details of this exploratory run used to calculate the DLS index are described below. Further model development work is undertaken since 2015 but did not lead to any change so far.

In the Bayesian state space surplus production model the biomass dynamics are given by a difference form of a Schaefer biomass dynamic model:

$$B_t = B_{t-1} + rB_{t-1}(1 - \frac{B_{t-1}}{K}) + C_{t-1}$$

where B_t is the biomass at time t, r is the intrinsic rate of population growth, K is the carrying capacity, and C_t is the catch, assumed known exactly. To assist the estimation the biomass is scaled by the carrying capacity, denoting the scaled biomass $P_t = B_t / K$. Lognormal error structure is assumed giving the scaled biomass dynamics (process) model:

$$P_t = (P_{t-1} + rP_{t-1}(1 - P_{t-1}) + \frac{C_{t-1}}{K})e^{\mu_t}$$

where the logarithm of process deviations are assumed normal $u_t = N(0, \sigma_2^{\mu})$ with σ_2^{μ} the process error variance.

The starting year biomass is given by *aK,* where a is the proportion of the carrying capacity in the first year. The biomass dynamics process is related to the observations on the indices through the measurement error equation:

$$I_{j,t} = q_j P_t K e^{\varepsilon_{j,t}}$$

where $I_{j,t}$ is the value of abundance index *j* in year *t*, q_j is survey-specific catchability, $B_t = P_t K$, and the measurement errors are assumed lognormally distributed with $u_t = N(0, \varepsilon_{e,j,t}^2)$ where $\varepsilon_{e,j,t}^2$ is the index-specific measurement error variance. $Var(I_{j,t})$ is obtained from the delta-lognormal survey fits. That is, the variance of the mean annual estimate per survey is inputted directly from the delta-lognormal fits (character(0) character(0)) as opposed to estimating a measurement error within the assessment. The measurement error is obtained from:

$$\sigma_{e,j,t}^2 = ln(1 + \frac{Var(I_{j,t})}{(I_{j,t})^2})$$

For the acoustic survey, the CV of the survey was transformed into a lognormal variance via

$$\sigma_{\varepsilon,acoustic,t}^2 = ln(CV_{acoustic,t}^2 + 1)$$

Prior assumptions on the parameter distributions were: * Intrinsic rate of population growth: *r ~ U(0.001, 2)*

- Natural logarithm of the carrying capacity: *ln(K) ~ U(ln(max(C), ln(10.sum(C)),* ln(10.sum(C)) caped at 5000000 in 2017
- Proportion of carrying capacity in first year of assessment: *a ~ U[0.001, 1.0]*
- Natural logarithm of the survey-specific catchabilities $ln(q_i) \sim U(-16, 0)$ (for IBTS only). The acoustic survey prior is discussed below.
- Process error precision $\frac{1}{\sigma_u^2} \sim gamma(0.001, 0.001)$

Specifications

During the 2013 WGWIDE meeting a number of different iterations of the model were run to discern the best parameters for the assessment. After four initial runs and four sensitivity runs the settings for the final run (run 2.2) were chosen. These settings are shown below and were used for the assessment model since 2014. (More details of the trial runs in 2013 can be found in the stock annex)

1. ***Acoustic survey***
   - Years: 2011-2018
   - Index value ($I_{acoustic,y}$): 'Total' in tonnes (i.e. Definitely Boarfish + Probably Boarfish + Boarfish in a Mix)
   - Catchability ($q_{acoustic}$): A free, but strong prior (i.e. the acoustic survey is treated as a relative index but is strongly informed, this allows the survey to cover <100% of the stock).
2. ***IBTS survey***

- 6 delta log normal indices (WCSGFS, SPPGFS, IGFS, ECSGFS, SPNGFS, EVHOE)
- First 5 and last 7 years (since 2017, because of change in survey design) omitted from WCSGFS
- First 9 years omitted from ECSGFS

Following plenary discussion of the sensitivity runs in 2013, it was decided that the final run be based on a run that includes all surveys with the omission of the first 5 years of the WCSGFS and first 9 years of the ECSGFS. The reasons for this decision were: * it is unclear whether boarfish were consistently recorded in the early part of the ECSGFS, * the WCSGFS is thought to be at the northern extreme of the distribution and may not be an appropriate index for the whole stock, * the SPNGFS commences in 1991 such that running the assessment from 1991 onwards includes at least three surveys without relying, solely on the ECSGFS and WCSGFS, * surveys are internally weighted such that highly uncertain values receive lower weight.

3. ***Catches***
   - 2003 - 2018 time series
4. ***Priors***
   - The final run assumes a strong prior $ln(q_{acoustic}) \sim N(1,1/4)$ (mean 1, standard deviation 0.25), which has 95% of the density between 0.5 and 2. Given the short acoustic series (6 years) it is not possible to estimate this parameter freely (i.e. using an uninformative prior). The prescription of a strong prior removes the assumption of an absolute index from the acoustic survey. This assumption will be continually updated as additional data accrue.
5. ***Pseudo-cohort Analysis***
   - Pseudo-cohort analysis is a procedure where mortality is calculated by means of catch curves derived from catch-at-age from a single year. This is in contrast to cohort analysis, which is the basis of VPA-type assessments. In cohort analysis, mortality is calculated across the ages of a year class, not within a single year. Because only seven years of sampling data were available and owing to the large age range currently in the catches a cohort analysis would only yield information for a very limited age and year range. Therefore, pseudo-cohort analysis was performed to supplement the Bayesian state space model. Pseudo-cohort Z estimates increased with the rapid expansion of the fishery but decreased in 2011 due to the introduction of the first boarfish TAC (Table C.1.2). By subtracting M (=0.16), an estimate of F was obtained for each year (ages 7-14). This series was revised to represent ages 7-14, rather than 6-14 as in previous years, because in 2013 age 6 boarfish were not fully selected, i.e. age 7 had higher abundance at age.
   - It can be seen from the table Table C.1.2 that $Z \approx M$ in 2007, the initial year of the expanded fishery, while F is negligible. F increased to a high of 0.26 in 2012 and has reduced to 0.18 in 2014 and 2015. There was a weak correlation between catches and pseudo-cohort F (r^2 = 0.40). Recent F estimated in this way is above F_{MSY} (0.14) and $F_{0.1}$ (0.13).

D. Short-term forecasting

As the assessment is exploratory and indicative of trends, no short term projections were conducted.

E. Medium-term forecasting

A yield per recruit analysis was conducted in 2011 (Minto *et al.* 2011) and $F_{0.1}$ was estimated to be 0.13 whilst F_{max} was estimated as in the range 0.23 to 0.33 (Figures E.1 & E.2). The estimation of $F_{0.1}$ was considered to be quite good.

F. Long-term forecasting

No long term projections were carried out.

G. Biological reference points

It does not appear that boarfish is an important prey species in the NE Atlantic. ICES (1997) considered that precautionary F targets (F_{pa}) should be consistent with $F < M$ for prey species, and $F = M$ for non-prey species. This approach would ensure that fishing does not outcompete natural predators for their prey. This would suggest that a good candidate precautionary F_{pa} is $F = M = 0.16y - 1$. This is considered appropriate because boarfish is not an important prey in the NE Atlantic. B_{lim} may be defined from the stock size estimates available from the stock assessment and set at $0.2 * K$ or 132,336 t based on the exploratory assessment in 2018.

Yield based reference points

Although the 2017 advice stands for both 2018 and 2019, reference were calculated based on the 2018 assessment.

in 2018, F_{MSY} is estimated to be equal to 0.185 while the $MSYB_{trigger}$ value available from stock assessment model is 165 420 t (parameter K / 4). This is proposed as a conservative basis for *MSY Btrigger*.

It should be noted that these values have changed slightly since 2015 and are based on the revised the perception of the stock after the inclusion of the latest data in the exploratory assessment described above.

Since 2017, these reference points may be used in the advice. Throughout the history of the fishery, estimates of stock biomass have remained above $MSYB_{trigger}$. Fishing mortality (F) was greater than F_{MSY} in 2009, 2010 and 2014, but has decreased since. In 2018, the stock is in the green area of the Kobe plot (Figure G.1).

H. Other issues

H1. Management and ICES advice

In 2010, an interim management plan was proposed by Ireland for boarfish in ICES Divisions VI, VII and VIII. The plan was as follows:

1. Until a long term management plan has been developed, and evaluated, the following interim TAC setting rule shall apply.
2. The TAC for 2011 (hereinafter referred to as the Reference TAC) shall be set in the range 22,000-33,000 t, 50%-75% of the Recent Average Yield 2007-2009.
3. The TAC for 2012 shall be based on the Reference TAC, adapted by the rule, below, based on the Exploitation Indicator (E) and Reproductive Capacity Indicator (R)*:
    a. If the average of either E or R in the past two years is 20% or more lower than in the preceding three years, a 15% TAC decrease applies.
    b. If the average of either E or R in the past two years is 20% or more higher than in the

preceding three years, a 15% TAC increase applies.

c. If the average of either E or R in the past two years is less than 20% different than in the preceding three years, no TAC change applies.

d. Notwithstanding 3.b above, in no case shall the TAC for a given year exceed the Reference TAC.

4. A precautionary closed season shall operate between the 15th March and the 31st August. This is because it is known that mackerel and boarfish are caught in mixed aggregations at these times.
5. A closed area shall be implemented in 7.g from 1st September to 31st October, in order to prevent catches of Celtic Sea herring, known to form feeding aggregations in this region at these times.
6. If catches of species covered by TAC, other than boarfish amount to more than 5% of the total catch by day by ICES statistical rectangle, then fishing must cease in that rectangle.
7. Vessels participating in the fishery for boarfish shall only land in designated ports.
8. Participating vessels already facilitate scientific studies, and observer coverage, and this cooperation shall be further developed

Indicator definition

Exploitation indicator E is defined as the mean length of fish of size greater than length at maturity as estimated in 2007 in the ICES western IBTS.

Reproductive Indicator R is defined as the total abundance of mature boarfish as estimated per year by the ICES western IBTS survey.

The total abundance of mature boarfish as estimated per year by the ICES western IBTS survey.

In 2011, ICES was asked by the European Commission to provide advice for boarfish in 2012 for the Celtic Sea and in the Bay of Biscay and the Iberian Coast. Data analysis suggests that a single management area exists in Subareas IV, V, VI, VII and VIII. This differs from the request made by the EC to ICES and also differs to the TAC area (VI, VII and VIII).

In 2012 a management plan was proposed by the Pelagic RAC. This management plan has not yet been fully evaluated by ICES. However, ICES identifies that Tier 1 of the proposed plan coincides with the ICES generic approach to giving advice for data-rich situations. Given that a Category 1 assessment is now being used for advice, ICES recommends that Tier 1.1 of the plan be considered consistent with the PA and MSY approaches for as long as a Category 1 assessment is available (ICES, 2013). This plan is presented below.

1. The TAC setting rules 1.1-1.6 shall apply. Precedence is in decreasing order from Rule 1.1. These are shown in the table below. The decision year for TAC setting is the last year in the assessment, and not the TAC year.

RULE	ASSESSMENT	UNCERTAINTY	CONDITION	PROCEDURE
1.1.a	SSB and F	Low	SSB > Btrigger	Ftarget
1.1.b			SSB < Btrigger	SSB * (Ftarget / Btrigger)
1.2.a	SSB and F	Higher	SSB > Btrigger	Ftarget
1.2.b			SSB < Btrigger	SSB * (Ftarget / Btrigger) * G
1.3.a	F	Any	F < Ftarget	Reference TAC * G
1.3.b			F > Ftarget,	RTAC + (-RTAC / Flim-Fpa)*(F-Fpa)* G
1.4.a	U	Any	U > Upa, TAC =	Reference TAC * G
1.4.b			U < Upa, TAC =	U * (Reference TAC / Upa) * G
1.5	Survey biomass	Any	TAC y,q3,4 = TACy+1	ASB * 1-exp-F0.1_ * G * 0.62
			q1 =	ASB * 1-exp-F0.1_ * G * 0.38
1.6	None		No information on stock status and no risk of recruitment impairment	TAC = 33,000 t (interim management plan TAC)

2. Notwithstanding Paragraph 1, if in the opinion of ICES, the stock is at risk of recruitment impairment, a TAC shall be based on advice given by ICES, and at a lower level than provided for in Paragraph 1, rules 1.1 to 1.6.

3. Closed seasons, closed areas and moving on procedures shall apply to all directed boarfish fisheries as follows:

   i. A closed season shall operate from 15th March to the 31st August. This is because it is known that herring and mackerel are present in these areas and may be caught with boarfish.

   ii. A closed area shall be implemented inside the Irish 12 mile limit south of 52$^{}$30 from 12^th6 February to 31st October, in order to prevent catches of Celtic Sea herring, known to form aggregations at these times.

   iii. If catches of other species covered by TAC, amount to more than 5% of the total catch by day by ICES statistical rectangle, then all fishing must cease in that rectangle for 5 consecutive days.

In 2015 the Pelagic Advisory Council submitted a revised draft management strategy for North-east Atlantic boarfish. The EU has requested ICES to evaluate the following management plan:

This management strategy aims to achieve sustainable exploitation of boarfish in line with the precautionary approach to fisheries management, FAO guidelines for new and developing fisheries, and the ICES form of advice.

1. *The TAC shall be set in accordance with the following procedure, depending on the ICES advice*
   a. *If category 1 advice (stocks with quantitative assessments) is given based on a benchmarked assessment, the TAC shall be set following that advice.*
   b. *If category 1 or 2 (qualitative assessments and forecasts) advice is given based on a non-benchmarked assessment the TAC shall be set following this advice.*
   c. *Categories 3-6 are described below as follows:*
      i. *Category 3: stocks for which survey-based assessments indicate trends. This category includes stocks with quantitative assessments and forecasts which for a variety of reasons are considered indicative of trends in fishing mortali-ty, recruitment, and biomass.*

ii. *Category 4: stocks for which only reliable catch data are available.This category includes stocks for which a time series of catch can be used to approximate MSY.*

iii. *Category 5: landings only stocks. This category includes stocks for which only landings data are available.*

iv. *Category 6: Category 6 - negligible landings stocks and stocks caught in minor amounts as bycatch*

2. *Notwithstanding paragraph 1, if, in the opinion of ICES, the stock is at risk of recruitment impairment, a TAC may be set at a lower level.*
3. *If the stock, estimated in the either of the 2 years before the TAC is to be set, is at or below Blim or any suitable proxy thereof, the TAC shall be set at 0 t.*
4. *The TAC shall not exceed 75,000 t in any year.*
5. *The TAC shall not be allowed to increase by more than 25% per year. However, there shall be no limit on the decrease in TAC.*
6. *Closed seasons, closed areas, and moving on procedures shall apply to all directed boarfish fisheries as follows:*
   a. *A closed season shall operate from 31st March to 31st August. This is because it is known that herring and mackerel are present in these areas and may be caught with boarfish.*
   b. *A closed area shall be implemented inside the Irish 12-mile limit south of 52°30 from 12th February to 31st October, in order to prevent catches of Celtic Sea herring, known to form aggregations at these times.*
   c. *If catches of other species covered by a TAC amount to more than 5% of the total catch by day by ICES statistical rectangle, then all fishing must cease in that rectangle for 5 consecutive days.*

H2. Review

This assessment was peer-reviewed by two independent experts on behalf of ICES in 2012. In 2013, a new assessment was provided, that was based on last previous year's work and took into account the reviewers' comments, which are detailed below.

The reviewers suggested that an age based model would be most appropriate. An age based model, however, is not attainable in the short term because:

- Insufficient age samples are available per year to derive representative CNAA.
- The age range of the species is wide and the year range of the fishery is narrow, making it impossible to populate the age-matrices of any such model in the short term.

The impediments to having an age based assessment can be overcome with time. The reviewers recommend the development of an age-based assessment in a 3-year time-frame. A cost-benefit analysis is required on whether to pursue an age based approach. At present there are insufficient resources for a full ageing programme. The reviewers suggested that more samples with fewer fish per sample and to refine the age length relationship for older fish. Perhaps the most expedient approach is to collect a large amount of samples, but only age a sub-set of these to maintain the indicator pseudo-cohort *F* estimates. If better resources are considered to be warranted, then the back-log of samples could be aged to produce CNAA over several years.

Given the problems with an age-based assessment, it was necessary to develop the bi-omass dynamic model further, whilst paying attention to the reviews conducted in 2012. The main points of the reviews on the biomass dynamic model are presented in the text table below, along with notes on how they were addressed.

REVIEWER.COMMENT	HOW.ADDRESSED
Provide indication of steepness of stock recruitment relationship	The model does not provide modelled recruitment, so this is not relevant to current model specification.
Better description of weighting of individual surveys	Surveys are weighted based on the survey index variability. A highly uncertain survey is therefore down-weighted within the assessment as detailed below. Apart from the index uncertainties, no a-priori weights are given to the indices although sensitivities to the exclusion of certain surveys were conducted and described below.
Clarification of rationale for model(run) selection	We now include a full clarification on final run selection.
Provide sensityivity analysis of prior assumptions	We include a sensitivity analysis to prior assumptions based on a "low resilience" assumption of WKLIFE (ICES, 2012) based on the maximum age for the species.
Need to describe process error to observation error	The process error and observation errors are described in full below.
Better description of Monte Carlo Markov Chain simulations	We now include traceplots of MCMC chains for the all runs to illustrate convergence accompanied by the Rhat statistic (ratio of between-chain to within-chain variance) with Rhat =1 indicating perfect convergence and Rhat < 1.1 indicative of acceptable convergence (Kéry, 2010). We also present autocorrelation functions of the final run to indicate MCMC sample independence.
Better description of catch used as inputs, including discards	Discards are described in Section 6.1.6.
Sensitivity analysis required on model results to assumptions on error variances	Measurement error variances come directly from the survey index analyses. The estimated process error variance is very strongly updated from a gamma prior on the precision so we don't think a sensitivity analysis is warranted for the error variances.
Show correlation among abundance indices	Now presented in Figures 6.6.2.5 and 6.6.2.6.
Include sensitivity analysis for including indices with zero or negative correlations with other indices	Again, the survey indices are internally weighted by their measurement error uncertainty and we do not a priori exclude series. Our sensitivity analyses remove the WCSGFS and ECGFS. The ECGFS survey displays negative correlation with the EVHOE and SPNGFS.

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Table A.2.1 . Boarfish in ICES Subareas 27.6, 7, 8 Landings by year (t), 2001–2017. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

	Denmark	Germany	Ireland	The.Netherlands	UK.England	UK.Scotland	Unallocated	Discards	Total	TAC
2001			120						120	-
2002			91						91	-
2003			458					10929	11387	-
2004			675					4476	5151	-
2005			165					5795	5959	-
2006			2772					4365	7137	-
2007			17615			772		3189	21576	-
2008	3098		21585			0.45		10068	34751	-
2009	15059		68629					6682	90370	-
2010	39805		88457			9241		6544	144047	-
2011	7797		20685			2813		5802	37096	33000
2012	19888		55949			4884		6634	87355	82000
2013	13182		52250			4380		5598	75409	82000
2014	8758		34622			38		1813	45231	133957
2015	29	4	16325	375	104			929	17766	53296
2016	337	7	17496	171	21			1284	19315	47637
2017	548		15485	182	0.13			1173	17388	27288

Table A.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Landings by year (t), 2001–2017 and area where available. (Data provided by Working Group members). These figures may not in all cases correspond to the official statistics and cannot be used for management purposes.

Year	Area	Denmark	Germany	Ireland	The.Netherlands	UKE	UKS	Total
2001	ALL			120				120
2002	ALL			91				91
2003	ALL			458				458
2003	6.a			65				65
2003	7.b			214				214
2003	7.j			179				179
2004	ALL			675				675
2004	6.a			292				292
2004	7.b			224				224
2004	8.d			38				38
2004	7.j			122				122
2005	ALL			165				165
2005	6.a			10				10
2005	7.b			105				105
2005	8.a			38				38
2005	7.j			12				12
2006	ALL			2772				2772
2006	6.a			21				21
2006	7.b			15				15
2006	7.g			375				375
2006	8.a			1				1
2006	7.j			2360				2360
2007	ALL			17615			772	18386
2007	5.b2			6				6
2007	6.a			93				93
2007	7.b			1259				1259
2007	7.g			120				120
2007	8.a			5				5
2007	7.j			16131			772	16903
2008	ALL			21584				21585
2008	6.a			28				28
2008	7.b			3				3
2008	7.g			184				184
2008	7.j			21370				21370
2009	ALL			68629				68629
2009	6.a			45				45
2009	7.b			73				73
2009	7.c			1				1
2009	7.g			4912				4912
2009	7.h			18225				18225
2009	7.j			45372				45372
2010	ALL	39805		88457			9241	137503
2010	6.a			1349			10	1359

Year	Area	Denmark	Germany	Ireland	The.Netherlands	UKE	UKS	Total
2010	6.aS			7				7
2010	7.b			2258				2258
2010	7.c			35			4	39
2010	7.e	2						2
2010	7.g	672		3649				4321
2010	7.h	1465		8453			1712	11629
2010	7.j	37667		72707			7515	117889
2011	ALL	7797		20685			2813	31295
2011	6.a			26				26
2011	7.b			274				274
2011	7.c			9				9
2011	7.g			811				811
2011	7.h	4155		8540			2813	15508
2011	8.a	18						18
2011	7.j	3624		11025				14648
2012	ALL	19888		55949			4884	80720
2012	6.a			125				125
2012	7.b	80		4501			838	5419
2012	7.c			108			907	1015
2012	7.g			616				616
2012	7.h	5837		10579			3139	19554
2012	8.a	1604		93				1697
2012	7.j	12366		39928				52294
2013	ALL	13182		52250			4380	69811
2013	6.a			538			15	553
2013	7.b			10405			100	10505
2013	7.e						883	883
2013	7.g			1808				1808
2013	7.h	955		11355			1728	14038
2013	8.a	1354		870				2224
2013	8.d			270				270
2013	7.j	10873		27003			1653	39529
2014	ALL	8758		34622			38	43418
2014	6.a			182			30	212
2014	7.b	12		3262				3274
2014	7.g			135				135
2014	7.h	4808		18389				23196
2014	8.a			119				119
2014	7.j	3886		12536			8	16429
2014	7.k	53						53
2015	ALL	29	5	16325	375	104		16837
2015	6.a	10		116		9		134
2015	7.b	8	4	2609		85		2706
2015	7.c			220				220
2015	7.g			547				547
2015	7.h	5		8506				8510

Year	Area	Denmark	Germany	Ireland	The.Netherlands	UKE	UKS	Total
2015	8.a	6	1	682				688
2015	7.j			3646		10		3655
2015	6				128			128
2015	7				33			33
2015	8				214			214
2016	ALL	337	7	17496	171	21		18031
2016	6.a			377	45			422
2016	7.b		5	1198	35	0.66		1239
2016	7.c				0.08			0.08
2016	7.e				0.02			0.02
2016	7.h	330		6771				7101
2016	7.j			1852	90	16		1959
2016	8.a	2	1	6173		5		6181
2016	8.b					0.11		0.11
2016	8.d	5		1124				1129
2017	ALL	548		15485	182	0.13		16215
2017	4.a				0.03			0.03
2017	6.a	37		907	34			979
2017	7.b			124	118			242
2017	7.c				20			20
2017	7.d	1						1
2017	7.e				0.08			0.08
2017	7.f					0.02		0.02
2017	7.g			1		0.02		1
2017	7.h	239		2961		0.09		3200
2017	7.j			33	9			43
2017	8.a	271		10543				10814
2017	8.d			915				915
ALL	ALL	90344	12	413378	727	126	22128	526711

Table B.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish age length key produced from 2011 commercial samples. Figures highlighted in grey are estimated.

TL(cm)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15+
7	1	1													
7.5	1	1													
8		1													
8.5		1	1												
9		1	1												
9.5			1												
10			1												
10.5			2	10	3										
11			1	29	14	2	2								
11.5				9	21	21	18	2	2	1					
12				4	17	22	38	12	8						1
12.5					5	9	42	37	14	6	2		1	1	1
13					2	4	31	28	24	12	6	2	3	1	5
13.5					1	3	25	22	21	14	6	5	4	2	11
14							6	8	18	22	8	3	7	1	20
14.5						1	1	2	3	8	1	6	6	6	30
15							1	1		2	2	2	5	2	19
15.5										2				2	19
16															8
16.5															1
17															1
17.5															1
18															1
18.5															1

Table B.2.2. Boarfish in ICES Subareas 27.6, 7, 8. Length-frequency distributions of the international catches (raised numbers in '000s) for the years 2007-2018.

TL (cm)	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
4.5									14				14
5									878				878
5.5									515				515
6				156					810		560	765	2291
6.5				439					14		3509	4607	8569
7				1090	522	56	52		513	417	4120	5250	12020
7.5			1354	1574			551		10598	1684	11119	12616	39496
8			677	375	1345	185	1419		80716	8685	10050	11473	114925
8.5				1082		555	3592	1064	49508	6412	9327	10115	81655
9			677	5382	851	555	7263	327	10219	7104	3369	3874	39621
9.5		7473	17367	7883	7012	641	47509	4916	213	23065	13303	14047	143429
10	9609	11209	54130	29410	33243	2791	94702	31649	1211	46010	31168	32346	377478
10.5		52308	174796	130889	15848	6132	59833	71344	3865	39071	34992	36242	625320
11	84555	63517	343283	361774	70615	24571	18359	108261	12226	14181	31177	32445	1164964
11.5		59781	321637	655875	93487	81928	20938	82470	28142	18249	30458	31589	1424554
12	44199	119561	297737	739025	189434	264888	98564	84288	41613	30975	32303	33618	1976205
12.5		70990	207739	564347	114904	398772	204868	112826	42461	51110	40233	41650	1849900
13	82633	52308	147965	353484	133539	419060	315063	172416	59990	57000	45034	46495	1884987
13.5		29890	149314	246146	51235	307533	285688	153742	52625	58696	41685	43121	1419675
14	117224	22418	105782	224611	50857	176710	210137	138549	50139	76872	43879	45353	1262531
14.5		14945	71273	127711	25309	89726	105571	74059	28771	37755	37943	39524	652587
15	65338	33627	47816	125463	25569	52791	62175	43347	16087	23137	21023	21854	538227
15.5		11209	13082	81386	5473	25065	31122	22629	8572	7841	4690	4932	216001
16	13452	11209	19397	24256	4181	13149	14990	7672	4331	625	1010	1020	115292
16.5		3736	4061	6209	2280	2738	4918	2134	2081	128			28285
17		3736	677	1913	456	827	1109	1361	289				10368
17.5							407		23				430
18				283			296						579
18.5							592						592

Table B.2.3. Boarfish in ICES Subareas 27.6, 7, 8. Proxy catch numbers-at-age of the international catches (raised numbers in '000s) for the years 2007-2017.

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1			1575	2415		28	301		5556	218	1862
2	352	5488	15043	11229	2894	893	7148	695	116135	2385	4387
3	2114	21140	65744	72709	41913	5467	156680	49503	32248	10737	8830
4	40851	105575	338931	294382	28148	41278	58522	127520	16588	25114	34448
5	48915	141300	475619	567689	30116	110272	59797	93705	24564	20263	27266
6	62713	195339	543707	878363	175696	146582	68949	67275	26566	18025	21103
7	26132	104031	307333	522703	143967	492078	302967	193061	74115	61229	55189
8	29766	66570	172783	293719	107126	365840	250341	139124	52052	47573	38229
9	56075	53159	155477	276672	77861	271916	212318	121042	44615	42478	32258
10	44875	46893	130148	232122	60022	173486	160137	94225	34264	35150	25716
11	14019	15289	42521	78588	46079	69396	63025	36078	12999	13297	9560
12	32359	21178	61350	114600	40468	40968	41490	24895	9114	9132	7564
13	4848	11854	39609	59932	24352	58888	59380	36309	13362	13774	10922
14	16837	13570	31569	59060	19724	30277	30355	19064	7152	6682	5924
15+	109481	112947	196967	349320	157707	217260	239366	150688	59139	49589	40797

Table B.2.4. Boarfish in ICES Subareas 27.6, 7, 8. Sampling intensity by country of commercial catches

Year	Q	Area	DK Landings	DK Samples	DK Measured	IRL Landings	IRL Samples	IRL Measured	SCT Landings	SCT Samples	SCT Measured
2007	1	6.a				12					
2007	1	8.a				5					
2007	1	7.j				5253			772		
2007	2	7.g				120					
2007	2	7.j				4130	2	197			
2007	3	7.b									
2007	4	5.b.2				6					
2007	4	6.a				82	1	20			
2007	4	7.b				1259					
2007	4	7.j				6748					
2007	All	All				17615	3	217	772		
2008	1	6.a				5					
2008	1	7.g				184					
2008	1	7.j				5041					
2008	2	7.j				46					
2008	3	7.j				4067					
2008	4	6.a				23			0.5		
2008	4	7.b				3					
2008	4	7.j				12216	1	152			
2008	All	All	3098			21584	1	152	0.5		
2009	1	7.b				55					
2009	1	7.g				2979					
2009	1	7.h				1971					
2009	1	7.j				10901	2	359			
2009	2	7.g				1933					
2009	2	7.h				3169					
2009	2	7.j				2727					
2009	3	7.h				10378					
2009	3	7.j				11423	1	175			
2009	4	6.a				45					
2009	4	7.b				18					
2009	4	7.h				2707					
2009	4	7.j				20321	6	941			
2009	All	All	15059			68629	9	1475			
2010	1	6.a							10		
2010	1	7.b				1069	1	102			
2010	1	7.g	577	1	77	2392					
2010	1	7.h	1079			326	1	94			
2010	1	7.j	32422	2	193	34466	12	1447	2504		
2010	2	7.h				102					
2010	2	7.j	344								
2010	3	7.g				338					
2010	3	7.h	377			5540	8	1316	548		
2010	3	7.j	2660			11531	31	3275	2171		
2010	4	6.a				1355	1	117			
2010	4	7.b				1189					
2010	4	7.c				35			4		
2010	4	7.e	2								
2010	4	7.g	94			920					
2010	4	7.h	9	3	384	2484	6	715	1165		
2010	4	7.j	2241	2	217	26710	27	2738	2840		
2010	All	All	39805	8	871	88457	87	9804	9241		
2011	1	7.b				39					
2011	1	7.h	32								
2011	1	8.a	18								
2011	1	7.j	1			38					

Year	Q	Area	DK Landings	DK Samples	DK Measured	IRL Landings	IRL Samples	IRL Measured	SCT Landings	SCT Samples	SCT Measured
2011	2	7.b				1					
2011	3	7.h				820			434		
2011	3	7.j				1092					
2011	4	6.a				26					
2011	4	7.b				235					
2011	4	7.c				9					
2011	4	7.g				811					
2011	4	7.h	4123	11	1347	7720	3	319	2379		
2011	4	7.j	3623	5	611	9894	8	1789			
2011	All	All	7797	16	1958	20685	11	2108	2813		
2012	1	7.b				4365	3	339			
2012	1	7.g				616					
2012	1	7.h	3789	1	150	1005					
2012	1	7.j	11403	3	102	27812	42	4987			
2012	1	8.a	1330	2	214						
2012	2	7.h	208								
2012	3	7.b				49					
2012	3	7.h				3176	5	682	1537		
2012	3	7.j				834	2	341			
2012	4	6.a				125	1	96			
2012	4	7.b	80			87			838		
2012	4	7.c				108			907		
2012	4	7.h	1840	4	445	6398	7	945	1602		
2012	4	8.a	274			93					
2012	4	7.j	963	2	180	11281	8	1175			
2012	All	All	19888	12	1091	55949	68	8565	4884		
2013	1	6.a				370			15		
2013	1	7.b				8314	15	2037	100		
2013	1	7..e							883		
2013	1	7.g				1443					
2013	1	7.h	955			1319	1	113	828		
2013	1	8.a	1354	3	369	100	1	147			
2013	1	7.j	10873	11	852	14338	21	2984	721		
2013	3	7.b				11					
2013	3	7.g				46					
2013	3	7.h				2307	3	480			
2013	3	8.a				770					
2013	3	7.j				3892	2	436	468		
2013	4	6.a				167.262	1	123			
2013	4	7.b				2080	2	198			
2013	4	7.g				320					
2013	4	7.h				7729	10	1467	901		
2013	4	8.d				270					
2013	4	7.j				8773	6	833	464		
2013	All	All	13182	14	1221	52250	62	8818	4380		
2014	1	6.a				14			30		
2014	1	7.b				808					
2014	1	7.h	2259			2409	5	550			
2014	1	7.j	2992			6062	11	871	8		
2014	2	7.j				10					
2014	3	7.b				31					
2014	3	7.h				2183	8	727			
2014	3	7.j				1547	4	416			
2014	4	8.a				119					
2014	4	6.a				167.8					
2014	4	7.b	12			2424	1	44			
2014	4	7.g				135					
2014	4	7.h	2549	11	1936	13797	19	1914			
2014	4	7.k	53								

Year	Q	Area	DK Landings	DK Samples	DK Measured	IRL Landings	IRL Samples	IRL Measured	SCT Landings	SCT Samples	SCT Measured
2014	4	7.j	894			4916	6	550			
2014	All	All	8758	11	1936	34622	54	5072	38		
2015	1	7.h	5			4606	14	1380			
2015	1	7.b				2123	3	263			
2015	1	7.j				306	2	175			
2015	1	6.a	4			42					
2015	1	7.g				547					
2015	1	8.a	6			460					
2015	3	7.j				2753	3	344			
2015	4	7.h				3900	7	934			
2015	4	7.j				587	1	115			
2015	4	7.c				220	1	145			
2015	4	6.a	6			74					
2015	4	7.b	8			486					
2015	4	8.a				222					
2015	All	All	29			16325	31	3356			
2016	1	6.a				220.236					
2016	1	7.b				724.807					
2016	1	7.h				4845.313	8	997			
2016	1	7.j				1152.369					
2016	1	8.a				200					
2016	1	8.d									
2016	3	7.h				848.3	2	298			
2016	3	7.j				700.108					
2016	3	8.d				94					
2016	4	6.a				156.384	2	134			
2016	4	7.b				473.222					
2016	4	7.h				1077.371	4	718			
2016	4	8.a				5973.136	8	1417			
2016	4	8.d				1030.5	3	297			
2016	All	All				17495.746	27	3861			
2017	1	6.a				267.122					
2017	1	7.b				95.476					
2017	1	7.d									
2017	1	7.h				188.3	1	164			
2017	1	7.j				33.35	1	195			
2017	1	8.a				7357.454	17	2678			
2017	1	8.d				914.877	3	504			
2017	3	7.h.1				95.255					
2017	3	8.a.1				49.8					
2017	4	6.a.2				640.138					
2017	4	7.b.2				28.756					
2017	4	7.g.2				1					
2017	4	7.h.2				2677.82					
2017	4	8.a.2				3135.44					
2017	All	All				15484.788	22	3541			

Table B.3.1 . Boarfish in ICES Subareas 27.6, 7, 8. Parameter estimates of the von Bertalanffy growth equation

	Estimate	Std. error	t value	Pr(>|t|)
L_{inf}	15.563073	0.134828	115.43	<2e-16 ***
K	0.190592	0.006698	28.45	<2e-16 ***
t0	-1.662997	0.109091	-15.24	<2e-16 ***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1				
Residual standard error: 0.8982 on 404 degrees of freedom				

Table B.4.1. Boarfish in ICES Subareas 27.6, 7, 8. IBTS length-frequency data converted to age-structured index by application of the common ALK.

Survey	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML.mature	Total	Total.mature
EVHOE	1997		5	11	7	17	197	2659	5020	3719	3598	4429	12065	16651	7198	3455	501	18	1			12	13	59548	47915
EVHOE	1998		1	4	26	76	2093	18283	8631	6125	5966	7095	11730	14078	9260	5076	934	8			1	11	13	89387	54148
EVHOE	1999			13	52	33	245	11177	26610	23947	6684	2899	4709	7868	6160	1353	267	7				10	12	92023	29947
EVHOE	2000		17	79	120	8	1504	26894	17674	9836	21967	16382	29585	36853	16522	5397	989	75				11	12	183903	127769
EVHOE	2001		1	45	687	489	913	21297	37171	13276	28355	31514	18309	12232	6471	3186	1270	81	4			10	12	175303	101422
EVHOE	2002		2	18	23	11	547	9631	29874	17777	13290	9470	9697	9751	6268	2484	641	37	1	1		10	12	109522	51639
EVHOE	2003			17	47	17	57	426	1655	7142	20018	24842	20989	21263	14494	7086	1550	36				12	12	119639	110277
EVHOE	2004			33	512	378	123	1248	1419	1307	1083	3102	7308	7224	6353	7866	3630	241	5			13	14	41833	36813
EVHOE	2005		2	93	975	1285	146	1100	2326	1229	1553	3183	13398	15758	9834	6010	1658	117	70			12	13	58738	51580
EVHOE	2006	1	26	112	79	75	15510	37566	10750	3622	2127	1521	1955	4131	3955	2535	921	94	2	12		8	13	84994	17253
EVHOE	2007		8	187	467	234	1503	22689	126065	64536	6341	6731	5431	6004	5911	4238	1409	118	11			9	12	251882	36193
EVHOE	2008		3	434	2807	827	5341	53189	247296	165392	163200	69382	38434	18390	17258	9178	3490	745	6	1		9	11	795371	320083
EVHOE	2009		6	128	194	72	1496	19769	35819	5264	3913	9556	12269	9402	10831	6720	775	38	1			10	13	116252	53505
EVHOE	2010		21	529	116	154	5755	46438	74986	27175	11952	37420	58313	34737	33774	14626	1561	249	8	1		10	12	347814	192641
EVHOE	2011		60	95	215	5	541	2247	8368	15256	33221	30237	50384	56559	36673	11867	3082	573	159	47		12	12	249590	222803
EVHOE	2012		9	145	584	137	2922	28865	26816	6124	11739	13606	22369	37135	44082	19963	4893	127	1			11	13	219516	153914
EVHOE	2013		3	48	91	10	306	2185	2165	2542	13649	9932	14987	37755	40524	20107	6918	666		2		13	13	151890	144540
EVHOE	2014		2	693	1386	508	84	1440	885	3074	8732	28586	39397	74122	69736	26871	3908	59	433			13	13	259915	251844
EVHOE	2015		5	183	5898	4143	607	19075	179269	119004	15765	18014	61575	62024	59904	21525	5487	541	429	8		10	13	573455	245271
EVHOE	2016	5	31	379	846	115	733	10284	14280	17251	42132	25304	68583	130633	131220	48538	11611	1358	26			13	13	503329	459405
EVHOE	2017		2	103	129	3	27	269	198	5												6		735	
IGFS	2003		1	32	22	7	22	129	172	879	2942	2322	1326	3822	4628	2898	896	163	38			13	13	20299	19035
IGFS	2004		23	63	34	8	96	532	1431	369	344	410	2253	4320	4698	3966	1017	87	2	1		13	14	19654	17098
IGFS	2005		8	59	52	20	203	1024	585	288	636	341	3463	11457	11348	7955	1744	382	2	0.97		13	14	39569	37330
IGFS	2006	5	60	68	48	35	212	969	621	2046	4190	8044	7946	24208	42119	32168	12296	2454	532			14	14	138021	133957
IGFS	2007	1	6	44	18	31	501	923	1251	1638	1166	2510	3581	8275	10740	7093	1934	92				13	14	39804	35391
IGFS	2008			26	18	23	127	672	531	2095	13780	17664	19268	16980	19484	15953	8789	1747	76	1		13	13	117231	113741
IGFS	2009		3	80	76	25	94	228	486	1000	1139	9081	7749	5138	6921	5592	1084	68	1			12	13	38763	36772
IGFS	2010		6	42	3	18	199	272	463	920	393	7914	34236	28611	16063	8161	1974	433				13	13	99709	97784
IGFS	2011		6	14	5	4	189	772	586	555	670	2578	20171	22082	10829	5298	2207	266	9	6		13	13	66247	64116

Survey	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML.mature	Total	Total.mature
IGFS	2012		7	36	20	10	131	271	378	702	2144	1183	11105	34010	22742	10906	3903	525	4			13	13	88077	86521
IGFS	2013	1	3	9	9	20	127	352	340	1320	2833	3971	15572	51637	52868	20485	6560	492	20			14	14	156620	154439
IGFS	2014		10	68	54	4	18	13	25	60	130	1127	3251	19125	23016	10355	2988	284	18			14	14	60547	60295
IGFS	2015		3	11	16	24	193	1008	3708	848	105	713	6314	29727	48221	33024	17350	1885	531			14	14	143681	137870
IGFS	2016	4	31	121	63	7	67	186	1515	4057	2891	1349	4110	32753	57753	40907	15527	3670	86			14	14	165097	159046
IGFS	2017		6	53	10169	689915	6406	1751	715	11818	21886	10164	11841	25588	42311	35049	17110	3299	369			7	14	888449	167616
SPNGFS	1991		1			31	690	1311	313	49	9	6	7	7	4				6			7	13	2433	39
SPNGFS	1992		57	38	9	178	3290	2743	282	48	10	8	69	162	390	779	246	95				8	15	8404	1760
SPNGFS	1993		57	1206	488	97	3730	3753	421	105	54	7	4	8	3	2						6	11	9934	77
SPNGFS	1994	1	40	33		342	4789	10162	8920	3195	53	106	20	9	12	1						7	11	27685	202
SPNGFS	1995		84	108	4	342	3063	2157	220	84	65	58	105	105	90	20	4					7	12	6510	447
SPNGFS	1996		218	537	143	245	4457	4449	267	820	722	82	145	126	219	96	39	2				7	12	12566	1431
SPNGFS	1997	2	102	809	441	235	3458	6824	2189	1923	534	156	353	161	88	3						7	11	17277	1295
SPNGFS	1998	3	2	7	4	49	1920	4685	1815	337	153	125	88	147	135	86	13	2	3			8	12	9573	752
SPNGFS	1999		6	59	13	134	2736	3010	193	106	83	109	143	390	645	402	69					8	14	8098	1841
SPNGFS	2000		7	3729	2046	17	554	1947	489	277	486	756	1252	999	1021	199	34	13				7	12	13827	4760
SPNGFS	2001		68	4	1	153	3241	5085	659	225	206	205	236	692	407	120	22	9				8	13	11331	1896
SPNGFS	2002		4	20		133	2333	2013	284	50	58	54	60	231	314	72	9					8	13	5634	798
SPNGFS	2003		4	950	567	4	77	221	57	39	28	16	22	17	23	16	5	1				5	12	2047	128
SPNGFS	2004		6	22	4	43	2289	3808	443	110	83	58	219	931	776	303	2	1				8	13	9097	2372
SPNGFS	2005		16	451	25	9	754	1007	207	85	102	30	54	257	218	90	44	2				8	13	3349	797
SPNGFS	2006		14	156	160	50	2238	8913	4507	175	94	9	36	229	419	169	9	2				7	14	17181	968
SPNGFS	2007		49	40	1	111	3025	6620	1099	129	260	81	7	93	215	89	21	3				7	12	11843	768
SPNGFS	2008	7	4	92	247	1	936	1561	1326	234	1483	304	537	11	833	201	186	11				9	12	7974	3566
SPNGFS	2009	1	17	53	125	9	2582	3816	4105	119	250	45	142	59	819	120	17	1	1			8	13	12283	1456
SPNGFS	2010		55	102	5	232	13090	22032	3169	1160	1056	89	82	179	1007	1981	518	9				8	14	44766	4920
SPNGFS	2011		29	260	105	46	2805	5511	1278	148	340	145	100	144	591	724	134	3	1			8	14	12364	2182
SPNGFS	2012		29	132	35	556	7550	7844	1364	88	53	59	170	1051	2394	1553	432	21				8	14	23331	5734
SPNGFS	2013			2	11	126	2163	4664	854	302	609	251	61	110	123	140	64	7				8	12	9486	1364
SPNGFS	2014		75	117	6	12	263	465	79	1083	1175	1174	1266	998	2444	3623	817	31	1			12	13	13630	11530
SPNGFS	2015		13	67	3	58	1889	4248	534	75	465	750	970	695	1173	1473	453	70	1			10	13	12937	6050
SPNGFS	2016		0.16	0.85	0.04	0.39	9	24	4	9	7	3	6	5	6	2	0.25	0.03				9	12	77	29
SPNGFS	2017	0.01	0.2	0.18	0.01	0.14	6	18	7	1	2	3	4	6	10	9	2	0.11	0.03			10	14	67	34
SPPGFS	2001		2		2	2	4		88	10	104	266	323	1334	2259	460	81					13	14	4934	4827
SPPGFS	2002									1	4	90	212	791	843	313	60					14	14	2314	2313
SPPGFS	2003						1		3	15	22	21	62	268	426	249	51	2	1			14	14	1121	1102
SPPGFS	2004		1				5	2		4	5	18	100	312	483	319	43	1				14	14	1293	1281
SPPGFS	2005		1		1	6	1	18	10	9	14	7	101	530	935	705	226	18				14	14	2581	2536
SPPGFS	2006			1	1	6	91	89	21	34	75	27	45	335	670	555	197	10	1			13	14	2158	1914
SPPGFS	2007					3	4	9	15	12	9	27	25	72	151	144	26	4				13	14	501	458
SPPGFS	2008		1				1	13	7	16	13	55	106	237	457	302	78	5				14	14	1292	1254

Survey	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML.mature	Total	Total.mature
SPPGFS	2009		6	5		2	7	8	1		1	154	318	924	1201	1172	324	7				14	14	4130	4101
SPPGFS	2010	1			1	5	14	3	1	5	2	31	284	521	717	459	123	10				14	14	2178	2148
SPPGFS	2011								3	16	18	5	147	671	792	429	122	13		2		14	14	2220	2200
SPPGFS	2012				1	1			2	2	1	8	70	369	468	218	66	3				14	14	1208	1202
SPPGFS	2013				1		7	22	6	9		1	42	435	889	480	141	12	1			14	14	2045	2000
SPPGFS	2014		10	9		1		3	17	62	11	6	85	2453	6703	3168	2115	162	82			14	14	14889	14787
SPPGFS	2015				2	1			1	1			32	300	471	316	151	43				14	14	1318	1313
SPPGFS	2016			0.04				0.02		0.16	0.06		0.1	2	4	3	1	0.25				14	14	11	11
SPPGFS	2017		1	0.35				0.2			0.02	0.35	0.52	3	10	10	5	0.33				14	15	31	29
WCSGFS	1986								0.5													8			
WCSGFS	1987								0.5	0.5	2	0.5										10	10	4	2
WCSGFS	1988				0.5																	4			
WCSGFS	1989							0.5														7			
WCSGFS	1990				1		0.5	1	2	24	54	50	43	12	1							11	11	188	160
WCSGFS	1991						1	0.5	8	38	183	266	316	48	16							11	11	876	829
WCSGFS	1992						1		10	38	468	1145	4001	1626	486							12	12	7775	7726
WCSGFS	1993							4		2	9	60	155	72	16		0.5					12	12	319	312
WCSGFS	1994									0.5	0.5	0.5			0.5							11	12	2	2
WCSGFS	1995									8	36	194	294	398	199	22						12	12	1150	1142
WCSGFS	1996				2		4	3				1	55	610	1574	304						14	14	2552	2544
WCSGFS	1997			4			0.5	6	9	4	6	25	108	203	157	40	4					13	13	568	544
WCSGFS	1998				1		1	5	2		1	2		3								9	12	15	6
WCSGFS	1999			1			2	5	1	1		1	2	1								8	12	14	4
WCSGFS	2000							2	2	39	110	216	288	182	92	46	6					12	12	983	940
WCSGFS	2001		1						1	4	15	28	59	134	240	103	10	4				14	14	599	593
WCSGFS	2002						1	8	2	1	82	742	3211	5601	5772	1497	167	1				13	13	17084	17072
WCSGFS	2003			1				3	52		53	281	1473	3066	4895	3083	309	28				14	14	13244	13188
WCSGFS	2004				1			2	2	43	82	743	4569	8600	9514	5692	948	84				14	14	30280	30232
WCSGFS	2005		2					24	3	23	25	110	435	1085	1708	792	130	6				14	14	4343	4291
WCSGF	2006		1	2	1		1	4		10	218	232	452	1396	2852	2051	434	72				14	14	7726	7706

Survey	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	ML	ML.mature	Total	Total.mature
S																									
WCSGFS	2007			2	2		2	1	3	21	159	780	2923	5194	6888	5283	1523	116				14	14	22897	22866
WCSGFS	2008		1	1			16	37	36	187	468	1395	3213	9893	22758	18399	6288	575	71			14	14	63338	63060
WCSGFS	2009			1			1		4	52	2442	2093	440	331	287	246	129	10				11	11	6038	5978
WCSGFS	2010											530	1443	1384	1357	828	149	29				13	13	5720	5720
WCSGFS	2011		1	4	1		1	5	254	1015	2034	7613	18918	14478	6445	2006	236	23				12	12	53034	51753
WCSGFS	2012			1			1	2		103	9	1267	6545	26337	29361	27333	15857	1505	496			14	14	108817	108710
WCSGFS	2013				1			1			1	143	3201	15282	11288	3934	858	6	1			14	14	34716	34714
WCSGFS	2014		48	457	386	48	3	7	63	21	98	876	11668	30267	39236	10933	1363	111	1			13	14	95587	94553
WCSGFS	2015			4	18	14	115	102	18	5			30	262	345	220	86	10	1		1	12	14	1230	955
WCSGFS	2016				1	2	49	1413	2439	2065	342	436	4088	24632	33254	14568	3484	508	102			14	14	87383	81414
WCSGFS	2017																								

Table B.4.2. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey results.

Age.(Yrs)	2011	2012	2013	2014	2015	2016	2017	2018
1	5	21.5	-	-	198.5	4.6	110.9	76.7
2	11.6	10.8	78	-	319.2	35.7	126.7	31.2
3	57.8	174.1	1842.9	15	16.6	45.5	344.6	115
4	187.4	64.8	696.4	98.2	34.3	43.6	367.3	68.3
5	436.7	95	381.6	102.3	80	6	156	106.7
6	1165.9	736.1	253.8	104.9	112	10	209	165.9
7	1184.2	973.8	1056.6	414.6	437.4	169	493.1	320.7
8	703.6	758.9	879.4	343.8	362.9	112.6	468.3	197.7
9	1094.5	848.6	800.9	341.9	353.5	117.6	397.2	293.4
10	1031.5	955.9	703.8	332.3	360	96.6	285.8	624.7
11	332.9	650.9	263.7	129.9	131.7	17	120.9	339.2
12	653.3	1099.7	202.9	104.9	113	32	82.1	264.1
13	336	857.2	296.6	166.4	174	48.7	74.4	198.4
14	385	655.8	169.8	88.5	108	18.3	220.4	116.5
15+	3519	6353.7	1464.3	855.1	1195	400.1	931	302.4
TSN								
('000)	11104	14257	9091	3098	3996	1157	4387	3221
TSB (t)	670176	863446	439890	187779	232634	69690	230062	186252
SSB (t)	669392	861544	423158	187654	226659	69103		184624
CV	21.2	10.6	17.5	15.1	17	16.4	21.9	19.9

Table C.1.1. Boarfish in ICES Subareas 27.6, 7, 8. Key parameter estimates from all runs. CV(TSB.2013) is the coefficient of variation of the estimated total stock biomass in 2013.

Run	r	K	FMSY	BMSY	TSB.2013	CV(TSB.2013)
1	0	731549	0	365775	500945	0
2	0	835581	0	417791	633617	0
3	0	634469	0	317234	472169	0
4	0	865294	0	432647	665705	1
1	1	768400	0	384200	493886	0
2	1	898583	0	449292	604780	0
3	1	660356	0	330178	470985	0
4	1	828299	0	414150	607527	0
2	0	911209	0	455605	653668	0

Table C.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Pseudo-cohort derived estimates of fishing mortality (F) and total mortality (Z), in comparison with total landings per year. Pearson correlation coefficient of F vs. landings (tonnes) indicated.

Age	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
	Raised numbers											Ln (raised numbers)										
1			1575	2415		28	301		5556	218	1862			7	8		3	6		9	5	8
2	352	5488	15043	11229	2894	893	7148	695	116135	2385	4387	6	9	10	9	8	7	9	7	12	8	8
3	2114	21140	65744	72709	41913	5467	156680	49503	32248	10737	8830	8	10	11	11	11	9	12	11	10	9	9
4	40851	105575	338931	294382	28148	41278	58522	127520	16588	25114	34448	11	12	13	13	10	11	11	12	10	10	10
5	48915	141300	475619	567689	30116	110272	59797	93705	24564	20263	27266	11	12	13	13	10	12	11	11	10	10	10
6	62713	195339	543707	878363	175696	146582	68949	67275	26566	18025	21103	11	12	13	14	12	12	11	11	10	10	10
7	26132	104031	307333	522703	143967	492078	302967	193061	74115	61229	55189	10	12	13	13	12	13	13	12	11	11	11
8	29766	66570	172783	293719	107126	365840	250341	139124	52052	47573	38229	10	11	12	13	12	13	12	12	11	11	11
9	56075	53159	155477	276672	77861	271916	212318	121042	44615	42478	32258	11	11	12	13	11	13	12	12	11	11	10
10	44875	46893	130148	232122	60022	173486	160137	94225	34264	35150	25716	11	11	12	12	11	12	12	11	10	10	10
11	14019	15289	42521	78588	46079	69396	63025	36078	12999	13297	9560	10	10	11	11	11	11	11	10	9	9	9
12	32359	21178	61350	114600	40468	40968	41490	24895	9114	9132	7564	10	10	11	12	11	11	11	10	9	9	9
13	4848	11854	39609	59932	24352	58888	59380	36309	13362	13774	10922	8	9	11	11	10	11	11	10	10	10	9
14	16837	13570	31569	59060	19724	30277	30355	19064	7152	6682	5924	10	10	10	11	10	10	10	10	9	9	9
15+	109481	112947	196967	349320	157707	217260	239366	150688	59139	49589	40797	12	12	12	13	12	12	12	12	11	11	11
Z (age 7-14)												0	0	0	0	0	0	0	0	0	0	0
F (Z-M), where M = 0.16												0	0	0	0	0	0	0	0	0	0	0
Catches (t)												21576	34751	90370	144047	37096	87355	75409	45231	17766	19315	17388
Correlation coefficient landing s vs. F												0										

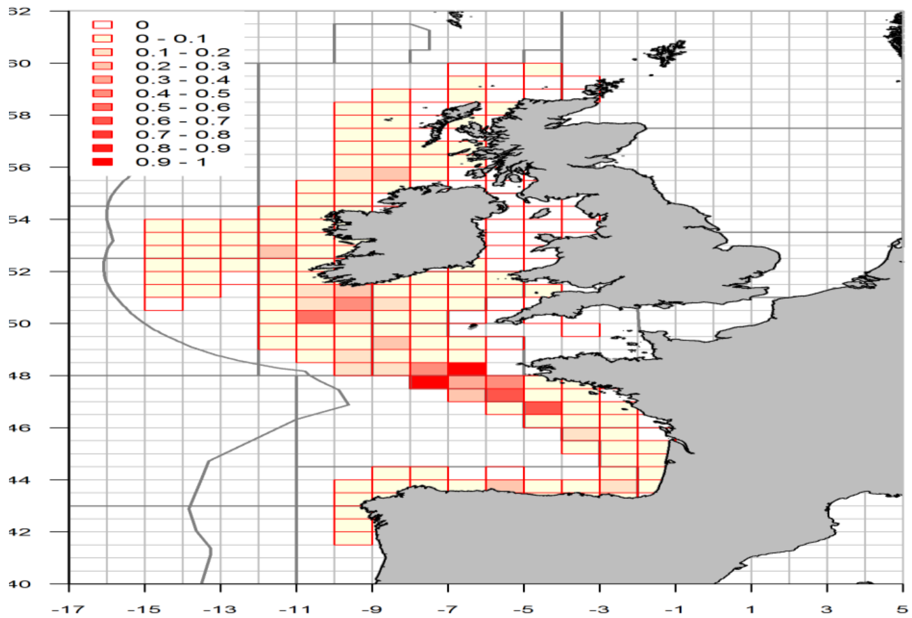

Figure A.1.1. Boarfish in ICES Subareas 5, 27.6, 7, 8. Distribution of boarfish from IBTS surveys in the NE Atlantic showing proposed management area.

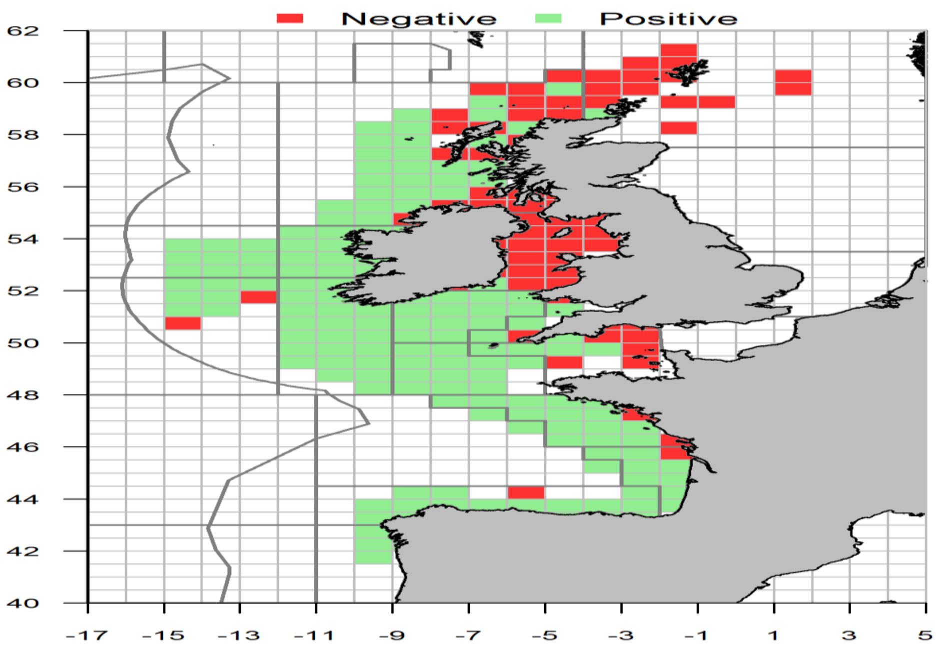

Figure A.1.2. Boarfish in ICES Subareas 27.6, 7, 8. Distribution of boarfish in the NE Atlantic area based on presence and absence in IBTS surveys.

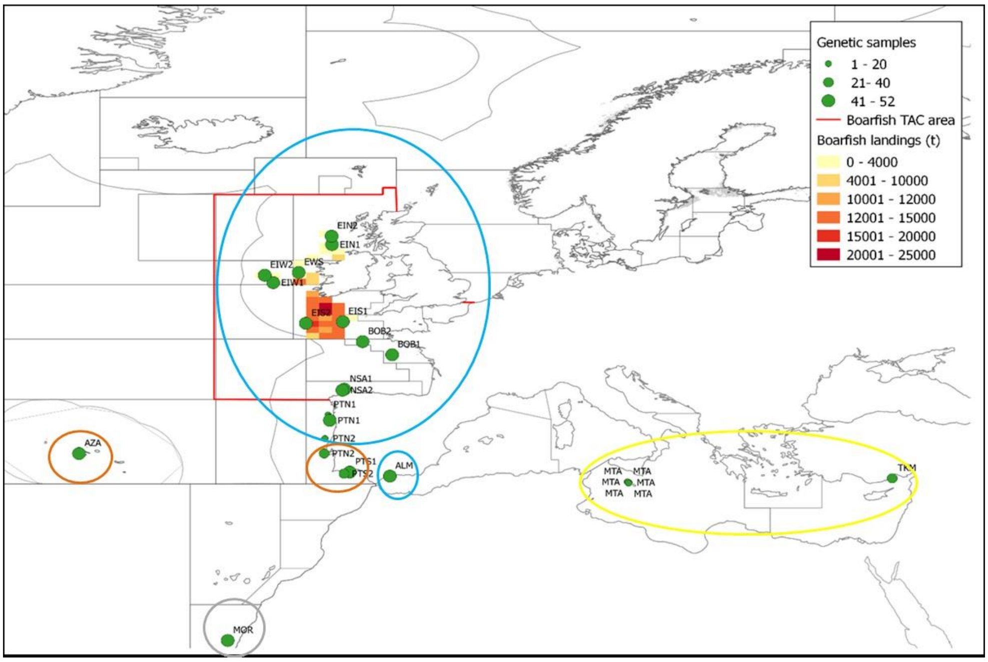

Figure A.1.3. Boarfish samples included in the genetic stock identification. Population clusters identified by multiple analyses are indicated by colour coded markers and circles.

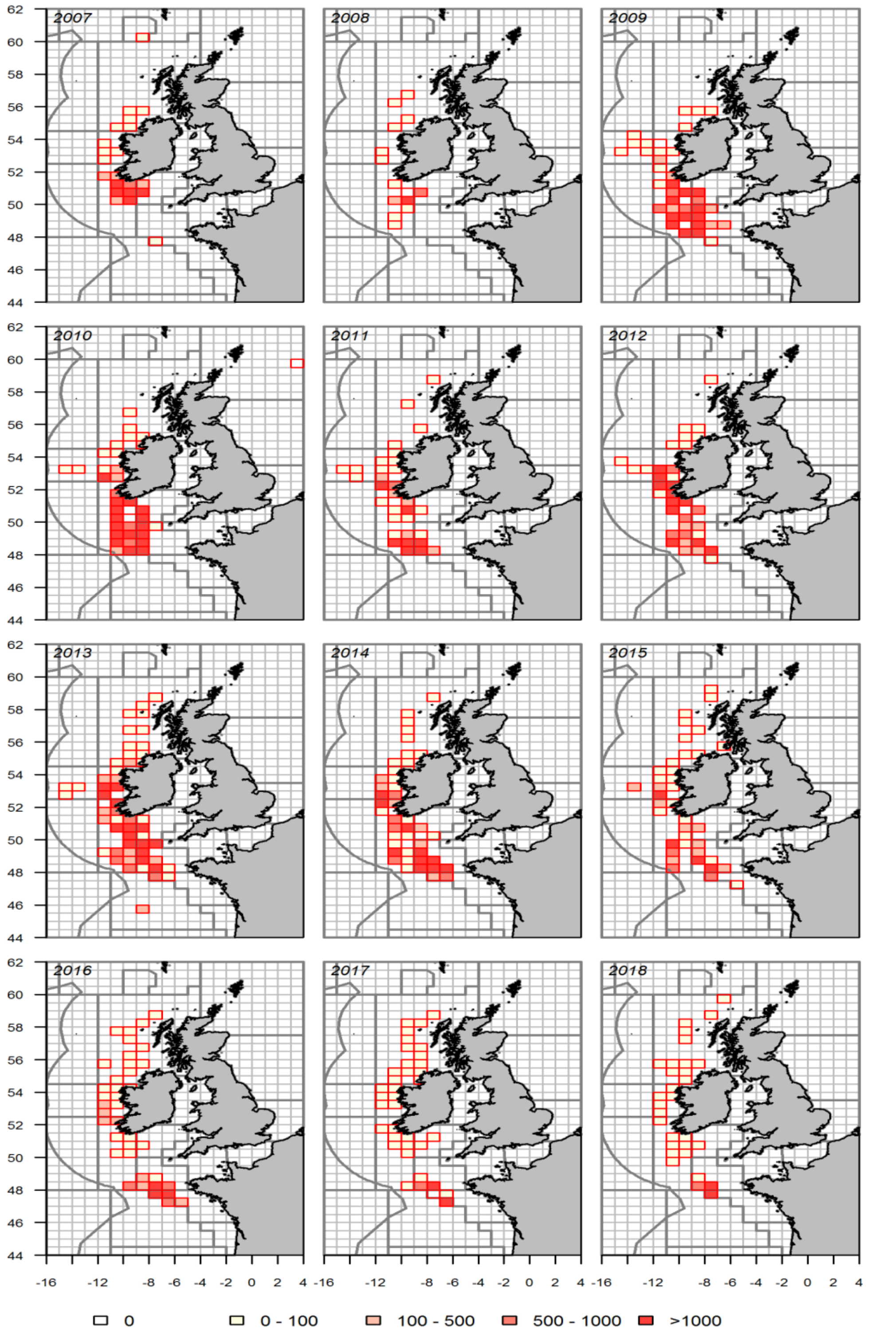

Figure A.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Combined Irish boarfish landings 2003–2017 by ICES rectangle (Above). Irish boarfish landings 2017 by ICES rectangle (Below).

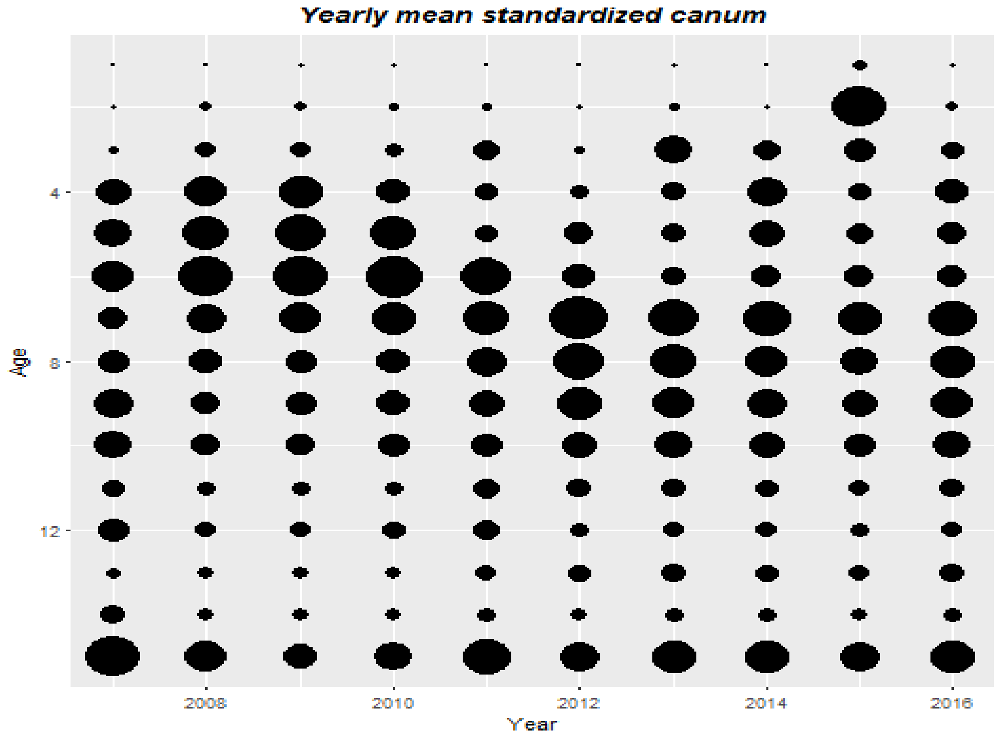

Figure B.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Catch numbers-at-age standardised by early mean. 15+ is the plus group.

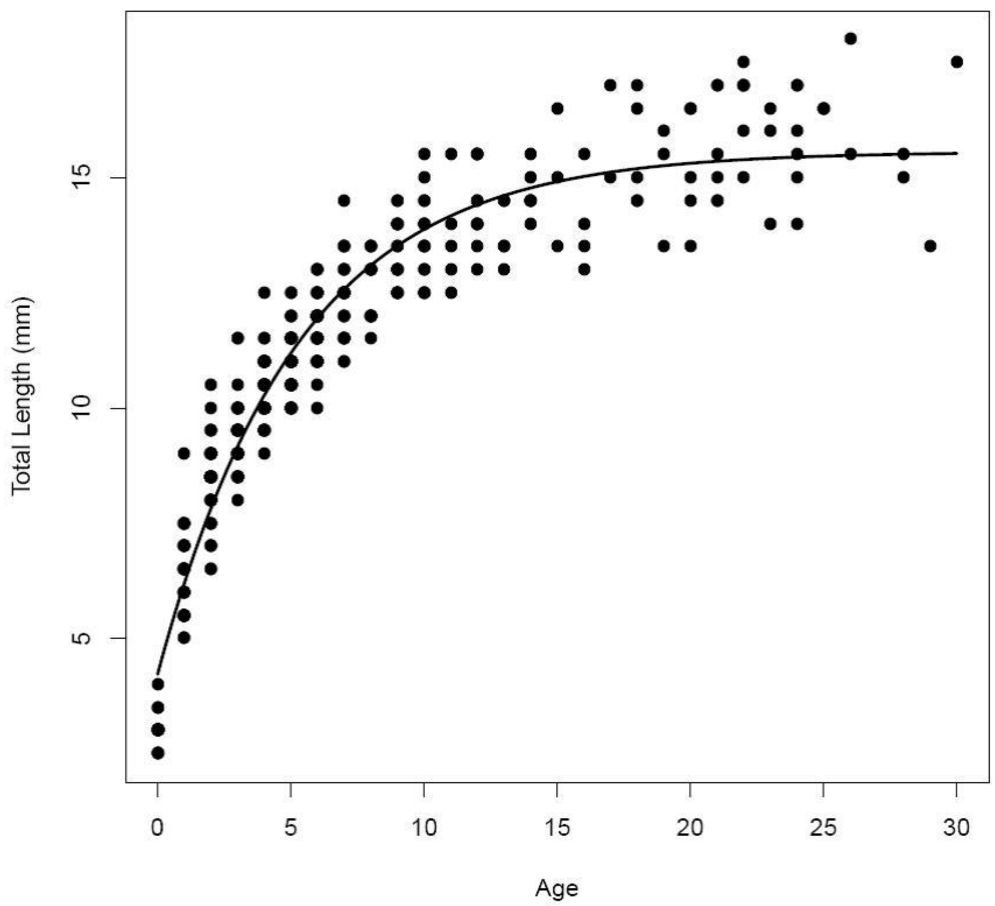

Figure B.3.1. Boarfish in ICES Subareas 27.6, 7, 8. Von Bertalanffy growth curve; see Table B.3.1 for parameter estimates

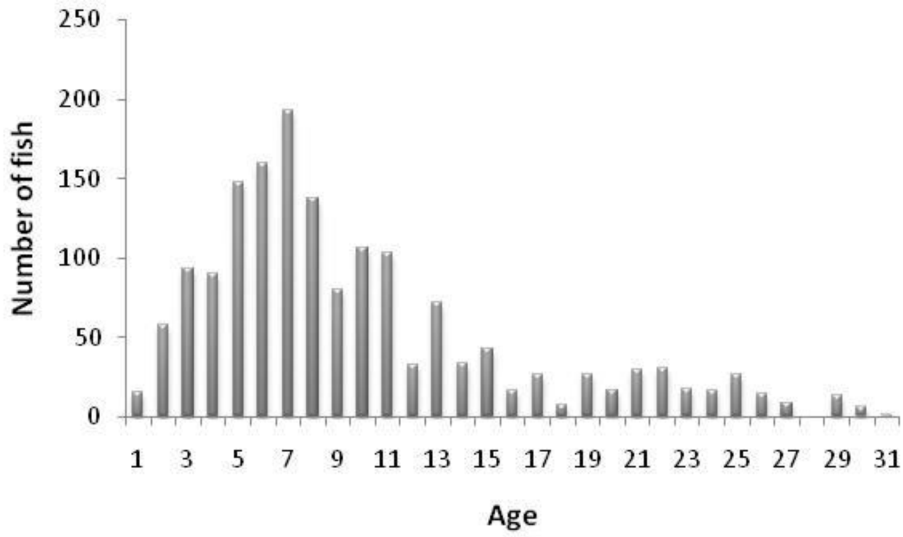

Figure B.3.2. Boarfish in ICES Subareas 27.6, 7, 8. Age distribution for n=1633 fish sampled

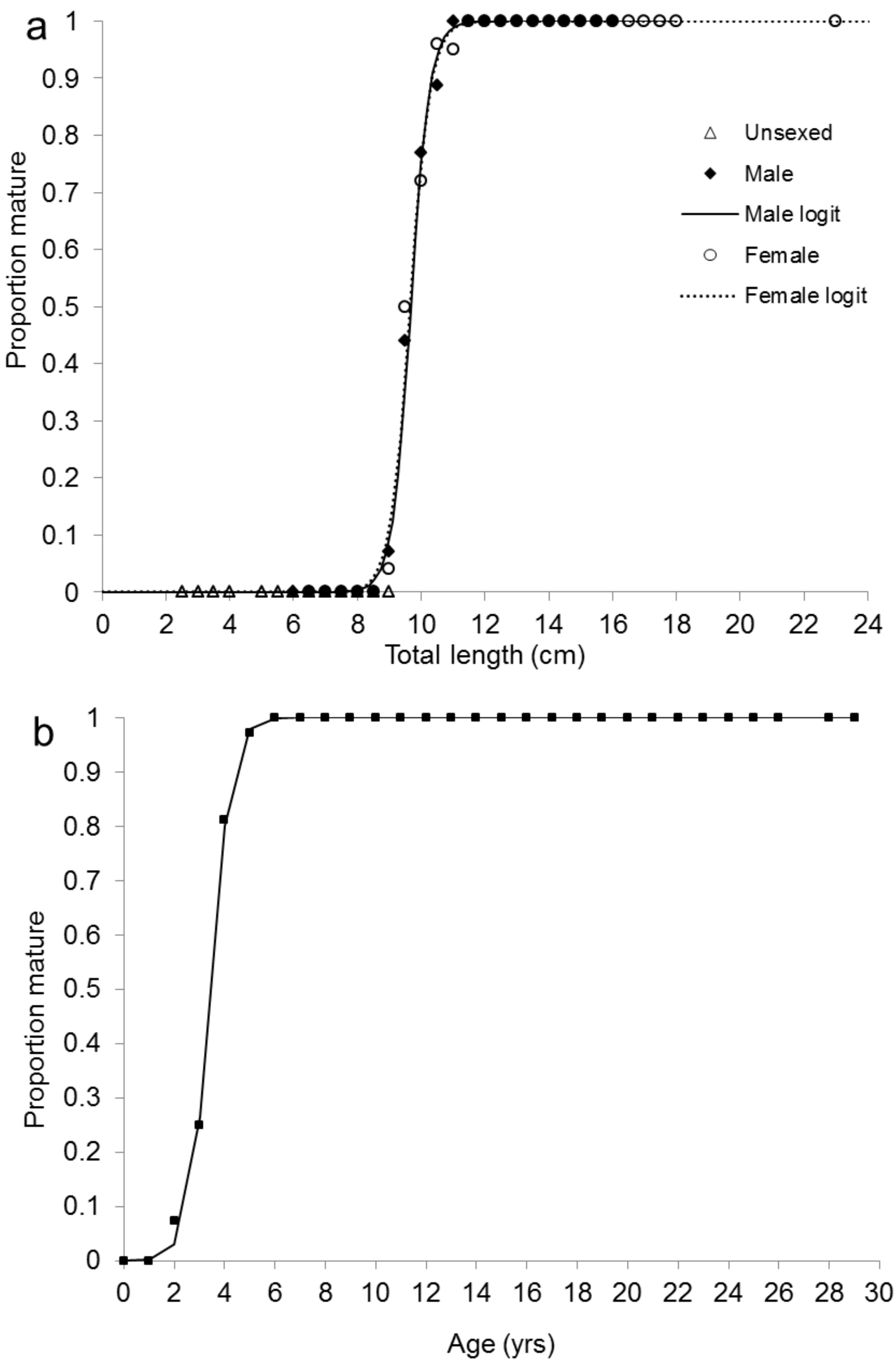

Figure B.3.3. Boarfish in ICES Subareas 27.6, 7, 8. Maturity ogives for (a) total length and (b) age for boarfish

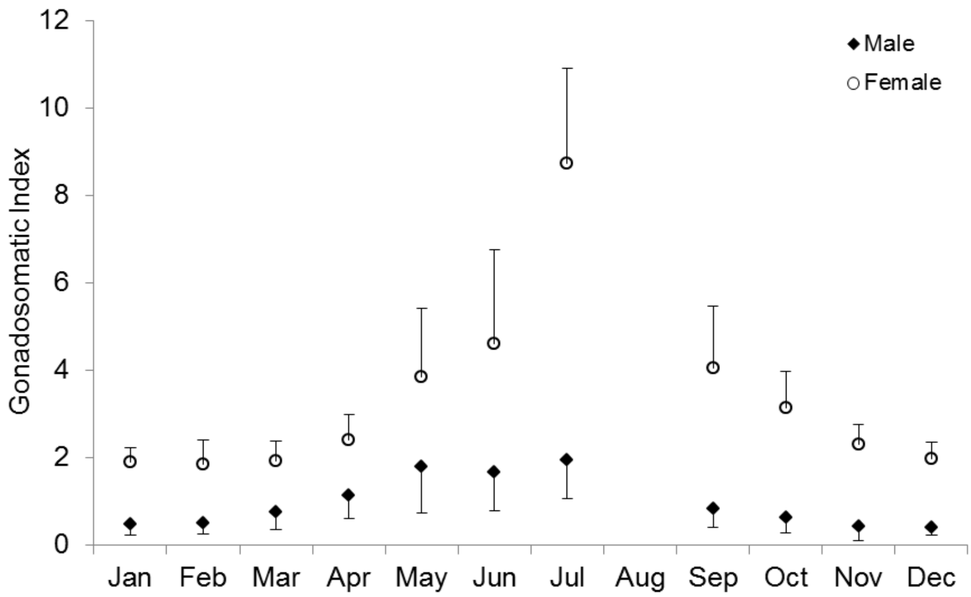

Figure B.3.4. Boarfish in ICES Subareas 27.6, 7, 8. Gonadosomatic index for male and female boarfish

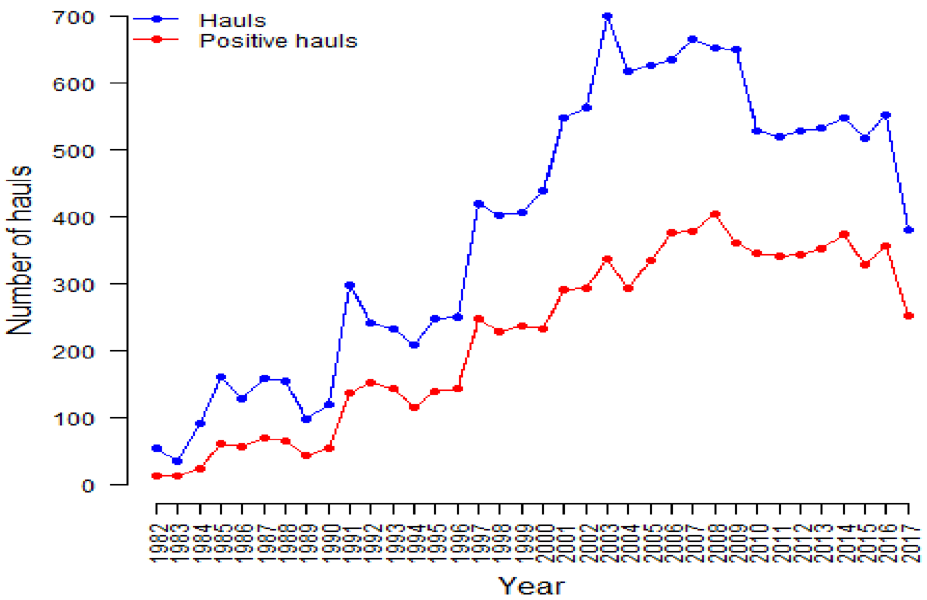

Figure B.4.1.1 . Boarfish in ICES Subareas 27.6, 7, 8. Occurrence of boarfish in ICES Rectangles sampled during the IBTS 1982 – 2017.

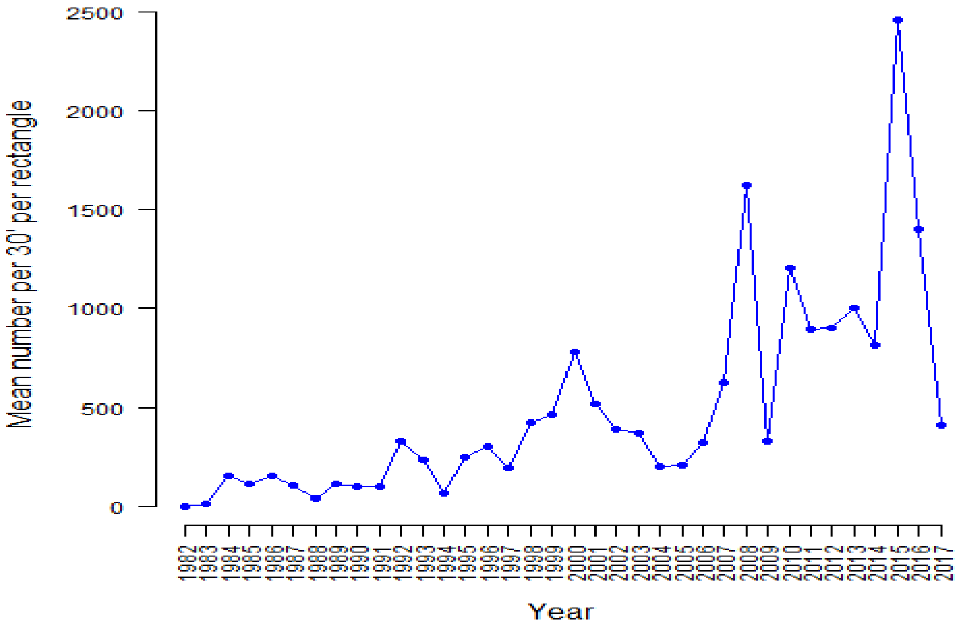

Figure B.4.1.2. Boarfish in ICES Subareas 27.6, 7, 8. CPUE in number per 30 minute haul of boarfish per rectangle in the western IBTS survey 1982 to 2017.

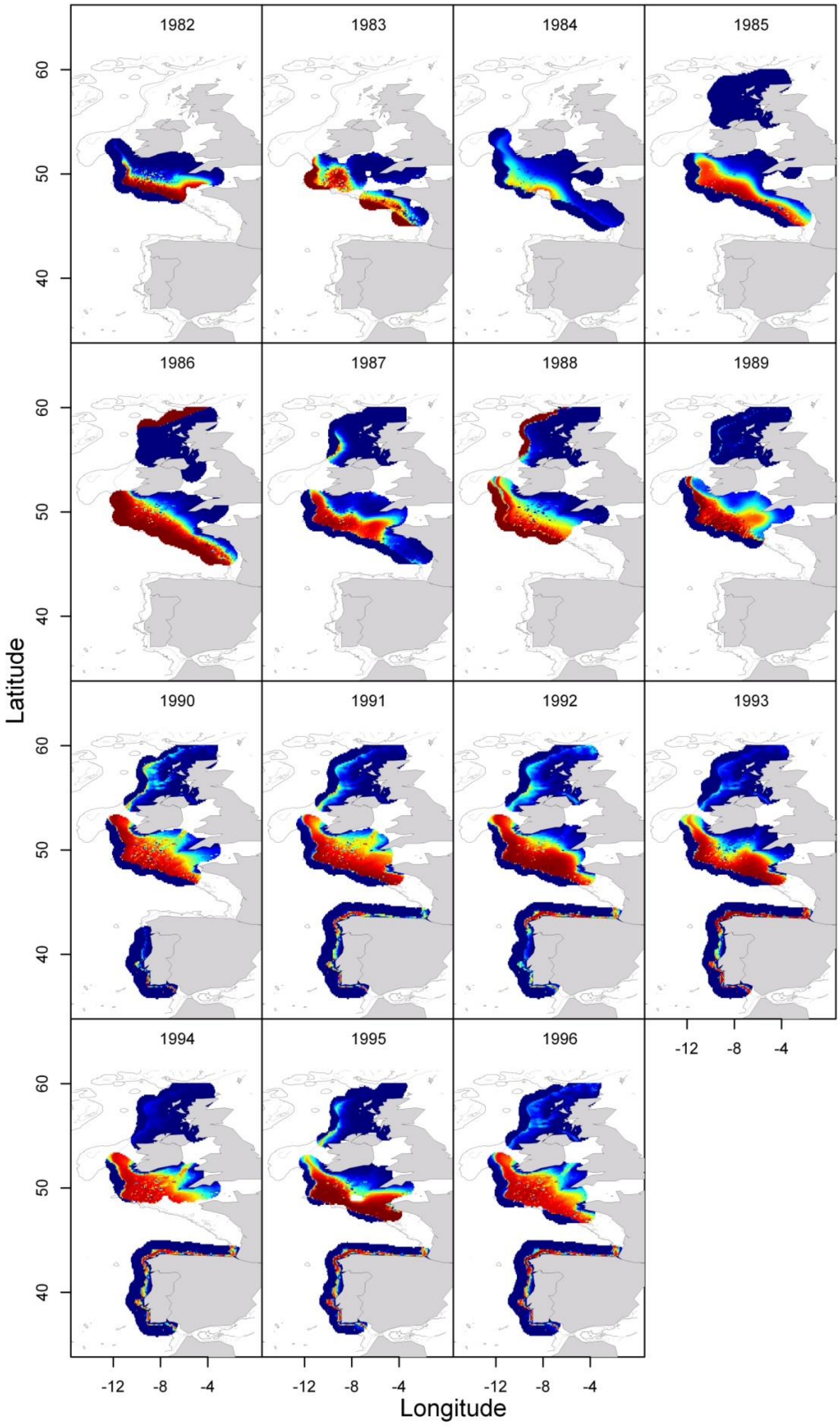

Figure B.4.1.3.a. Boarfish in ICES Subareas 27.6, 7, 8. The occurrence GAM of the probability of occurrence of boarfish in a survey area 1982 – 1996. Red indicates definite occurrence and blue indicates absence.

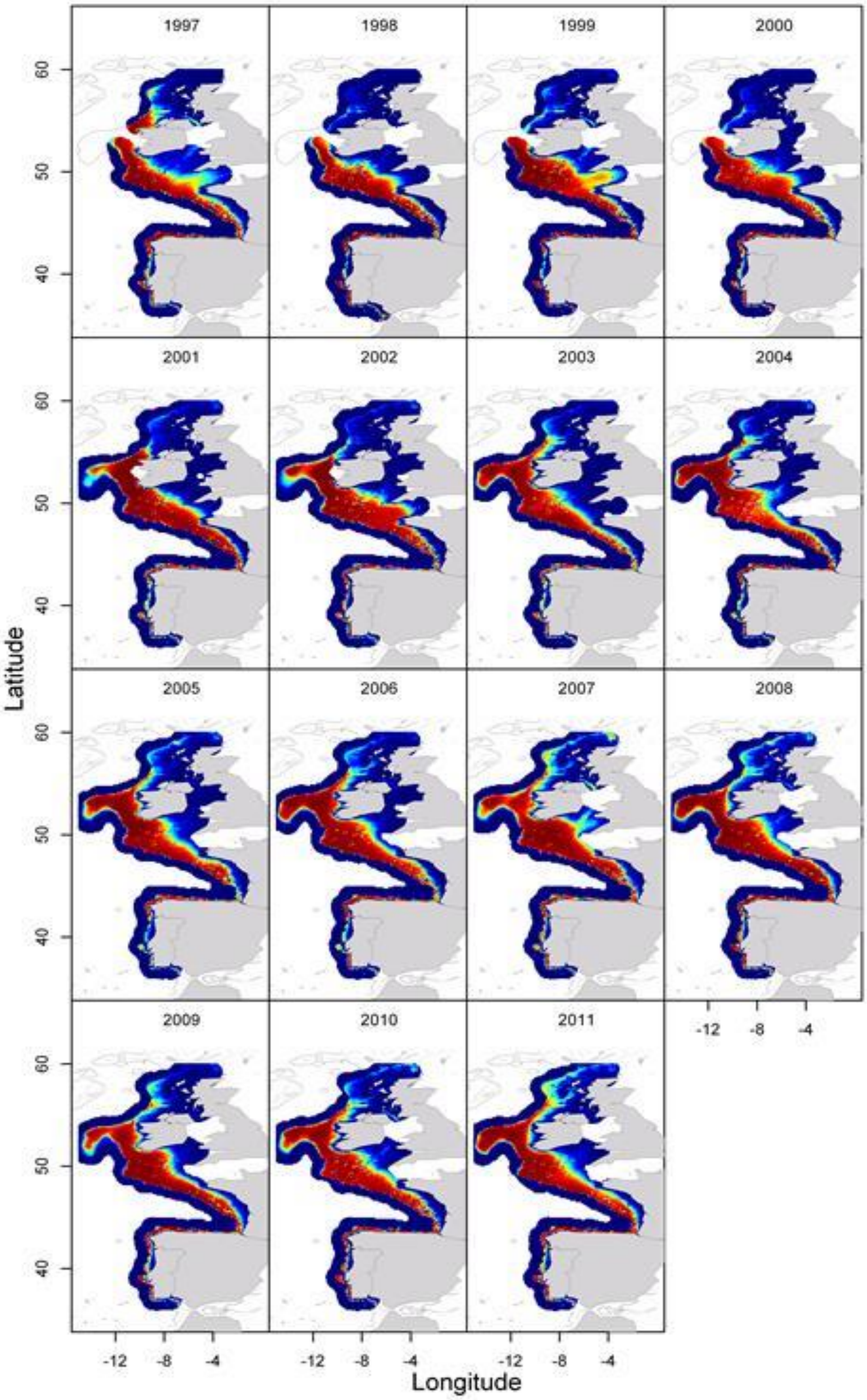

Figure B.4.1.3.b. Continued boarfish in ICES Subareas 27.6, 7, 8. The occurrence GAM of the probability of occurrence of boarfish in a survey area 1997 – 2011. Red indicates definite occurrence and blue indicates absence.

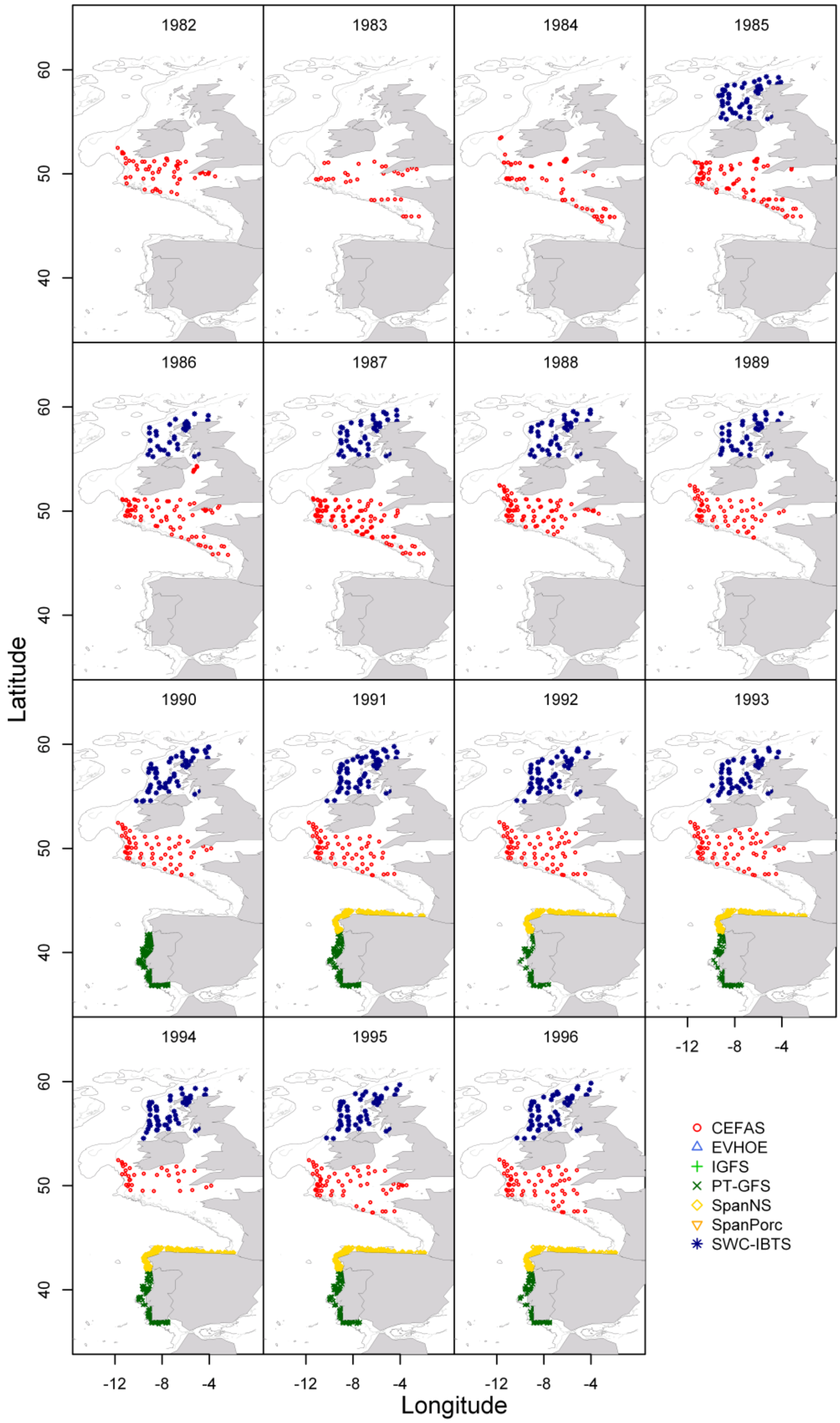

Figure B.4.1.4.a. Boarfish in ICES Subareas 27.6, 7, 8. The haul positions of bottom trawl surveys by year (1982-1996) analysed as part of the GAM modelling.

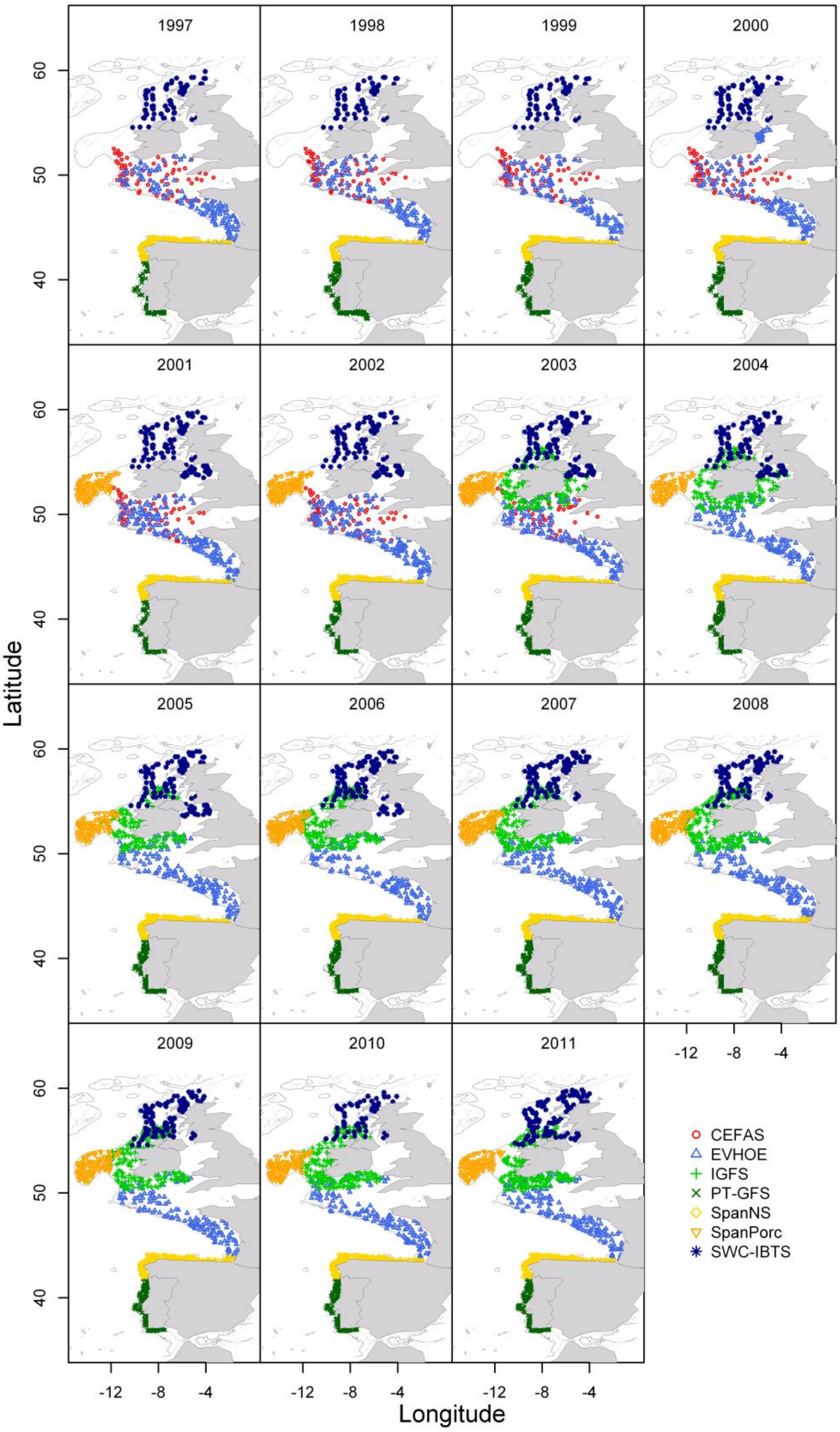

Figure B.4.1.4.b. Continued boarfish in ICES Subareas 27.6, 7, 8. The haul positions of bottom trawl surveys by year (1997-2011) analysed as part of the GAM modelling

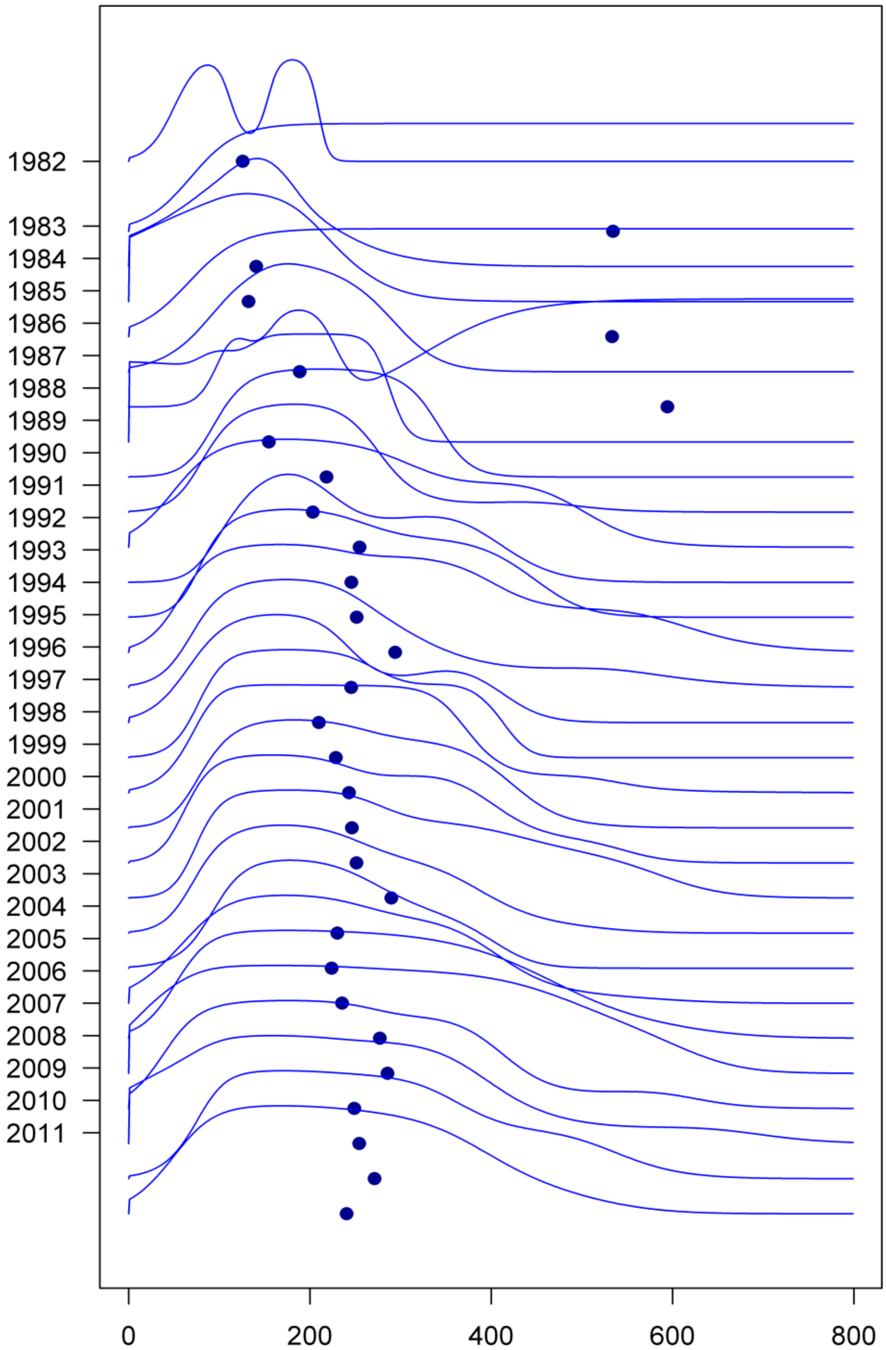

Figure B.4.1.5. Boarfish in ICES Subareas 27.6, 7, 8. The depth distribution profile of boarfish within the IBTS surveys.

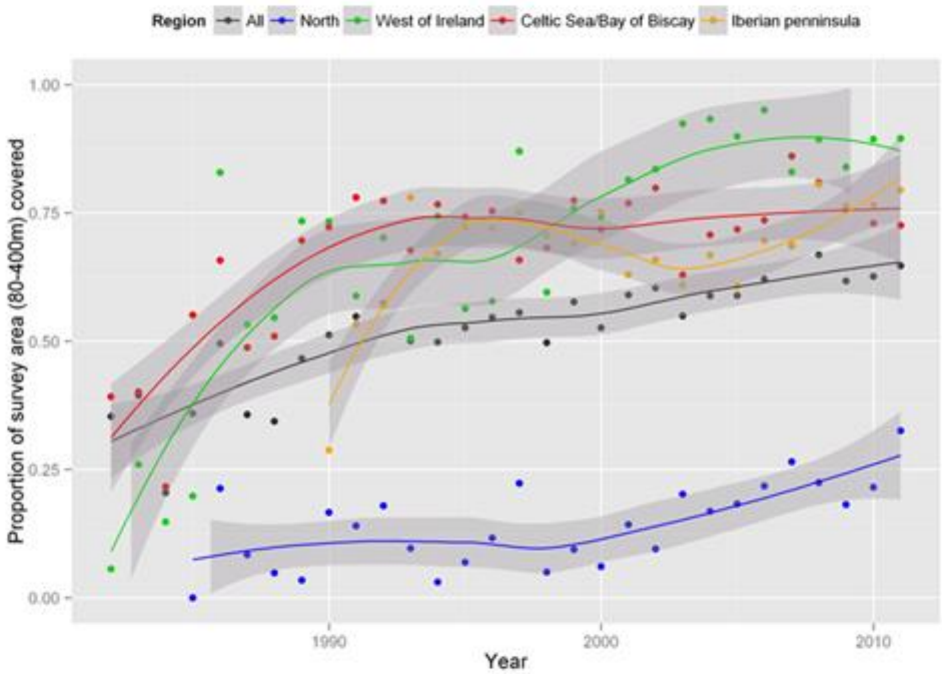

Figure B.4.1.6. Boarfish in ICES Subareas 27.6, 7, 8. The proportion of survey area covered by boarfish per region and per year.

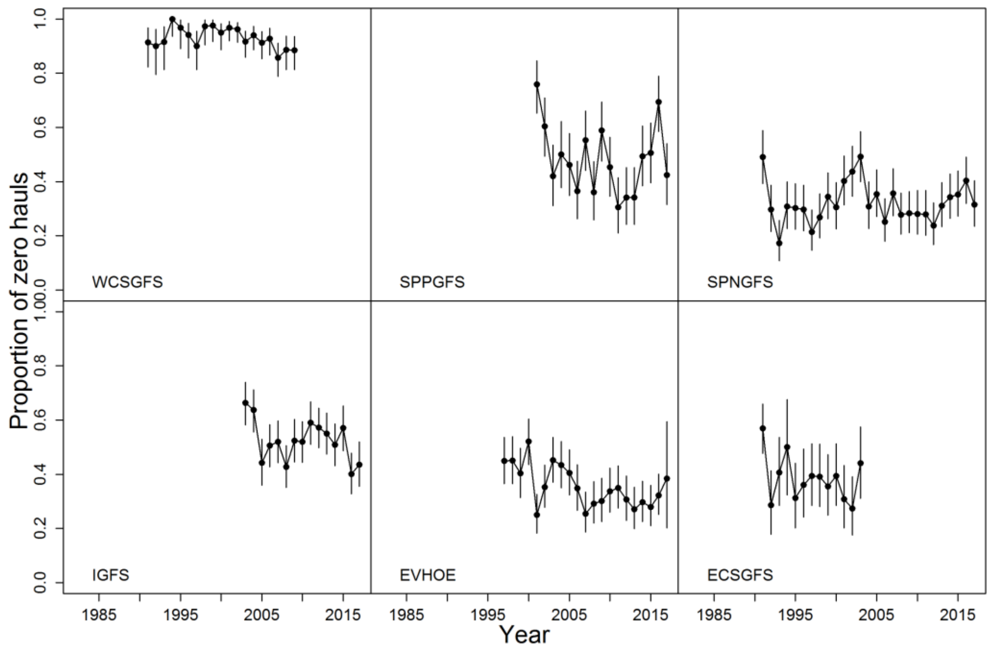

Figure B.4.1.7. Boarfish in ICES Subareas 27.6, 7, 8. The proportion of zero hauls per IBTS survey.

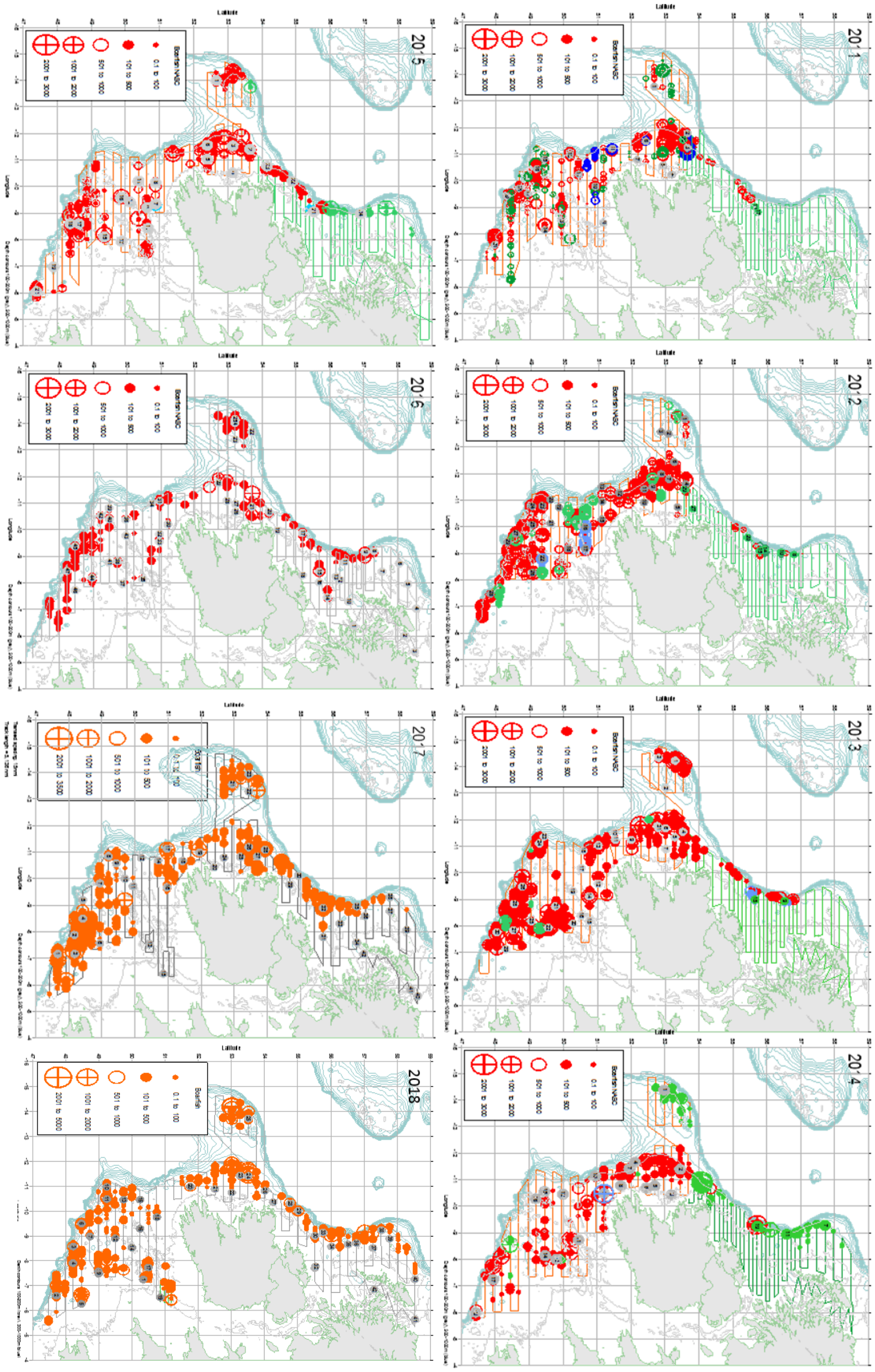

Figure B.4.2.1. Boarfish in ICES Subareas 27.6, 7, 8. Boarfish acoustic survey track and haul positions from acoustic survey 2011-2018. Red circles represent 'definitely' boarfish, green: 'probably boarfish', blue: 'boarfish mix' (all included in the biomass estimate).

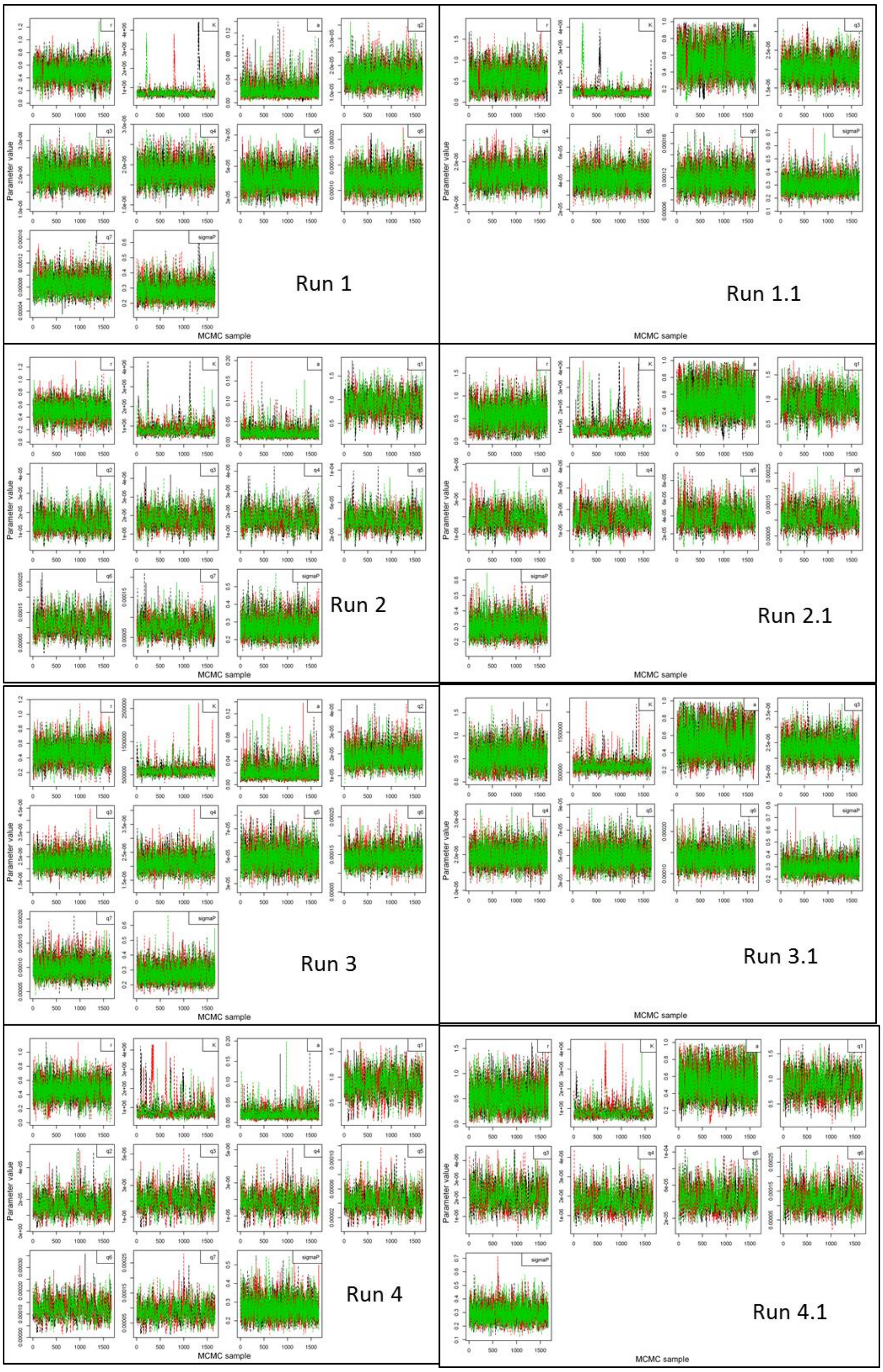

Figure C.1. Boarfish in ICES Subareas 27.6, 7, 8. Parameters for runs 1-4 and sensitivity runs 1.1, 2.1, 3.1, 4.1 converged with good mixing of the chains.

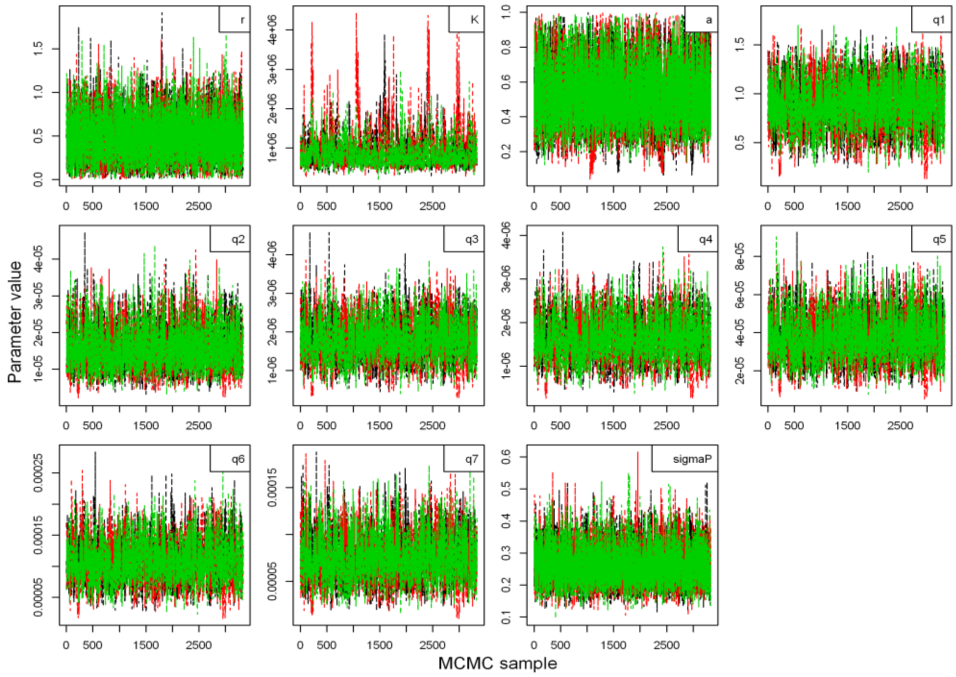

Figure C.2. Boarfish in ICES Subareas 27.6, 7, 8. Parameters for run 2.2 converged with good mixing of the chains.

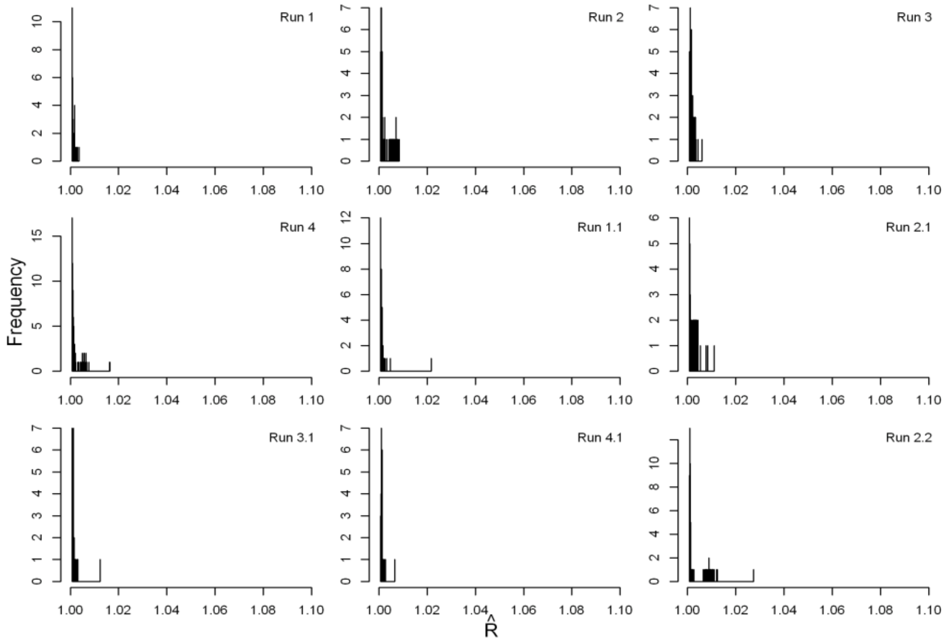

Figure C.3. Boarfish in ICES Subareas 27.6, 7, 8. Rhat values lower than 1.1 indicating convergence.

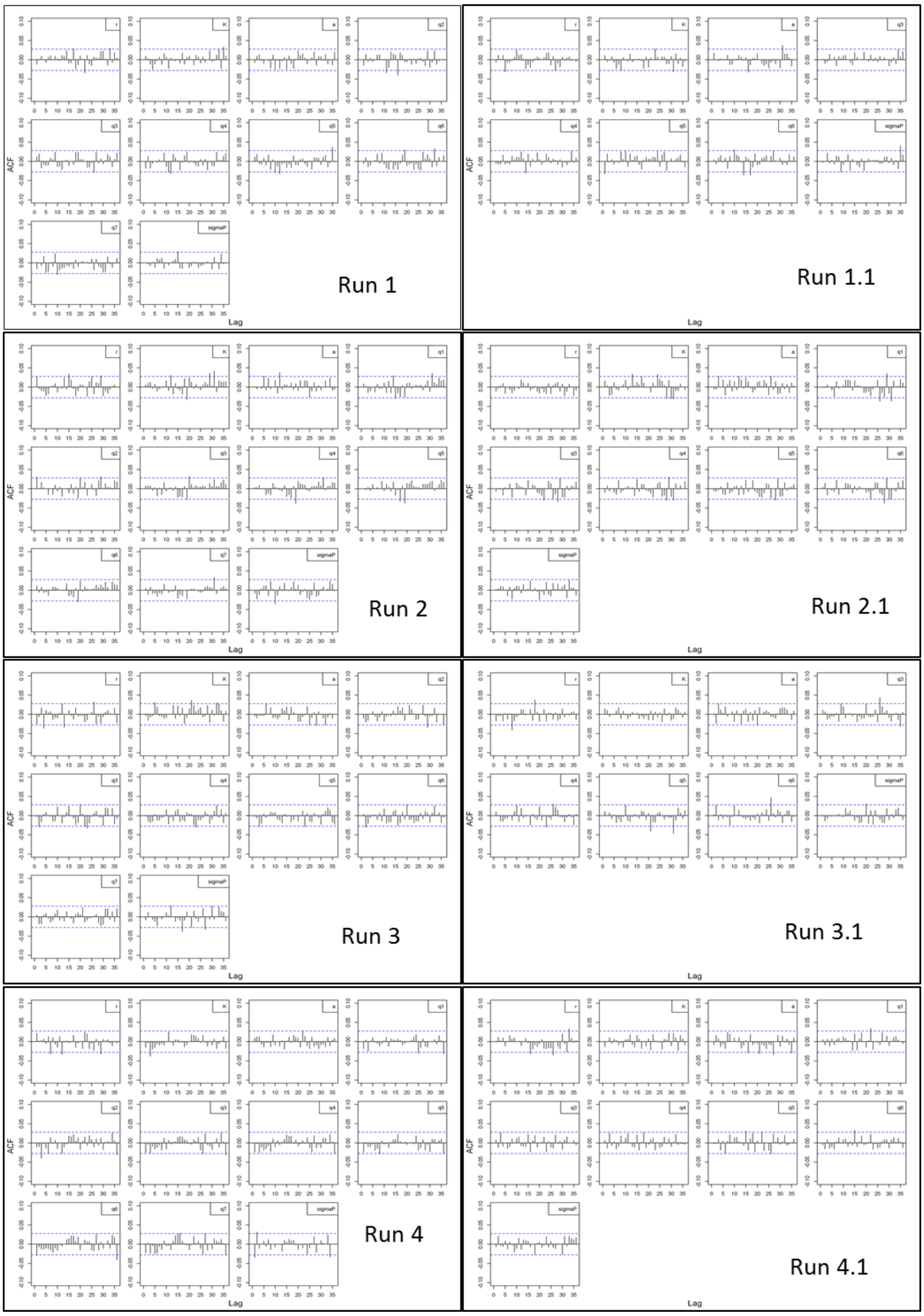

Figure C.4. Boarfish in ICES Subareas 27.6, 7, 8. MCMC chain autocorrelation for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1.

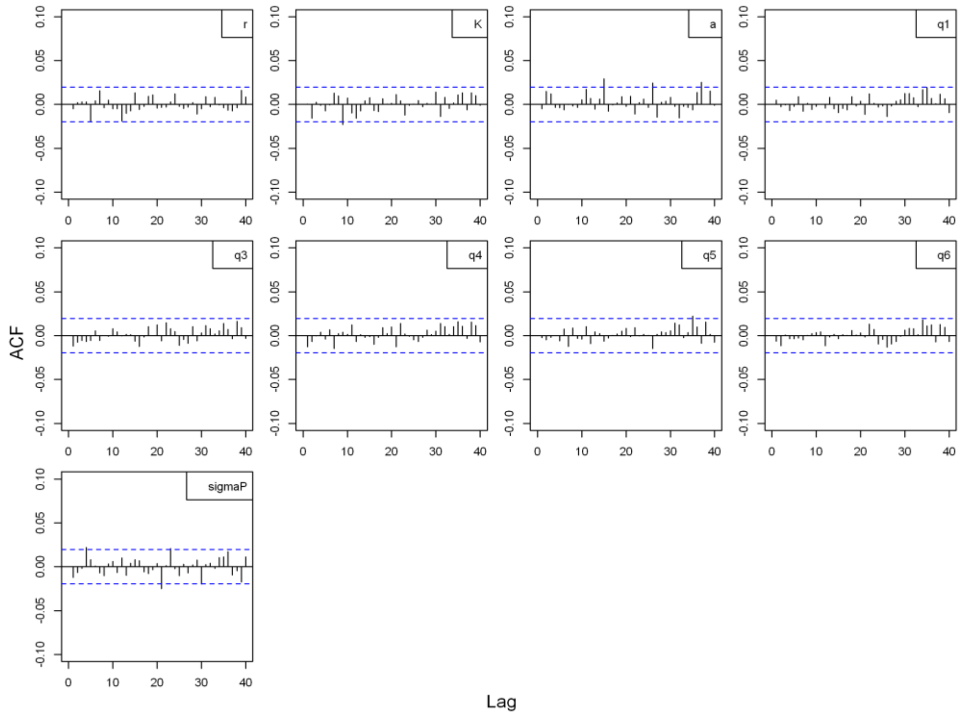

Figure C.5. Boarfish in ICES Subareas 27.6, 7, 8. MCMC chain autocorrelation for run 2.2.

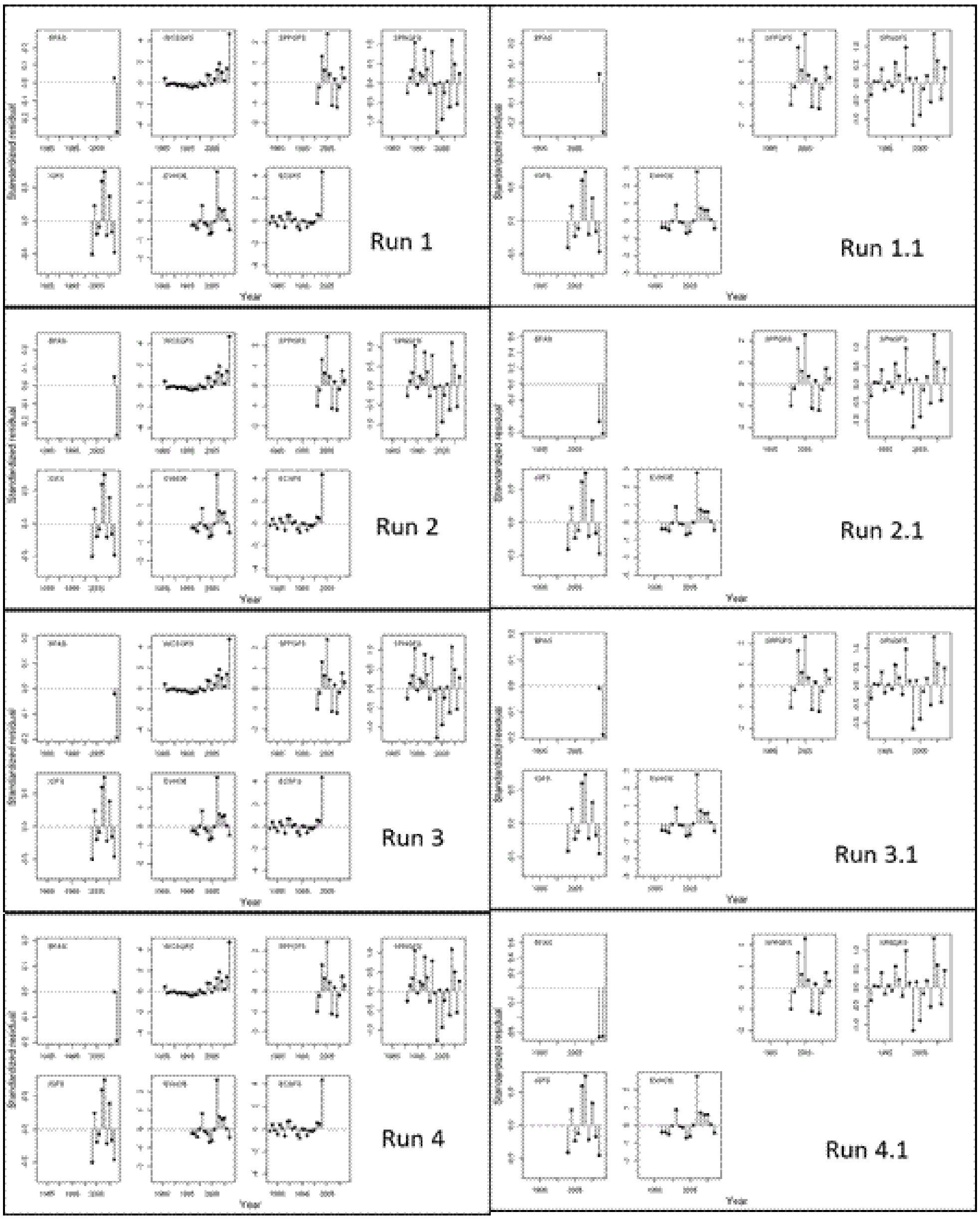

Figure C.6. Boarfish in ICES Subareas 27.6, 7, 8. Residuals around the model fits for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1.

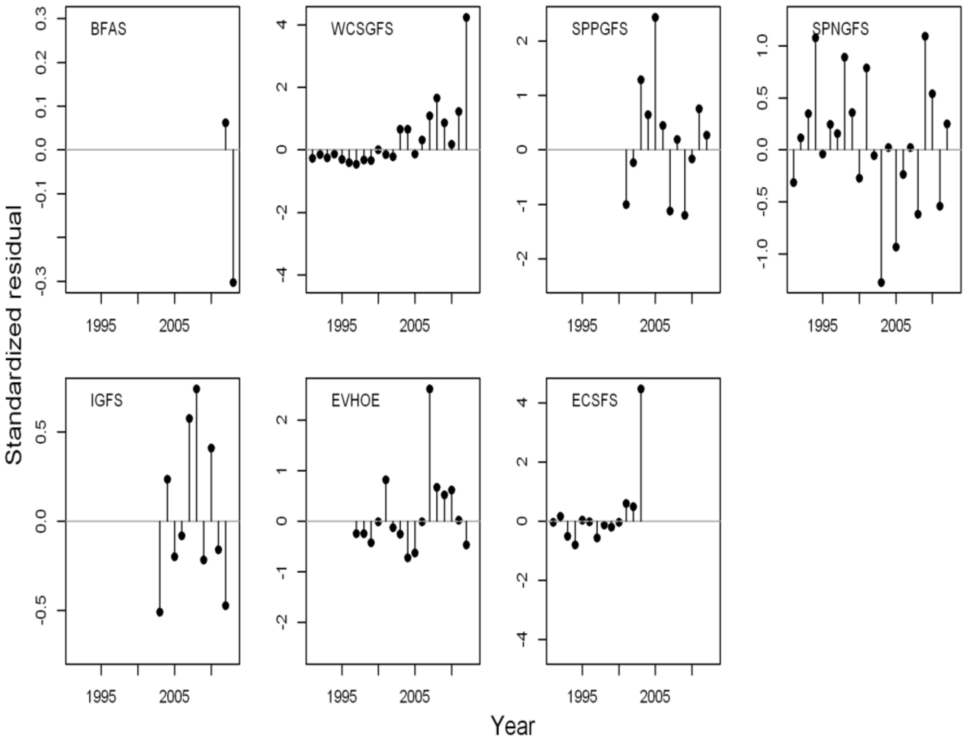

Figure C.7. Boarfish in ICES Subareas 27.6, 7, 8. Residuals around the model fit for run 2.2.

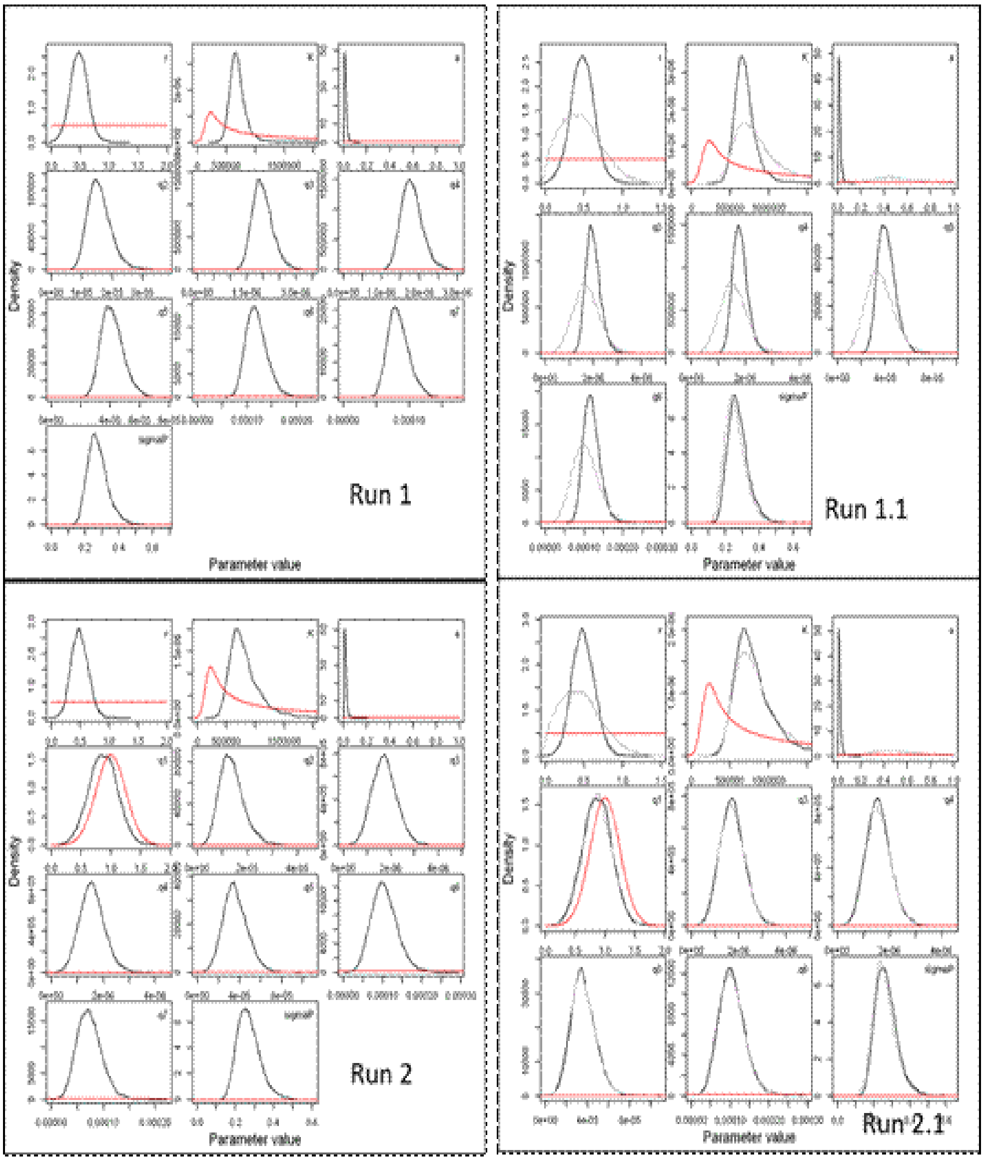

Figure C.8. Boarfish in ICES Subareas 27.6, 7, 8. prior and posterior distributions of the parameters of the biomass dynamic model. Runs 1, 1.1, 2 and 2.1.

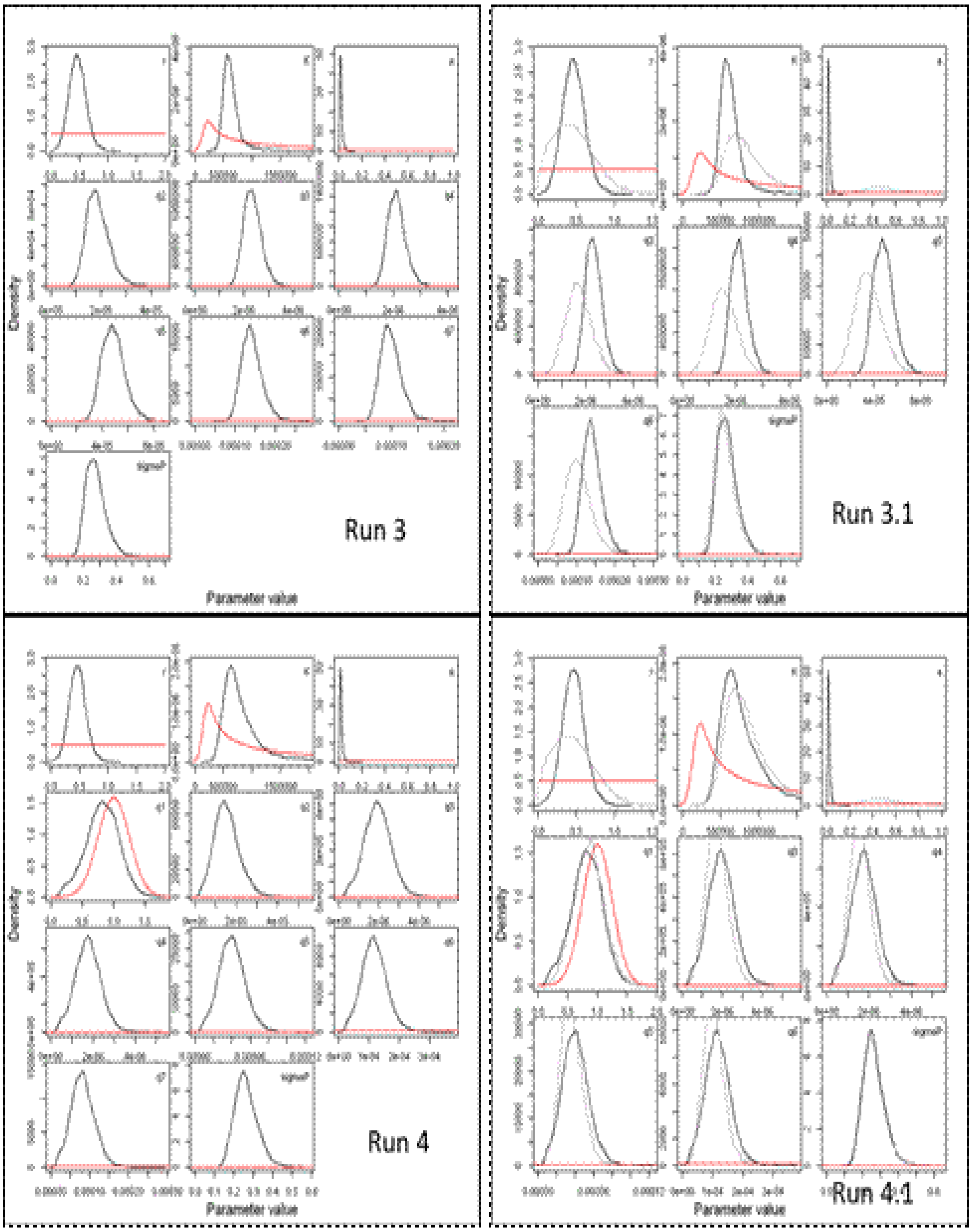

Figure C.9. Boarfish in ICES Subareas 27.6, 7, 8. Prior and posterior distributions of the parameters of the biomass dynamic model. Runs 3, 3.1, 4 and 4.1.

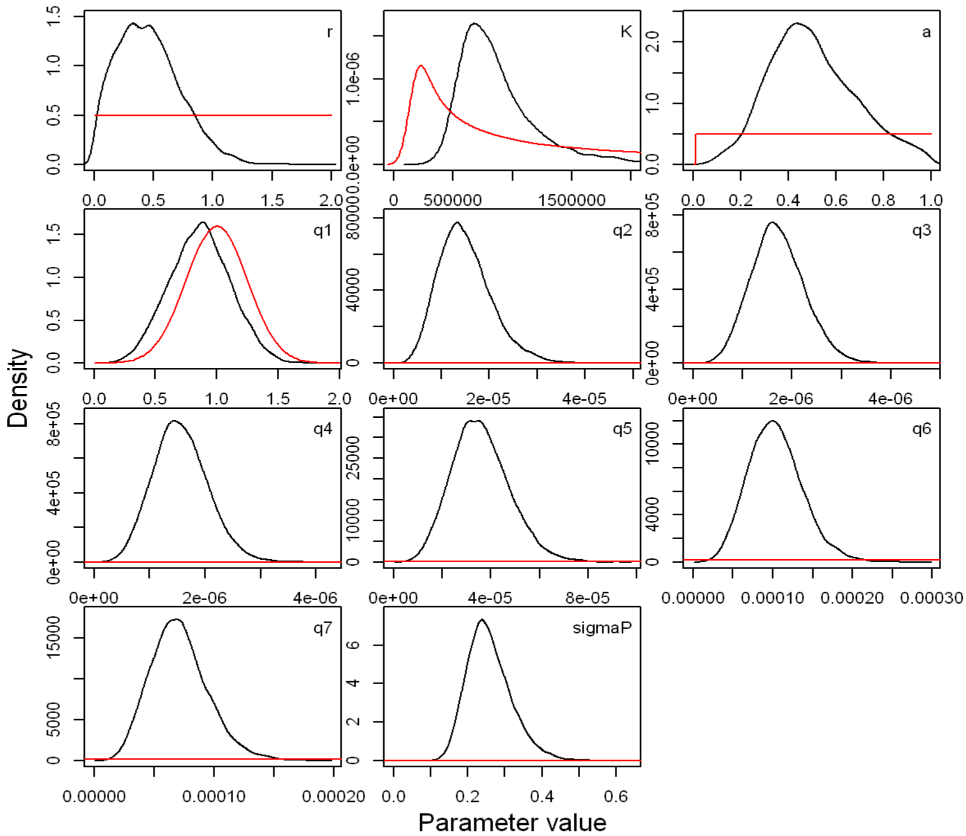

Figure C.10. Boarfish in ICES Subareas 27.6, 7, 8. Prior and posterior distributions of the parameters of the biomass dynamic model. Run 2.2.

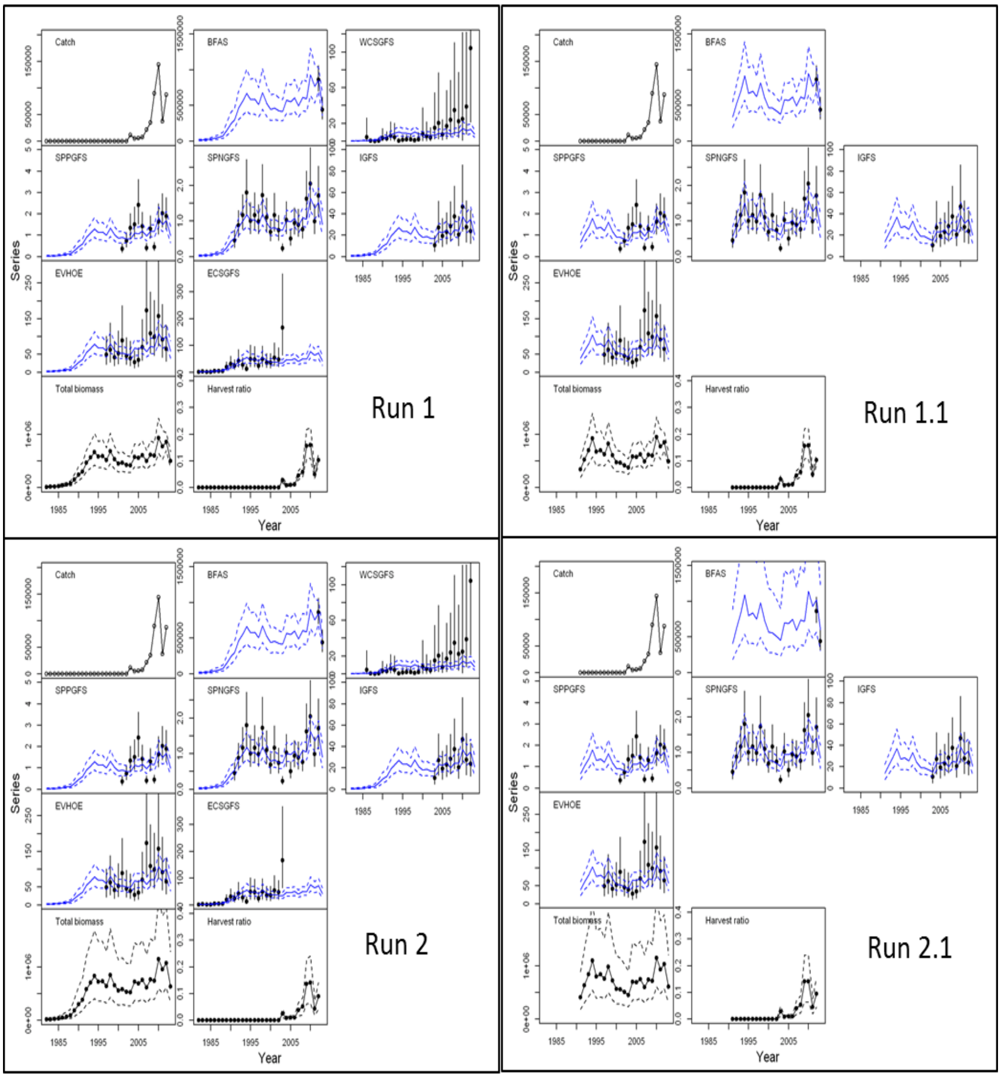

Figure C.11. Boarfish in ICES Subareas 27.6, 7, 8. Trajectories of observed and expected indices for runs 1, 1.1, 2 and 2.1. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

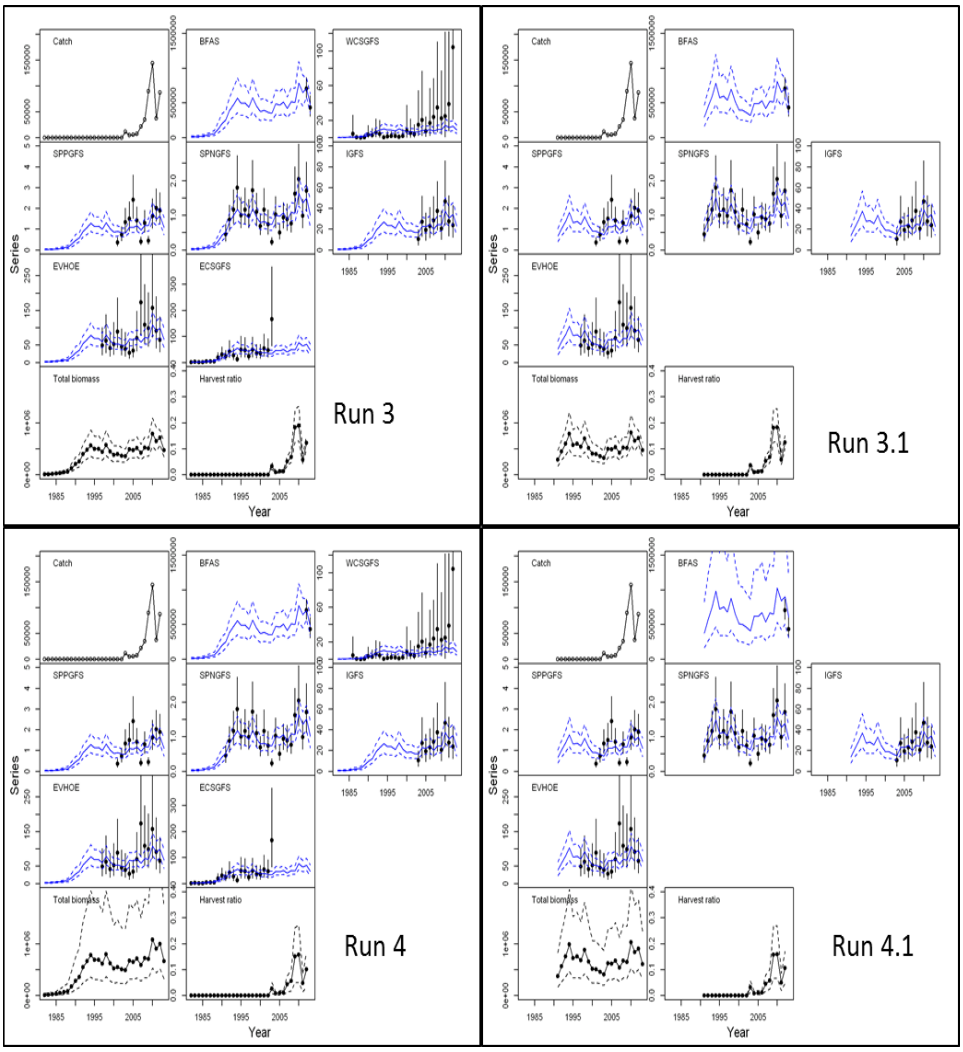

Figure C.12. Boarfish in ICES Subareas 27.6, 7, 8. Trajectories of observed and expected indices for runs 3, 3.1, 4 and 4.1. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

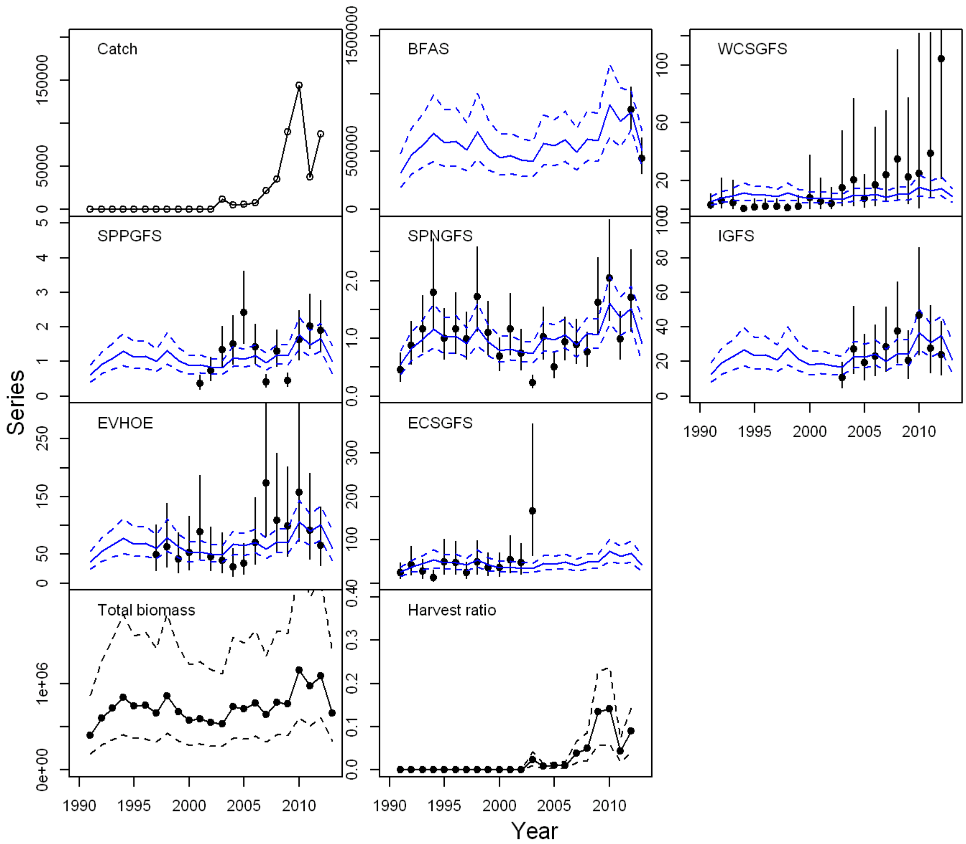

Figure C.13. Boarfish in ICES Subareas 27.6, 7, 8. Trajectories of observed and expected indices for run 2.2. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

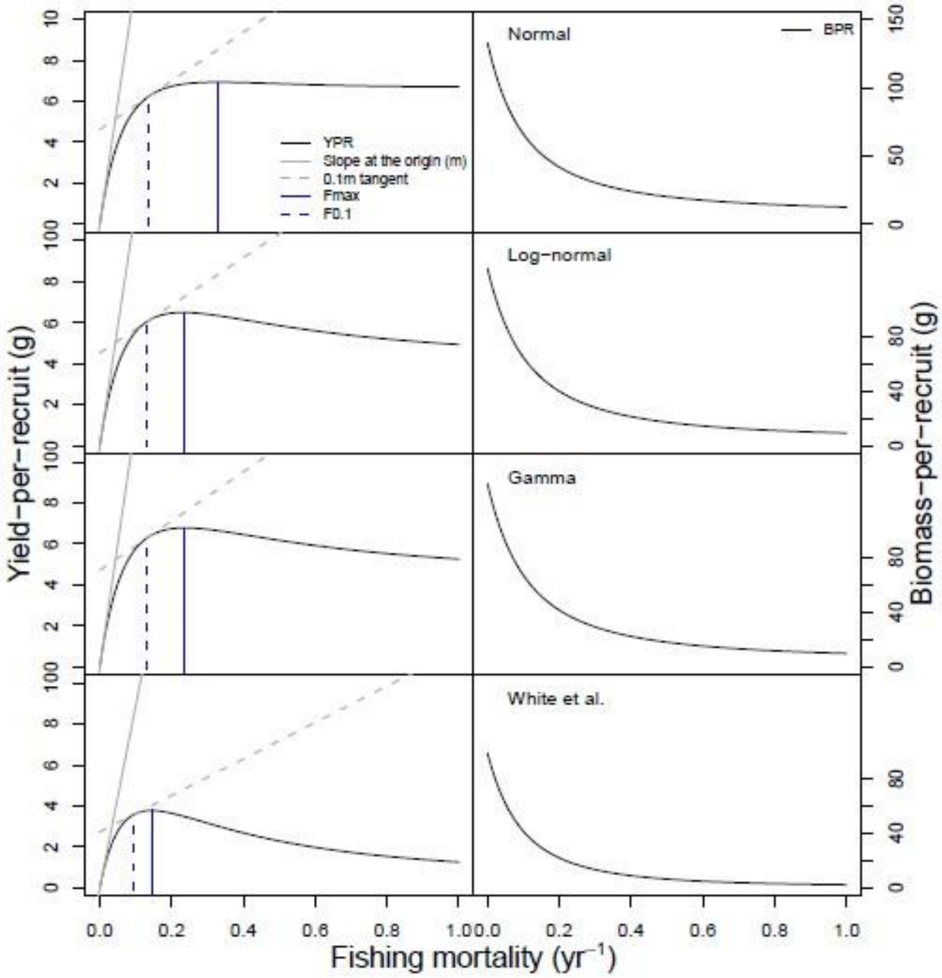

Figure E.1. Boarfish in ICES Subareas 27.6, 7, 8. Results of exploratory yield per recruit analysis. Beverton and Holt model applied to various fits of the VBGF and for comparison with the VBGF parameters provided by White *et al.* 2011.

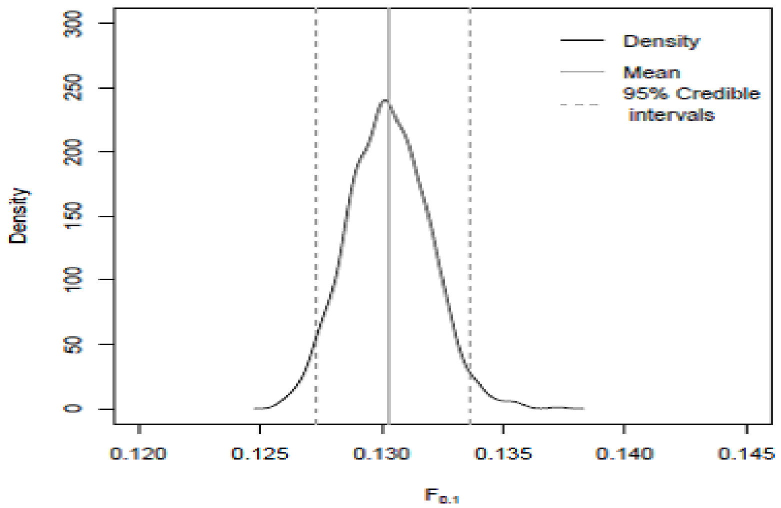

Figure E.2 . Boarfish in ICES Subareas 27.6, 7, 8. Sensitivity of estimation of F0.1.

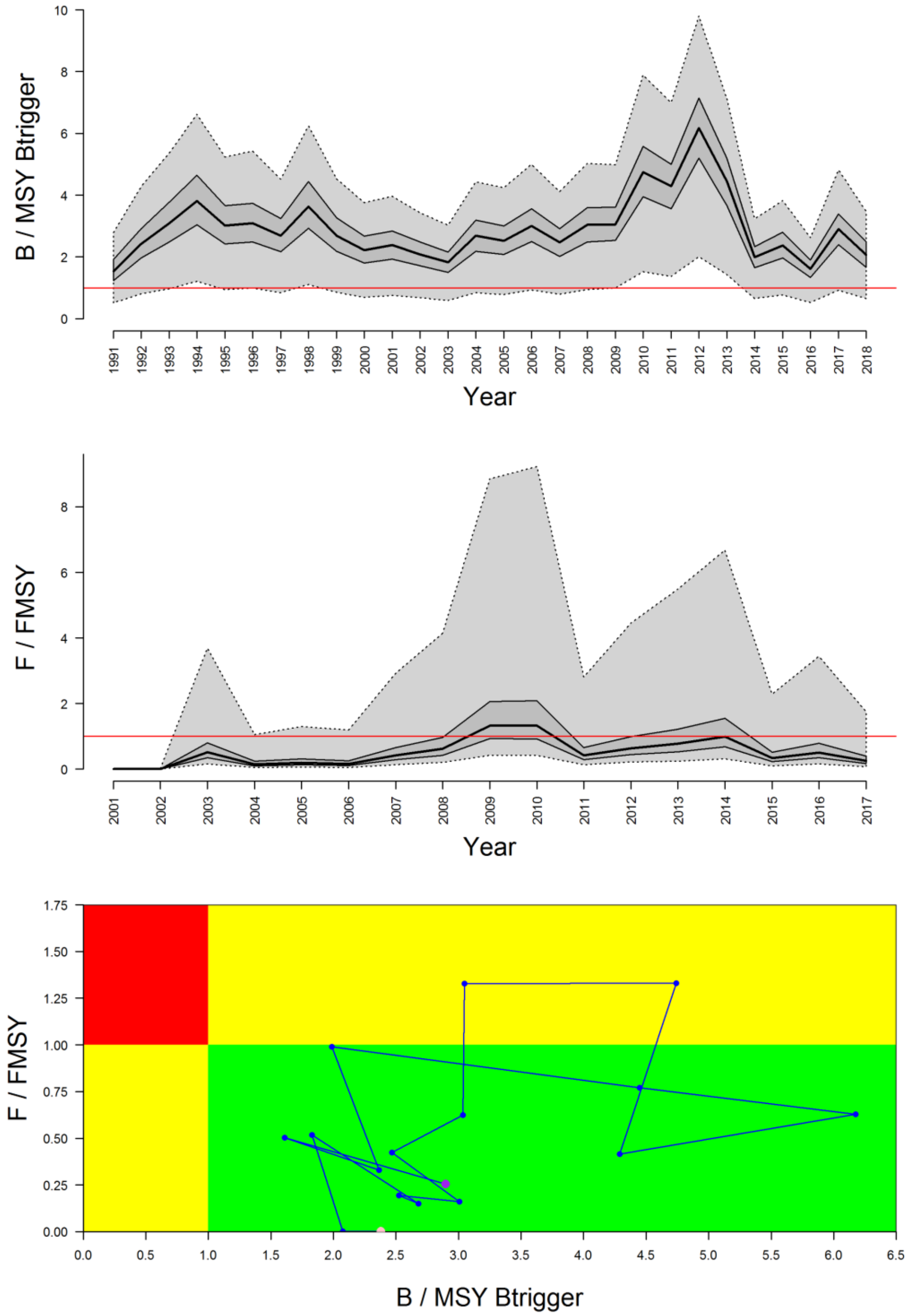

Figure G.1. Boarfish in ICES Subareas 27.6, 7, 8. Ratios 'B / MSYB$_{trigger}$' and 'F / FMSY' through time and corresponding Kobe plot. Confidence intervals (50 and 95%) are given for the first two panels, the third displays median estimates only with the pink point representing the first point of the time series and the purple point the last.