Annex 02E – Stock Annex: Northeast Atlantic Boarfish

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	**Boarfish in Sub areas V, IV, VI, VII, VII**
Working Group:	**WGWIDE 2014**
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A. General

A.1. 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 and Vandermeirsch, 2005). An analysis of IBTS data suggests a continuity of distribution spanning Subareas IV, VI, VII and VIII (Figure A.1.1). Isolated small occurrences appear in the North Sea in some years and an isolated landing in area Vb2 indicates spill-over into these areas (Figure A.1.2). A hiatus in distribution is apparent between Divisions VIIIc and IXa south. Boarfish are considered very rare in northern Portuguese waters but are abundant further south (Cardador and Chaves, 2010). Based on these results, a single stock is considered to exist in Subareas IV, V, VI, VII and VIII. This distribution is broader than the current EC TAC area: VI, VII, and VIII.

An analysis of bottom trawl survey data suggests a continuity of distribution spanning ICES Subareas IV, VI, VII, VIII and IX (Figure A.1.3). Isolated small occurrences appear in the North Sea (ICES Subarea IV) in some years indicating spill-over into this region. A hiatus in distribution was suggested between ICES Divisions VIIIc and IXa as boarfish were considered very rare in northern Portuguese waters but abundant further south (Cardador and 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 ICES Subareas IV, VI, VII, VIII and IXa. This distribution is broader than the current EC TAC area: VI, VII and VIII and for the purposes of assessment in 2014 only data from these areas were utilised. A dedicated study on the stock structure of boarfish within the Northeast Atlantic and Mediterranean Sea commenced in October 2013, the results of which will feed into future assessments.

A.2. Fishery

Previous to the development of the fishery, boarfish was a discarded bycatch in pelagic fisheries for mackerel in Subareas VII and VIII. 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 295 000 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 trawl nets with mesh sizes ranging from of 32 to 54 mm. Preliminary information suggests that only the smallest boarfish escape this gear. To date only RSW trawlers have participated in the fishery. From 2001 to 2006 only Ireland participated in the fishery. In 2007 UK-Scotland also participated, landing less than 1 000 t. In all years the vast majority of catches have come from SubareaVIIj (Figure A.1.2 and Table A.2.2). In 2010, 137 503 t were caught. Ireland continued to be the main participant (88 456 t), with Denmark taking 39 805 t and Scotland, 9 241 t.

A notional TAC was set for this species for the first time in 2011, covering ICES Subareas VI, VII and VIII. 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% ($F_{0.1}$, as an F_{msy} proxy). For 2013, the TAC was set at 82 000 t by the Council of the European Union.

For 2014, ICES advised that, based on F_{MSY} (0.23), catches of boarfish should not be more than 133 957t, or 127 509t when the average discard rate of the previous ten years (6 448t) is taken into account. For 2014 the TAC was set at 127 509t by the Council of the European Union.

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	2031	7779
2012	2148	7829
2013	1702	7799
2014	1392	5736

A.3. 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 (*Pagellus acarne*) and blacktail comber (*Serranus atricauda*) (Clarke *et al*., 1995; Morato *et al*., 1999; Morato *et al*., 2000; Morato *et al*., 2001; Barreiros *et al*., 2002; Morato *et al*., 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 and 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'Sullivan *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*) and Cory's shearwater (*Calonectris diomedea*) (Granadeiro *et al*., 1998; Granadeiro *et al*., 2002). This is surprising given that in the Mediterranean discarded boarfish were rejected by seabirds whereas in the Azores they were actively preyed on (Oro and 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 and Fernandes, 2001). However, the upper depth range of boarfish is within maximum diving depth recorded for auks (50 m) as recorded by Barrett and 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 (Table A.3.1) 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; Granadeiro *et al*., 2002).

B. Data

B.1. 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, 1880-1884; Couch, 1844; Cunningham, 1888). Gatcombe, writing in 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 (Farina *et al.*, 1997; Pinnegar *et al.*, 2002; Blanchard and 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 and Vandermeirsch, 2005).

Based on the above information the external reviewers in 2012 noted the possibility that boarfish was a deep-water 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 *et al.*, 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 (see main text Section 6.6.2). 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 (Figure B.4.3). 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.

B.2. Commercial catch

For 2013 catch number-at-age see main text.

For 2012 catch number-at-age were prepared for Irish, Danish and Scottish landings using the ALK in table B.2.1. This general ALK was constructed based on 814 aged fish from Irish, Danish and Scottish caught samples. There were a number of data quality issues (see main text Section 6.2.2) and unsampled métiers. Allocations were made according to table B.2.2. Only Irish collected samples were deemed reliable enough for length frequency and length weight analyses. In total 68 Irish samples were collected and 8565 fish were measured for length frequency.

For 2011, catch number-at-age were prepared for Irish, Danish and Scottish landings using the ALKs in table B.2.1. There were a number of unsampled metiers and allocations were made appropriately. In total 27 samples were collected (16 by Denmark and 11 by Ireland), 4 066 fish were measured for length frequency and 704 fish were aged for construction of the ALKs (Table B.2.3).

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.2.4). Length-frequencies of commercial catches are available from 2007 onwards (Table B.2.5). Ageing is based on the method that has been validated for ages 0-7 by Hüssy *et al*. (2012; in press). 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 2007-2011 to produce a proxy catch numbers-at-age (Figure B2.1 and Table B.2.6). It can be seen that many older fish are still present in catches, though there appears to be a reduction of older ages since 2007. The modal age in all four years is 6. Other dominant age classes ranged from 4 to 8.

B.3. 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 and Özaydin (1995) 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 VIa, VIIb, VIIh, VIIj and VIIIa 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 dependant 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):

$TL_{age} = L_{inf}*(1-exp(-K*(age-t0)))$

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 uni-modal with a peak at 7 years (corresponding to approx. 12cm). Length classes were continuous up to 18cm after which only one individual fish was present in the 23cm length class. The abundance of females peaked in the 12cm length class, while the highest number of males was observed in the 11cm 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.

B.4. Surveys

B.4.1. IBTS

The following data was used in the 2013 assessment model (see Section C). For 2014 assessment input see main text.

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 2012
- IGFS, Irish Groundfish Survey, (Q4) 2003 to 2012
- WCSGFS, West of Scotland, (Q1 and Q4) 1986 to 2012 (no Q4 survey in 2010)
- SPPGFS, Spanish Porcupine Bank Survey, (Q3) 2001 to 2012
- SPNGFS, Spanish North Coast Survey, (Q3/Q4) 1991 to 2012
- ECSGFS, CEFAS English Celtic Sea Groundfish Survey, (Q4) 1982 to 2003

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. Length frequencies are presented in Table B.4.1 for each survey. The complete area was sampled from 2003-2011.

The shoaling nature of the species results in occasional large hauls. This is evidenced in the 2008 data which appears to indicate a peak in abundance. Therefore, the number of rectangles sampled was compared with the number of rectangles in which boarfish were caught (Figure B.4.1). The occurrence of boarfish increased from 2003 to 2007 despite a decrease in the number of rectangles sampled from 2004 to 2010. From 2007 to

2010 there was a slight decrease in the occurrence of boarfish but this appears to have levelled off in 2011.

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 (Figure A.1) correspond to the main fishing grounds (Figure A.2). Figure B.4.2 shows the signal in abundance, increasing in the 1990s, declining again in the early 2000s, before increasing again. These trends have been reported by (Farina *et al.*, 1997; Pinnegar *et al.*, 2002; Blanchard and 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 VIIj 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 B4.3 and B4.4). 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 (Figure B.4.5). The proportion of each region over which boarfish were distributed per year was also investigated and shows an increasing trend over time (Figure B.4.6). 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 to 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.*, 2004).

B.4.2. Acoustic Survey

The Boarfish Acoustic Survey (BFAS) series was initiated in July 2011 and is now in its fourth 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 *et al.*, 2012a). 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 456 115 t. Estimates of boarfish biomass by category are presented in Table B.4.4 and the spatial distribution of the echotraces attributed to boarfish in each year can be seen in Figure B.4.2.1.

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	"Definitely" echotraces were 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	"Probably" was attributed to smaller echotraces that had not been fished but which had similar characteristics to "definite" boarfish traces.
Mixture	"Mixture" was 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	"Possibly" was 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 *et al*., 2012b; 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 *et al.*, 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 57,020nmi². 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 423 158 t (Table B.4.4).

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 (Fässler *et al.*, 2013; O'Donnell, 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 large change in biomass observed between the surveys cannot be easily explained and is no doubt the result of multiple factors (O'Donnell *et al.*, 2013). Expected interannual variation between successive acoustic estimates is in part responsible. However, factors outside survey effects should also be considered including hydrographic conditions and prey availability. As boarfish continue to feed during spawning the availability of prey will also determine spatial distribution of schools locally and clusters of schools at larger scales. If conditions for spawning are not optimum then the prey availability will drive distribution. As the survey covered the same area using the same survey design and good trawl sampling was achieved it is methodologically a replicate of that performed in 2012. However, factors outside of the survey have no doubt influenced the distribution of the stock both in the large scale (how it was distributed over the greater survey area) and at the smaller scale (in terms of schooling behaviour). The latter being directly related to how available boarfish were to the acoustic recording equipment. As no bottom trawl was available during the survey it was not possible to target the seabed within the acoustic dead zone (ADZ) for presence/absence of boarfish. Unquantified sonar observations and off track investigations indicated that echosounder observations were indeed representative of aggregations present in the wider area. This raises the possibility that boarfish could have also been distributed within the ADZ and out of the range of echosounder and midwater trawl sampling.

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 *et al.*, 2013).

C. Assessment: data and method

Assessments, projections and reference points (Sections C to H) from 2013 are presented here. For 2014 assessment see main text.

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

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

Model Options chosen:

- Run 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 q_i ~ U(-16,0) (for IBTS)
- $1/\sigma_\eta^2$ ~ Gamma(0.001,0.001)

Model Outputs:

Full run estimates:

- *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 10xsum 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 qi ~ 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	$q_{acoustic}$	$I_{acoustic,2012}$ (t)	$I_{acoustic,2013}$ (t)
1	Fixed at 1	Total (863,446)	Total (439,897)
2	Free (strong prior)	Total	Total
3	Fixed at 1	Definitely (708,019)	Definitely (431,571)
4	Free (strong prior)	Definitely	Definitely

$q_{acoustic}$ 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 $q_{acoustic}$ ~ 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 center 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 R_{hat} 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 and C.5).

Diagnostic plots for these runs are provided in Figures C.6 and 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 and 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 and 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.1.2. 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.

D. Short-Term Projection

A short term forecast was performed by projecting run 2.2 forward by one year. However, as there is no recruitment estimate it is not possible to construct a traditional style catch forecast for management purposes. Instead, short term projections over a range of fishing mortality and catch options are provided on a risk based approach. An intermediate year catch constraint was applied (2013 TAC, 82 000 t + average discards of 6 448 t). The population is then projected forward within the assessment under a range of management objectives that included the yield at:

- F_{MSY}=0.23 based on *r*/2 from run 2.2
- $F_{0.1}$=0.13 based on yield-per-recruit analysis
- F_{lim}=0.367 based on the F associated with a long-term biomass of *K*/5 (0.2 carrying capacity used for B_{lim})
- F_{pa}=exp(-1.645*CV(TSB_{2013}))*F_{lim} = exp(-1.645*0.436)* 0.367 = 0.179
- C_{2014}=C_{2013}
- C_{2014}=0 (zero catch option)
- C_{2014}=1.2*C_{2013} (20% increase in catch)
- C_{2014}=0.8*C_{2013} (20% decrease in catch)

A forward projection on the risk of the stock falling below B_{msy} ($B_{trigger}$), B_{lim} and fishing mortality exceeding F_{lim} are estimated. Fishing mortality for the fixed catch projections is calculated as -ln(1-C_{2014}/TSB_{2014}).

E. Medium-Term Projections

A yield per recruit analysis was conducted in 2011 (Minto *et al.* WD 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. (Figure E.1 and E.2). The estimation of $F_{0.1}$ was considered to be quite good.

F. Long-Term Projections

No long term projections were carried out.

G. Biological Reference Points

The following reference points were applicable to the 2013 assessment. Some have since been updated in 2014. See main text section 6.9 for more details.

ICES (1997) considered that precautionary F targets (F_{pa}) should be consistent with F<M for prey species. This approach would ensure that fishing does not out-compete natural predators for their prey. This would suggest that a good candidate precautionary F_{pa} can be defined as exp(-1.645*CV(TSB_{2013}))*F_{lim}=0.179. B_{lim} may be defined from the stock size estimates available from the stock assessment. It is proposed that B_{lim} be set at 0.2* *K*, (0.2 * 911 209 t = 182 241 t), based on the results of Run 2.2.

Yield per recruit analysis, following the method of Beverton and Holt (1957) found $F_{0.1}$ to be robustly estimated at 0.13 (ICES WGWIDE, 2011; Minto *et al.*, WD 2011).

An estimate of F_{msy} is available from the stock assessment as 0.23, which is in close agreement with the lower range of F_{max} from yield per recruit analyses (0.23 to 0.33; Minto *et al.*, WD 2011).

An estimate of B_{msy} is available from stock assessment Run 2.2 (455 605 t). This is proposed as a conservative basis for MSY $B_{trigger}$.

H. Other Issues

H.1 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.

1) 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.

2) A closed area shall be implemented in VIIg 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.

3) 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.

4) Vessels participating in the fishery for boarfish shall only land in designated ports.

5) Participating vessels already facilitate scientific studies, and observer coverage, and this cooperation shall be further developed.

***Indicator Definitions**

Exploitation Indicator E is defined as follows:

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 follows:

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, q1 =	ASB * 1-exp-F0.1_ * G * 0.62 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 12th 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.

H.2 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 timeframe. 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 backlog 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 biomass 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 Subareas V, VI, VII, VIII. Landings by year (t), 2001–2012. (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	Ireland	Denmark	Scotland	Total landings	Estimated Discards	Total Catch inc discards
2001	120	0	0	120	NA	120
2002	91	0	0	91	NA	91
2003	458	0	0	458	10929	11387
2004	675	0	0	675	4476	5151
2005	165	0	0	165	5795	5959
2006	2772	0	0	2772	4365	7137
2007	17615	0	772	18387	3189	21576
2008	21585	3098	0.45	24683	10068	34751
2009	68629	15059	0	83688	6682	90370
2010	88457	39805	9241	137503	6544	144047
2011	20685	7797	2813	31295	5802	37096
2012	55949	19888	4884	80720	6634	87355

Table A.2.2 Boarfish in ICES Subareas V, VI, VII, VIII. Landings by year (t), 2001–2012 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.

	Denmark	Ireland	Scotland	Total
2001	0	120	0	120
2002	0	91	0	91
2003	0	458	0	458
VI		65		65
VII		393		393
2004	0	675	0	675
VI		292		292
VII		345		345
VIII		38		38
2005	0	165	0	165
VI		10		10
VII		117		117
VIII		38		38
2006	0	2772	0	2772
VI		21		21
VII		2750		2750
VIII		1		1
2007	0	17615	772	18386
V		6		6
VI		93		93
VII		17510	772	18282
VIII		5		5
2008	3098	21584	0	24683
VI		28	0	28
VII		21557		21557
2009	15059	68629	0	83688
VI		45		45
VII		68584		68584
2010	39805	88457	9241	137503
VI		1355	10	1365
VII	39805	87101	9231	136138
2011	7797	20685	2813	31295
VI		26		26
VII	7779	20659	2813	31251
VIII	18			
2012	19888	55949	4884	80720
VI		125		125
VII	18283	55731	4884	78898
VIII	1604	93		1697
Total	**85647**	**277199**	**17710**	**380556**

Table A.3.1 Boarfish in ICES Subareas VI, VII, VIII. IBTS length-frequency data.

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	8	1																		
Q4	8.5																			
VIIh	9																			
	9.5	1	5																	
	10		7	3																
	10.5		6	2		2														
	11		1	3	1	4	2	2												
	11.5				2	9	2	2												
	12					5	4	4	2											
	12.5					2	3	2	2	1	3									
	13					3	3		3	2					1			2		1
	13.5						1	1	1	1	2	3	1			1	1	2		1
	14										1	2	2	1	1	1				1
	14.5									1					1			2		1
	15															1		2		1

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	9		1																	
Q4	9.5		1																	
VIIj	10		1		2															
	10.5		1				1													
	11			2	2	2	1	1												
	11.5			1	4	15	8	4	2											
	12				1	12	10	8	7	5		1								
	12.5				1	8	12	6	7	6	4	2								
	13					1	4	8	5	6	5	8	2	2	1	1		1	1	
	13.5						2	1	3	5	2	5	5	5	2	1	4	2	1	6
	14								1	2	1	4	6	2	4	3	1	2	2	12
	14.5									1		2	3	5		5	2	2		14
	15										1	1	1	1		5	4	2	1	19
	15.5															2	1	2	1	19
	16																			8
	16.5																			2
	17																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIh	8	1																		
	9	1	5	1																
	10		18	10	5	4														
	11		1	6	12	20	6	5												
	12				1	13	20	13	6	3	4									
	13					4	9	5	6	8	5	3	2	1	5	1	1	4		3
	14								1	1	3	4	4	2	3	2		4	3	9
	15												1	1	1	4	2	3	2	9
	16																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIJ	8		1																	
	9		1																	
	10		2	2	2		1													
	11			3	6	21	14	5	2											
	12				2	25	25	18	16	12	4	3								
	13					2	9	10	11	12	10	13	7	9	3	3	4	3	2	6
	14								1	5	3	8	9	7	5	9	6	6	2	28
	15										1	1	1	2	1	7	5	4	2	38
	16													1	1					11
	17																			1

Table B.2.1. Boarfish age length key produced from 2011 commercial samples. Figures highlighted in grey are estimated.

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	8	1																		
Q4	8.5																			
VIIh	9																			
	9.5	1	5																	
	10		7	3																
	10.5		6	2		2														
	11		1	3	1	4	2	2												
	11.5				2	9	2	2												
	12					5	4	4	2											
	12.5					2	3	2	2	1	3									
	13					3	3		3	2					1			2		1
	13.5						1	1	1	1	2	3	1			1	1	2		1
	14										1	2	2	1	1	1				1
	14.5									1					1			2		1
	15															1		2		1

		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
IRL	9		1																	
Q4	9.5		1																	
VIIj	10		1		2															
	10.5		1				1													
	11			2	2	2	1	1												
	11.5			1	4	15	8	4	2											
	12				1	12	10	8	7	5		1								
	12.5				1	8	12	6	7	6	4	2								
	13					1	4	8	5	6	5	8	2	2	1	1		1	1	
	13.5						2	1	3	5	2	5	5	5	2	1	4	2	1	6
	14								1	2	1	4	6	2	4	3	1	2	2	12
	14.5									1		2	3	5		5	2	2		14
	15										1	1	1	1		5	4	2	1	19
	15.5															2	1	2	1	19
	16																			8
	16.5																			2
	17																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIh	8	1																		
	9	1	5	1																
	10		18	10	5	4														
	11		1	6	12	20	6	5												
	12				1	13	20	13	6	3	4									
	13					4	9	5	6	8	5	3	2	1	5	1	1	4		3
	14								1	1	3	4	4	2	3	2		4	3	9
	15												1	1	1	4	2	3	2	9
	16																			1

IRL & DNK		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
Q4	7	1																		
VIIJ	8		1																	
	9		1																	
	10		2	2	2		1													
	11			3	6	21	14	5	2											
	12				2	25	25	18	16	12	4	3								
	13					2	9	10	11	12	10	13	7	9	3	3	4	3	2	6
	14								1	5	3	8	9	7	5	9	6	6	2	28
	15										1	1	1	2	1	7	5	4	2	38
	16													1	1					11
	17																			1

Table B.2.2. Age length key allocations made to unsampled metiers in 2011.

Country	Area	Quarter	Landed (t)	ALK
IRL	VIIb	1	39	IRL_VIIj_Q4
IRL	VIIj	1	38	IRL_VIIj_Q4
IRL	VIIb	2	1	IRL_VIIj_Q4
IRL	VIIh	3	820	IRL_VIIh_Q4
IRL	VIIj	3	1092	IRL_VIIj_Q4
IRL	VIa	4	26	IRL_VIIj_Q4
IRL	VIIb	4	235	IRL_VIIj_Q4
IRL	VIIc	4	9	IRL_VIIj_Q4
IRL	VIIg	4	811	IRL_VIIj_Q4
IRL	VIIh	4	7720	IRL_VIIh_Q4
IRL	VIIj	4	9894	IRL_VIIj_Q4
DNK	VIIh	1	32	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIIa	1	18	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIj	1	1	Combined IRL&DNK (1.0cm)_VIIj_Q4
DNK	VIIh	4	4123	Combined IRL&DNK (1.0cm)_VIIh_Q4
DNK	VIIj	4	3623	Combined IRL&DNK (1.0cm)_VIIj_Q4
SCT	VIIh	3	434	IRL_VIIh_Q4
SCT	VIIh	4	2379	IRL_VIIh_Q4

Table B.2.3. Boarfish in ICES Subareas V, VI, VII, VIII. Sampling intensity by country of commercial catches.

			DK				IRL				SCT			
Year	Q	Area	Landings	Samples	Measured	Allocated	Landings	Samples	Measured	Allocated	Landings	Samples	Measured	Allocated
2007	1	VIa					12	0	0	VIIj_Q2 and VIa_Q4				
	1	VIIIa					5	0	0	VIIj_Q2 and VIa_Q4				
	1	VIIj					5253	0	0	VIIj_Q2 and VIa_Q4	772	0	0	Irish 2007 combined
	2	VIIg					120	0	0	VIIj_Q2 and VIa_Q4				
	2	VIIj					4130	2	197	VIIj_Q2 and VIa_Q4				
	3	VIIb					0	0	0	VIIj_Q2 and VIa_Q4				
	4	Vb2					6	0	0	VIIj_Q2 and VIa_Q4				
	4	VIa					82	1	20	VIIj_Q2 and VIa_Q4				
	4	VIIb					1259	0	0	VIIj_Q2 and VIa_Q4				
	4	VIIj					6748	0	0	VIIj_Q2 and VIa_Q4				
	Total		0	0	0		17615	3	217		772	0	0	
2008	1	VIa					5	0	0	VIIj_Q4				
	1	VIIg					184	0	0	VIIj_Q4				
	1	VIIj					5041	0	0	VIIj_Q4				
	2	VIIj					46	0	0	VIIj_Q4				
	3	VIIj					4067	0	0	VIIj_Q4				
	4	VIa					23	0	0	VIIj_Q4	0.5	0	0	Irish 2008 combined
	4	VIIb					3	0	0	VIIj_Q4				
	4	VIIj					12216	1	152	VIIj_Q4				
	Total		3098	0	0		21584	1	152		0.5	0	0	
2009	1	VIIb					55	0	0	VIIj_Q3				
	1	VIIg					2979	0	0	VIIj_Q3				
	1	VIIh					1971	0	0	VIIj_Q3				
	1	VIIj					10901	2	359	VIIj_Q3				
	2	VIIg					1933	0	0	VIIj_Q3				
	2	VIIh					3169	0	0	VIIj_Q3				
	2	VIIj					2727	0	0	VIIj_Q3				
	3	VIIh					10378	0	0	VIIj_Q3				
	3	VIIj					11423	1	175					
	4	VIa					45	0	0	VIIj_Q4				
	4	VIIb					18	0	0	VIIj_Q4				
	4	VIIh					2707	0	0	VIIj_Q4				
	4	VIIj					20321	6	941					
	Total		15059	0	0		68629	9	1475		0	0	0	
2010	1	VIa									10	0	0	Irish 2010 VIIb_Q1
	1	VIIb					1069	1	102					
	1	VIIg	577	1	77		2392	0	0	VIIj_Q1				
	1	VIIh	1079	0	0	VIIg+VIIj_Q1	326	1	94					
	1	VIIj	32422	2	193		34466	12	1447		2504	0	0	Irish 2010 VIIj_Q1
	2	VIIh					102	0	0	VIIh_Q3				
	2	VIIj	344	0	0	VIIj_Q1								
	3	VIIg					338	0	0	VIIh_Q3				
	3	VIIh	377	0	0	VIIh_Q4	5540	8	1316		548	0	0	Irish 2010 VIIh_Q3
	3	VIIj	2660	0	0	VIIj_Q4	11531	31	3275		2171	0	0	Irish 2010 VIIj_Q3
	4	VIa					1355	1	117					
	4	VIIb					1189	0	0	VIIj_Q4				
	4	VIIc					35	0	0	VIIj_Q4	4	0	0	Irish 2010 VIIj_Q4
	4	VIIe	2	0	0	VIIh_Q4								
	4	VIIg	94	0	0	VIIh+VIIj_Q4	920	0	0	VIIh_Q4				
	4	VIIh	9	3	384		2484	6	715		1165	0	0	Irish 2010 VIIh_Q4
	4	VIIj	2241	2	217		26710	27	2738		2840	0	0	Irish 2010 VIIj_Q4
	Total		39805	8	871		88457	87	9804		9241	0	0	
2011	1	VIIb					39	0	0	VIIj_Q4				
	1	VIIh	32	0	0	VIIh_Q4								
	1	VIIIa	18	0	0	VIIh_Q4								
	1	VIIj	1	0	0	VIIj_Q4	38	0	0	VIIj_Q4				
	2	VIIb					1	0	0	VIIj_Q4				
	3	VIIh					820	0	0	VIIh_Q4	434	0	0	Irish 2011 VIIh_Q4
	3	VIIj					1092	0	0	VIIj_Q4				
	4	VIa					26	0	0	VIIj_Q4				
	4	VIIb					235	0	0	VIIj_Q4				
	4	VIIc					9	0	0	VIIj_Q4				
	4	VIIg					811	0	0	VIIj_Q4				
	4	VIIh	4123	11	1347		7720	3	319		2379	0	0	Irish 2011 VIIh_Q4
	4	VIIj	3623	5	611		9894	8	1789					
	Total		7797	16	1958		20685	11	2108		2813	0	0	
2012	1	VIIb					4365	3	339					
	1	VIIg					616	0	0	IRL_Q3_VIIh				
	1	VIIh	3789	1	150	IRL_Q3_VIIh	1005	0	0	IRL_Q3_VIIh				
	1	VIIj	11403	3	102	IRL_Q1_VIIj	27812	42	4987					
	1	VIIIa	1330	2	214	IRL_Q3_VIIh								
	2	VIIh	208	0	0	IRL_Q3_VIIh								
	3	VIIb					49	0	0	IRL_Q1_VIIb				
	3	VIIh					3176	5	682		1537	0	0	IRL_Q3_VIIh
	3	VIIj					834	2	341					
	4	VIa					125	1	96					
	4	VIIb	80	0	0	IRL_Q1_VIIb	87	0	0	IRL_Q1_VIIb	838	0	0	IRL_Q1_VIIb
	4	VIIc					108	0	0	IRL_Q1_VIIb	907	0	0	IRL_Q1_VIIb
	4	VIIh	1840	4	445	IRL_Q4_VIIh	6398	7	945		1602	0	0	IRL_Q4_VIIh
	4	VIIIa	274	0	0	IRL_Q4_VIIj	93	0	0	IRL_Q4_VIIh				
	4	VIIj	963	2	180	IRL_Q4_VIIj	11281	8	1175					
Total			19888	12	1091		55949	68	8565		4884	0	0	

Table B.2.4. Boarfish in ICES Subareas V, VI, VII, VIII. Age length key produced from combined commercial and survey samples. Shaded portion indicates commercial fishery size and age range.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	28	29
2.5	3																												
3	10																												
3.5	2																												
4	1																												
5		2																											
5.5		7																											
6		5																											
6.5		6	2																										
7		5	3																										
7.5		4	3																										
8			5	1																									
8.5			17	6																									
9		1	7	9	1																								
9.5			3	11	6																								
10			1	6	17	7	1																						
10.5			1	1	14	10	1																						
11					13	15	7	2																					
11.5				2	2	8	7	4	1																				
12						3	14	3	5																				
12.5					1	2	5	8		4	3	1																	
13							3	3	4	4	2	1	1	1			1												
13.5								3	3	2	3	1	1	2		1	1			1	1								1
14										4	3	1	3		1		1							1	1				
14.5								1		2	2		2	2	3				2		1	2							
15											1				1	1		1	1		1	1	1		1			1	
15.5											1	1	3		1		1			1		1			1		1	1	
16																				1			1	1					
16.5																1			1		1			1		2			
17																		1	1			2	3		2				
17.5																							1						
18																											1		
23																													

Table B.2.5. Boarfish in ICES Subareas V, VI, VII, VIII. Length-frequency distributions of the international catches (raised numbers in '000s) for the years 2007-2012.

TL (cm)	2007	2008	2009	2010	2011	2012	Total
6	0	0	0	156	0	0	156
6.5	0	0	0	439	0	0	439
7	0	0	0	1090	522	56	1667
7.5	0	0	1354	1574	0	0	2928
8	0	0	677	375	1345	185	2581
8.5	0	0	0	1082	0	555	1637
9	0	0	677	5382	851	555	7464
9.5	0	7473	17367	7883	7012	641	40375
10	9609	11209	54130	29410	33243	2791	140392
10.5	0	52308	174796	130889	15848	6132	379974
11	84555	63517	343283	361774	70615	24571	948316
11.5	0	59781	321637	655875	93487	81928	1212708
12	44199	119561	297737	739025	189434	264888	1654845
12.5	0	70990	207739	564347	114904	398772	1356751
13	82633	52308	147965	353484	133539	419060	1188989
13.5	0	29890	149314	246146	51235	307533	784119
14	117224	22418	105782	224611	50857	176710	697602
14.5	0	14945	71273	127711	25309	89726	328964
15	65338	33627	47816	125463	25569	52791	350603
15.5	0	11209	13082	81386	5473	25065	136215
16	13452	11209	19397	24256	4181	13149	85644
16.5	0	3736	4061	6209	2280	2738	19024
17	0	3736	677	1913	456	827	7609
17.5	0	0	0	0	0	0	0
18	0	0	0	283	0	0	283

Table B.2.6. Boarfish in ICES Subareas V, VI, VII, VIII. Proxy catch numbers-at-age of the international catches (raised numbers in '000s) for the years 2007-2012.

	2007	2008	2009	2010	2011	2012
1	0	0	1575	2415	0	28
2	352	5488	15043	11229	2894	893
3	2114	21140	65744	72709	41913	5467
4	40851	105575	338931	294382	28148	41278
5	48915	141300	475619	567689	30116	110272
6	62713	195339	543707	878363	175696	146582
7	26132	104031	307333	522703	143967	492078
8	29766	66570	172783	293719	107126	365840
9	56075	53159	155477	276672	77861	271916
10	44875	46893	130148	232122	60022	173486
11	14019	15289	42521	78588	46079	69396
12	32359	21178	61350	114600	40468	40968
13	4848	11854	39609	59932	24352	58888
14	16837	13570	31569	59060	19724	30277
15+	109481	112947	196967	349320	157707	217260

Table B.3.1 Parameter estimates of the von Bertalanffy growth equation

	Estimate	Std. error	t value	Pr(>|t|)
Linf	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.3.2. Boarfish in area VI, VII and VIII. IBTS length-frequency data converted to age-structured index by application of the common ALK.

All	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1997	9186	11460	5356	4603	4209	7331	6050	4331	4970	4375	1498	2491	1741	1248	635	1242	161	676	635	3814
1998	17475	19641	6886	6423	5693	7515	5791	3814	4860	4439	1481	2883	1654	1644	685	1240	236	917	685	4965
1999	11838	33029	20031	8826	3580	3421	2837	1990	2911	2552	804	1716	1045	1010	320	705	80	539	320	2435
2000	19340	29071	12974	18627	16220	19669	14950	10117	11553	9928	3345	5427	3955	2717	1310	2709	265	1470	1310	7757
2001	20344	44451	20694	25753	22184	16593	9665	4839	5137	4484	1492	2471	1545	1362	643	1109	175	824	643	4482
2002	10040	33131	18597	13158	9120	9171	6846	4380	6006	5313	1699	3476	2053	2046	696	1430	202	1115	696	5313
2003	840	4714	8356	20850	19443	18478	13092	7863	10801	10051	3279	7063	3662	4270	1598	2792	629	2439	1598	12890
2004	5958	5660	2092	2537	3567	8255	7560	5288	8479	8618	2871	6954	2968	4378	1924	2576	866	2794	1924	16191
2005	4201	4323	2012	2784	3836	9869	9393	6931	10296	9875	3269	7332	3684	4419	1814	2913	759	2642	1814	14728
2006	44120	35631	8054	7238	6703	8802	9417	6528	14774	15648	4994	14441	5398	9659	3847	4781	1967	6478	3847	37015
2007	24531	128029	67188	19124	7326	8707	7376	4824	8405	8454	2739	7014	2967	4520	1748	2495	799	2784	1748	15325
2008	43985	262478	172674	148047	91323	53729	31280	15702	23250	22959	7433	17778	7213	11602	5022	6177	2310	7992	5022	45589
2009	18107	42788	14748	10829	12257	14366	9760	5252	7847	7656	2476	5816	2443	3766	1259	2049	642	2128	1259	11324
2010	58552	98227	37475	25665	30828	52503	37174	21833	27440	24593	8035	15093	8215	8983	3253	6110	1257	4997	3253	25820
2011	8615	17617	17110	34003	34910	52378	39952	26259	31789	27728	9181	16113	10503	8764	3850	7350	1012	5048	3850	26631
2012	32050	40410	12771	13406	14205	27201	28554	21680	36693	35756	11588	28599	13608	17833	7714	10766	2944	11650	7714	64807
EVHOE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
1997	1876	6003	3741	3911	3938	7065	5867	4218	4832	4259	1461	2428	1699	1214	623	1215	159	659	623	3737
1998	12977	15997	6248	6247	5591	7435	5732	3777	4806	4386	1463	2843	1635	1619	676	1224	232	904	676	4888
1999	7576	31223	19915	8732	3499	3308	2715	1905	2720	2357	743	1540	975	893	285	647	62	474	285	2102
2000	17676	27730	12586	17986	15525	18740	14297	9737	11041	9490	3208	5160	3797	2556	1266	2604	253	1384	1266	7385
2001	14389	41313	20357	25467	21921	16211	9247	4525	4543	3951	1332	2057	1322	1098	578	959	153	684	578	3884
2002	6719	31728	18455	12784	8389	7115	4767	2851	3429	3018	994	1806	1123	1009	421	796	117	573	421	2964
2003	509	3993	7348	18371	17276	16113	10798	6270	7620	6852	2267	4294	2501	2456	1009	1838	326	1387	1009	7340
2004	1265	1976	1261	1722	2227	4124	3228	2061	2871	3058	1066	2426	939	1509	901	917	382	1142	901	7311
2005	2102	2603	1497	2098	3015	7160	5992	4177	5301	4873	1642	3144	1796	1776	833	1368	285	1065	833	6107
2006	35834	26593	4803	2199	1386	1489	1332	947	1521	1484	485	1170	557	725	311	445	125	464	311	2596
2007	16818	122140	65369	16986	4919	4316	2967	1715	2452	2392	788	1802	820	1124	484	678	204	715	484	4049
2008	41611	258758	168378	134061	77106	37738	18750	8277	9132	8183	2660	4868	2458	2992	1226	1876	492	1919	1226	10417
2009	13338	36829	12194	5626	5982	7788	5443	3054	4443	4230	1364	3079	1382	1965	618	1114	309	1064	618	5485
2010	33601	83903	35048	21678	23503	34210	23037	12643	16303	14519	4647	9008	4716	5551	1689	3457	690	2957	1689	14298
2011	2212	12471	14982	28729	26114	31844	23915	15535	19473	16964	5542	10176	6534	5663	2262	4513	597	3197	2262	16235
2012	20089	34348	11535	11098	10795	14979	13308	9004	15662	14714	4598	11467	5540	7325	2325	4142	920	4164	2325	20439
IGFS+WCSGFS+EVHOE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
2003	636	4552	8306	20803	19406	18414	13013	7804	10668	9916	3237	6942	3612	4190	1573	2752	617	2393	1573	12654
2004	1685	3414	1912	2444	3481	8017	7255	5037	8031	8189	2735	6610	2796	4164	1860	2446	838	2683	1860	15644
2005	2930	3604	1895	2694	3773	9738	9200	6777	9949	9514	3154	7004	3553	4203	1731	2801	721	2505	1731	13978
2006	36687	28176	6830	7100	6633	8714	9277	6421	14479	15337	4898	14144	5288	9457	3779	4686	1933	6356	3779	36365
2007	17873	124020	66810	18929	7205	8648	7322	4790	8309	8353	2708	6917	2932	4453	1729	2464	788	2746	1729	15126
2008	42240	260577	172031	147113	90691	53328	31023	15587	22918	22641	7344	17496	7113	11395	4967	6101	2285	7861	4967	44972
2009	13607	37705	13658	10616	12063	14060	9426	5030	7283	7072	2296	5275	2243	3396	1141	1878	582	1909	1141	10185
2010	33976	84649	35967	24858	30441	52245	36921	21671	26982	23992	7828	14456	8055	8546	3060	5910	1145	4712	3060	24053
2011	2884	13954	16666	33742	34724	52174	39716	26089	31387	27290	9039	15699	10356	8486	3752	7213	958	4882	3752	25707
2012	20395	35049	12386	13340	14140	26984	28191	21406	35924	34955	11342	27840	13323	17314	7548	10525	2861	11338	7548	63197
SPNGFS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20+**
1997	7306	5446	1609	681	249	203	121	67	69	56	18	22	18	11	4	11	0	6	4	23
1998	4493	3640	638	175	101	79	58	37	54	53	17	40	19	25	9	15	4	14	9	77
1999	4258	1802	116	93	80	112	121	85	191	195	61	175	70	117	35	58	18	65	35	333
2000	1661	1325	347	518	553	750	537	315	443	379	116	237	139	146	37	91	10	78	37	325
2001	5952	3099	308	205	161	197	190	148	199	175	58	114	77	62	25	53	6	34	25	169
2002	3315	1395	104	54	43	55	63	47	98	88	26	71	37	46	10	25	3	24	10	97
2003	203	155	38	26	16	14	10	5	9	9	3	7	3	4	2	2	1	3	2	15
2004	4267	2243	177	82	68	171	219	186	303	279	89	209	118	124	37	85	14	63	37	294
2005	1253	701	108	78	46	50	60	51	84	78	25	59	33	35	15	24	4	22	15	116
2006	7297	7378	1191	85	34	36	56	44	116	112	33	100	43	68	14	32	8	35	14	154
2007	6646	3990	367	180	106	37	30	18	55	54	16	50	20	35	8	15	4	20	8	92
2008	1736	1886	629	908	597	329	178	62	202	183	47	158	53	122	28	36	10	81	28	352
2009	4487	5077	1085	168	104	79	71	26	174	155	37	147	56	113	9	34	6	58	9	194
2010	24558	13572	1504	792	346	101	85	41	222	365	132	436	76	306	146	130	91	206	146	1347
2011	5730	3656	432	244	163	94	77	38	140	182	61	198	48	140	50	59	33	84	50	493
2012	11653	5359	383	62	55	160	276	202	620	657	201	638	228	441	140	198	73	266	140	1382

Table B4.4 Boarfish in ICES Subareas V, VI, VII, VIII. Boarfish acoustic survey results.

2011 *MFV Felucca* - 24 hour operations

	Abun (mil)	Biomass (t)	%
Total estimate			
Definitely	7,049	393,893	86.4
Probably	1,134	62,222	13.6
Mixture	-	-	-
Total estimate	**8,183**	**456,115**	**100**
Possibly			
CV TSB	17.5	17.6	
SSB Estimate			
Definelty	7,019	393,312	86.4
Probably	1,126	62,063	13.6
Mixture	0	0	0.0
SSB estimate	**8,145**	**455,375**	**100**
Possibly	-	-	

2012 *MFV Father McKee* - daylight only (04:00 - 24:00) operations

	Abun (mil)	Biomass (t)	%
Total estimate			
Definitely	11,684	708,019	82.0
Probably	2,072	123,723	14.3
Mixture	501	31,704	3.7
Total estimate	**14,257**	**863,446**	**100**
Possibly	16	1,017	
CV TSB	10.6	10.7	
SSB Estimate			
Definelty	11,615	706,582	82.0
Probably	2,050	123,286	14.3
Mixture	500	31,676	3.7
SSB estimate	**14,165**	**861,544**	**100**
Possibly	16	1,017	

2013 *MFV Felucca* - daylight only (04:00 - 24:00) operations

	Abun (mil)	Biomass (t)	%
Total estimate			
Definitely	8,834	431,571	98.1
Probably	240	7,187	1.6
Mixture	17	1,139	0.3
Total estimate	**9,091**	**439,897**	**100**
Possibly	-	-	
CV TSB	17.5	16.7	
SSB Estimate			
Definelty	8,120	416,124	98.3
Probably	179	5,895	1.4
Mixture	17	1,139	0.3
SSB estimate	**8,316**	**423,158**	**100**
Possibly	-	-	

Biomass derived using a modelled boarfish TS-Length relationship (-66.2dB).

Table B4.5. Boarfish in ICES Subareas V, VI, VII, VIII. 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	2007	2008	2009	2010	2011	2012
	Raised numbers						ln (raised numbers)					
1	0	0	1575	2415	0	28	0	0	7	8	0	3
2	352	5488	15043	11229	2894	893	6	9	10	9	8	7
3	2114	21140	65744	72709	41913	5467	8	10	11	11	11	9
4	40851	105575	338931	294382	28148	41278	11	12	13	13	10	11
5	48915	141300	475619	567689	30116	110272	11	12	13	13	10	12
6	62713	195339	543707	878363	175696	146582	11	12	13	14	12	12
7	26132	104031	307333	522703	143967	492078	10	12	13	13	12	13
8	29766	66570	172783	293719	107126	365840	10	11	12	13	12	13
9	56075	53159	155477	276672	77861	271916	11	11	12	13	11	13
10	44875	46893	130148	232122	60022	173486	11	11	12	12	11	12
11	14019	15289	42521	78588	46079	69396	10	10	11	11	11	11
12	32359	21178	61350	114600	40468	40968	10	10	11	12	11	11
13	4848	11854	39609	59932	24352	58888	8	9	11	11	10	11
14	16837	13570	31569	59060	19724	30277	10	10	10	11	10	10
15+	109481	112947	196967	349320	157707	217260	12	12	12	13	12	12
Z							0.19	0.35	0.35	0.34	0.28	0.31
F (Z-M), where M = 0.16							0.03	0.19	0.19	0.18	0.12	0.15
Catches (t)							21576	34751	90370	144047	36937	86414
Corrrellation coefficient landings vs. F							0.61					

Table C 1.1. Boarfish in ICES Subareas V, VI, VII, VIII. Results of VIT pseudo-cohort analysis based on 2010 mortality estimates.

Catch mean age	8.66
Catch mean length	12.81
Mean F	0.14
Mean Z	0.3
Number of recruits, R	52 752
Spawning Stock Biomass, SSB	2 053 583 t
Total Stock Biomass, SSB	2 814 472 t

Table C 1.2. Boarfish in ICES Subareas VI, VII, VIII. 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*	F_{MSY}	B_{MSY}	TSB_{2013}	CV(TSB_{2013})
1	0.481	731549	0.241	365775	500945	0.156
2	0.493	835581	0.247	417791	633617	0.44
3	0.467	634469	0.233	317234	472169	0.153
4	0.466	865294	0.233	432647	665705	0.555
1.1	0.552	768400	0.276	384200	493886	0.161
2.1	0.551	898583	0.275	449292	604780	0.444
3.1	0.528	660356	0.264	330178	470985	0.157
4.1	0.517	828299	0.259	414150	607527	0.434
2.2	0.459	911209	0.229	455605	653668	0.436

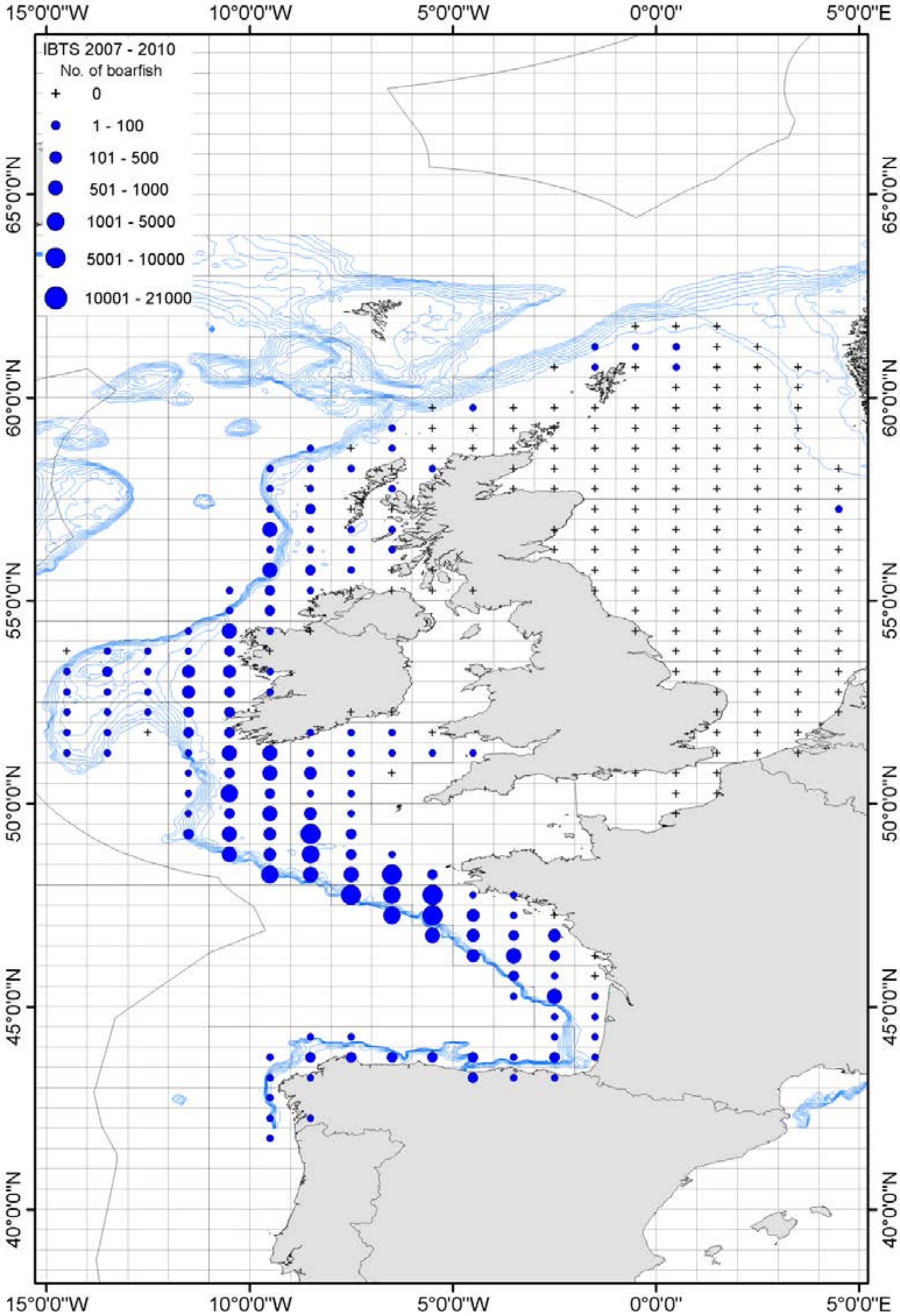


Figure A.1.1 Boarfish in ICES Subareas V, VI, VII, VIII. Distribution of boarfish in the NE Atlantic showing proposed management area.

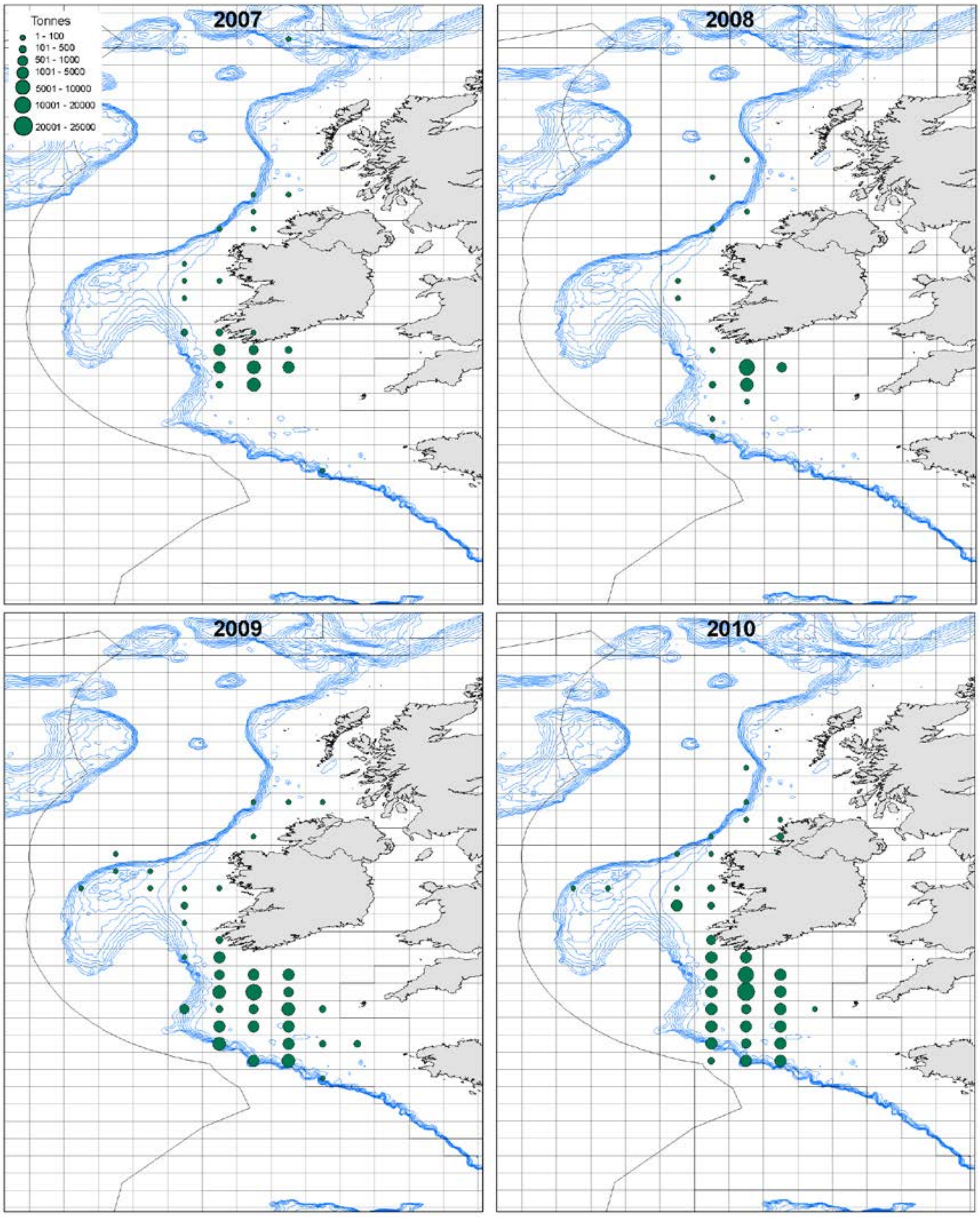


Figure A.1.2. Boarfish in ICES Subareas V, VI, VII, VIII. Irish catches by rectangle and year .

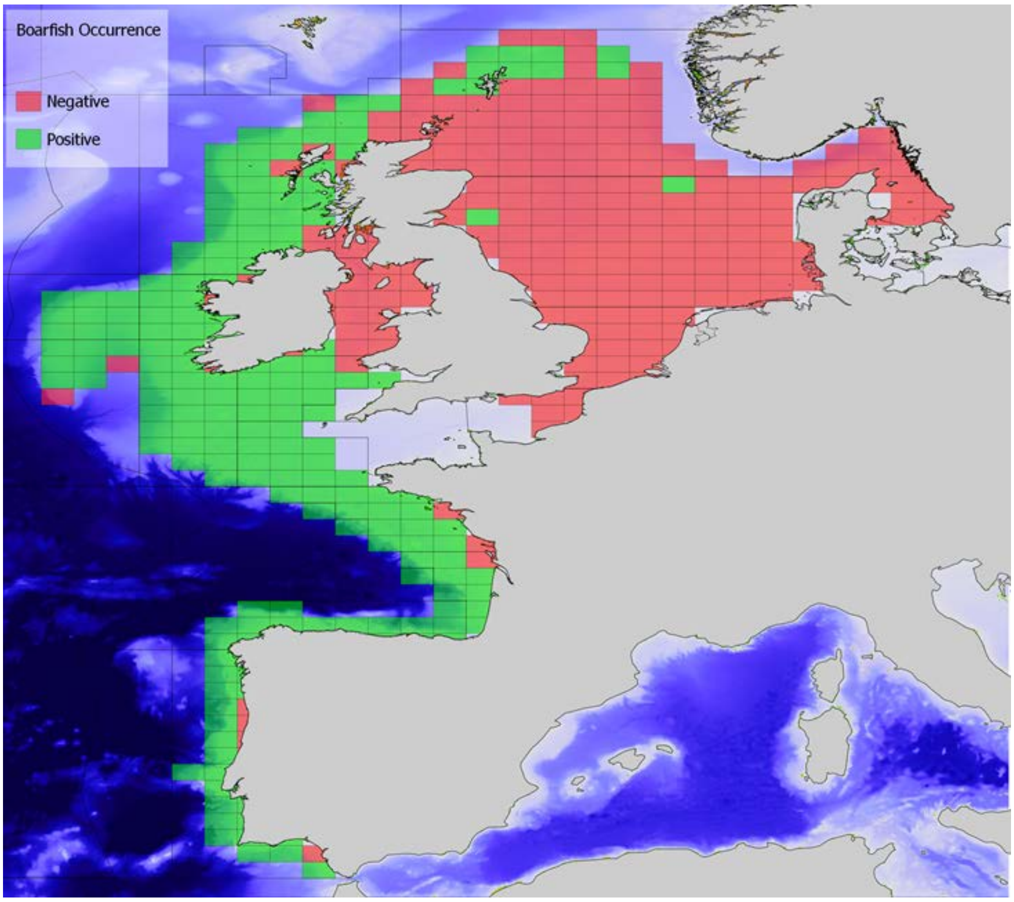


Figure A.1.3. Boarfish in ICES Subareas VI, VII, VIII. Distribution of boarfish in the NE Atlantic area based on presence and absence in IBTS surveys.

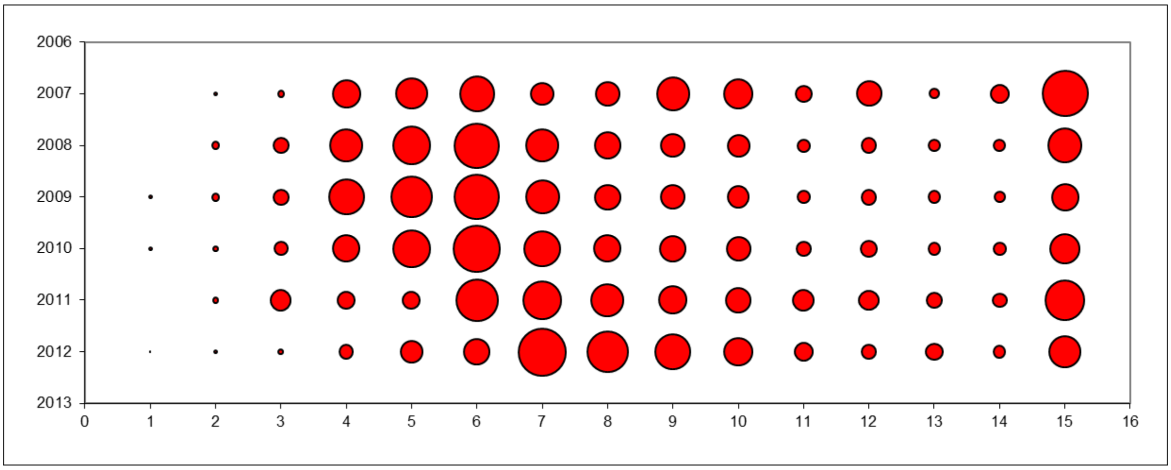


Figure B.2.1. Boarfish in ICES Subareas V, VI, VII, VIII. Catch numbers-at-age standardised by early mean. 20+ is the plus group.

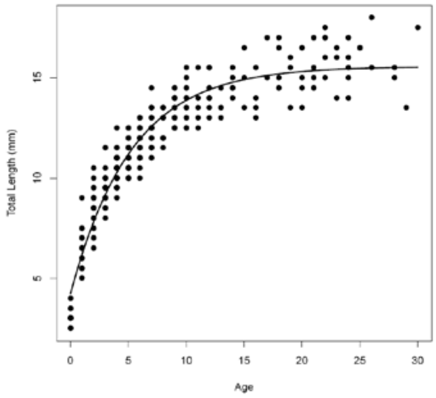


Figure B.3.1 von Bertalanffy growth curve; see Table B.3.1 for parameter estimates

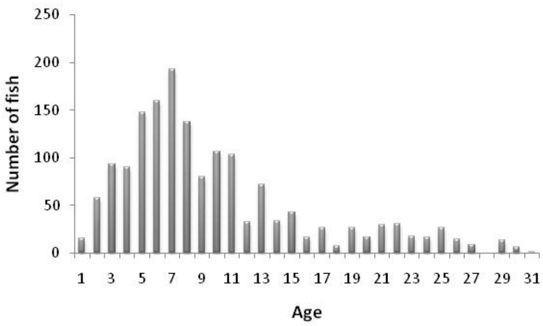


Figure B.3.2 Age distribution for n=1633 fish sampled

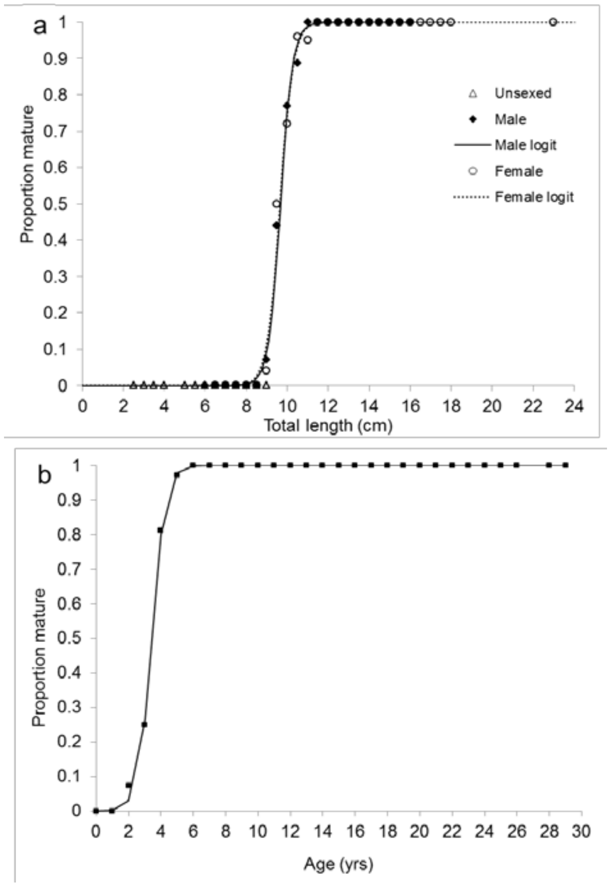


Figure B.3.3 Maturity ogives for (a) total length and (b) age for boarfish

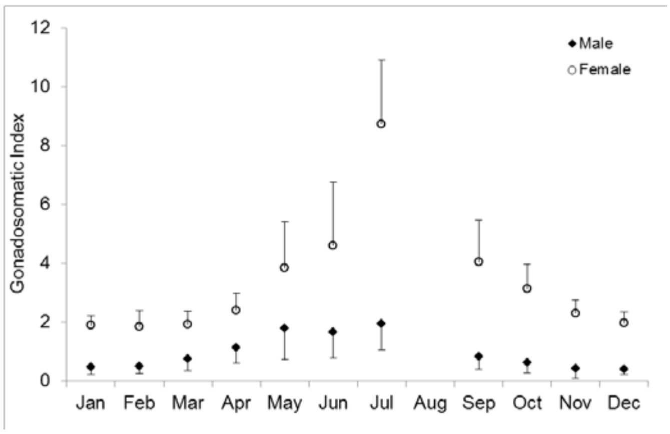


Figure B.3.4 Gonadosomatic index for male and female boarfish

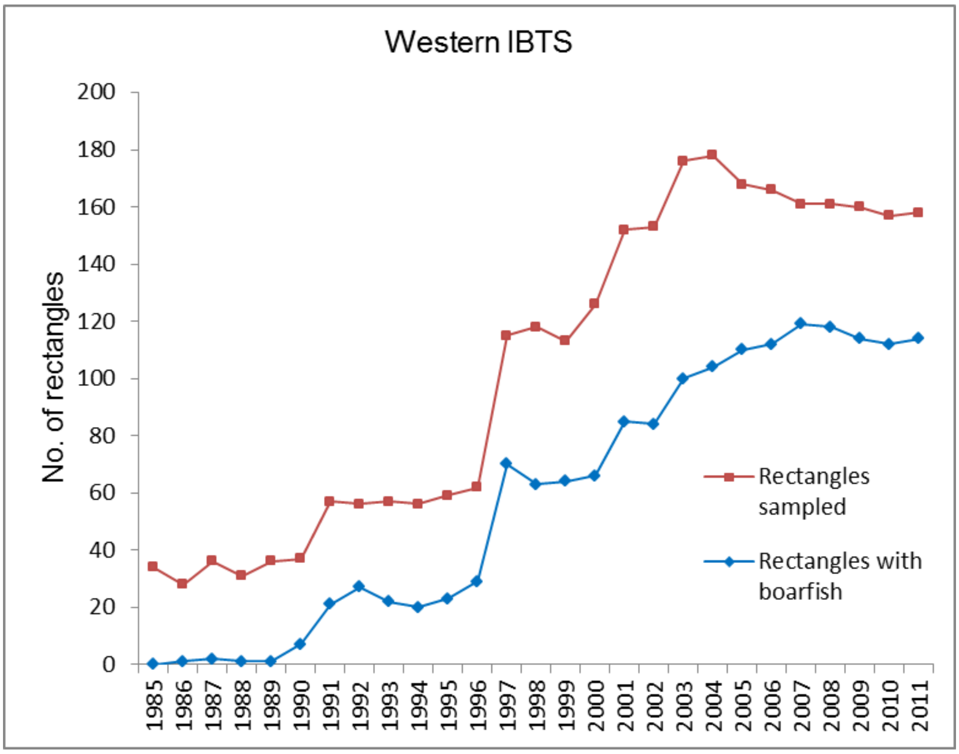


Figure B.4.1 Occurrence of boarfish in ICES Rectangles sampled during the western IBTS 1985 – 2011.

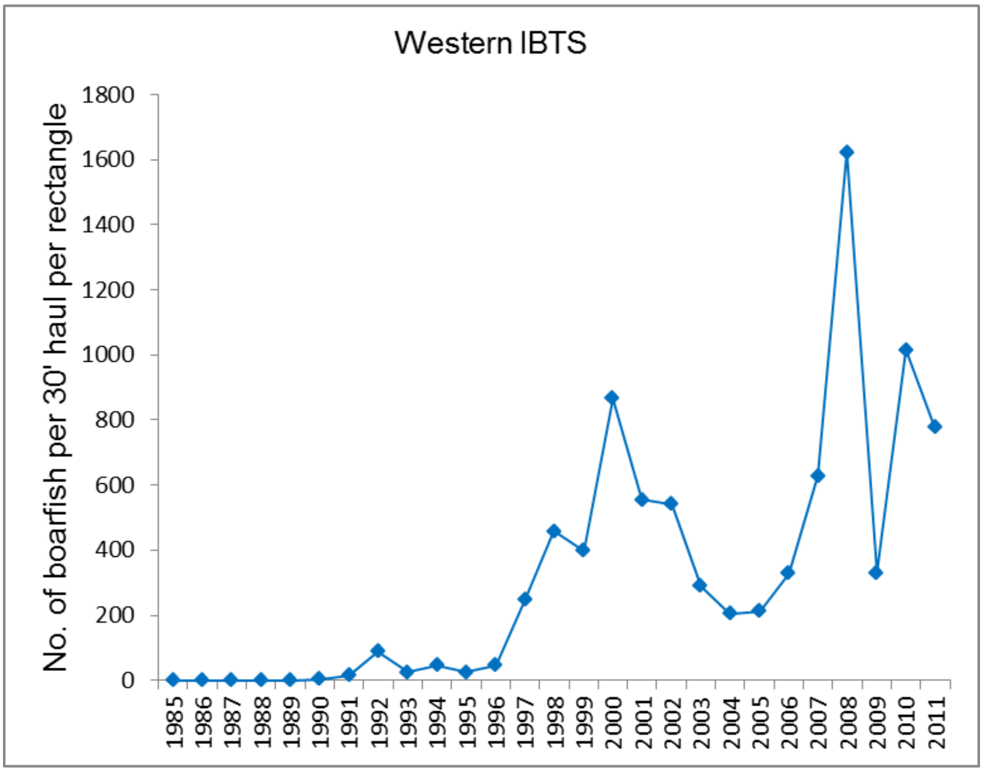
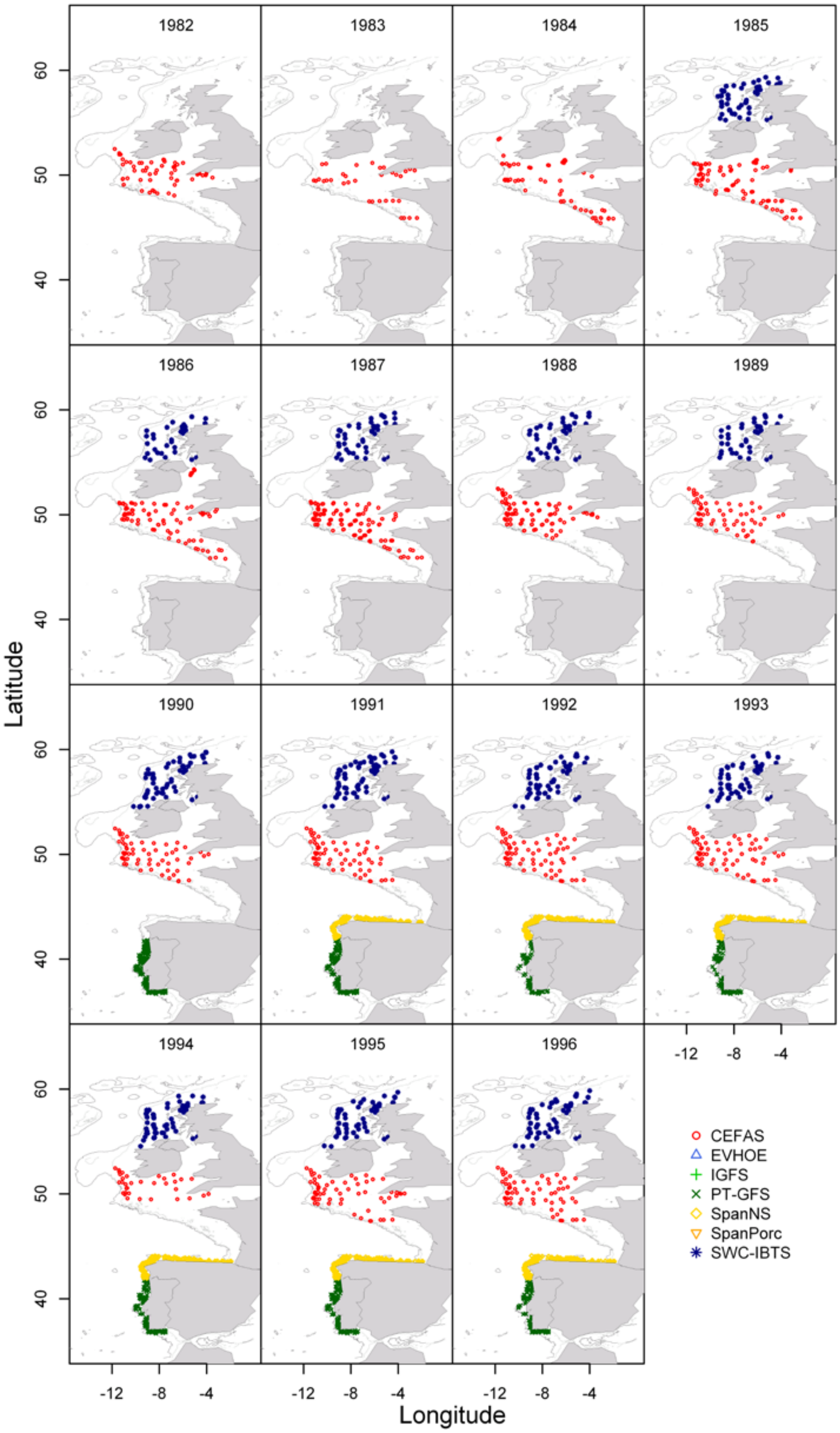


Figure B.4.2 Boarfish in ICES Subareas VI, VII, VIII. CPUE in number per 30 minute haul of boarfish per rectangle in the western IBTS survey 1985 to 2011.


1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Latitude
Longitude
60
50
40
-12
-8
-4
CEFAS
EVHOE
IGFS
PT-GFS
SpanNS
SpanPorc
SWC-IBTS

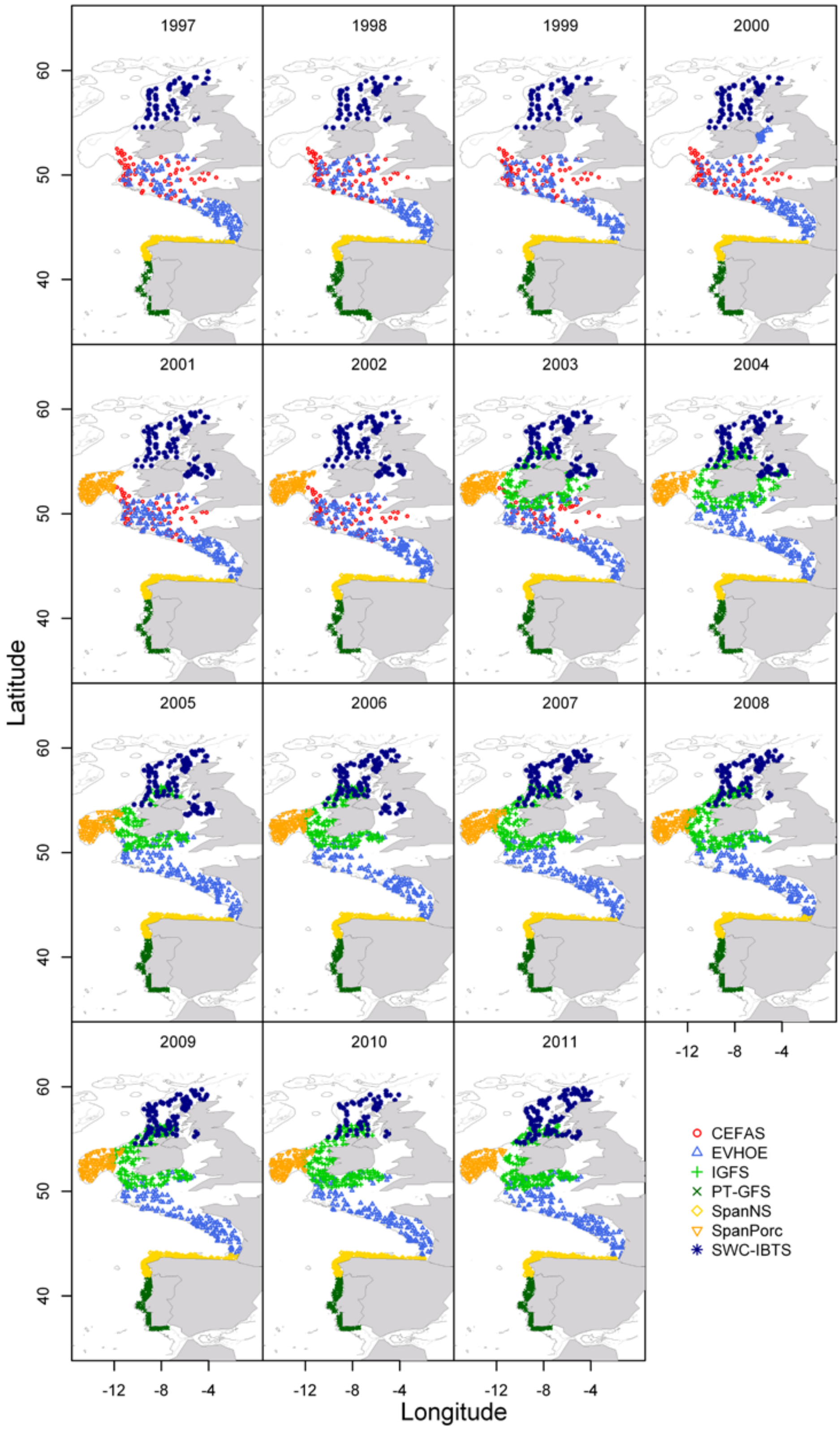
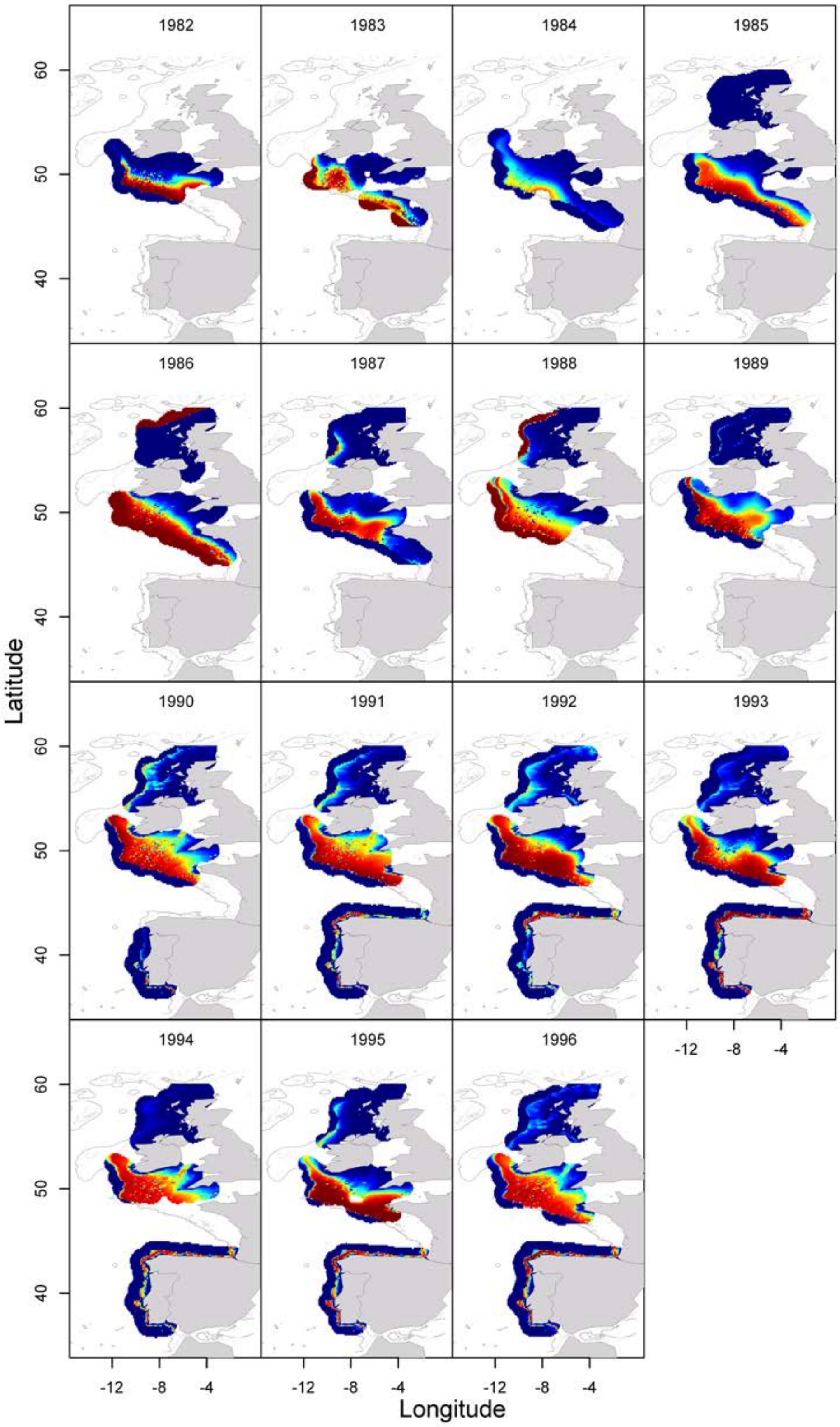


Figure B.4.3 Boarfish in ICES Subareas VI, VII, VIII. The haul positions of bottom trawl surveys by year analysed as part of the GAM modelling.


1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Latitude
60
50
40
-12
-8
-4
Longitude

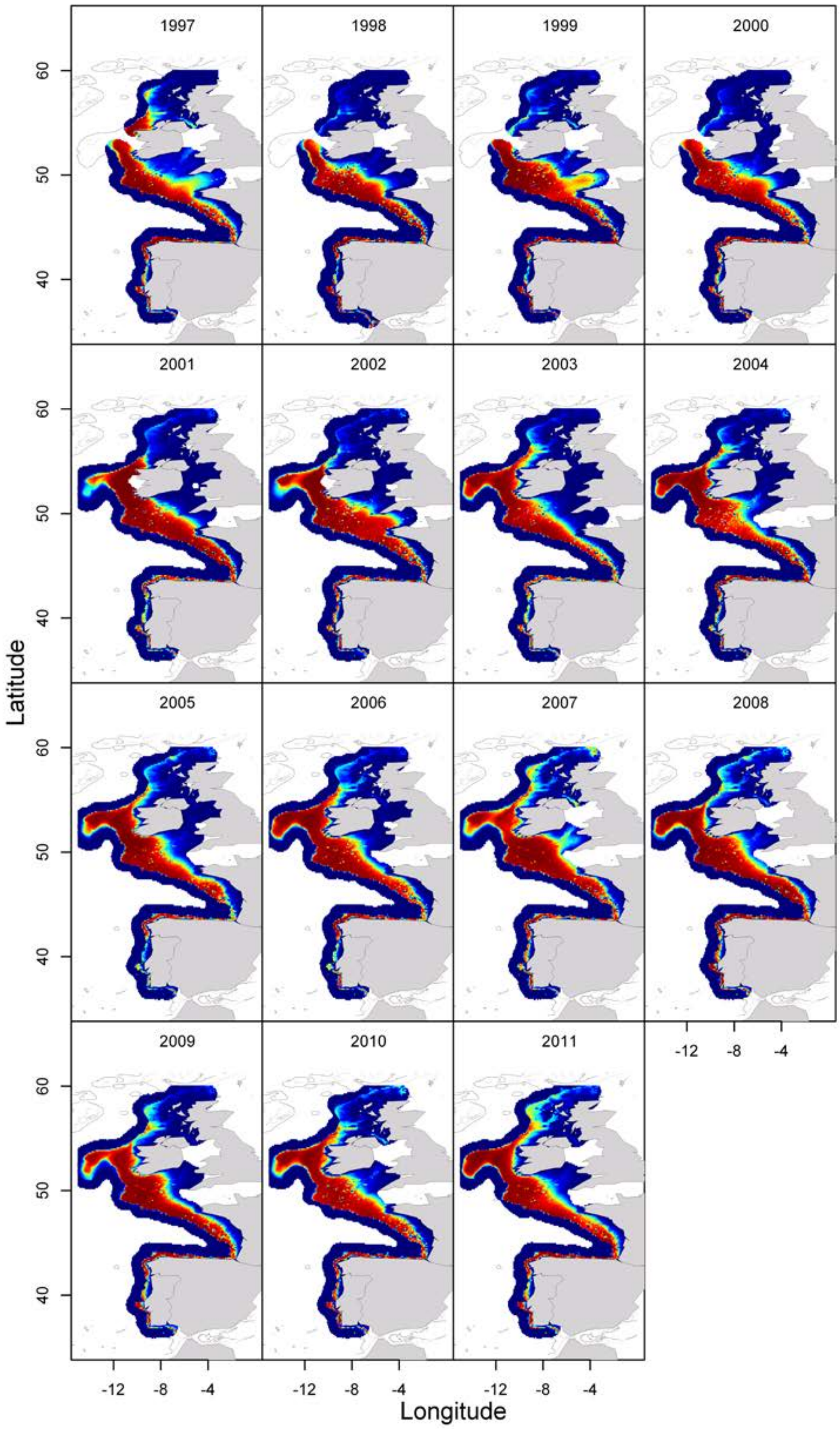


Figure B.4.3. Boarfish in ICES Subareas VI, VII, VIII. The occurrence GAM of the probability of occurrence of boarfish in a survey area 1997 – 2011. Red indicates definite occurrence and blue indicates absence.

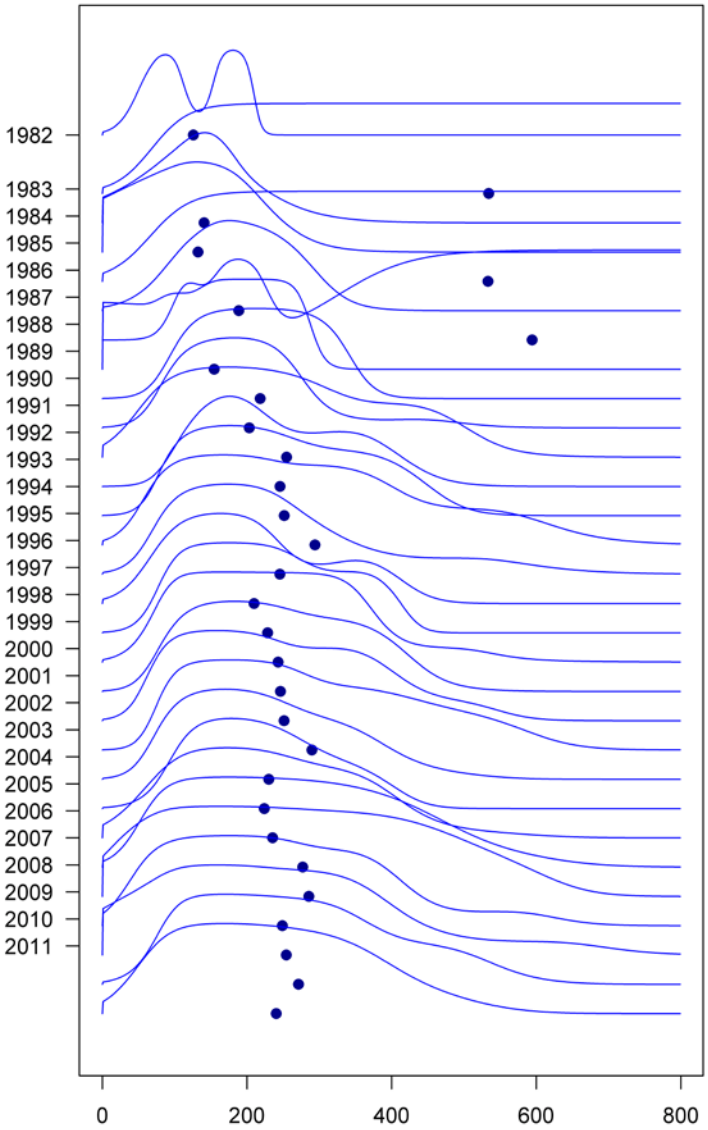


Figure B.4.5. Boarfish in ICES Subareas VI, VII, VIII. The depth distribution profile of boarfish within the IBTS surveys.

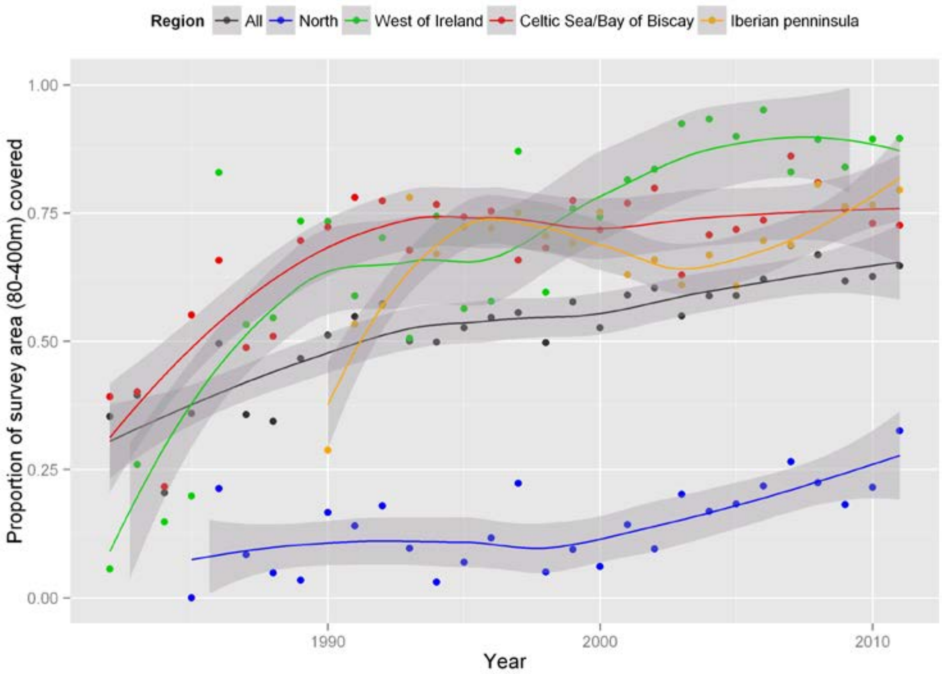


Figure B.4.6. Boarfish in ICES Subareas VI, VII, VIII. The proportion of survey area covered by boarfish per region and per year.

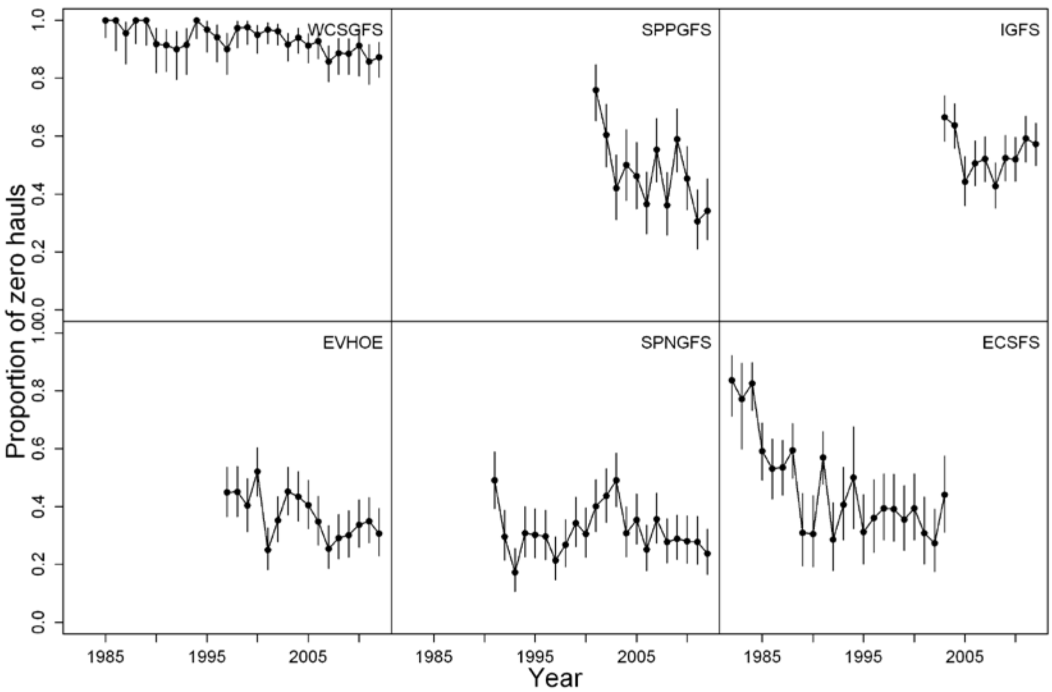


Figure B.4.7. Boarfish in ICES Subareas VI, VII, VIII. The proportion of zero hauls per IBTS survey.

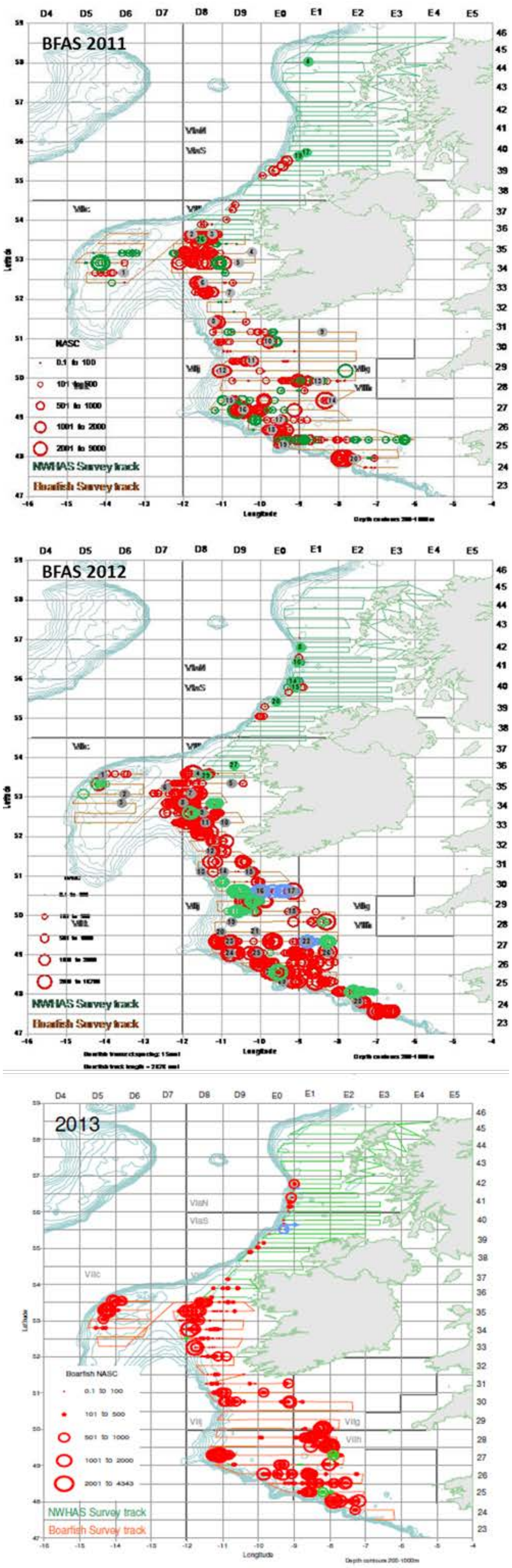


Figure B.4.2.1. Boarfish acoustic survey track and haul positions from acoustic surveys 2011 to 2013.

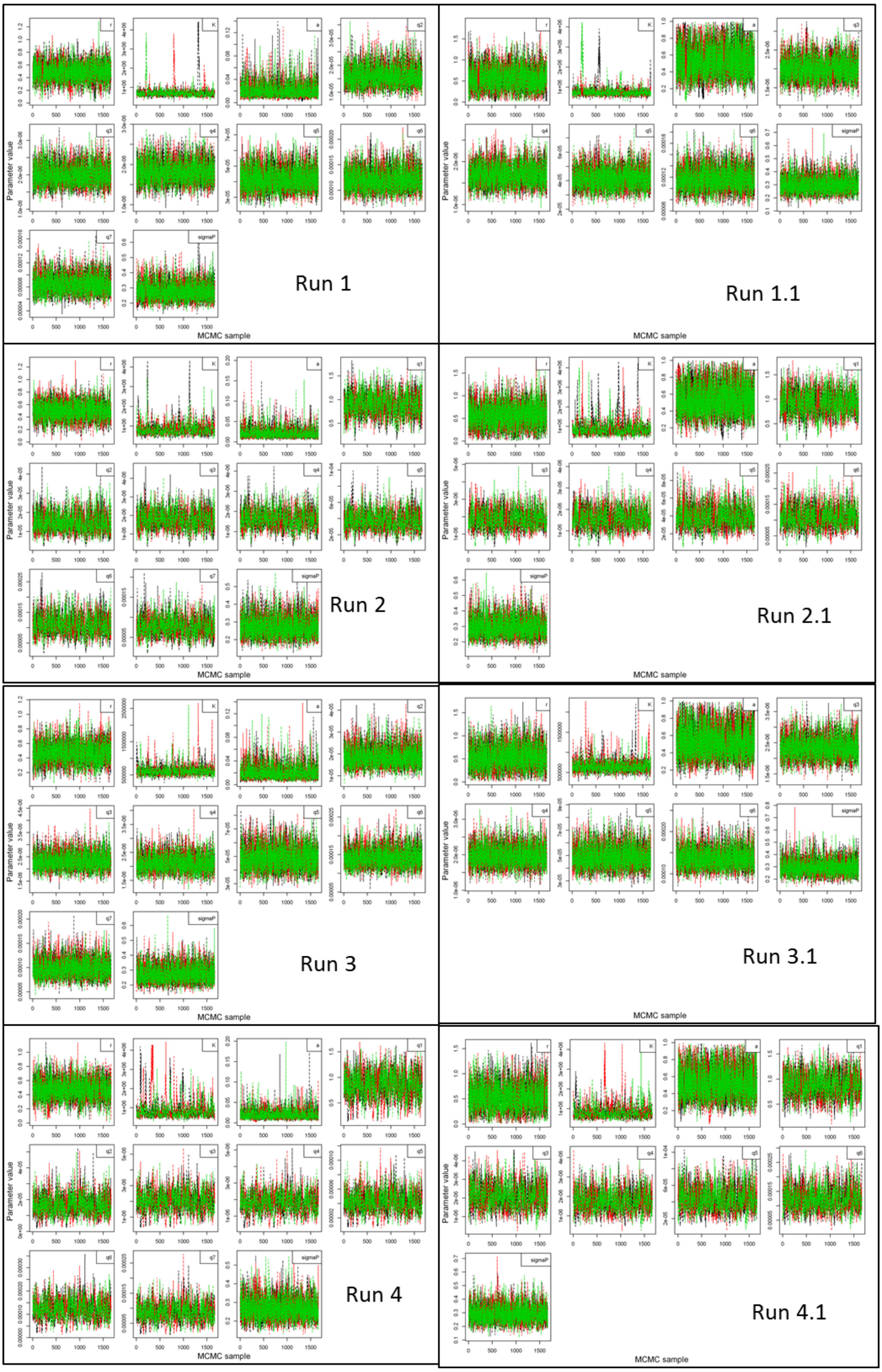


Figure C.1. Boarfish in ICES Subareas VI, VII, VIII. Parameters for runs 1-4 and sensitivity runs 1.1, 2.1, 3.1, 4.1 converged with good mixing of the chains.

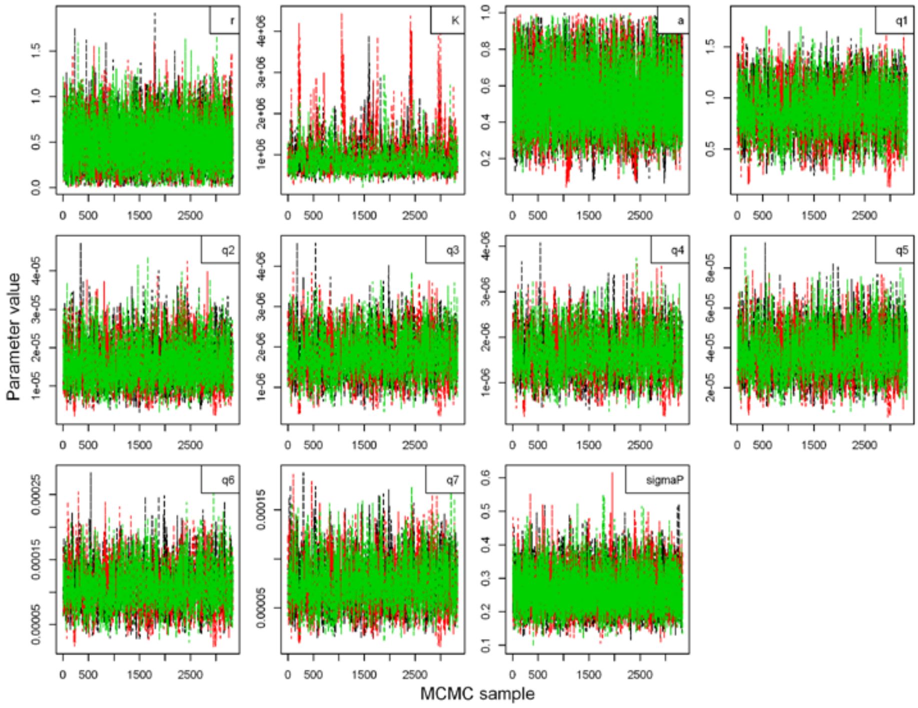


Figure C.2. Boarfish in ICES Subareas VI, VII, VIII. Parameters for run 2.2 converged with good mixing of the chains.

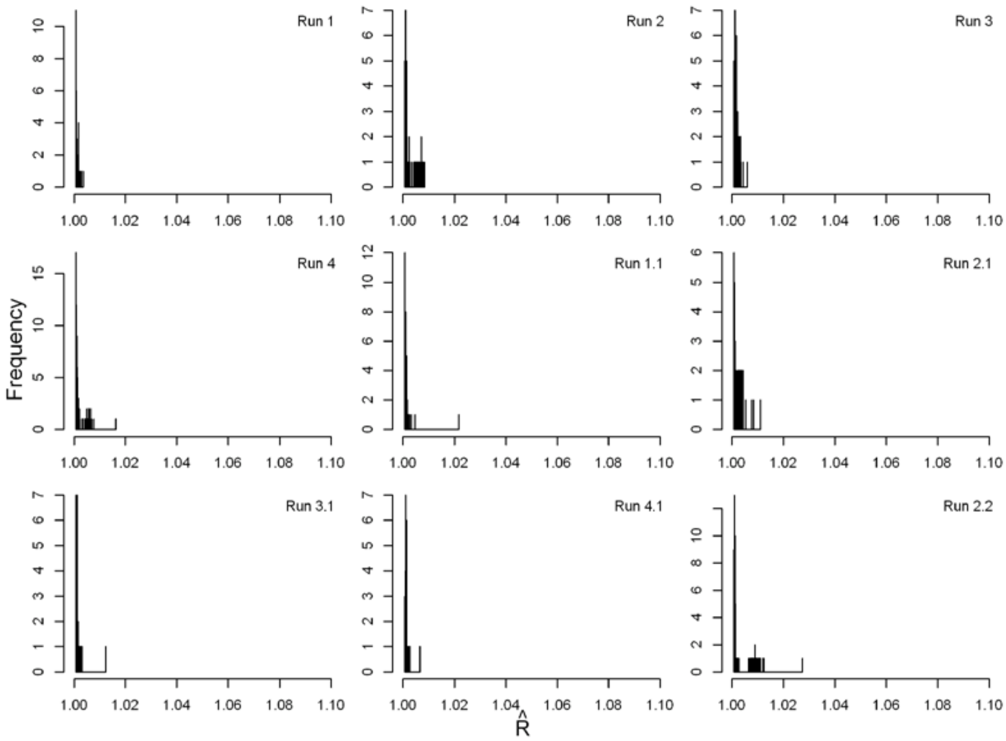


Figure C.3. Boarfish in ICES Subareas VI, VII, VIII. Rhat values lower than 1.1 indicating convergence.

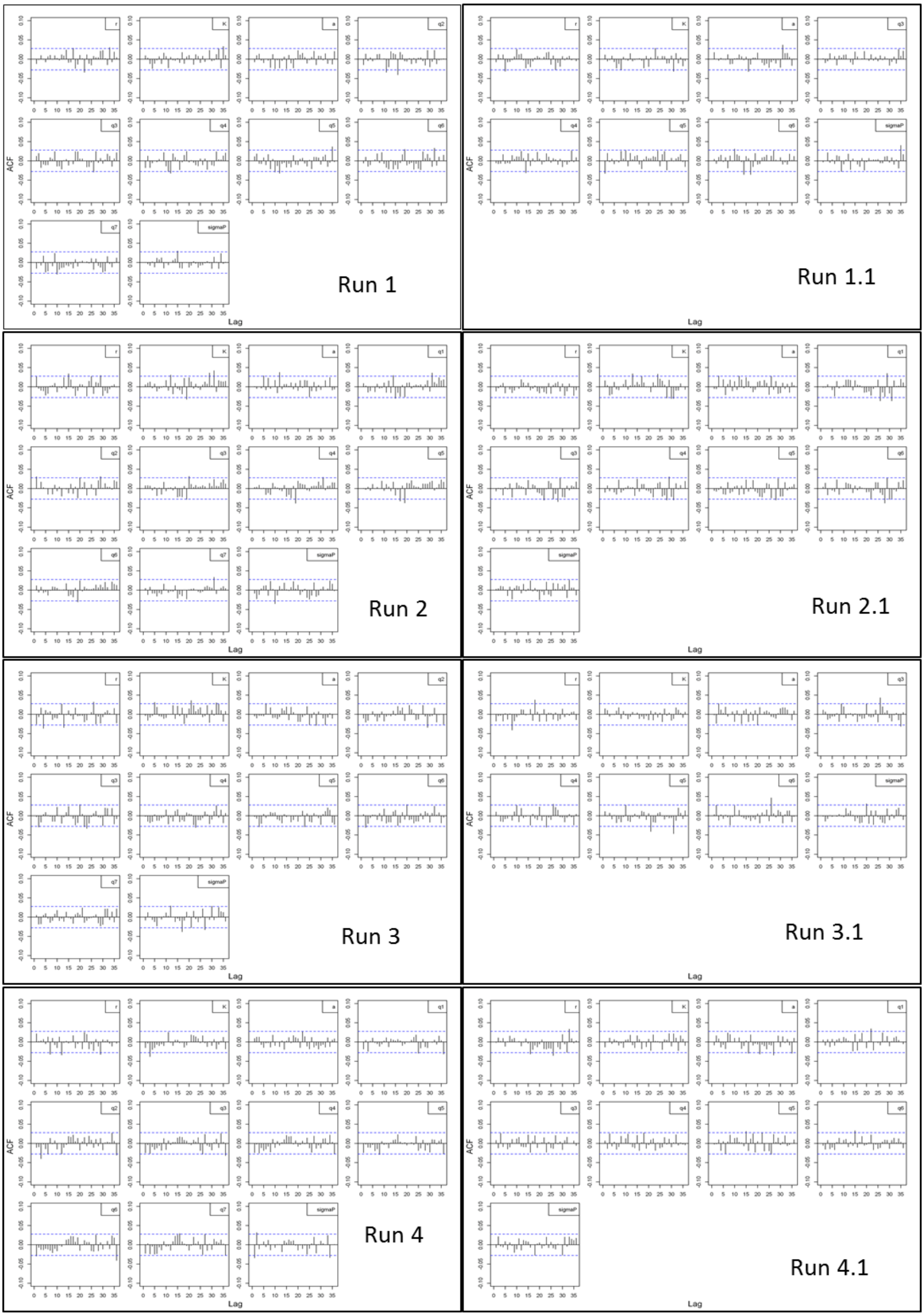


Figure C.4. Boarfish in ICES Subareas VI, VII, VIII. MCMC chain autocorrelation for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1.

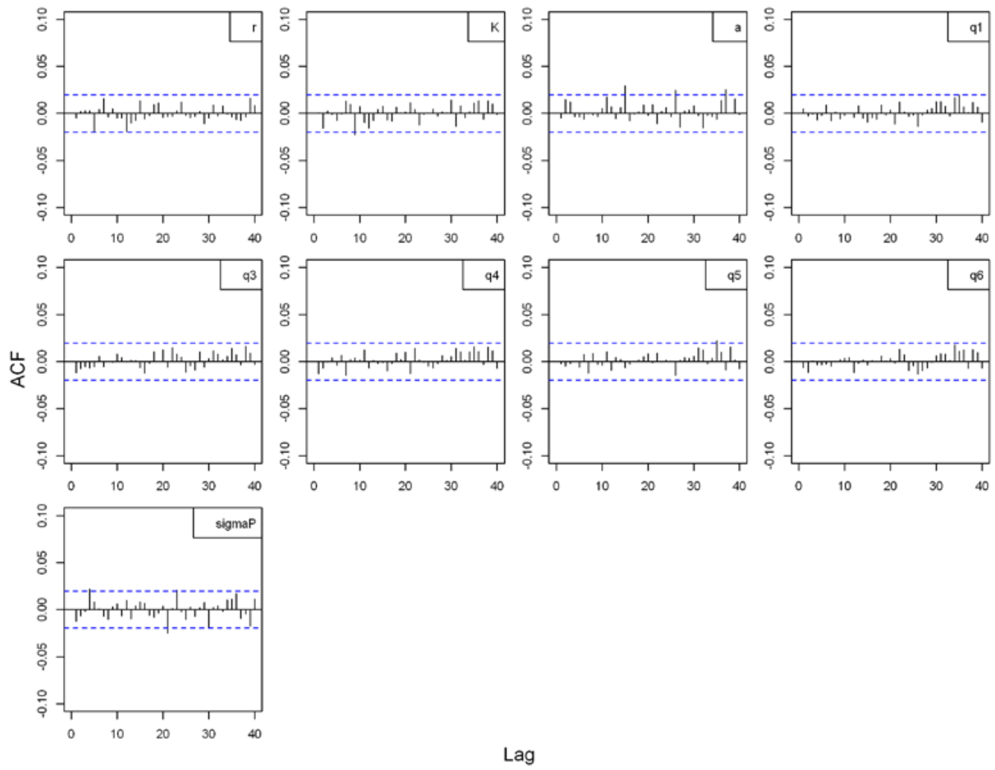


Figure C.5. Boarfish in ICES Subareas VI, VII, VIII. MCMC chain autocorrelation for run 2.2.

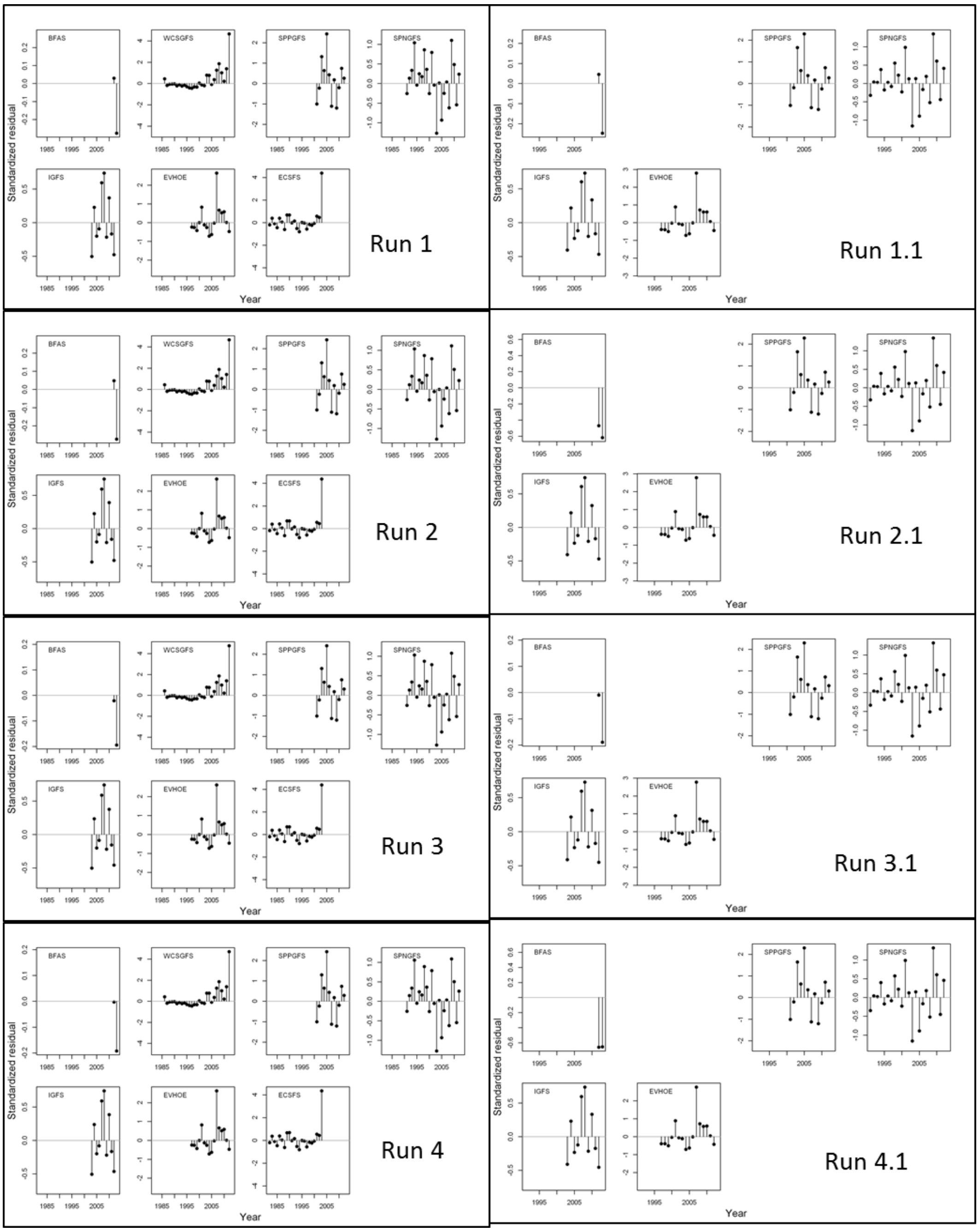


Figure C.6. Boarfish in ICES Subareas VI, VII, VIII. Residuals around the model fits for runs 1-4, sensitivity runs 1.1, 2.1, 3.1, 4.1.

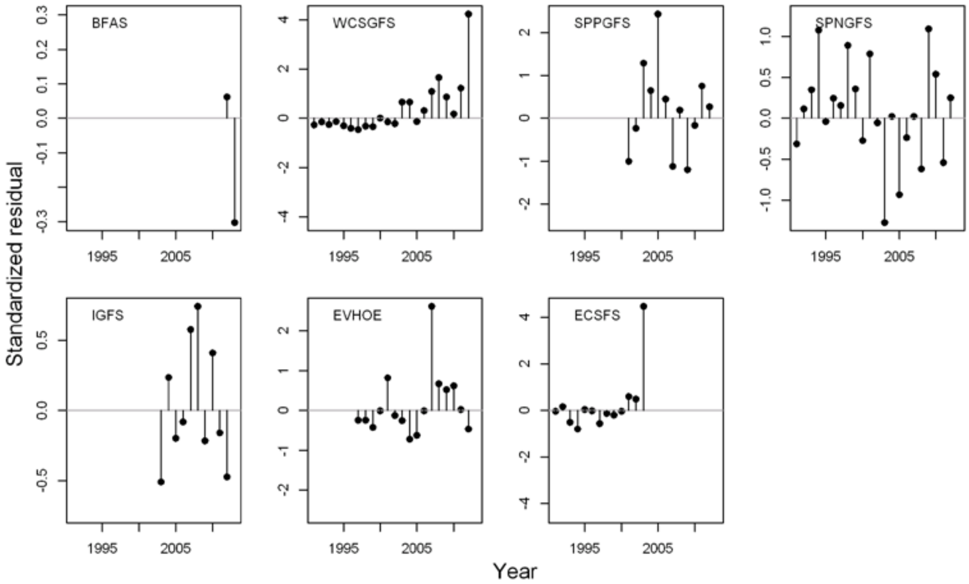


Figure C.7. Boarfish in ICES Subareas VI, VII, VIII. Residuals around the model fit for run 2.2.

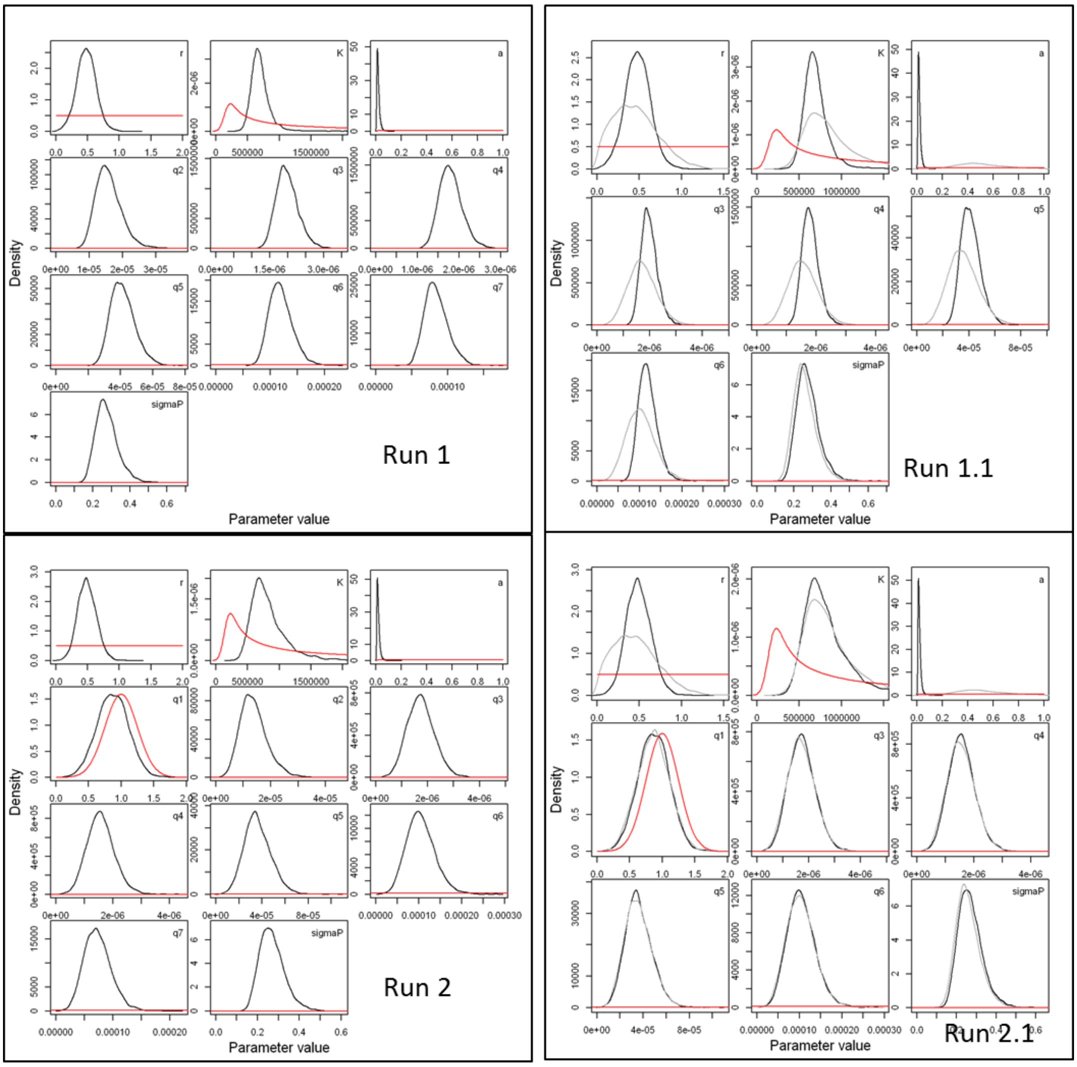


Figure C.8. Boarfish in ICES Subareas VI, VII, VIII. prior and posterior distributions of the parameters of the biomass dynamic model. Runs 1, 1.1, 2 and 2.1.

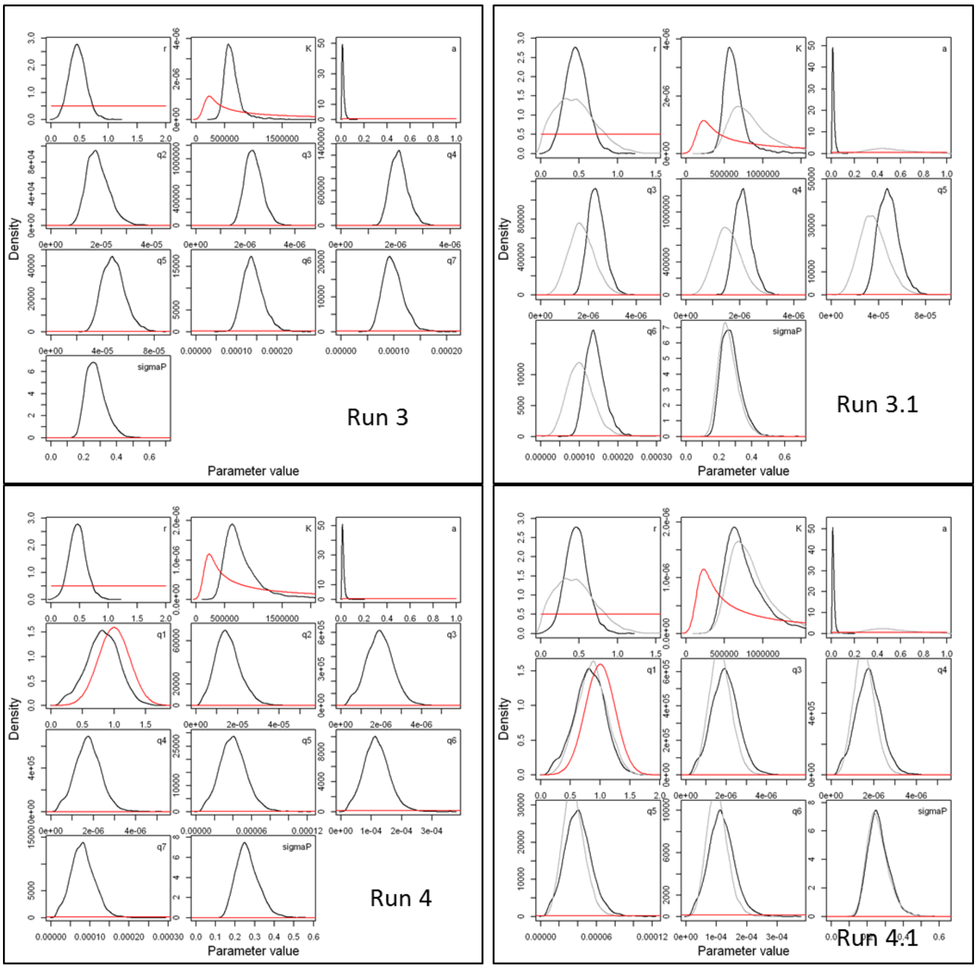


Figure C.9. Boarfish in ICES Subareas VI, VII, VIII. prior and posterior distributions of the parameters of the biomass dynamic model. Runs 3, 3.1, 4 and 4.1.

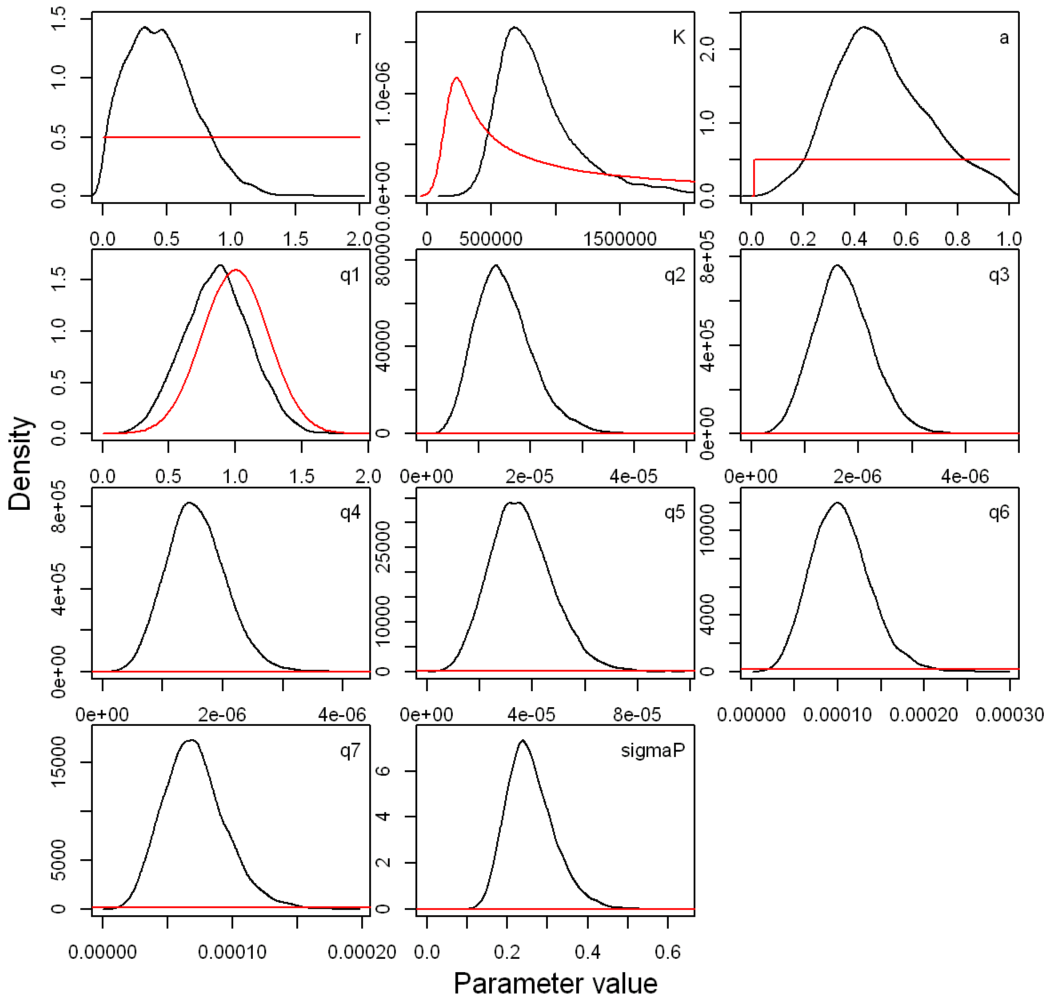


Figure C.10. Boarfish in ICES Subareas VI, VII, VIII. prior and posterior distributions of the parameters of the biomass dynamic model. Run 2.2.

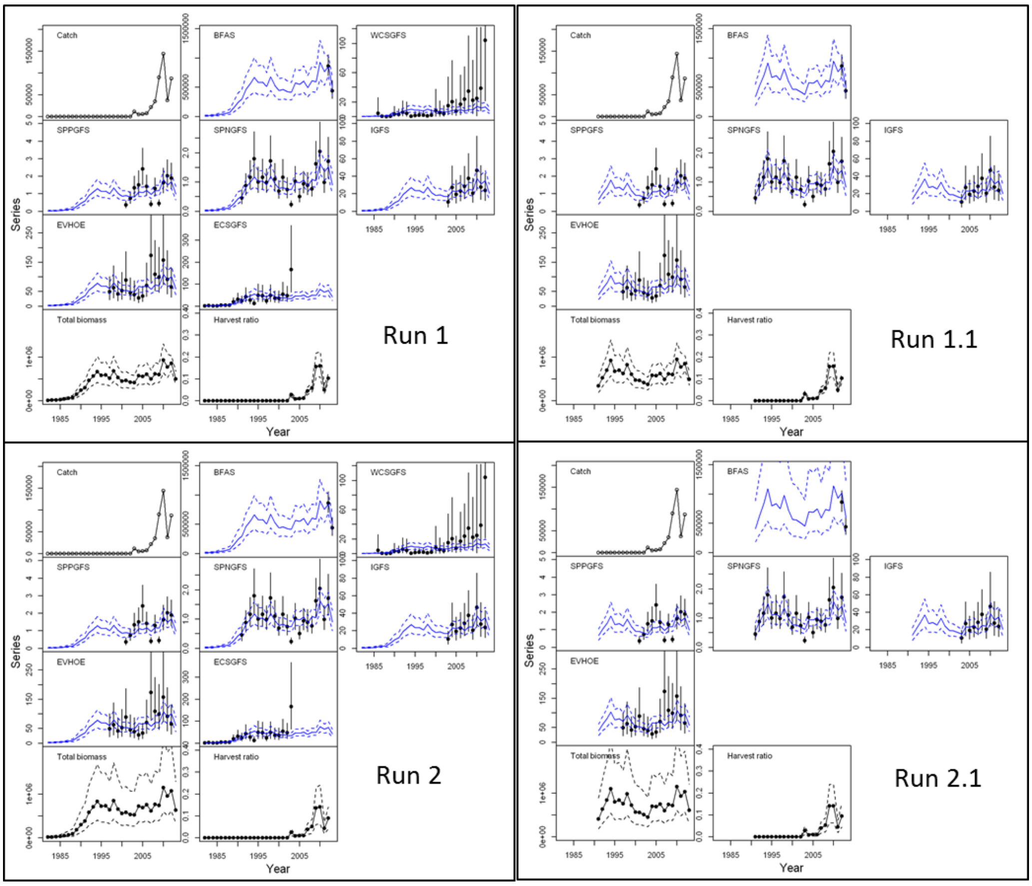


Figure C.11. Boarfish in ICES Subareas VI, VII, VIII. Trajectories of observed and expected indices for runs 1, 1.1, 2 and 2.1. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

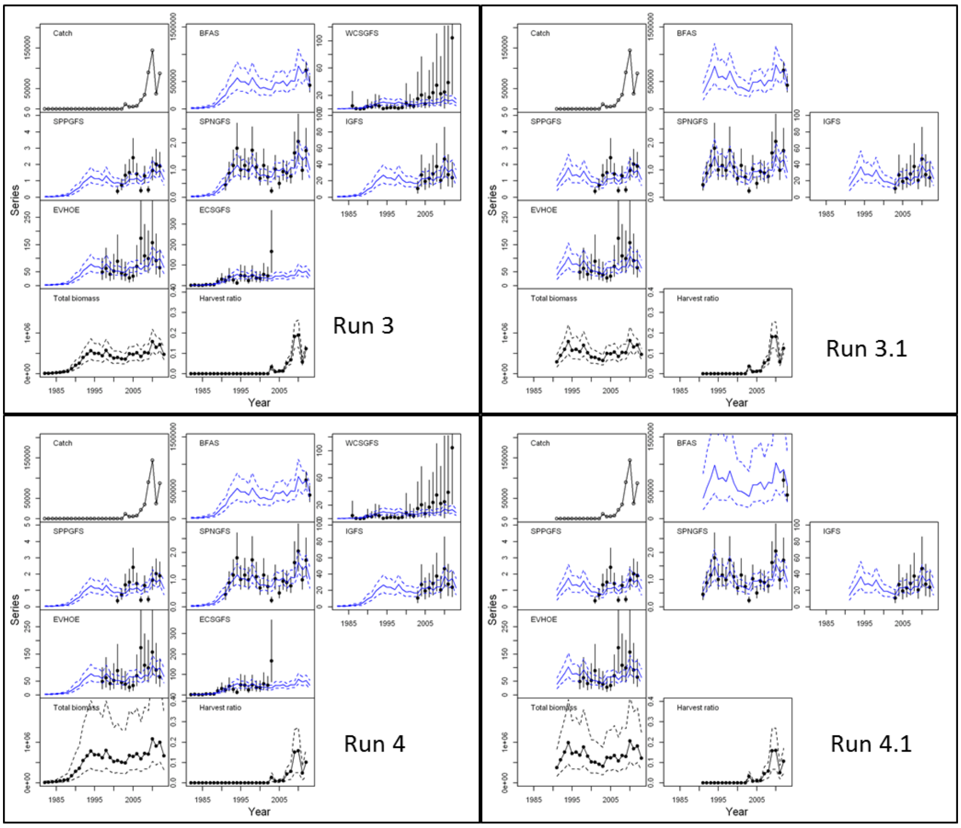


Figure C.12. Boarfish in ICES Subareas VI, VII, VIII. Trajectories of observed and expected indices for runs 3, 3.1, 4 and 4.1. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

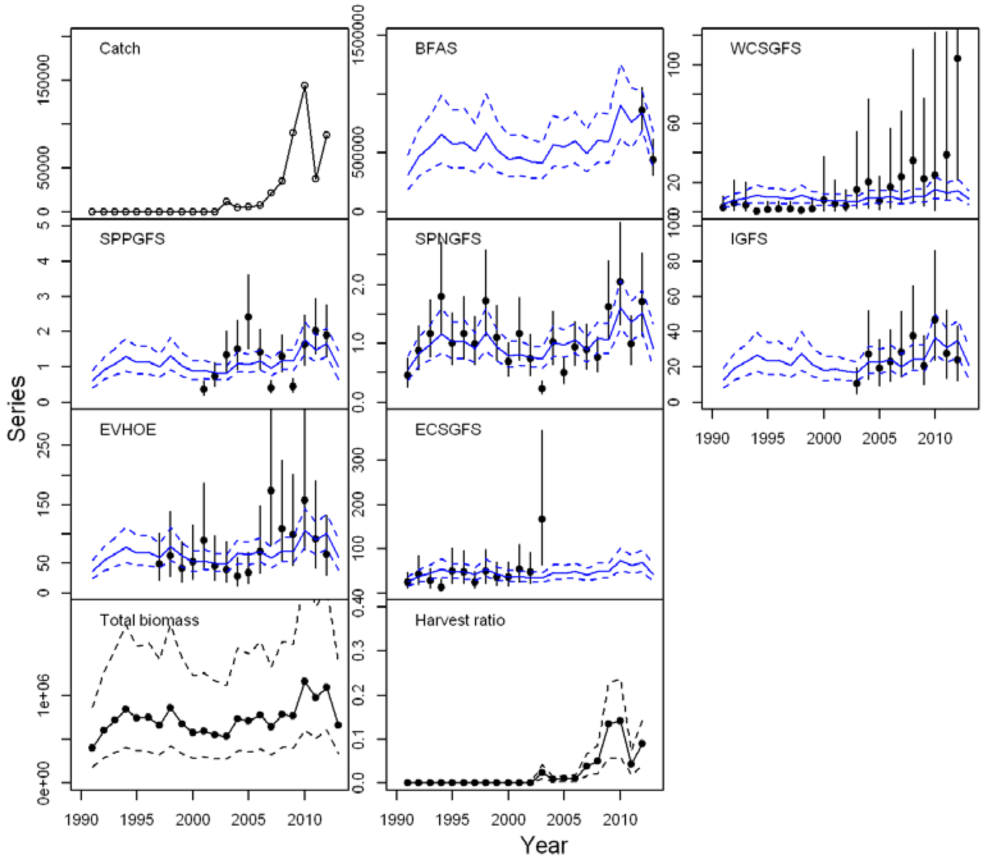


Figure C.13. Boarfish in ICES Subareas VI, VII, VIII. Trajectories of observed and expected indices for run 2.2. The stock size over time and a harvest ratio (total catch divided by estimated biomass) are also shown.

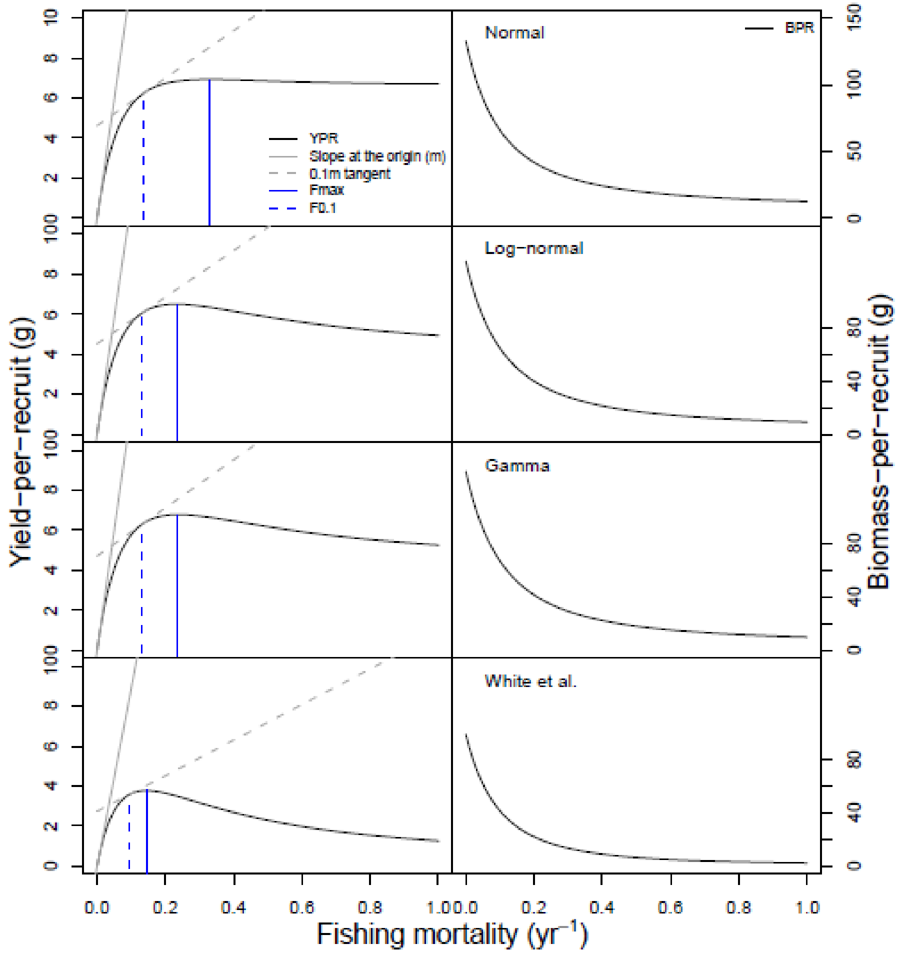


Figure E.1 Boarfish in ICES Subareas V, VI, VII, VIII. Results of exploratory yield per recruit analysis. Beverton and Holt model applied to various fits of the VBGF and for comparison with the VBGF parameters provided by White et al. 2011.

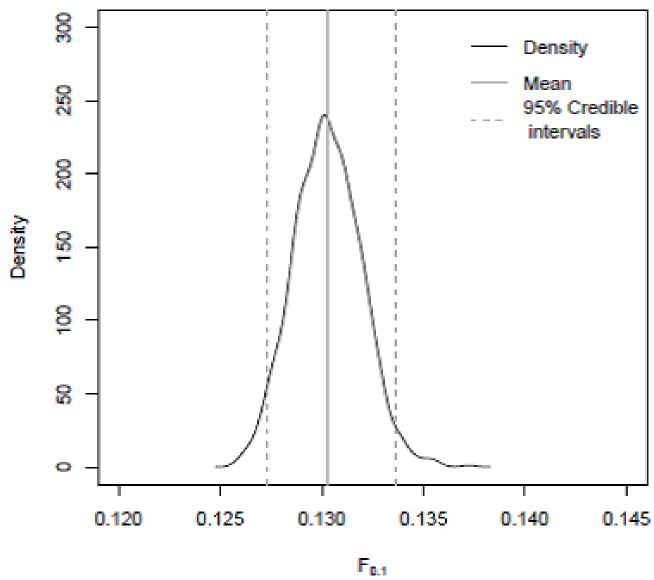


Figure E.2 Boarfish in ICES Subareas V, VI, VII, VIII. Sensitivity of estimation of $F_{0.1}$.