8 Blue shark in the North Atlantic (North of 5ºN)

8.1 Stock distribution

There is a discrete North Atlantic stock of blue shark *Prionace glauca* (Heessen, 2003; Fitzmaurice *et al*., 2005; ICCAT, 2008), with 5°N latitude as the southern stock boundary, and a separate South Atlantic stock (ICCAT, 2008). This delineation is based on mark-recapture data (e.g. Kohler *et al.*, 2002), and oceanographic features. In addition, this division facilitates comparison with fisheries statistics of other North Atlantic stocks, such as tuna-like species, that have the same southern stock boundary. Hence, the ICES area is only part of the stock area.

Recent genetic studies on blue shark reveal genetic homogeneity across whole ocean basins in Atlantic (Verissimo *et al*., 2017) and Pacific oceans (Ovenden *et al*., 2009; Taguchi *et al*., 2015). These are at odds with the currently assumed distinction of northern and southern stocks within each ocean basin. The bulk of the evidence gathered thus far indicates that the blue shark exhibits dispersal with gene flow over very large spatial scales, and little to no philopatry to the sampled nursery areas or to distinct ocean basins. However, in cases as in blue sharks where effective populations sizes are ~1000s, the levels of genetic divergence associated with migration rates which could lead to demographic connectivity (~10%; Hastings, 1993) may be difficult to detect using traditional molecular markers. In these cases, the precautionary approach in conservation and fisheries management would be to consider each nursery area as independent, with potentially different demographic parameters and vulnerability to fishing pressure. If each nursery area currently exchanges only a few migrant individuals per generation with other nurseries, the replenishment of each stock would be mostly dependent on recruit survival rather than on immigration from adjacent stocks.

8.2 The fishery

8.2.1 History of the fishery

In recent years, more information has become available about fisheries taking blue shark in the North Atlantic. Catch data are incomplete, but provide information on the fisheries and trends. Although there are no large-scale target fisheries for blue shark, it is a major bycatch in tuna and billfish fisheries, where it can comprise up to 70% of the total catches and even exceed the catch of target species (ICCAT, 2005). In the North Atlantic, EU fleets (Portugal and Spain) are responsible for approximately 82% of the total landings (Anon., 2015). Observer data indicates that substantially more blue sharks are caught as bycatch than reported in catch statistics.

Since 1998, there has been a seasonal (June to November) Basque artisanal longline fishery targeting blue shark and other pelagic sharks in the Bay of Biscay (Díez *et al*., 2007). Initially 3–5 vessels were involved but, as a consequence of changes in local fishing regulations, the number of vessels reduced to two after 2008.

Blue sharks are also caught, in considerable numbers, in recreational fisheries, including from the Celtic Sea and western Channel (e.g. Vas, 1990; Mitchell *et al.*, 2014) and other parts of the ICES area (Campana *et al*., 2005).

In the North Atlantic, thirteen fisheries (in descending order of volume: EU-Spain, EU-Portugal, Japan, Canada, USA_LL, Chinese Taipei, EU-France, Belize, Panama, USA_SP., China PR, Korea and, Venezuela) accounted for 99% of the total removals (1990–2014). The majority (except: USA sport fishery, EU-France unclassified gear) are longline fisheries (Anon., 2015). There are also blue shark landings in Mediterranean fisheries (Anon., 2015).

8.2.2 The fishery in 2021

No new information.

No major changes noted in 2020/2021, although potential changes to fishing effort (and observer coverage) caused by the effects of COVID-19 have not yet been quantified.

8.2.3 Advice applicable

ACOM has never provided advice for blue shark in the ICES area. Assessment of this stock is considered to be the responsibility of ICCAT.

In July 2015, members of WGEF participated in the ICCAT blue shark stock assessment meeting that took place in Lisbon, Portugal (ICCAT, 2015). ICCAT considered that the status of the North Atlantic stock is unlikely to be either overfished or subject to overfishing. However, due to the level of uncertainty in the assessment results no specific management recommendations were provided (ICCAT, 2015).

ICCAT adopted Recommendation 2016-12, which in paragraph 2 identified a catch limit for blue sharks in the North Atlantic ("*If the average total catch of the North Atlantic blue shark in any consecutive two years from 2017 onward exceeds the average level observed during the period 2011-2015 (i.e. 39,102 t), the Commission shall review the implementation and effectiveness of these measures*"). This measure applied from 2017. Preliminary catch data from ICCAT's Standing Committee on Research and Statistics (SCRS) indicated that catches in 2017 and 2018 were 39 675 t and 33 853 t, respectively (SCRS, 2019).

A subsequent Recommendation (2019-07) refined these catch limits, stating that "*An annual TAC of 39 102 t for North Atlantic blue shark is established. The annual TAC may be revised subject to a decision of the Commission based on the updated advice of the SCRS in 2021, or at an earlier stage if enough information is provided by the SCRS*". Catch limits were established for the EU (32 578 t), Japan (4 010 t) and Morocco (1 644 t), with all other CPCs to "*endeavour to maintain their catches at recent levels*".

These overall catch limits of North Atlantic blue shark were retained in Recommendation 2021-10, with the European Union also authorised to transfer 32.58 t from the EU catch limit to the UK.

8.2.4 Management applicable

There are no measures fully regulating all the catches of blue shark in the North Atlantic.

European regulations for annual fishing opportunities have given an overall TAC (39 102 t) for blue shark in the Atlantic Ocean north of 5°N since 2017. Whilst this nominal TAC has remained unchanged, an allocation key was included in the 2020 and 2021 fishing opportunities (Council Regulations (EU) 2020/123 and 2021/92), under which the EU quota was set at 32 578 t (83.3% of the 39 102 t TAC, and in accordance with ICCAT Rec. 2019-07), and this was allotted to Spain (27 062 t), Portugal (5363 t), France (152 t) and Ireland (1 t).

The fishing opportunities were amended for 2022 (Council Regulation (EU) 2022/109), with Ireland allocated 0.96 t, Spain 27 035.09 t, France 151.7 t, Portugal 5357.67 t, with the overall EU TAC being 32 545.42 t, thus accounting for the transfer of 32.58 t to the UK.

EC Regulation No. 1185/2003 (updated by EU Regulation No 605/2013) prohibits the removal of shark fins of these species, and subsequent discarding of the body. This regulation is binding on EC vessels in all waters and non-EC vessels in Community waters.

8.3 Catch data

8.3.1 Landings

It is difficult to accurately quantify landings of blue shark in the North Atlantic. Data are incomplete, and the generic reporting of shark catches has resulted in underestimations. Landing data from different sources (ICCAT, FAO and national statistics) can vary (Figures 8.1–8.3). Table 8.1 gives the catch data (total landings and discards by stock, flag and major gears) collated by ICCAT, which appears to provide the most complete catch data for this stock, though there can be small changes in these data over time (Tables 8.2–8.3). ICCAT considers that reported landings of blue shark were underestimated in the early part of the time-series (prior to 1997), with official landings and estimates of a comparable magnitude since 1997, when annual landings have been *ca.* 20 000–40 000 t. In the North Atlantic, blue shark is reported predominantly by Spain, Portugal, Japan, USA and Canada (Figure 8.1).

In 2015, alternative approaches to estimate catch series were discussed by ICCAT (Anon., 2015), including (i) ratios between blue shark catches and species-specific catches derived from ICCAT Task I data; (ii) catch/effort and standardised CPUE; and (iii) shark fin trade data. Figure 8.4 shows the catch series (1971–2013) for North Atlantic blue shark available for the 2015 stock assessment (SA2015), the 2008 stock assessment catches (SA2008), and the catch series obtained using shark-fin ratios (three different series, see for example Clarke *et al.,* 2006). Both stock assessment series followed a similar trend (but with large differences in some years) with catches oscillating several times between 15 000 t and 55 000 t. The three shark-fin series showed completely different trends (continuous upward trend) with catches starting around 10 000 t in the 1980s and growing to nearly 60 000 t in 2011 (Anon., 2015). Generally, the overall data for blue shark (and sharks in general) reported to ICCAT has improved over time (more complete series by species, lesser quantities of unclassified sharks, less weight of unclassified gears in the shark series, etc.). However, many unclassified shark species, mostly grouped by family (e.g. Lamnidae, Carcharhinidae, Sphyrnidae) and genera (e.g. *Rhizoprionodon, Carcharhinus, Sphyrna* and *Alopias* spp.) were reported to ICCAT in the past. The largest portion of unclassified sharks (1982–2013) is concentrated in longline and gillnet fisheries (Anon., 2015).

Japanese catches (landings and discards) from tuna longliners in the North Atlantic are estimated to have fluctuated between 1400–2400 t in 2006–2014, but a large increase to about 8200 t was observed in 2015. These are higher than reported landings of the target species (bluefin tuna) from Japanese longliners in this period (ICCAT, 2008). Another study of Japanese bluefin tuna longline fisheries showed that the ratio of blue shark to the target species was about 1:1 (Boyd, 2008). Data from observations onboard a Chinese Taipei (Taiwanese) vessel targeting bluefin tuna in the southern part of the North Atlantic showed that blue shark accounted for 76% of shark bycatch, though no information was presented on the percentage of blue shark in the total catch (Dai and Jang, 2008). Together, blue shark and shortfin mako account for between 69% and 72% of catches from Spanish and Portuguese surface longliners in the North Atlantic (Oceana, 2008).

The most recent ICCAT data publicly available for Task 1 data (landings and dead discards) for blue shark from the North Atlantic indicated a decrease in 2017–2020 (though 2019 data may be incomplete) compared to 2016 (Table 8.3). The landings in 2020 (20.827 t) are well below the TAC.

This would imply a reduction in landings in line with the ICCAT Recommendations relating to catch limits (see Section 8.2.3).

8.3.2 Discards

Historically, the relative low value of blue shark meant that it was not always retained for the market, with the fins the most valuable body part. In some fisheries the fins were retained and the carcasses discarded. In 2013, the EU prohibited this practice (see Section 8.2.4).

Accurate estimates of discarding are required to quantify total removals from the stock. Currently no such estimates are available. Differences between estimated and reported catch in various fisheries (ICCAT, 2008 and references cited therein) suggest that discarding is widespread in fisheries taking blue shark.

Discard estimates are available for fisheries from Chinese Taipei, Korea Rep., USA, and UK (Bermuda) in recent years and from 2000 onwards from USA. However, they represent a limited part of total discards. The full extent of blue shark bycatch cannot be assessed using the data available, but evidence suggests that longline operations can catch more blue sharks than target species. There is considerable bycatch of blue sharks in Japanese and Taiwanese tuna longliners operating in the Atlantic. However, it is not possible, to estimate discard rates from these fleets from the information available. Discards are generally assumed to be far higher than reported (Campana *et al*., 2005), especially in high seas fisheries.

Information on elasmobranchs discards in demersal otter trawl, deep-water set longlines, set gillnet and trammel net fisheries for ICES Division 9.a (2004–2013) showed that blue shark was caught infrequently and discarded in the longline fishery but not in the other fisheries (Prista *et al*., 2014).

8.3.3 Discard survival

Blue shark is one of the most frequent shark species captured in pelagic longline fisheries, and there are several estimates of survival (Boggs, 1992; Francis *et al*., 2001; Campana *et al*., 2005; Diez and Serafy, 2005). It is thought that most discards of whole sharks would be alive on return to the sea. For instance, discard survival rates are estimated to be about 60% in longline fisheries and 80% in rod and reel fisheries (Campana *et al*., 2005). More generally, the at-vessel mortality of longline-caught blue shark ranges from about 5–35% (summarised in Ellis *et al.*, 2017). Discard survival in such fisheries can be influenced by several factors, including hook type, soak time and size of shark.

However, discarding can increase overall mortality attributable to fisheries: a study conducted on Canadian pelagic longliners targeting swordfish in the Northwest Atlantic (Campana *et al.*, 2009) showed that "*overall blue shark bycatch mortality in the pelagic longline fishery was estimated at 35%, while the estimated discard mortality for sharks that were released alive was 19%. The annual blue shark catch in the North Atlantic was estimated at about 84 000 t, of which 57 000 t is discarded. A preliminary estimate of 20 000 t of annual dead discards for North Atlantic blue sharks is similar to that of the reported nominal catch, and could substantially change the perception of population health if incorporated into a population-level stock assessment*".

The survival rate at hauling for blue shark was estimated to be 49% for the French pelagic longliners targeting swordfish in the southwest Indian Ocean. Field trials conducted with gears equipped with hook timers indicated that 29% were alive 8 h after their capture (Poisson *et al.*, 2010). The survival rate of blue shark (at haul back) after a night-time soak may be lower than that during day-time soaks.

8.3.4 Quality of catch data

Catch data are incomplete, and the extent of finning in high seas fisheries is unclear. The historical use of generic shark categories is also problematic, although European countries now report more species-specific data.

In 2012, the ICCAT Secretariat noted some large discrepancies between the data in the EUROSTAT database and that of the ICCAT database, with EUROSTAT records showing captures almost double those of ICCAT in recent years.

Methods developed to identify shark species from fins (Sebastian *et al*., 2008; Holmes *et al*., 2009) could help to gather data on species targeted by illegal fishers, this information will greatly assist in management and conservation.

The variability of blue shark mortality estimates, relating to the proportion of live discards, hampers the estimation of total removals, although there are improving approaches to reporting of live discards to the ICCAT SCRS (Anon., 2015).

Given the uncertainty on the 2015 assessment of blue shark North Atlantic stock, ICCAT recommended continued monitoring of the fisheries by observer and port sampling programmes (ICCAT, 2015).

8.4 Commercial catch composition

No new information.

8.4.1 Conversion factors

Information on the length–weight relationship is available from several scientific studies (Table 8.4), as are the relationships between various length measurements (Table 8.5a and 8.5b). Campana *et al*., 2005 calculated the conversion relationships between dressed weight (W_D) and live weight or round weight (W_R) for NW Atlantic blue shark (n = 17) to be $W_R = 0.4 + 1.22\ W_D$ and $W_D = 0.2 + 0.81\ W_R$.

For French fisheries, the proportion of gutted fish to round weight is 75.19%. There is also a factor for landed round weight to live weight (96.15%), meaning that there is a 4% reduction in weight because of lost moisture (Hareide *et al*., 2007). Various estimates of fin weight to body weight are available (Mejuto and García-Cortés, 2004; Santos and Garcia, 2005; Hareide *et al*., 2007; Santana-Garcon *et al*., 2012; Biery and Pauly, 2012).

8.5 Commercial catch and effort data

For the North Atlantic stock, reported catches showed an increase in 1998, followed by a gradual decline until 2002 and then an increase (Figure 8.3). The CPUE input data available were comprehensively described and presented in the 2015 blue shark data preparatory meeting report (Anon., 2015). Following the work conducted for the 2008 SCRS blue shark stock assessment, CPUE were combined through a GLM with two choices of weighting: by the catch of the flag represented by each index and by the area of the flag represented by each index. Additionally, a hierarchical index of abundance that combines all available indices into a single series was also developed. However, it was noted that the process of combining CPUE indices was discouraged as they tend to mask the individual trends of the series and the underlying reasons as to why the series are different. It also indicated that some models can stochastically make use of the different series without need to combine these indices. It was suggested that it may be more useful to group CPUEs according to similar trends, and to include these as separate scenarios as was discussed during the 2015 bigeye tuna assessment.

Table 8.6 shows the various CPUE indices currently available (EU-Portugal, EU-Spain, USA, Japan, Chinese Taipei, and Venezuela), which have been considered for use in the assessment. These CPUE indices show a relatively flat trend throughout the time-series, but with high variance (Tables 8.6–8.7; Figure 8.5).

8.6 Fishery-independent surveys

No fishery-independent data are available for the NE Atlantic, although such data exist for parts of the NW Atlantic (Hueter *et al*., 2008). A survey from 1977–1994 conducted by the US NMFS documented a decline among juvenile male blue sharks by 80%, but not among juvenile females, which also occur in fewer numbers in the area, the western North Atlantic off the coast of Massachusetts (Hueter *et al*., 2008). The authors concluded that vulnerability to overfishing in blue sharks is present despite their enhanced levels of fecundity relative to other carcharhinid sharks.

8.7 Life-history information

Blue shark has one of the widest ranges of all the shark species, being common in pelagic, oceanic waters in tropical and temperate oceans worldwide, as well as closer to shore (Coelho *et al*., 2018). Various papers have reviewed the biology of blue shark (Nakano & Seki, 2003; da Silva *et al*., 2021).

In a satellite telemetry study, Queiroz *et al.* (2010) described complex and diverse types of behaviour depending on water stratification and/or depth (Figure 8.6). Females tagged in the Western channel were able to spend up to 70 days in the shelf edge area in the Bay of Biscay; whereas tagged juveniles showed relatively extensive vertical movements away from the southern nursery areas. Results indicated that the species inhabited waters with a wide temperature range (10–20°C).

The US National Marine Fisheries Service also conducts a Cooperative Shark Tagging Programme (CSTP; Kohler *et al*., 1998; NMFS, 2006), with tagging in the NE Atlantic also being undertaken under the auspices of the Inshore Fisheries Ireland (formerly the Irish Central Fishing Board) Tagging Programme (Green, 2007 WD) and UK Shark Tagging Programme, and there have been other earlier European tagging studies (e.g. Stevens, 1976). The tag and release results presented by ICCAT (2012; Figure 8.7) highlights the large number of blue shark tagged to date, and the extensive horizontal movements undertaken by blue shark in the Atlantic.

In Australian waters, blue shark exhibits oscillatory dive behaviour between the surface layers to as deep as 560–1000 m. Blue sharks mainly occupied waters of 17.5–20.0°C and spent 35–58% of their time in <50 m depths and 10–16% of their time >300 m (Stevens *et al*., 2010). The distribution and movements of blue sharks are strongly influenced by seasonal variations in water temperature, reproductive condition and prey availability. Blue shark often occurs in large single-sex schools containing individuals of similar size.

Adult blue sharks have no known predators, although sub-adults and juveniles are eaten by shortfin mako, white shark and sea lions. Fishing is likely to be a major contributor to adult mortality. An estimation of fishing mortality rate via satellite tagged sharks being recaptured by fishing vessels ranged from 9–33% (Queiroz *et al*., 2010).

Various studies have compiled biological information on this species in the North Atlantic and other areas, with some of these data summarized in Tables 8.4 (length–weight relationships), 8.3a and 8.3b (length–length relationships), Table 8.8 (growth parameters) and Table 8.9 (other life-history parameters). Based on life-history information, the blue shark is considered to be among the most productive shark species (ICCAT, 2008).

New life history inputs were obtained from data first assembled at the ICCAT 2014 Intersessional Meeting of the Shark Species Group (SCRS/2014/012) and additional information provided during the 2015 blue shark data preparatory meeting (SCRS/2015/142). These included maximum population growth rates (rmax) and steepness (h) values of the Beverton–Holt stock–recruitment relationship for North and South Atlantic stocks of blue shark, based on the latest biological information available gathered at the 2015 blue shark data preparatory meeting. To encompass a plausible range of values, uncertainty in the estimates of life history inputs (reproductive age, lifespan, fecundity, von Bertalanffy growth parameters, and natural mortality) was incorporated through Monte Carlo simulation by assigning statistical distributions to those biological traits in a Leslie matrix approach. Estimated productivity was high (rmax = 0.31–0.44 y^{-1} for the North Atlantic stock), similar to other stocks of this species. Consequently, analytically derived values of steepness were also high (h = 0.73–0.93 for the North Atlantic stock).

The influence of different biological parameters (e.g. growth coefficients, reproductive periodicity, first maturation age, natural mortality and longevity) on estimated blue shark productivity was assessed. Age at first maturity and growth coefficients substantially influenced the estimated productivity (e.g. a low age at first maturity and high growth coefficient results in high productivity), and reproductive periodicity also affected productivity (i.e. a longer breeding period decreased productivity). Biological parameters should be carefully considered when they are used in the stock analysis, especially when estimated productivity is inconsistent with trends in abundance indices. The level of depletion experienced by blue shark stocks may affect the productivity or population growth through density dependence, and differences in environmental water temperature may also affect growth rates (Anon., 2015).

8.8 Exploratory assessment models

8.8.1 Previous assessments

In 2004, ICCAT completed a preliminary stock assessment (ICCAT, 2005). Although results suggested that the North Atlantic stock were above biomass in support of MSY, the assessment remained conditional on the assumptions made. These assumptions included (i) estimates of historical shark catch, (ii) the relationship between catch rates and abundance, (iii) the initial state of the stock in 1971, and (iv) various life-history parameters. It was pointed out that the data used for the assessment did not meet the requirements for proper assessment (ICCAT, 2006), and further research and better-resolved data collection was highly recommended.

In 2008, three models were used in stock assessment conducted by ICCAT (ICCAT, 2008 and references cited therein): a Bayesian surplus production model, an age-structured model that did not require catch data (catch-free model), and an age-structured production model. Results with the Bayesian surplus production model produced estimates of stock size well above MSY levels (1.5–2* B_{MSY}), and estimated F to be very low (at F_{MSY} or well below it). The carrying capacity of the stock was estimated so high that the increasing estimated catches (25–62 000 t over the time-series) generated very low F estimates. Sensitivity analyses showed that the stock size estimate was dependent on the weighting assigned to the Irish CPUE series. Equal weighting of this and the other series produced a stock size at around B_{MSY}. Other sensitivity analyses indicated similar results to the base case run, with the stock well above MSY levels.

The age-structured biomass model displayed different results with either a strong decrease in biomass throughout the series to about 30% of virgin levels, or a less pronounced decline. The prior for the virgin biomass assigned high values to a very small number of biomass values but also indicated that the range of plausible values of this parameter has a heavy tail. This is probably because there is not enough information in the data to update the model and thus provide a narrower range of plausible values and thus provide a more precise estimate of the biomass of the stock.

The age-structured model not requiring catch information estimated that F was higher than F_{MSY}, but still low and that the current SSB estimated at around 83% of virgin levels.

As a consequence of the results in 2008, ICCAT concluded that biomass was estimated to be above the level that would support MSY (ICCAT, 2008). These results agreed with earlier work (ICCAT, 2005). Stock status appeared to be close to unfished biomass levels and fishing mortality rates were well below those corresponding to the level at which MSY is reached. However, ICCAT (2008) pointed out that the results were heavily dependent on the underlying assumptions. In particular, the choice of catch data to be used, the weighting of CPUE series and various life-history parameters used as input in the model. ICCAT was unable to conduct sensitivity analyses of the input data and assumptions (ICCAT, 2008).

Owing to those weaknesses, no firm conclusions were drawn from the preliminary assessments conducted by ICCAT. ICCAT, 2008 stated that most models used predicted that this stock was not overfished but did not use these results to infer stock status and to provide management advice.

8.9 Stock assessment

The North Atlantic Blue shark stock was assessed by ICCAT in 2015 using two different approaches (see ICCAT, 2015 for more details): Bayesian Surplus Production Model (BSPM) and length-based age-structured models - Stock Synthesis (SS3).

The Bayesian Surplus Production Models adjusted consistently estimated a posterior distribution for *r* that was similar to the prior, and a posterior for *K* with a long right tail with high mean and CV (ICCAT, 2015). The estimated biomass trajectory stayed close to *K* for most runs, and the harvest rate estimate was low (Figure 8.8). The inclusion of a process error in the model did not improve the results. When each CPUE index was fitted separately, the posterior mean of *K* varied and the CVs were large, implying that none of the indices were particularly informative about the value of *K*.

Several SS3 runs were undertaken. Run 4 and 6 (see details below) which utilized multiplication factors to reduce the input sample size assigned to length composition data in the model likelihood resulted in reasonable convergence diagnostics (described below).

Model Run	Model Adjustments				
Preliminary Run 1	Natural weights used in model likelihood				
	Length composition input sample size (n = observed)				
	Abundance indices (inverse CV weighting; SCRS/2015/151)				
Preliminary Run 2	Same as Preliminary Run 1 + Adjust CV of S9 (ESP-LL-N)				
CV adjustment	Constant CV of 20% applied to S9 (ESP-LL-N)				
Preliminary Run 3	Same as Preliminary Run 2 + Adjust input sample size for length comp				
Sample size adjustments	Maximum length composition input sample size (n=200)				
Preliminary Run 4	Same as Preliminary Run 2 + Apply variance adjustment to length comp.				
Fleet	F1	F2	F3	F4	F5
Variance adjustments	0.01	0.01	0.1	0.1	0.1
Preliminary Run 5	Same as Preliminary Run 2 + Apply variance adjustment to length comp.				
Fleet	F1	F2	F3	F4	F5
Variance adjustments	0.0184	0.0478	0.0261	0.1373	0.2236
Preliminary Run 6	Same as Preliminary Run 2 + Apply variance adjustment to length comp.				
Fleet	F1	F2	F3	F4	F5
Variance adjustments	0.0019	0.0047	0.0046	0.0573	0.0403

Model fits to CPUE and length composition data were similar for both runs. The fitting to abundance tracked trends well and were within most annual 95% confidence intervals for many abundance indices, including S3 (JPLL-N-e), S4 (JPLL-N-l), S6 (US-Obs-cru), S7 (POR-LL), and S9 (ESP-LL-N) (Figures 8.9–8.10). Model fits tracked trends reasonably well for abundance index S2 (US-Obs), but were often outside annual 95% confidence intervals. Predicted abundance was flat for abundance indices S8 (VEN-LL) and S10 (CTP-LL-N), probably because of large 95% confidence intervals for S8 and high inter-annual fluctuations in the early years for S10. Indices S1 (US-Log) and S5 (IRL-Rec) were only included in the model for exploratory purposes, were not fit in the model likelihood (lambda = 0), and had no influence on model results or predicted values. Model fits to length composition were reasonable for aggregate data (Figure 8.11).

Both run 4 and run 6 resulted in sustainable spawning stock size and fishing mortality rates relative to maximum sustainable yield (Figures 8.12–8.14). However, run 6 (the model run with relatively less weight applied to the length composition data in the model likelihood) resulted in a relatively more depleted stock size, compared to run 4.

Both models suggested sustainable spawning stock size and fishing mortality rates relative to maximum sustainable yield. The model with a relatively lower sample size assigned to the length composition data resulted in a relatively more depleted stock size. However, model fits to length composition were insufficient for annual length composition data, for which a bimodal pattern was evident. This is related to spatial segregation of the population. It was suggested that more work should be done to improve the fits to length composition data before using the model to provide management advice.

8.10 Quality of assessments

At the 2015 ICCAT assessment meeting, considerable progress was made on the integration of new data sources (in particular size data) and modelling approaches (in particular model structure). Uncertainty in data inputs and model configuration was explored through sensitivity analyses, which revealed that results were sensitive to structural assumptions of the models. The production models showed a poor fit to the flat or increasing trends in the CPUE series combined with increasing catches. Overall, assessment results are uncertain (e.g. level of absolute abundance varied by an order of magnitude between models with different structures) and should be interpreted with caution.

For the North Atlantic stock, scenarios with the BSPM estimated that the stock was not overfished (B_{2013}/B_{MSY} = 1.50–1.96) and that overfishing was not occurring (F_{2013}/F_{MSY} = 0.04–0.50). Estimates obtained with SS3 varied more widely, but still predicted that the stock was not overfished (SSF_{2013}/SSF_{MSY} = 1.35–3.45) and that overfishing was not occurring (F_{2013}/F_{MSY} = 0.15–0.75). Comparison of results obtained in the assessment conducted in 2008 and the current assessment revealed that, despite significant differences between inputs and models used, stock status results did not change drastically (B_{2007}/B_{MSY} = 1.87–2.74 and F_{2007}/F_{MSY} = 0.13–0.17 for the 2008 base runs using the BSP and a catch-free age-structured production model).

8.11 Reference points

ICCAT uses F/F_{MSY} and B/B_{MSY} as reference points for stock status of this stock. These reference points are relative metrics rather than absolute values. The absolute values of B_{MSY} and F_{MSY} depend on model assumptions and results and are not presented by ICCAT for advisory purposes.

8.12 Conservation considerations

The global IUCN listing for blue shark is Near Threatened (Rigby *et al.*, 2019), and it has the same listing in European waters, although is listed as Critically Endangered in the Mediterranean Sea (https://www.iucnredlist.org).

Blue shark was listed on Appendix II of the Convention on the Conservation of Migratory Species of Wild Animals (CMS) in 2017. However, it was not subsequently listed on Annex 1 of the Sharks-MoU.

8.13 Management considerations

Based on the scenarios and models explored, ICCAT considered the status of the North Atlantic stock as unlikely to be overfished nor subject to overfishing. However, due to the level of uncertainty, no specific management recommendations have been developed until 2017. Since 2017 Recommendation 16–12 is in place which states: "*If the average total catch of the North Atlantic blue shark in any consecutive two years from 2017 onward exceeds the average level observed during the period 2011–2015 (i.e. 39 102 t), the Commission shall review the implementation and effectiveness of these measures. Based on the review and the results of the next stock assessment scheduled for 2021 or at an earlier stage if enough information is provided to SCRS, the Commission shall consider introduction of additional measures*".

A further update in 2019 in Recommendation 19-07 is a follows: "*If in any year the total catches of the North Atlantic blue shark exceed the TAC, the Commission shall review the implementation of these measures. Based on the review and the results of the next stock assessment scheduled for 2021 or at an earlier stage if enough information is provided to the SCRS, the Commission shall consider introduction of additional measures*." In this same Recommendation (19-07) catch limits for the EU, Japan and Morocco were set.

Catch data are highly unreliable. Some CPUE series exist, and where data are available, show a relatively flat trend throughout the time-series, but with high variance. Further work is required to explain the trends and to better quantify removals from the stock.

Catch data are considered incomplete, and underestimated. There have been unaccounted discards and a substantial occurrence of finning over parts of the time series. Data reported to ICES, ICCAT and FAO can vary.

For accurate stock assessments of pelagic sharks, better fishery data are required. In addition, reporting procedures must be strengthened so that all landings are reported, and that landings are reported to species level, rather than generic "shark nei" categories. In the absence of reliable landings and catch data, catch ratios and market information derived from observers can provide useful information for understanding blue shark fishery dynamics.

For the North Atlantic stock, smaller sized blue sharks have been observed to dominate north of 30ºN, while larger sized blue sharks dominated south of 30ºN. In order to be able to account for the differences in size composition of fish in different areas, future implementations of SS3 should consider this spatial structure in the fleets. This will require estimating fleet and area specific CPUE indices, catch and size distributions. Ideally the model could also be separated by sex.

Blue shark is considered to be one of the most productive sharks in the North Atlantic. As such, it can be expected to be more resilient to fishing pressure than other pelagic sharks. However, the high degree of susceptibility to longline fishing and the poor quality of the information available to assess the stock is a cause for concern. Given the uncertainty of the results and that this species is a significant bycatch, especially in tuna and billfish fisheries, there is a need for continued monitoring of the fisheries by observer and port sampling programmes. There are currently no fishery-independent data available for that part of the stock in the ICES area.

8.14 References

Aasen, O. 1966. Blahaien, *Prionace glauca* (Linnaeus, 1758). *Fisken og Havet*, 1: 1–15.

Anon. 2015. Report of the 2015 blue shark data preparatory meeting. Tenerife, Spain, March 23 to 27: 33 p.

Biery, L., and Pauly, D. 2012. A global review of species-specific shark fin to body mass ratios and relevant legislations. *Journal of Fish Biology*, 80: 1643–1677.

Boggs, C. H. 1992. Depth, capture time and hooked longevity of longline-caught pelagic fish. Timing bites of fish with chips. *Fishery Bulletin*, 90:642−658.

Boyd, J. M. 2008. The Japanese bluefin tuna longline fishery in the Northeast Atlantic: Report of an Irish observer. Irish Fisheries Investigations No.20/2008.

Buencuerpo, V., Ríos, S., and Morón, J. 1998. Pelagic sharks associated with the swordfish, *Xiphias gladius*, fishery in the eastern North Atlantic Ocean and the Strait of Gibraltar. *Fishery Bulletin*, 96: 667–685.

Campana, S. E., Joyce, W., and Manning, M. J. 2009. Bycatch and discard mortality in commercially caught blue sharks *Prionace glauca* assessed using archival satellite pop-up tags. *Marine Ecology Progress Series*, 387: 241–253.

Campana, S. E., Marks, L., Joyce, W. Kohler, N. 2005. Catch, by-catch, and indices of population status of blue shark (*Prionace glauca*) in the Canadian Atlantic. *ICCAT Collective Volume of Scientific Papers*, 58(3): 891–934.

Campana, S., Gonzalez, P., Joyce, W. And Marks, L. 2002. Catch, bycatch and landings of blue shark (*Prionace glauca*) in the Canadian Atlantic. Canadian Stock Assessment, Research Document, 2002/101, Ottawa.

Castro, J. I. 1983. The sharks of North American waters. Texas A&M Univ. Press, College Station, TX, 180 pp.

Castro, J. A. and Mejuto, J. 1995. Reproductive parameters of blue shark, *Prionace glauca*, and other sharks in the Gulf of Guinea. *Marine Freshwater Research*, 46: 967–973.

Clarke S. C., McAllister, M. K., Milner-Gulland, E. J., Kirkwood, G. P., Michielsens, C. G. J., Agnew, D. J., Pikitch, E. K., Nakano, H. And Shivji M. S. 2006. Global estimates of shark catches using trade records from commercial markets. *Ecology Letters*, 9: 1115–1126.

Coelho, R., Mejuto, J., Domingo, A., Yokawa, K., Liu, K.M. *et al.* 2018. Distribution patterns and population structure of the blue shark (*Prionace glauca*) in the Atlantic and Indian Oceans. *Fish and Fisheries*, 19: 90–106.

Cortés, E. 1999. Standardized diet compositions and trophic levels of sharks. *ICES Journal of Marine Science* 56: 707–717.

Dai, X.J and Jiang, R.L. 2008. Shark bycatch observation in the ICCAT waters by Chinese longline observer in 2007. ICCAT SCRS/2008156.

da Silva, T. E. F., Lessa, R. and Santana, F. M. 2021. Current knowledge on biology, fishing and conservation of the blue shark *(Prionace glauca*). *Neotropical Biology and Conservation*, 16: 71–88.

Díez G., Santurtún, M., Ruiz, J., Iriondo, A., Gonzalez. I. And Artetxe, I. 2007. The long line Basque fishery on blue shark (*Prionace glauca*) in the Bay of Biscay (1998–2006). Working Document for ICES Working Group on Elasmobranch Fishes, Galway. 22–28 June, 2007, 9 pp.

Diez, G. A., and J. E. Serafy. 2005. Longline-caught blue shark (*Prionace glauca*): factors affecting the numbers available for live release. *Fishery Bulletin* 103: 720−724.

Ellis, J. R., McCully, S. R. and Poisson, F. 2014. A global review of elasmobranch discard survival studies and implications in relation to the EU 'discard ban'. Working Document to the ICES Working Group on Elasmobranch Fishes, Lisbon, Portugal. June 2014. 48 pp.

Fitzmaurice, P, Green, P., Keirse, G., Kenny, M. And Clarke, M. 2005. Stock discrimination of blue shark, based on Irish tagging data. ICCAT Collective Volume of Scientific Papers, 58(3): 1171–1178.

Francis, M. P., and Duffy, C. 2005. Length at maturity in three pelagic sharks (*Lamna nasus, Isurus oxyrinchus,* and *Prionace glauca*) from New Zealand. *Fishery Bulletin* 103: 489–500.

Francis, M. P., L. H. Griggs and S. J. Baird. 2001. Pelagic shark bycatch in the New Zealand tuna longline fishery. Mar. Freshwat. Res. 52:165−178.Francis, M. P. And Duffy, C. 2005. Length at maturity in three pelagic sharks (*Lamna nasus*, *Isurus oxyrinchus* and *Prionace glauca*) from New Zealand. *Fishery Bulletin*, 103: 489–500.

García-Cortés, B. and J. Mejuto. 2002. Size–weight relationships of the swordfish (*Xiphias gladius*) and several pelagic shark species caught in the Spanish surface longline fishery in the Atlantic, Indian and Pacific Oceans. *ICCAT Collective Volume of Scientific Papers*, 54 (4): 1132–1149.

Green, P. 2007. Central Fisheries Board Tagging Programme 1970 to 2006. Working document to WGEF 2007 (PowerPoint display).

Hareide, N. R., Carlson, J., Clarke, M., Clarke, S., Ellis, J., Fordham, S., Fowler, S., Pinho, M., Raymakers, C., Serena, F., Seret, B. and Polti, S. 2007. European Shark Fisheries: a preliminary investigation into fisheries, conversion factors, trade products, markets and management measures. European Elasmobranch Association EEA 2007, 71 pp.

Hastings, A. (1993). Complex interactions between dispersal and dynamics: Lessons from coupled logistic equations. Ecology, 74, 1362–1372.

Heessen, H. J. L. (Ed.) 2003. Development of elasmobranch assessments DELASS. Final report of DG Fish Study Contract 99/055, 605 pp.

Henderson, A. C., Flannery, K. And Dunne, J. 2001. Observations on the biology and ecology of the blue shark in the North-east Atlantic. *Journal of Fish Biology*, 58: 1347–1358.

Holmes, B. H., Steinke D. and Ward R. D. 2009. Identification of shark and ray fins using DNA barcoding. *Fisheries Research*, 95: 280–288.

Hueter, R. E. and Simpfendorfer, C. 2008. Case study: Trends in blue shark abundance in the western North Atlantic as determined by a fishery-independent survey. In: *Sharks of the Open Ocean* (M. D. Camhi, E. K. Pikitch and E. Babcock, Eds.), 236–241.

ICCAT. 2005. Report of the 2004 Inter-sessional Meeting of the ICCAT Subcommittee on Bycatches: Shark Stock Assessment. SCRS/2004/014.

ICCAT. 2006. Chapter 8.12 SHK-Sharks Report of the Standing Committee on Research and Statistics (SCRS) ICCAT. PLE-014/2006 Madrid, Spain, October 2–6, 2006. 106–113.

ICCAT. 2008. Report of the 2008 shark stock assessments meeting. Madrid, Spain, 1–5 September, 2008. SCRS/2008/017–SHK Assessment, 89 pp.

ICCAT. 2012. Chapter 4.1 Shortfin Mako Stock Assessment and Ecological Risk Assessment Meeting. Olhao, Portugal June 11–18, 2012.

ICCAT. 2014. Inter-sessional meeting of the sharks species group. Piriapolis, Uruguay, March 10–14 2014; 72 pp. (www.iccat.int/Documents/Meetings/Docs/2014_SHK_INTER-SESS_REP.pdf).

ICCAT. 2015. Report of the 2015 ICCAT blue shark stock assessment session Oceanário de Lisboa, Lisboa, Portugal July 27 to 31, 2015, 115 pp. (https://www.iccat.int/Documents/Meetings/Docs/2015_BSH%20ASSESS_original.pdf).

Kohler, N. E., Casey, J. G. and Turner, P. A. 1995. Length–weight relationships for 13 species of sharks from the western North Atlantic. *Fishery Bulletin*, 93: 412–418.

Kohler, N. E., Casey, J. G. and Turner, P. A. 1998. NMFS cooperative shark tagging programme, 1962–1993: An atlas of shark tag and recapture data. *Marine Fisheries Review*, 60: 86 pp.

Kohler, N. E., Turner, P. A., Hoey, J. J., Natanson, L. J., and Briggs, R. 2002. Tag and recapture data for three pelagic shark species: blue shark (*Prionace glauca*), shortfin mako (*Isurus oxyrinchus*), and porbeagle (*Lamna nasus*) in the North Atlantic Ocean. *ICCAT Collective Volume of Scientific Papers*, 54 (4): 1231–1260.

MacNeil, M. A. and Campana, S. E. 2002. Comparison of whole and sectioned vertebrae for determining the age of young blue shark (*Prionace glauca*). *Journal of Northwest Atlantic Fishery Science*, 30: 77–82.

Mejuto, J. and García-Cortés, B. 2004. Preliminary relationships between the wet fin weight and body weight of some large pelagic sharks caught by the Spanish surface longline fleet. *ICCAT Collective Volume of Scientific Papers*, 56(1): 243–253.

Mejuto, J. and García-Cortés, B. 2005. Reproductive and distribution parameters of the blue shark *Prionace glauca*, on the basis of on-board observations at sea in the Atlantic, Indian and Pacific Oceans. *ICCAT Collective Volume of Scientific Papers*, 58(3): 951–973.

Mitchell, J.D., Collins, K.J., Miller, P.I. and Suberg, L.A. 2014. Quantifying the impact of environmental variables upon catch per unit effort of the blue shark *Prionace glauca* in the western English Channel. *Journal of Fish Biology*, 85: 657–670.

Nakano, H. and Seki, M. P. 2003. Synopsis of biological data on the blue shark, *Prionace glauca* Linnaeus. *Bulletin Fisheries Research Agency Japan*, 6: 18–55.

NMFS. 2006. Final Consolidated Atlantic Highly Migratory Species Fishery Management Plan. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Sustainable Fisheries, Highly Migratory Species Management Division, Silver Spring, MD. Public Document. 1600 pp.

Oceana. 2008. Description of European Union surface longline fleet operating in the Atlantic Ocean and compilation of detailed EuroStat data on shark catches by EU fleets in the Atlantic shark catches. ICCAT SCRS 2008/158.

Ovenden, J. R., Kashiwagi, T., Broderick, D., Giles, J., and Salini, J. 2009. The extent of population genetic subdivision differs among four co-distributed shark species in the Indo-Australian archipelago. BMC Evolutionary Biology, 9.

Palma, C., Ortiz, M., de Bruyn, P., Kell, L. and Pallares, P. 2012. Building a consolidated database to cross-check ICCAT Task-I nominal catch, against EUROSTAT and FAO equivalent statistics. *ICCAT SCRS 2012/078*.

Poisson, F., Gaertner, J.C., Taquet, M., Durbec, J.P., and Bigelow, K. 2010. Effects of lunar cycle and fishing operations on longline-caught pelagic fish: fishing performance, capture time, and survival of fish. *Fishery Bulletin*, 108:268–281.

Pratt, H. L. 1979. Reproduction in the blue shark, *Prionace glauca*. *Fishery Bulletin*, 77: 445–470.

Prista, N., Fernandes, A.C., Maia, C., Moura, T. and Figuerido, I. 2014. Discards of elasmobranchs in the Portuguese fisheries operating in ICES Division XIa: Bottom otter trawl, deep-water set longlines, set gillnet and trammel net fisheries (2004–2013). Working document to ICES WGEF 2014.

Rigby, C.L., Barreto, R., Carlson, J., Fernando, D., Fordham, S., Francis, M. P., Herman, K., Jabado, R. W., Liu, K. M., Marshall, A., Pacoureau, N., Romanov, E., Sherley, R. B. and Winker, H. 2019. *Prionace glauca*. The IUCN Red List of Threatened Species 2019: e.T39381A2915850. https://dx.doi.org/10.2305/IUCN.UK.2019-3.RLTS.T39381A2915850.en. Downloaded on 18 June 2021.

Queiroz, N, Humphries, N.E., Noble, L.R., Santos, A. M. and Sims, D. W. 2010. Short-term movements and diving behaviour of satellite-tracked blue sharks *Prionace glauca* in the northeastern Atlantic Ocean. *Marine Ecology Progress Series*, 406: 265–279.

Santana-Garcon, J., Fordham, S. and Fowler, S. 2012. Blue shark *Prionace glauca* fin-to-carcass-mass ratios in Spain and implications for finning ban enforcement. *Journal of Fish Biology*, 80: 1895–1903.

Santos, M. N., and Garcia, A. 2005. Factors for conversion of fin weight into round weight for the blue shark (*Prionace glauca*). *ICCAT Collective Volume of Scientific Papers*, 58(3): 935–941.

SCRS, 2019. Report of the Standing Committee on Research and Statistics (SCRS), Madrid 30 September – 4 October 2019, ICCAT Commission, 459 pp.

Sebastian, H., Haye, P. A. and Shivji, M. S. 2008. Characterization of the pelagic shark-fin trade in north-central Chile by genetic identification and trader surveys. *Journal of Fish Biology*, 73: 2293–2304.

Skomal, G. B. and Natanson, L. J. 2002. Age and growth of the blue shark (*Prionace glauca*) in the North Atlantic Ocean. *ICCAT Collective Volume of Scientific Papers*, 54 (4): 1212–1230.

Skomal, G. B. and Natanson, L. J. 2003. Age and growth of the blue shark (*Prionace glauca*) in the North Atlantic Ocean. *Fishery Bulletin*, 101:627–639.

Skomal, G. B. 1990. Age and growth of the blue shark, *Prionace glauca*, in the North Atlantic. Master's Thesis. University of Rhode Island, Kingston, RI. 82 pp.

Smith, S. E., Au, D. W. and Show, C. 1998. Intrinsic rebound potentials of 26 species of Pacific sharks. *Marine and Freshwater Research*, 49: 663–78.

Stevens, J. D., Bradford, R. W., West, G. J. 2010. Satellite tagging of blue sharks (*Prionace glauca*) and other pelagic sharks of eastern Australia: depth behaviour, temperature experience and movements. *Marine Biology*, 157: 575–591.

Stevens, J. D. 1975. Vertebral rings as a means of age determination in the blue shark (*Prionace glauca*). *Journal of the Marine Biological Association of the United Kingdom*, 55: 657–665.

Stevens, J. D. 1976. First results of shark tagging in the North-east Atlantic, 1972–1975. *Journal of the Marine Biological Association of the United Kingdom*, 56: 929–937.

Taguchi, M., King, J. R., Wetklo, M., Withler, R. E., and Yokawa, K. 2015. Population genetic structure and demographic history of Pacific blue sharks (*Prionace glauca*) inferred from mitochondrial DNA analysis. *Marine and Freshwater Research*, 66, 267–275-

Vas, P., 1990. The abundance of the blue shark, *Prionace glauca*, in the western English Channel. *Environmental Biology of Fishes*, 29(3), pp.209–225.

Veríssimo, A., Sampaio, Í., McDowell, J. R., Alexandrino, P., Mucientes, G., Queiroz, N., Silva, C., Jones,C. S., and Noble, L. R. 2017. World without borders—genetic population structure of a highly migratory marine predator, the blue shark (*Prionace glauca*). *Ecology and Evolution*. 1–14.

Table 8.1. Blue shark in the North Atlantic. Reported catch (t) of North Atlantic blue shark by ICCAT Statistical Area (1990-2020). Data source: ICCAT Task 1 catch data (accessed 16 June 2020; version of 27/01/2022). These are considered underestimates, especially prior to 1997.

Year	BIL91	BIL92	BIL93	BIL94A	BIL94B	BIL94C	Total
1990	1.8	481	16	680	1520	339	3038
1991	1.0	682	11	774	2445	393	4306
1992	0.2	400	24	1277	1860		3561
1993	1.9	1816	24	1702	6048		9591
1994	1.9	600	19	1260	5020		6901
1995	0.9	368	16	1494	5002	272	7153
1996	2.1	541	29	528	5124	695	6919
1997	0.6	300	40	831	12397	12547	26116
1998		357	10	612	9706	13051	23736
1999	1.2	248	48	547	11899	12654	25396
2000	0.8	359	44	624	9381	14844	25253
2001	9.3	106	47	581	8034	9440	18218
2002	0.5	22	35	836	7301	8835	17029
2003		10	40	349	8175	11143	19717
2004		54	12	966	6665	12245	19943
2005	0.5	26	28	1135	7955	11125	20269
2006		24	12	1098	7129	11931	20194
2007	0.1	10	20	843	7243	12810	20926
2008	0.2	65	10	145	8180	14530	22931
2009	0.1	102	114	697	15574	17056	33543
2010	0.4	187	128	746	15591	19029	35681
2011	0.2	234	189	1885	12592	22939	37838
2012	0.7	98	195	1795	13992	20496	36576
2013	0.2	134	73	1824	13926	20850	36806
2014	0.7	91	149	961	14184	21193	36579
2015	0.7	98	155	220	18473	20680	39627
2016	0.3	213	131	9057	26301	8366	44068
2017	2.7	71	17	9806	22323	7445	39664
2018	4.1	81	6	8714	18582	6576	33964
2019	0.0	39	254	5432	16027	5445	27197
2020	0.0	193	175	3565	13019	4044	20997

Table 8.2. Blue shark in the North Atlantic. Reported catch (t) of North Atlantic blue shark by reporting category (C = catch, L = Landings, DD = Dead discards; 1990-2020). Data source: ICCAT Task 1 catch data (accessed 16 June 2020; version of 27/01/2022). These are considered underestimates, especially prior to 1997.

Year	C	DD	L	Total
1990	2209	741	88	3038
1991	3226	772	308	4306
1992	3161	184	215	3561
1993	7773	1136	682	9591
1994	6299	572	31	6901
1995	1789	618	4746	7153
1996	1089	704	5127	6919
1997	25723	180	214	26116
1998	23289	192	256	23736
1999	22870	100	2426	25396
2000	24150	137	966	25253
2001	17445	106	667	18218
2002	16080	68	881	17029
2003	19229	55	433	19717
2004	18898	65	980	19943
2005	19036	66	1168	20269
2006	19036	45	1113	20194
2007	20005	54	867	20926
2008	22671	130	131	22931
2009	30218	103	3222	33543
2010	27284	167	8230	35681
2011	29024	206	8608	37838
2012		120	36456	36576
2013		109	36697	36806
2014		128	36451	36579
2015		124	39503	39627
2016		88	43980	44068
2017		138	39526	39664
2018		113	33851	33964
2019		193	27004	27197
2020		418	20579	20997

Table 8.3a. Blue shark in the North Atlantic. Reported catch (t) of North Atlantic blue shark by nation (1990-2020). Data source: ICCAT Task 1 catch data (accessed 16 June 2020; version of 27/01/2022). These are considered underestimates, especially prior to 1997. Data shown for: Spain, Portugal, Japan, Canada, USA, Morocco, Belize, France, Panama, Korea Rep., Venezuela and Chinese Taipei.

Year	ESP	PRT	JPN	CAN	USA	MAR	BLZ	FRA	PAN	KOR	VEN	TWN	Total
1990		1387		680	829			130			9		3038
1991		2257		774	1080			187			7		4306
1992		1583		1277	400			276			24		3561
1993		5726		1702	1818			322			23		9591
1994		4669		1260	603			350			18		6901
1995		4722		1494	642			266			16		7153
1996		4843	274	528	988			278			6		6919
1997	24497		153	831	393			213			27		26116
1998	22504	0		612	448			163			7		23736
1999	21811	2209		547	317			399			47		25396
2000	24112			624	429						43		25253
2001	17362			581	145						47		18218
2002	15666	283		836	68			112			29		17029
2003	15975	3230		346	56			57			40		19717
2004	17314	1573		965	71						10		19943
2005	15006	4027		1134	68						28		20269
2006	15464	3591		977	47			99			12		20194
2007	17038	2960		843	54			4			19		20926
2008	20788	1935		0	139			12	40		8		22931
2009	24465	6252	2007	0	108		114	14	316		73		33543
2010	26094	6957	1763	0	236		461	24			75		35681
2011	27988	6509	1227	0	279		1035	14		537	117		37838
2012	28666	3768	2437	1	167		903	5		299	98	107	36576
2013	28562	3694	1808	0	160		1216	216	289	327	52	123	36806
2014	29041	3060	3287	1	166		392	132	153	113	113	83	36579
2015	30078	3859	4011	6	114	873	4	259		18	129	238	39627
2016	29019	7819	4217	16	74	1623	6	352	262	11	116	287	44068
2017	27316	5664	4444	32	67	1475	201	124	0	132	105	76	39664
2018	21685	5195	4111	71	30	1644	317	94	437	92	111	153	33964
2019	16314	4507	3855	4	36	1524	369	80	242	138	55	38	27197
2020	12325	3836	2328	193	32	1498	301	57	170	48	59	74	20997

Table 8.3b. Blue shark in the North Atlantic. Reported catch (t) of North Atlantic blue shark by nation (1990-2020). Data source: ICCAT Task 1 catch data (accessed 16 June 2020; version of 27/01/2022). These are considered underestimates, especially prior to 1997. Data shown for: China PR, United Kingdom, Ireland, St Vincent and Grenadines, Mauritania, Trinidad and Tobago, Senegal, Denmark, Barbados, Liberia and Mexico.

Year	CHN	GBR	IRL	VCT	MRT	TTO	SEN	DNK	BRB	LBR	MEX	Total
1990		0.6						2.0				3038
1991								1.0				4306
1992								1.0				3561
1993												9591
1994		0.3						1.0				6901
1995		11.8						2.0			0.1	7153
1996								3.0				6919
1997								1.0				26116
1998		0.8						1.0				23736
1999		0.1	65.7									25396
2000		12.0	31.0					2.0			0.1	25253
2001		9.3	66.0					1.0			6.1	18218
2002		5.6	11.1			6.0		13.0				17029
2003		3.8	1.9			2.9		5.0				19717
2004		6.2	0.1			2.3		1.0				19943
2005		5.4	0.3			0.6						20269
2006		3.4				0.7						20194
2007		6.0	0.3			0.4					0.1	20926
2008		6.0	0.2			1.9						22931
2009	88.0	96.1	0.0			8.2						33543
2010	52.8	8.3	0.4			9.4		0.1			0.3	35681
2011	108.8	10.3	1.3			10.5					0.1	37838
2012	97.6	8.2	2.9			10.8	4.6	0.1			0.2	36576
2013	326.7	9.7	1.9			8.3	11.9				0.2	36806
2014		10.1	0.8			9.9	16.8				0.7	36579
2015	1.2	12.2				3.5	12.7		8.5		0.1	39627
2016	27.3	16.8	0.0	118.9	93.3	1.6	2.9		5.7		0.2	44068
2017	2.4	11.3	0.4			1.8	4.3		6.8		0.1	39664
2018	5.7	6.3				0.3	1.5		4.1	7.2	0.0	33964
2019	17.9	3.3				0.3			2.2	9.6	0.0	27197
2020	65.4	2.7		2.0		0.1			2.4	3.3	0.0	20997

Table 8.3c. Blue shark in the North Atlantic. Reported catch (t) of North Atlantic blue shark by nation (1990-2020). Data source: ICCAT Task 1 catch data (accessed 16 June 2020; version of 27/01/2022). These are considered underestimates, especially prior to 1997. Data shown for: St Pierre et Miquelon, Netherlands, Russian Federation, Iceland, UK-Bermuda and Cape Verde.

Year	SPM	NLD	RUS	ISL	BMU	CPV	Total
1990							3038
1991							4306
1992							3561
1993							9591
1994						0.0	6901
1995							7153
1996							6919
1997							26116
1998							23736
1999							25396
2000							25253
2001							18218
2002							17029
2003							19717
2004							19943
2005							20269
2006							20194
2007							20926
2008		0.1					22931
2009	1.0	0.6					33543
2010							35681
2011							37838
2012					0.1		36576
2013					0.0		36806
2014	0.1			0.5	0.0		36579
2015					0.0		39627
2016					0.1		44068
2017			0.1		0.0		39664
2018	0.0		0.2		0.0		33964
2019			0.4		0.0		27197
2020			0.0		0.0		20997

Table 8.3c. Blue shark in the North Atlantic. Reported catch (t) of Mediterranean blue shark by nation (1990-2020). Data source: ICCAT Task 1 catch data (accessed 16 June 2020; version of 27/01/2022). Data shown for: Algeria, Chinese Taipei, Cyprus, Spain, France, Italy, Malta, Portugal, Japan and Libya.

Year	DZA	TWN	CYP	ESP	FRA	ITA	MLT	PRT	JAP	LBY	Total
1990							1.3				1.3
1991							3.4				3.4
1992							1.0				1.0
1993							0.4				0.4
1994							0.6		5.0		5.6
1995							1.4		7.0		8.4
1996							1.4		1.0		2.4
1997				146.5			2.2		1.0		149.7
1998				59.2			2.2	1.5			62.8
1999				20.3			1.6				21.8
2000			8.8	30.9			1.2	4.5			45.4
2001				5.6			0.8	40.9			47.3
2002				3.1			0.6	13.5			17.2
2003			3.4	2.9			0.4	2.9	1.0		10.6
2004			6.3	4.1		113.3	0.0		1.0		124.7
2005			4.8	8.2		0.8	0.5	55.6	2.0		71.8
2006				61.2		94.7	0.3	21.8	0.0		178.1
2007				3.0	0.4	46.1	0.6				50.1
2008		0.0		2.4	0.3	75.1	1.5		2.2		81.5
2009		0.0		7.0	0.5	175.5	1.7		0.3		184.9
2010		0.0		47.8	0.5	165.1	0.8	1.6			215.9
2011		0.0		38.2	0.4		1.1				39.7
2012		0.0		38.9	0.2		2.4				41.5
2013	0.0	0.0		37.1	3.7	56.8	2.4		0.0		100.0
2014	0.0	0.0		52.6	4.9	173.4	3.7		0.0		234.5
2015	0.6			65.0	14.5		5.3		0.0	580.0	665.4
2016		0.0		58.5		17.9	3.1			650.0	729.4
2017		0.0		39.9	2.4	58.7	3.6		0.0		104.6
2018	7.5	0.0		19.2	1.7	17.3	2.4		0.0	10.0	58.0
2019	3.5	0.0		17.5	2.4	33.0	1.6		0.0	6.0	63.9
2020	2.3	0.0		33.6	2.3	26.5	2.3		0.0	6.4	73.4

Table 8.4. Blue shark in the North Atlantic. Length–weight relationships for blue shark from different populations. Lengths in cm, and weights in kg unless specified in equation. W_R = round weight; W_D = dressed weight.

L (cm) W (kg) relationship	Sex	n	Length range (cm)	Source
W_D = (8.04021 x 10–7) L_F ^ 3.23189	C	354	75–250 (L_F)	García-Cortés and Mejuto, 2002
W_R = (3.1841 x 10–6) L_F ^ 3.1313	C	4529		Castro, 1983
W_R = (3.92 x 10–6) LT ^ 3.41	Male	17		Stevens, 1975
W_R = (3.184 x 10–7) L_T ^ 3.20	Female	450		Stevens, 1975
W_R = (3.2 x 10–6) L_F ^ 3.128	C	720		Campana *et al*., 2005
W_D = (1.7 x 10–6) L_F ^ 3.205	C	382		Campana *et al*., 2005

Table 8.5(a). Blue shark in the North Atlantic. Length–length relationships for male, female blue shark and both sexes combined from the NE Atlantic and Straits of Gibraltar (Buencuerpo *et al*., 1998). L_S = standard length; L_F = fork length; L_T = total length; L_{UC} = upper caudal lobe length.

Females	Males	Combined
L_F = 1.076 L_S + 1.862 (n = 1043)	L_F = 1.080 L_S + 1.552 (n = 1276)	L_F = 1.079 L_S + 1.668 (n = 2319)
L_T = 1.249 L_S + 7.476 (n = 1043)	L_T = 1.272 L_S + 4.466 (n = 1272)	L_T = 1.262 L_S + 5.746 (n = 2315)
L_{UC} = 0.219 L_S + 4.861 (n = 1038)	L_{UC} = 0.316 L_S + 2.191 (n = 1264)	L_{UC} = 0.306 L_S + 3.288 (n = 2302)
L_T = 1.158 L_F + 5.678 (n = 1043)	L_T = 1.117 L_F + 2.958 (n = 1272)	L_T = 1.167 L_F + 4.133 (n = 2315)

Table 8.5(b). Blue shark in the North Atlantic. Length–length relationships for both sexes combined of blue shark from various populations and sources.

Stock	Relationship	n	Source
NW Atlantic	L_F = (0.8313) L_T + 1.3908	572	Kohler *et al*., 1995
NE Atlantic	L_F = 0.8203 L_T –1.061		Castro and Mejuto, 1995
NW Atlantic	L_F = –1.2 +0.842 L_T	792	Campana *et al*., 2005
NW Atlantic	L_T = 3.8 + 1.17 L_F	792	Campana *et al*., 2005
NW Atlantic	L_{CF} = 2.1 + 1.0 L_{SF}	782	Campana *et al*., 2005
NW Atlantic	L_{SF} = –0.8 + 0.98 L_{CF}	782	Campana *et al*., 2005
NW Atlantic	L_F = 23.4 + 3.50 L_{ID}	894	Campana *et al*., 2005
NW Atlantic	L_{ID} = –4.3 + 0.273 L_F	894	Campana *et al*., 2005

Table 8.6. Blue shark in the North Atlantic. Indices of abundance for North and South Atlantic blue shark stocks. Source: ICCAT (2015).

			North Atlantic					
Year	Usobs	JPLLe	JPLLI	USOLD	PORLL	VENLL	ESPLL	CHTPLL
1957				0.98				
1958				0.48				
1959				1.11				
1960				1.18				
1961				1.13				
1962				1.5				
1963				0.7				
1964				0.87				
1965				1.55				
1966				1.27				
1967				1.43				
1968				1.31				
1969				1.96				
1970				0.97				
1971		0.87		1.08				
1972		1.46		1.93				
1973		1.12						
1974		2.62						
1975		1.85		0.88				
1976		1.07		0.75				
1977		1.89		1.82				
1978		1.58		1.06				
1979		1.3		0.860				
1980		2.21		0.830				
1981		2.19		1.050				
1982		2.08		0.780				
1983		1.81		1.010				
1984		1.22		0.680				
1985		1.51		0.740				
1986		1.52		0.480				
1987		2.13		0.500				
1988		1.21		0.440				
1989		1.51		0.800				
1990		1.34		0.940				
1991		1.26		1.220				
1992	7.455	1.9		0.63				
1993	11.076	2.43		0.95				
1994	9.717		2.33	0.98		0.047		
1995	10.17		2.1	0.73		0.073		
1996	8.208		2.05	0.47		0.017		
1997	14.439		2.05	1.25	158.14	0.154	156.83	
1998	18.408		1.72	1.16	169.02	0.216	154.45	
1999	6.663		1.89	0.76	149.83	0.117	179.91	
2000	9.541		1.58	0.78	201.44	0.151	213.05	
2001	2.306		1.71		222.14	0.133	215.63	
2002	2.277		1.37		200.86	0.074	183.94	
2003	1.876		1.97		238.77	0.044	222.88	
2004	9.503		1.79		266.16	0.034	177.27	0.749
2005	3.193		1.9		218.55	0.006	166.82	2.195
2006	4.674		2.16		212.63	0.013	177.11	1.308
2007	9.645		2.18		241.32	0.060	187.06	0.561
2008	8.512		2.48		225.68	0.088	215.80	0.495
2009	8.322		2.46		228.30	0.045	196.08	0.570
2010	13.545		2.45		276.76	0.040	209.03	0.877
2011	21.806		2.37		233.29	0.044	221.13	0.765
2012	8.128		2.6		305.53	0.107	238.00	0.668
2013	7.374		2.09		304.08	0.044	203.49	1.045

Table 8.7. Blue shark in the North Atlantic. Coefficients of variation (CVs) for North and South Atlantic blue shark stocks. Source: ICCAT (2015).

			North Atlantic					
Year	Usobs	JPLLe	JPLLl	USOLD	PORLL	VENLL	ESPLL	CHTPLL
1957				0.17				
1958				0.16				
1959				0.25				
1960				0.38				
1961				0.35				
1962				0.27				
1963				0.25				
1964				0.17				
1965				0.17				
1966				0.23				
1967				0.21				
1968				0.21				
1969				0.22				
1970				0.32				
1971		0.53		0.23				
1972		0.39		0.21				
1973		0.45						
1974		0.32						
1975		0.34		0.19				
1976		0.47		0.29				
1977		0.27		0.2				
1978		0.32		0.11				
1979		0.24		0.11				
1980		0.29		0.09				
1981		0.36		0.09				
1982		0.36		0.09				
1983		0.37		0.1				
1984		0.50		0.1				
1985		0.44		0.1				
1986		0.39		0.09				
1987		0.35		0.1				
1988		0.49		0.12				
1989		0.44		0.39				
1990		0.49		0.17				
1991		0.47		0.11				
1992	0.31	0.43		0.1				
1993	0.29	0.40		0.09				
1994	0.29		0.50	0.1		1.08		
1995	0.29		0.55	0.1		0.87		
1996	0.50		0.51	0.3		1.90		
1997	0.33		0.52	0.13	0.084	`	0.008	
1998	0.35		0.53	0.15	0.076	0.67	0.008	
1999	0.34		0.49	0.13	0.077	0.84	0.008	
2000	0.32		0.28	0.12	0.083	0.74	0.008	
2001	0.39		0.56		0.089	0.77	0.008	
2002	0.39		0.62		0.086	1.03	0.008	
2003	0.37		0.59		0.082	1.26	0.009	
2004	0.30		0.69		0.084	1.53	0.009	0.12
2005	0.35		0.71		0.087	3.88	0.010	0.19
2006	0.31		0.69		0.084	2.24	0.010	0.06
2007	0.32		0.61		0.085	1.35	0.011	0.22
2008	0.32		0.69		0.085	1.16	0.011	0.28
2009	0.31		0.64		0.086	1.56	0.012	0.17
2010	0.31		0.64		0.089	1.54	0.010	0.10
2011	0.29		0.51		0.079	1.51	0.010	0.12
2012	0.34		0.51		0.081	1.00	0.010	0.11
2013	0.31		0.21		0.085	1.84	0.011	0.14

Table 8.8. Blue shark in the North Atlantic. Von Bertalanffy growth parameters ($L\infty$ in cm (L_T), k in years^{-1}, t0 in years) from published studies.

Area	L∞	k	t0	Sex	Study
North Atlantic	394	0.133	–0.801	Combined	Aasen, 1966
North Atlantic	423	0.11	–1.035	Combined	Stevens, 1975
NW Atlantic	343	0.16	–0.89	Males	Skomal, 1990
NW Atlantic	375	0.15	–0.87	Females	Skomal, 1990
NE Atlantic	377	0.12	–1.33	Combined	Henderson *et al.*, 2001
North Atlantic	282	0.18	–1.35	Males	Skomal and Natanson, 2002
North Atlantic	310	0.13	–177	Females	Skomal and Natanson, 2002
North Atlantic	287	0.17	–1.43	Combined	Skomal and Natanson, 2003
NW Atlantic	300	0.68	–0.25	Combined	MacNeil and Campana, 2002 (whole ages)
NW Atlantic	302	0.58	–0.24	Combined	MacNeil and Campana, 2002 (section ages)

Table 8.9. Blue shark in the North Atlantic. Biological parameters for blue shark.

Parameter	Values	Sample Size	Area	Reference
Reproduction	Placental viviparity			various
Litter size	25–50 (30 average)			various
Size-at-birth	30–50 cm LT			Various
Sex ratio (males: females)	1.5:1		NE Atlantic	García-Cortés and Mejuto, 2002
	1:1.44		NE Atlantic	Henderson *et al.*, 2001
	1.33:1		NW Atlantic	Kohler *et al.*, 2002
	1:2.13		NE Atlantic	Kohler *et al.*, 2002
	1:1.07	801	NE Atlantic (N. coast Spain)	Mejuto and García-Cortés, 2005
	1:0.9	158	NE Atlantic (S. coast Spain)	
	1:0.38	2187	N central Atlantic	
	1:0.53	4550	NW Atlantic	
Gestation period	9–12 months			Campana *et al.*, 2002
% of females revealing fecundation signs	0.74	415	NE Atlantic (N. coast Spain)	Mejuto and García-Cortés, 2005
	0	76	NE Atlantic (S. coast Spain)	
	36.27	601	N central Atlantic	
	18.15	1573	NW Atlantic	
% of pregnant females	0	415	NE Atlantic (N. coast Spain)	Mejuto and García-Cortés, 2005
	0	76	NE Atlantic (S. coast Spain)	
	14.6	601	N central Atlantic	
	9.8	1573	NW Atlantic	

Parameter	Values	Sample Size	Area	Reference
Male age-at-maturity (years)	4–6			various
Female age-at-maturity (years)	5–7			various
Male length-at-maturity	180–280 cm (LF)		NW Atlantic	Campana *et al*., 2002
	190–195 cm (LF)			Francis and Duffy, 2005
	201 cm (LF; 50% maturity)		NW Atlantic	Campana *et al*., 2005
Female length-at-maturity	220–320 cm (LF)			Campana *et al*., 2002
	170–190 cm (LF)			Francis and Duffy, 2005
	> 185 cm (LF)			Pratt, 1979
Longevity (years)	16–20			Skomal and Natanson, 2003
Natural mortality (M)	0.23		Worldwide	Campana *et al*., 2005 (mean of various studies)
Productivity (R2m) estimate: intrinsic rebound	0.061 (assuming no fecundity increase)		Pacific	Smith *et al*., 1998
Potential rate of increase per year	43% (unfished)		NW Atlantic	Campana *et al*., 2005
Population doubling time TD (years)	11.4 (assuming no fecundity increase)		Pacific	Smith *et al*., 1998
Trophic level	4.1	14		Cortés, 1999

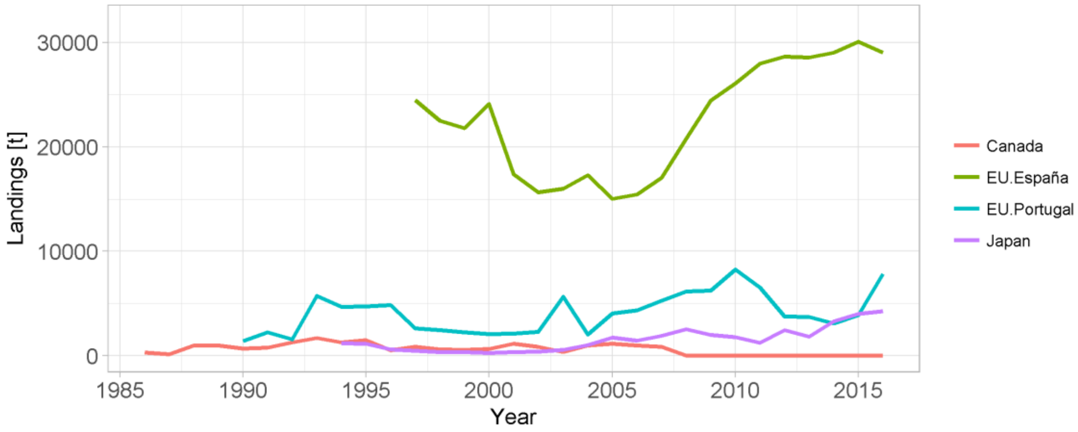


Figure 8.1. Blue shark in the North Atlantic. Preliminary estimates of landings of blue shark in the Atlantic for the four main countries (Source: ICCAT Task I data, Accessed June 2018).

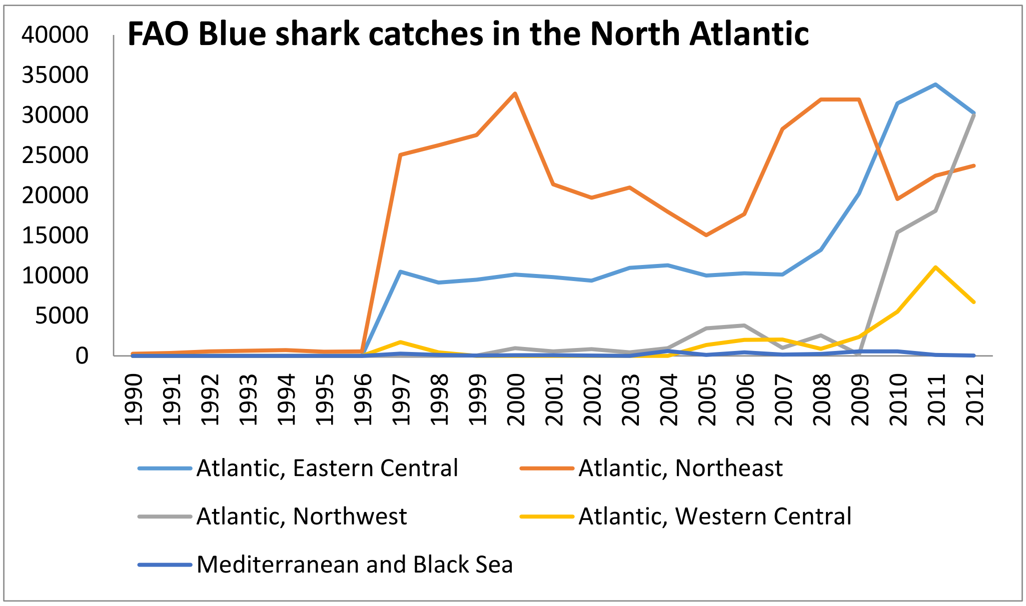


Figure 8.2. Blue shark in the North Atlantic. Preliminary estimates of landings of blue shark in the Atlantic Ocean for the different areas (Source: FAO, 2014).

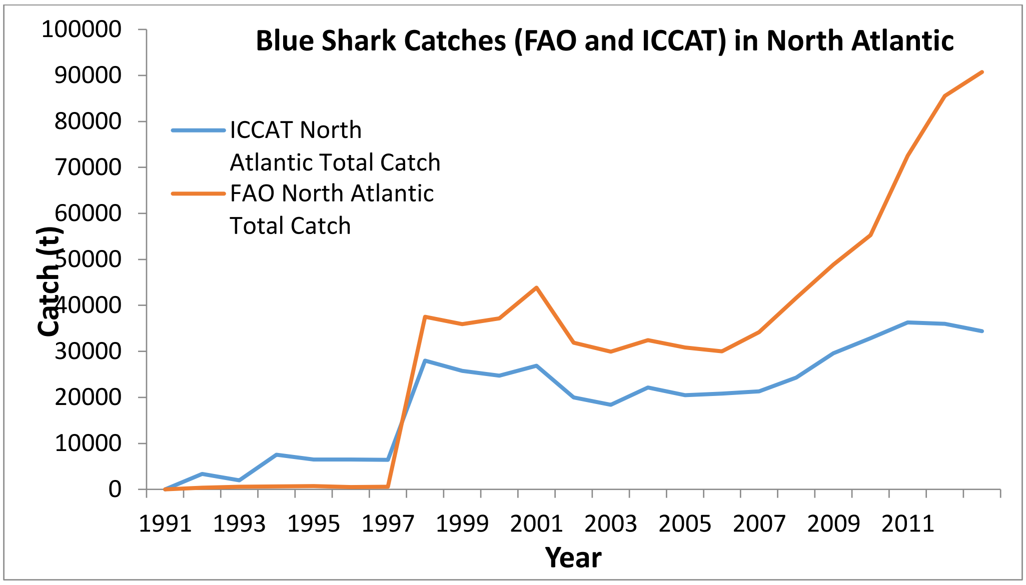
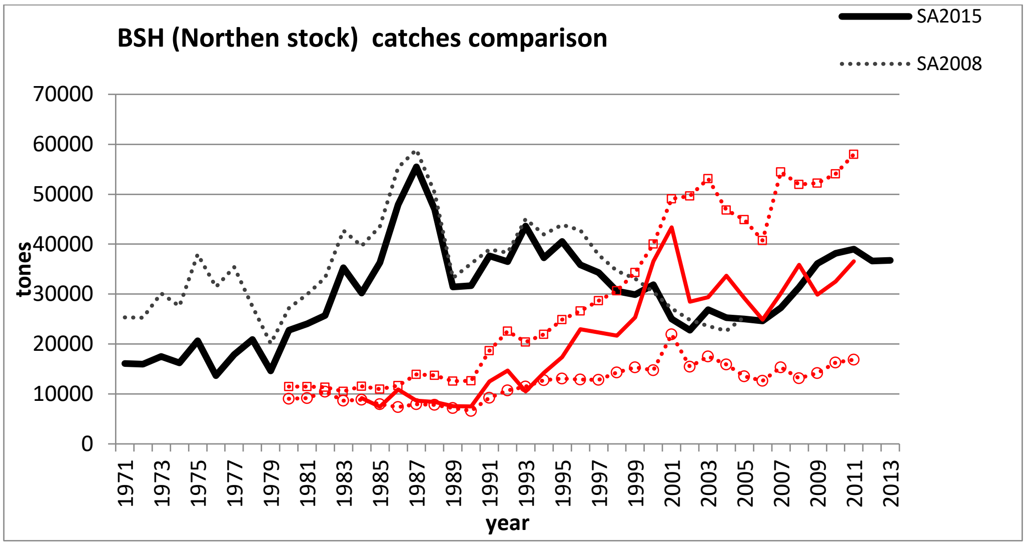


Figure 8.3. Blue shark in the North Atlantic. Blue shark catches in the North Atlantic from FAO and ICCAT data (1990–2013) illustrating the difference between data sources.



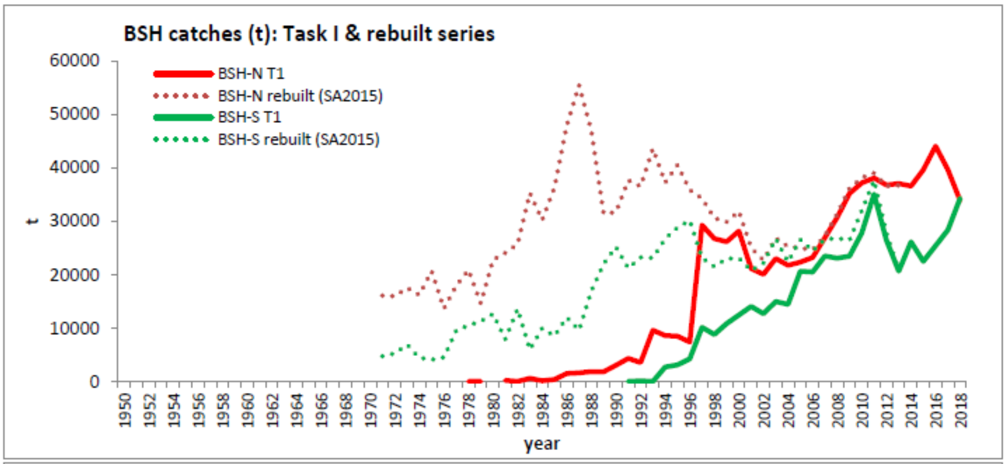


Figure 8.4. Top. Blue shark in the North Atlantic. Comparison of various catch series for the North Atlantic stock of blue shark (1971–2013). In black, the stock assessment catches from the 2008 stock assessment (dotted line) and 2015 estimations (solid line). In red, three catch series obtained using shark-fin ratios with three different approaches (area, effort, target level). Bottom: Update of catches reported to ICCAT (Task I) and estimated by SCRS (SCRS, 2019). Dotted lines are values from the 2008 assessment, solid line those of the 2015 estimates.

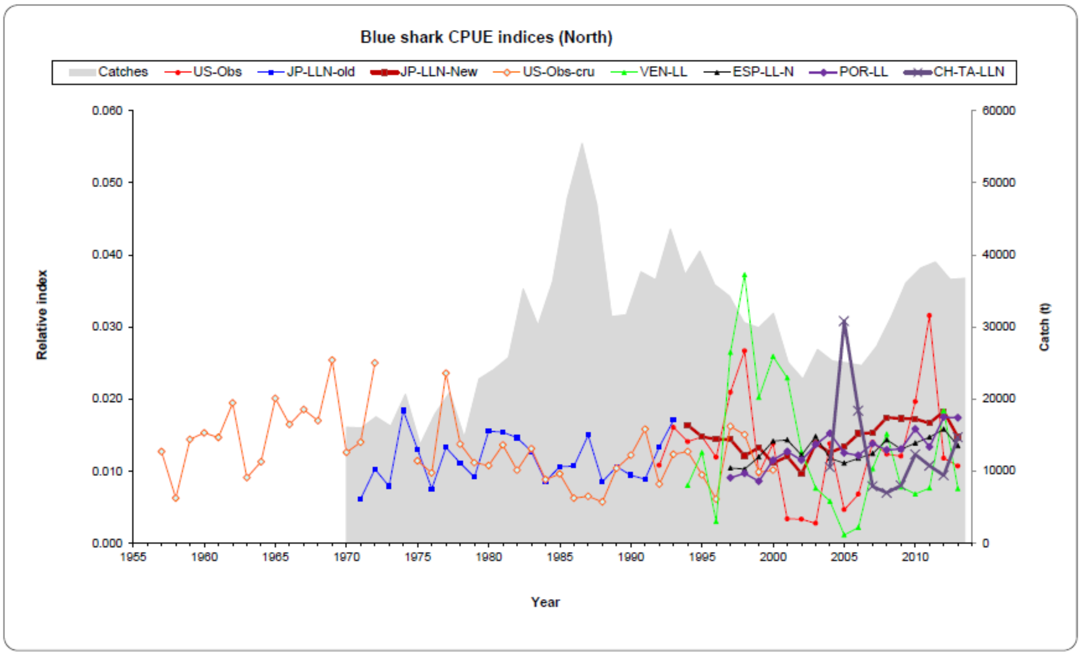


Figure 8.5. Blue shark in the North Atlantic. Indices of abundance and catches. Source: ICCAT (2019).

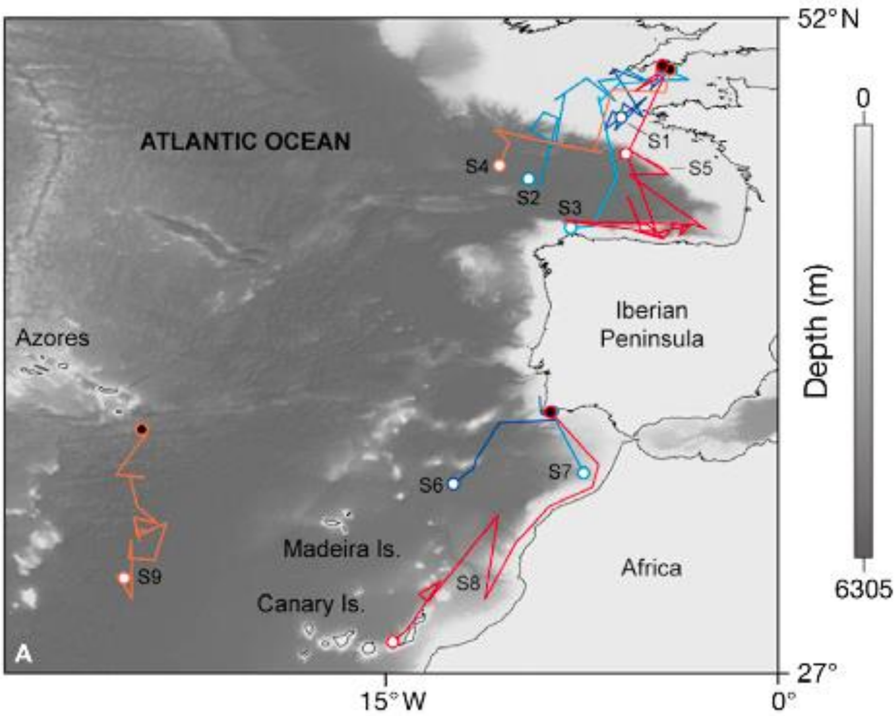
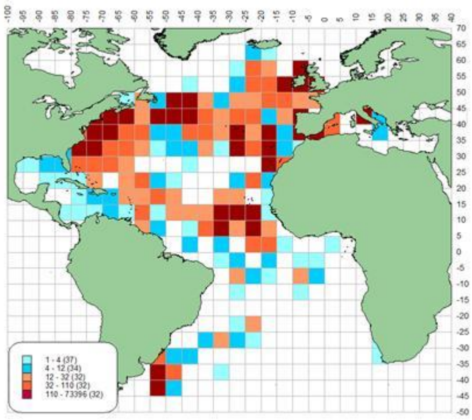
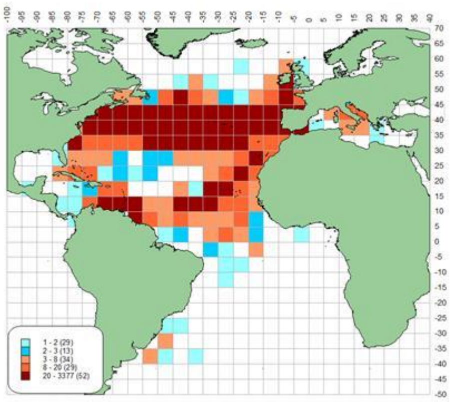


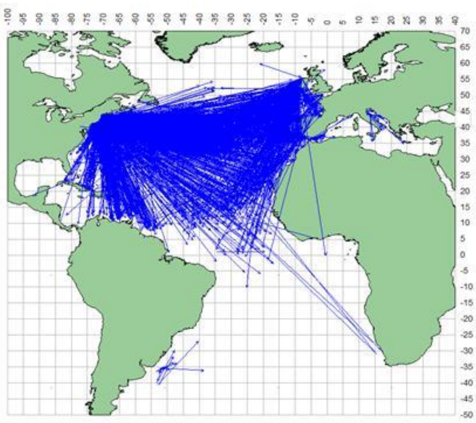
Figure 8.6. Blue shark in the North Atlantic. Pop-off satellite-tagged blue shark movement patterns. (A) General movements overlaid on bathymetry; black circles denote tagging locations and white circles the pop-up/capture locations. (B to J) Individual tracks overlaid on sea surface temperature maps; white circles are geolocated positions with date. Source: Queiroz *et al.* (2010).



a)



b)



c)

Figure 8.7. Blue shark in the North Atlantic. Blue shark tagging maps, presented by ICCAT (2012), showing (a) density of releases, (b) density of recoveries, and (c) straight line displacement between release and recovery locations.

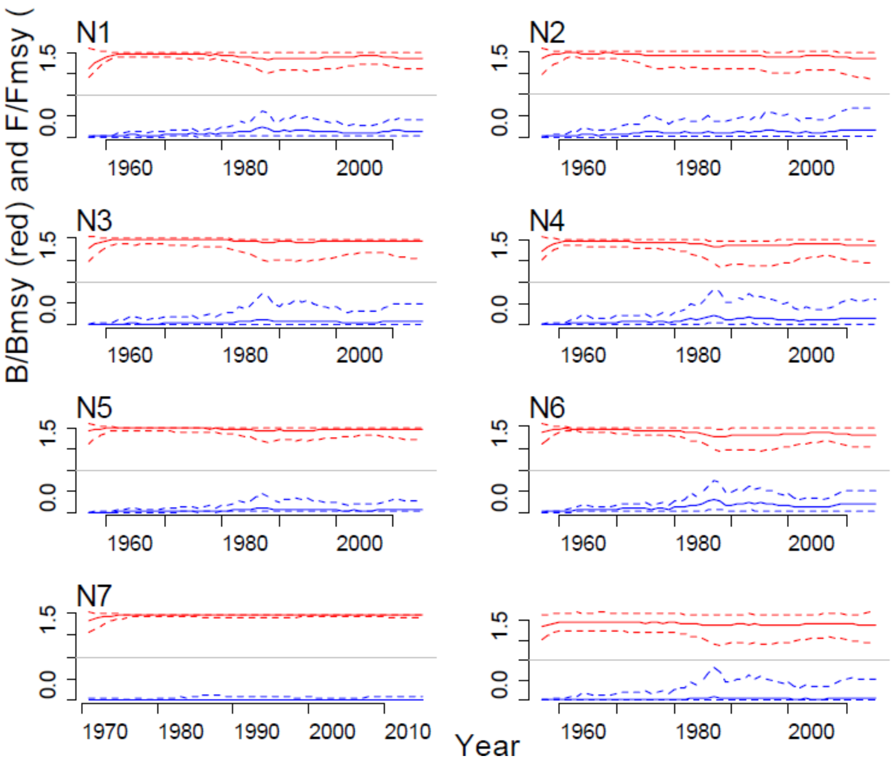


Figure 8.8. Blue shark in the North Atlantic. Estimated biomass relative to B_{MSY} (in red) and harvest rate relative to the MSY level (blue), for the BSP runs. Source: ICCAT (2015).

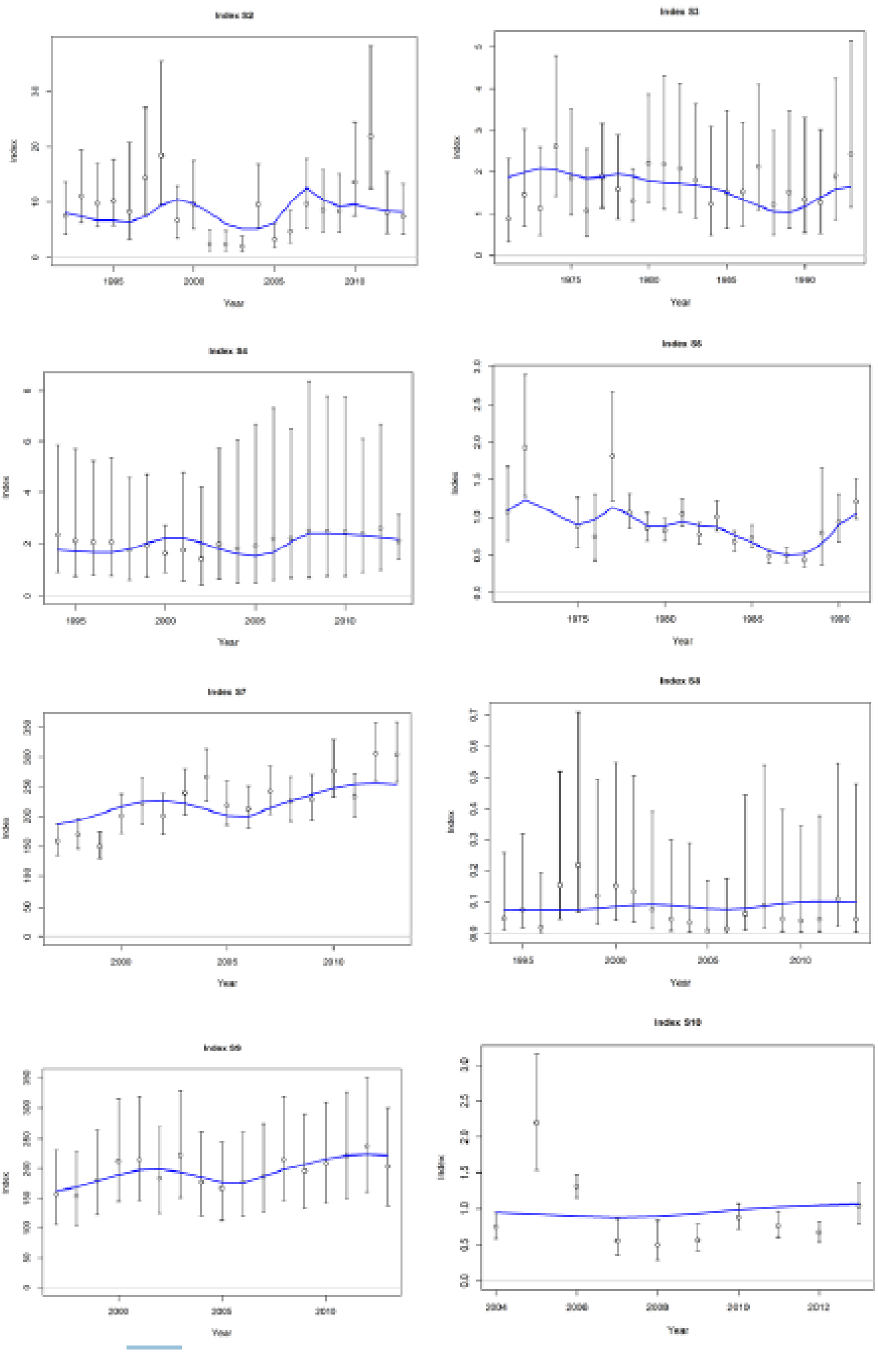


Figure 8.9. Blue shark in the North Atlantic. Preliminary Run 4 observed CPUE (open circles ± 95% confidence intervals assuming lognormal error) and model predicted CPUE (blue line) for abundance indices fit in the model likelihood: S2 (US-Obs, upper left), S3 (JPLL-N-e, upper right), S4 (JPLL-N-l, middle left), S6 (US-Obs-cru, middle right), S7 (POR-LL, middle left), S8 (VEN-LL, middle right), S9 (ESP-LL-N, lower left), and S10 (CTP-LL-N, lower right). Source: ICCAT (2015).

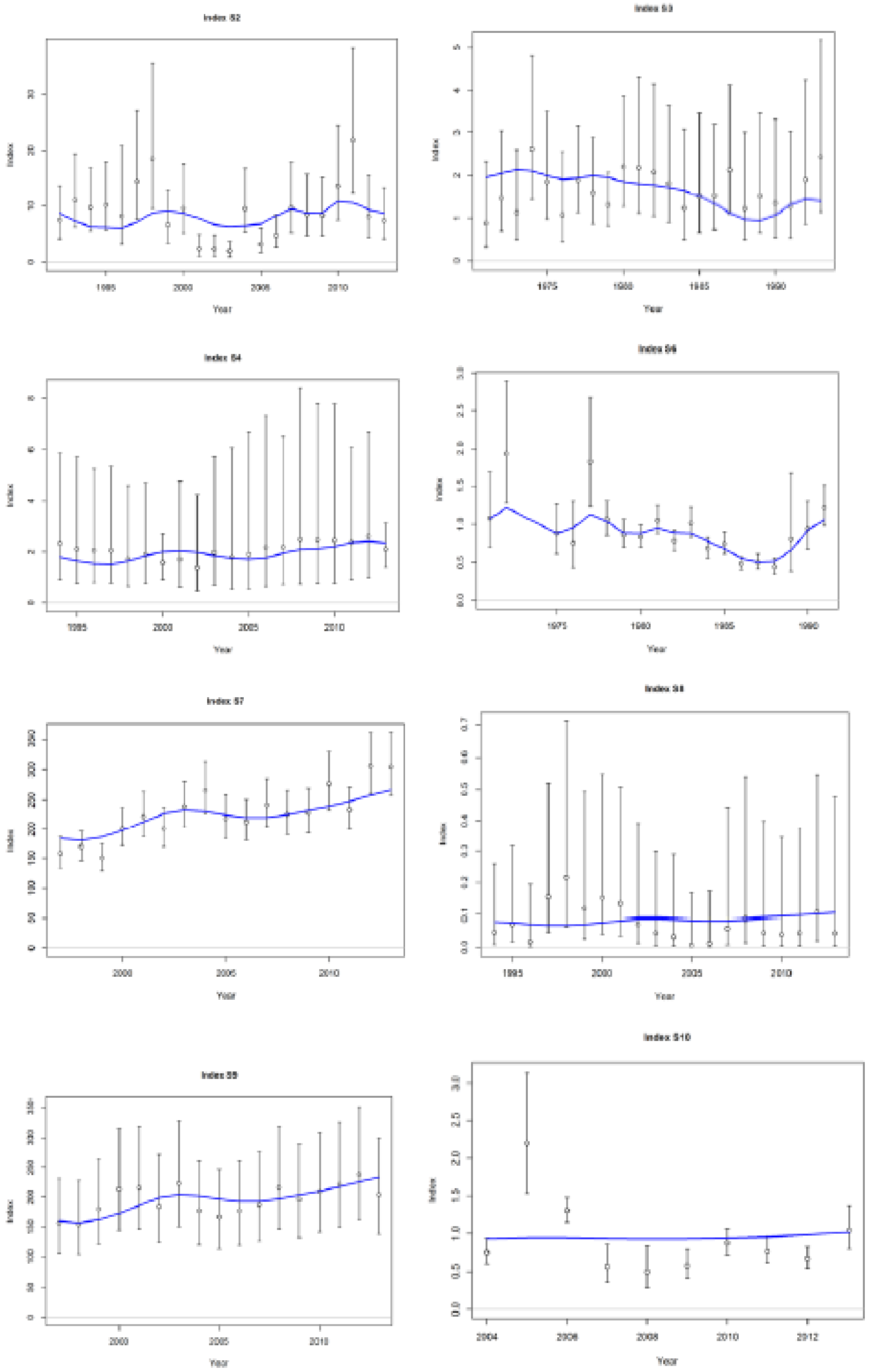
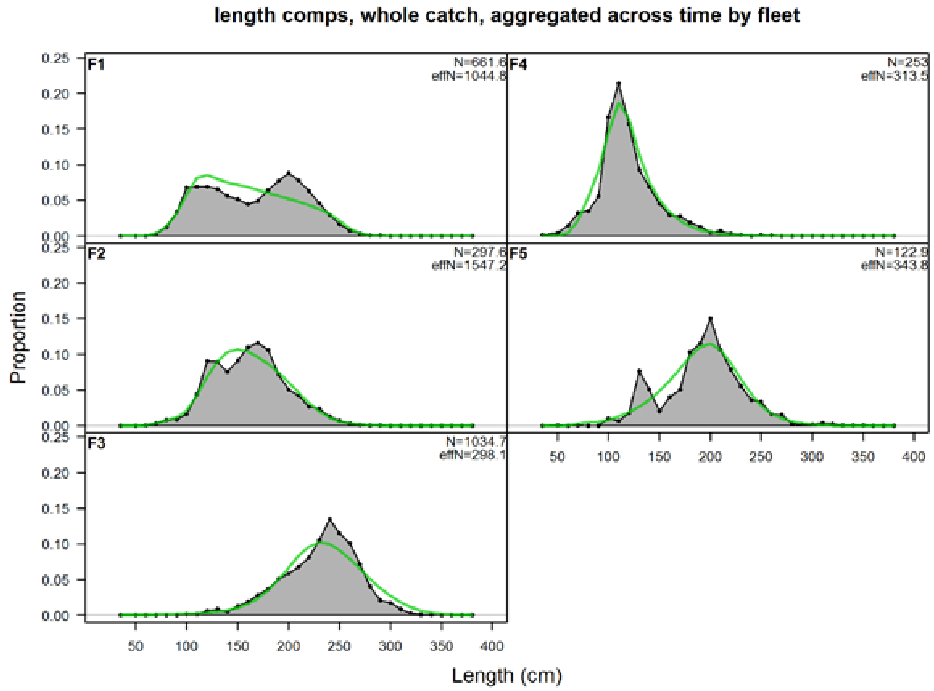


Figure 8.10. Blue shark in the North Atlantic. Preliminary Run 6 observed CPUE (open circles ± 95% confidence intervals assuming lognormal error) and model predicted CPUE (blue line) for abundance indices fit in the model likelihood: S2 (US-Obs, upper left), S3 (JPLL-N-e, upper right), S4 (JPLL-N-l, middle left), S6 (US-Obs-cru, middle right), S7 (POR-LL, middle left), S8 (VEN-LL, middle right), S9 (ESP-LL-N, lower left), and S10 (CTP-LL-N, lower right). Source: ICCAT (2015).



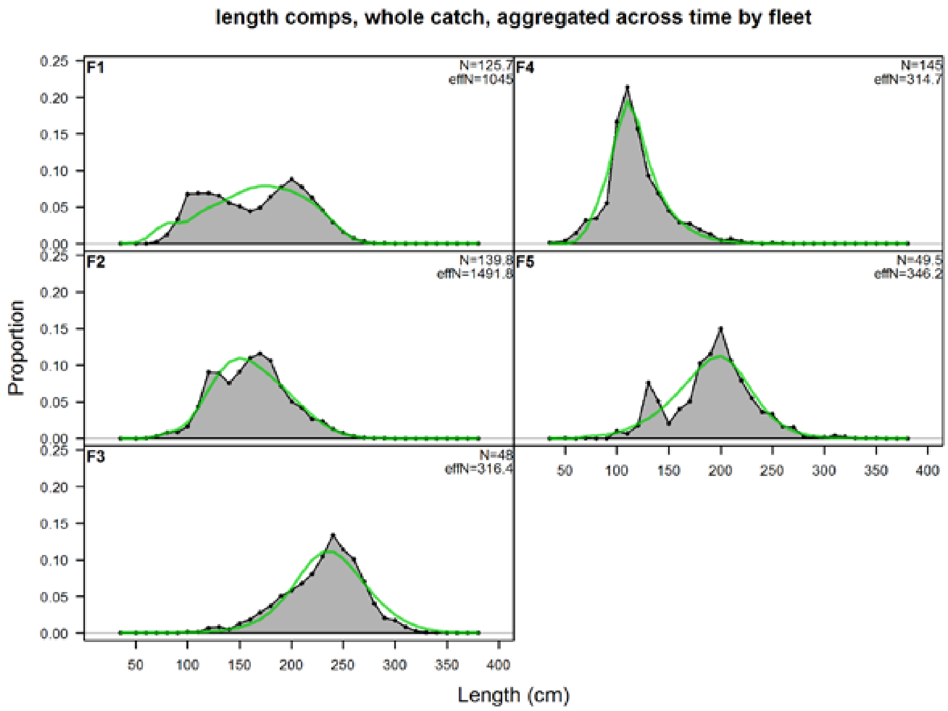


Figure 8.11. Blue shark in the North Atlantic. Model predicted (line) and observed (shaded) aggregated annual length compositions (female + male) for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). Source: ICCAT (2015).

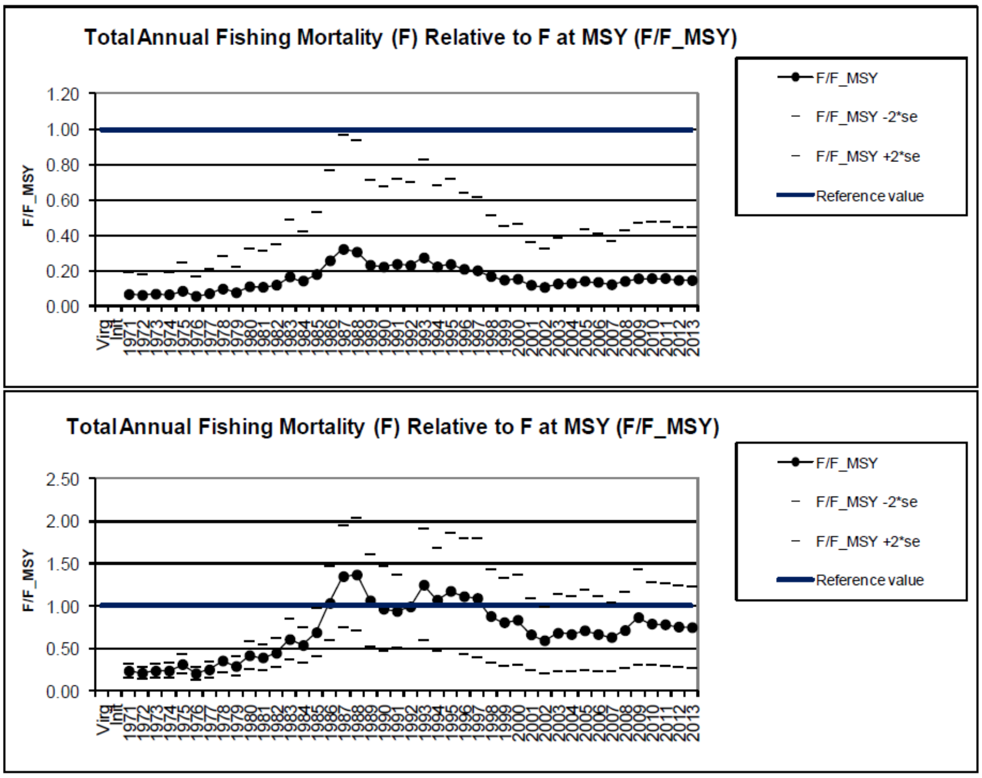


Figure 8.12. Blue shark in the North Atlantic. Estimated annual total exploitation rate in numbers (total fishing mortality for all fleets combined) relative to fishing mortality at MSY (F/F_{MSY}), obtained from Stock Synthesis output for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). Source: ICCAT (2015).

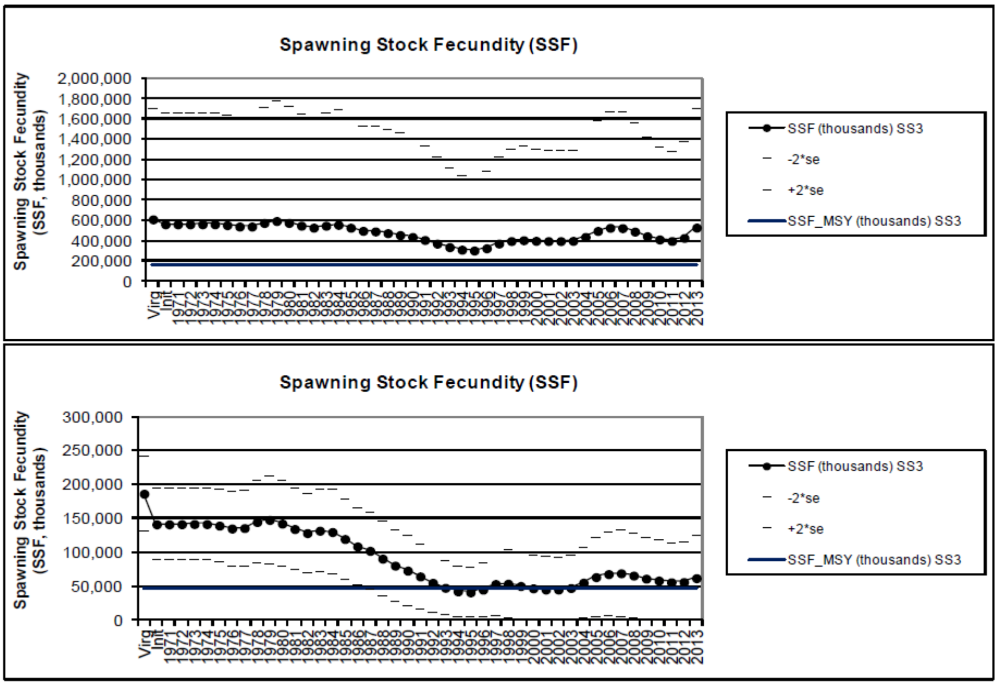


Figure 8.13. Blue shark in the North Atlantic. Estimated spawning stock size (spawning stock fecundity, SSF) along with approximate 95% asymptotic standard errors (±2*s.e.) relative to spawning stock size at MSY (SSFMSY) for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). Source: ICCAT (2015).

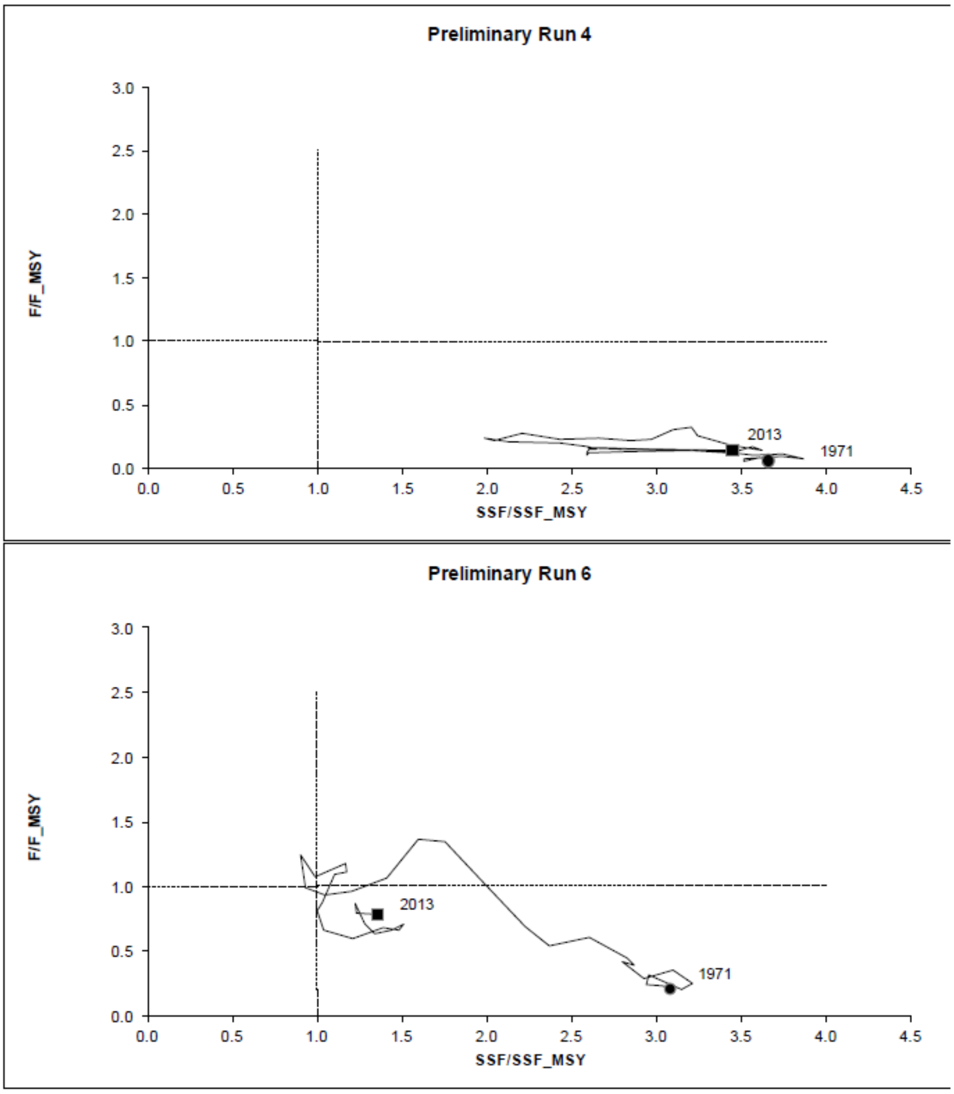


Figure 8.14. Blue shark in the North Atlantic. Kobe Phase plots for Preliminary Run 4 (upper panel) and Preliminary Run 6 (lower panel). The circle indicates the position of the start year of the model (1971) and the square represents the end year of the model (2013). The horizontal (dotted) line identifies the fishing mortality reference at maximum sustainable yield (F_{MSY}). The vertical (dotted) line identifies the reference spawning stock fecundity at maximum sustainable yield (SSF_{MSY}). Source: ICCAT (2015).