6 North Sea Horse Mackerel: Divisions 27.4.a (Q1 and Q2), 27.3.a (excluding Western Skagerrak Q3 and Q4), 27.4.b, 27.4.c and 27.7.d

6.1 ICES Advice applicable to 2020 and 2021

In 2012, the North Sea horse mackerel (NSHM) was classified as a category 5 stock, based on the ICES approach to data-limited stocks (DLS). Since then, a progressive reduction in TAC was advised by ICES, from 25 500 tonnes in 2013–2014 to 15 200 tonnes in 2015–2016. This reduction in the advised catch was supported by the analysis of information from the North Sea International Bottom Trawl Survey (NS-IBTS) traditionally used in the assessment, but also new information from the French Channel Ground Fish Survey (CGFS) since 2014. Additionally, in 2015, information on discards in non-directed fisheries became available that has been taken into account in the advice since 2017.

In 2017, this stock was benchmarked and the NS-IBTS and CGFS survey indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHM stock was upgraded to category 3. The joint index showed an increasing trend in 2014 to 2016, but was followed by a decrease again in 2017. In 2018, the index remained at a similar level as in 2017, while the index slightly increased again in 2019. Length-based DLS methods have been applied to data from 2016 onwards. The length-based F/F_{MSY} ratio has been decreasing since 2016, and F was estimated to be still slightly above F_{MSY} in 2019. Stock size relative to reference points is unknown.

Biannual advice for 2020 and 2021 was provided in 2019, based on the data up to 2018 (ICES, 2019). The uncertainty cap was applied, as the index ratio indicated a decrease of more than 20% in 2017-2018 compared to 2014-2016. The precautionary buffer was applied in 2017, and therefore not applied this time. This resulted in a catch advice for 2020 and 2021 of 14 014 tonnes.

6.2 Fishery of North Sea horse mackerel stock

Based on historical catches taken by the Danish industrial fleet for reduction into fish-meal and fish oil in the 1970s and 1980s, approximately 48% of the EU North Sea horse mackerel TAC was taken by Denmark. Catches were taken in the fourth quarter mainly in Divisions 27.4.b and 27.7.d. The 1990s saw a drop in the value of industrial fish, limited fishing opportunities and steep increases in fuel costs that affected the Danish quota uptake. In 2001, an individual quota scheme for a number of species was introduced in Denmark, but not for North Sea horse mackerel. This lead to a rapid restructuring and lower capacity of the Danish fleet, which in combination with the above mentioned factors led to a decrease of the Danish North Sea horse mackerel catches.

Since the 1990's, a larger proportion of the catches has been taken in a directed horse mackerel fishery for human consumption by the Dutch freezer-trawler fleet. This is possible because Denmark has traded parts of its quota with the Netherlands for other species. However, due to the structure of the Danish quota management setup only a limited amount of quota can be made available for swaps with other countries. These practical implications of the management scheme largely explain the consistent underutilisation of the TAC over the period 2010-2014 (approximately 50%; Figure 6.2.1)). However, following the sharp reduction in TAC in 2015 uptake increased significantly in the years thereafter. In 2019, 78% of the TAC was used, with the highest catches taken by the UK, followed by Norway, Netherlands, Lithuania, France and Germany (Figure 6.2.2; Lithuania not shown).

Catches taken in Divisions 27.3.a and 27.4.a during the two first quarters and all year round in Divisions 27.4.b, 4.c and 27.7.d are regarded as North Sea horse mackerel (Section 5, Table 5.4.1). The catches were relatively low during the period 1982—1997 with an average of 18 000 tonnes, but increased between 1998 (30 500 tonnes) and 2000 (451 30 tonnes). From 2000 to 2010, the catches varied between 24 149 and 45 883 tonnes. Since 2014 a steep decline in catches is observed, both due to the reduction in the TAC since 2014 but also due to the underutilization of the quota. In 2019 the catch was 11 803 tonnes, with 68% of the total catch being caught in area 27.7.d, which is a smaller share of the overall catch than in the years before (2018: 80.5%; Figure 6.2.4).

Over the period 1985–2001 most catches were taken in the area 27.4.b (Figure 6.2.3). However, since the early 2000s the proportion of catches from area 27.7.d increased steadily until 2013, when the 92% of total catches were fished in this area (Figure 6.2.4). In 2019, the UK accounted for most of the landings, followed by Norway, the Netherlands, Lithuania, France and Germany (Figure 6.2.5). The majority was still caught in quarter 4 in 27.7d, whereas the Norwegian catches were taken during quarter 1 and 2 in 27.4.a. Most of the discards were reported in 27.7.d by the French bottom-trawl fleet. Discarding in the target pelagic fisheries is considered negligible. New information in 2015 from bottom-trawl fisheries not directed at horse mackerel indicated an overall discard rate of 16.7% for the stock as a whole, while in 2016 this rate was 10%. In 2017 and 2018 the discard rate was 8.3% and 1.8%, respectively, while it decreased to 1.6% in 2019. However, due to a coding mistake in the French data some 2019 discards in quarter 3 in 27.7.d had to be excluded from the overall amount such that actual discards may be higher. Complete discard information for earlier years has not been submitted to ICES. Information from national discard reports for the non-directed bottom-trawl fisheries indicates a similar level of discarding in earlier years.

6.3 Biological Data

6.3.1 Catch in Numbers at Age

In 2019, as in recent years, the coverage of biological sampling remains very low. Samples were available from two countries with regards to Q1 and Q2 in area 27.4.a and in Q4 in area 27.7.d. Overall, only a small proportion (1/3) of landings was sampled, in comparison to 2013 and 2014 when 71% and 63% were sampled respectively (Section 5, Figure 5.9.1). Although most landed catch was taken from 27.7.d in Q4 and in 4a in Q1 and 2, parts of the landings were fished in other areas and quarters (Figure 6.2.5). In order to avoid a biased perception of the age distribution of catches over the year and areas, this partial and uneven sampling effort should be avoided in future years.

Annual catch numbers at age are shown in Table 6.3.1. Catch-at-age for the whole period 1995-2019 are given in Table 6.3.2 and in Figures 6.3.1 and 6.3.2. These data show that since 2005 the age distribution of catches has experienced a reduction, with a decrease in the range of ages of importance in total catches. However, this decrease could be due to the low age sampling, in particular in 2018 (maximum age observed 7 years). In parallel to the rejuvenation of catches, the comparison of catch-at-age data after 1998 by area (Figure 6.3.2) shows that since 2010 commercial catches have increased in area 27.7.d in comparison to the areas 27.3.a and 4.a,b and c where the opposite pattern was found. Due to the low level of sampling effort in 2018, data for this year are only based on a single sample from area 27.7.d in Q4.

Although the 2015 cohort seems to be clear in the catch-at-age distribution, in general, cohort structure is not clearly detectable in the data. In addition to the low sampling levels, this may partly be due to the shifts in the distribution of the fishery. In addition, it may partly be due to age reading difficulties, which are a known to be encountered (e.g. Bolle *et al*., 2011). Most clearly detectable is the relatively large 2001 year-class, although it is not clearly present in the catch data in all years. There are indications that environmental conditions may be an important factor (possibly stronger than stock size) contributing to spawning success of horse mackerel. This is, for example, illustrated by the largest year-classes (1982 and 2001) observed in the Western stock which were produced at the lowest observed stock sizes. Since 2001 is considered to have been a relatively strong year class in the Western stock as well, it is plausible that circumstances in the North Sea were similar to those in Western areas and also allowed for relatively high spawning success in the North Sea.

Lastly, potential mixing of fish from the Western and North Sea stock in area 27.7.d and 27.7.e in winter may also confuse the cohort signals. For example, the large recruitment in the Western stock may have led to more of these fish being located in the North Sea stock area as age 1 fish in 2002. On behalf of the Pelagic Advisory Council and the EAPO Northern Pelagic Working Group, a research project on genetic composition of horse mackerel stocks was initiated in 2015 with University College Dublin (Ireland) with the intention of clarifying the mixing among the North Sea and the Western horse mackerel stocks. Genetic samples have been taken over the whole distribution area of horse mackerel during the years 2015, 2016, and 2017, with a specific focus on the separation between horse mackerel in the western waters and horse mackerel in the North Sea. The results of the whole-genome sequencing indicated that the North Sea horse mackerel stock is clearly genetically different from the Western stock (Farrell and Carlsson, 2019; Fuentes-Pardo *et al*., 2020). Markers were identified that could distinguish with up to 95% accuracy between individuals collected in the North Sea and Western stocks. Follow-up work on this project with a large-scale analysis of samples and a greater temporal and spatial coverage will improve stock delineation further.

6.3.2 Mean weight at age and mean length at age

The mean weight and mean length-at-age in the commercial catches of 2019 are presented in Tables 6.3.3 and 6.3.4 respectively by quarter.

The mean annual weight and length over the period 2000–2019 are presented in Table 6.3.2 and Figures 6.3.3 and 6.3.4, respectively. Although there are no strong differences over this period, since 2010 there seems to be a slight increase in weight of age for age 3-6 years and in length-at-age for age 2-5 years.

6.3.3 Maturity-at-age

Peak spawning in the North Sea occurs in May and June (Macer, 1974), and spawning occurs in the coastal regions of the southern North Sea along the coasts of Belgium, the Netherlands, Germany, and Denmark.

There is no information available about the maturity-at-age of the North Sea Horse mackerel stock.

6.3.4 Natural mortality

There is no specific information available about natural mortality of this stock.

6.4 Data Exploration

6.4.1 Catch curves

The log-catch numbers were plotted by cohort to calculate the negative slope to get an estimate of total mortality (Z). Fully selected ages 3 to 15+ from the 1992–2008 period provide complete data for the 1992 to 2008 cohorts (Figure 6.4.1). The estimated negative slopes by cohort (Figure 6.4.2) indicate an increasing trend in total mortality up to the late 1990s, after which Z fluctuates from year to year. However, due to the low quality of the signals for some cohorts these Z estimates have to be considered with caution.

An analysis of the catch number at age data carried out in 2011 showed that only the 1vs.2, 2vs.3, 7vs.8 and 9vs.10 age groups were positively and significantly correlated in the catch. This analysis has not been updated since, but these results suggest limitations in the catch-at-age data.

6.4.2 Assessment models and alternative methods to estimate the biomass

In 2002 Rückert *et al.* estimated the North Sea horse mackerel biomass based on a ratio estimate that related CPUE data from the IBTS to CPUE data of whiting (*Merlangius merlangus*). The applied method assumes that length specific catchability of whiting and horse mackerel are the same for the IBTS gear. Subsequently, they use the total biomass of whiting derived from an analytical stock assessment (MSVPA) to estimate the relationship between CPUE and biomass.

At the 2014 WGWIDE meeting some exploratory model fits were attempted with the JAXass model, using the data available. The JAXass (JAX assessment) model is a simple statistical catch-at-age model fitted to an age-aggregated index of (2+) biomass, total catch data and proportions at age from the catch. It is based on Per Sparre's "separable VPA" model, an *ad hoc* method tested for the first time at WGWIDE in 2003, and later 2004. A new analysis using this model was also done in 2007 using an IBTS index. In 2014 the model has been coded in ADMB (Fournier *et al.*, 2012) and updated with an improved objective function (dnorm), extra years of data and new methods for calculating the index (see above).

Difficulties in fitting an assessment model for this stock include:

- Unclear stock boundaries
- Difficulty aging horse mackerel
- Lack of strong cohort signals in catch-at-age data
- Scientific index derived from a survey not specifically designed for horse mackerel and not covering one of the main fishing grounds for the stock (7.d)

Catches taken in area 27.7.d are close to the management boundary between the (larger) Western horse mackerel stock and the NS horse mackerel stock. It is quite possible that given changes in oceanographic conditions, or changes in abundance of either of the two stocks, that some proportion of the catches taken in area 27.7.d actually originated from the Western horse mackerel stock. Nevertheless, all assessment models used assume that 100% of fish caught in area 27.7.d belong to the North Sea horse mackerel stock. This is in agreement with stock and management definitions.

In 2018, the working group tried applying the Surplus Production model in Continuous Time (SPiCT) model to North Sea horse mackerel. SPiCT is one of the methods in the ICES guidelines to estimate MSY reference points for category 3 and 4 stocks (ICES, 2018). The model was run using the joint survey index as input or with separate survey indices (NS-IBTS and CGFS). The model with the joint survey index led to conflicting results with the perception of the stock, as B was estimated to be above B_{MSY} and F below F_{MSY}. The model with two separate indices resulted in stock biomass and fishing mortality that were more in line with the perception of the stock. However, there were strong retrospective patterns and wide confidence intervals in recent years. Furthermore, more work is necessary on the setting of the priors, and on ensuring that model assumptions are not violated.

6.4.3 Survey data

6.4.3.1 Egg Surveys

No egg surveys for horse mackerel have been carried out in the North Sea since 1991. Such surveys were carried out during the period 1988—1991. SSB estimates are available historically. However, they were calculated assuming horse mackerel to be a determinate spawner. Horse mackerel is now considered an indeterminate spawner (Gordo *et al.* 2008). Therefore, egg abundance could only be considered a relative index of SSB. The mackerel egg surveys in the North Sea do not cover the spawning area of horse mackerel.

6.4.3.2 North Sea International Bottom Trawl Survey

Many pelagic species are frequently found close to the bottom during daytime (which is when the North Sea IBTS survey operates) and migrate upwards predominantly during the night when they are susceptible to semi-pelagic fishing gear and to bottom trawls (Barange *et al.* 1998). Macer (1977) observed hat dense shoals are formed close to the bottom during daytime, but the top of the shoals may extend into midwater. Eaton *et al.* (1983) argued that horse mackerel of 2 years and older are predominantly demersal in habit. Therefore, in the absence of a targeted survey for this stock, the IBTS is considered a reasonable alternative.

IBTS data from quarter Q3 were obtained from DATRAS and analysed. Based on a comparison of IBTS data from all 4 quarters in the period 1991—1996, Rückert *et al.* (2002) showed that horse mackerel catches in the IBTS were most abundant in the third quarter of the year. In 2013 WGWIDE considered that using an 'exploitable biomass index' estimated with the abundance by haul of individuals larger than 20 cm is the most appropriate for the purpose of interpreting trend in the stock.

To create indices, a subset of ICES rectangles were selected. Rectangles that were not covered by the survey more than once during the period 1991—2012 were excluded from the index area. In 2012, WGWIDE expressed concern that the previously selected index area did not sufficiently cover the distribution area of the stock, especially in years that the stock would be relatively more abundant and spread out more. Rückert *et al.* (2002) also identified a larger distribution area of the North Sea stock. Based on the above, WGWIDE 2013 identified 61 rectangles to be included in the index area as shown in Figure 6.4.3.

6.4.3.3 French Channel Groundfish Survey

In order to improve data basis for the North Sea horse mackerel assessment, alternative survey indices have been explored. Previous indices only covered the North Sea distribution of the stock, while the majority of catches in recent years come from the eastern English Channel (27.7.d). We evaluated the potential contribution of the French Channel Groundfish Survey in 27.7.d in Quarter 4. The CGFS is carried out since 1990 and has frequent captures of horse mackerel. Though this survey is conducted in a different quarter than the North Sea IBTS, the observed seasonal migration patterns of horse mackerel indicate that fish move into the channel following quarter Q3, so the timing is considered appropriate.

In 2015, the RV "Gwen Drez" was replaced by the RV "Thalassa" to carry out the CGFS. In 2014 an inter-calibration process was conducted to quantify the differences in catchability for a large number of species. ICES reviewed this inter-calibration exercise and found a number of drawbacks that may undermine the reliability of the estimated conversion factors. The main concerns were:

- The analyses were limited in the number of tows. Considering that a number of these tows could be zeros for one of the two vessels and possibly resulting in highly uncertain estimates.
- Lack of length-specific correction factor.
- At a standardized depth of 50 m and above, wing spread estimates for the R/V Thalassa as measured by the MARPORT sensor were deemed erroneous, which may question the validity of estimated area swept by the net on the R/V Thalassa and the effect it may have on correction factors for species caught at depth at 50m and greater.
- A number of tow locations including areas outside 27.7.d were excluded. Changing the depth range of a survey can add serious bias in the calibration and the current approach seems to be ignoring this issue.
- Correction coefficients were not measured without error.

However, these limitations were considered by WGWIDE to be of minor importance for the North Sea horse mackerel since:

- Despite being still a low sample size the North Sea horse mackerel was present in all the 32 paired hauls.
- There are no important differences in size distribution (Figure 6.4.4).
- The analysis with and without the areas excluded in the new sampling design did not show important differences (ICES, 2017).
- CPUE of North Sea horse mackerel for hauls deeper than 50 m was relatively low (Figure 6.4.5), and it is expected than the potential problems in determining the conversion factor below that depth range would have a relatively minor impact in the estimated abundance.

For these reasons it was considered appropriate to continue using the CGFS, standardizing the time-series of abundance for the period 1990–2015 with the estimated conversion factor 10.363.

6.4.3.4 Modelling the survey data

In January 2017, a benchmark of the NS horse mackerel assessment was conducted (ICES, 2017). Based on a capacity to model the over-dispersion and the high proportion of zero values in the survey catch data, the hurdle model was considered the best option of all model alternatives tested. The log-likelihood ratio test, the AIC and the evidence ratio statistic supported that the model that best represented the data was a hurdle model with Year and Survey as explanatory factors (including the interaction term) in the count model (GLM-negative binomial), and Year and Survey (without the interaction) in the zero model (GLM-binomial).

The probability of having a CPUE of zero was modelled by a logistic regression with a GLM-binomial distribution model:

$$logit(\pi_i) = Intercept_{zero} + Year_{i,zero} + Survey_{i,zero}$$

where π_i is the mean probability of having a CPUE of zero in haul *i* as a function Year and Survey.

The expected CPUE of North Sea horse mackerel per haul i, conditional to not having a zero in hurdle models (not having a false zero in zero-inflated models), was modelled with a GLM-negative binomial distribution model:

$$\log(CPUE_i) = Intercept_{count} + Year_{i,count}\ x\ Survey_{i,count}$$

This model was used to synthesise the information from both the CGFS and IBTS and predict the average annual CPUE index as an indicator of trends in stock abundance. Separate models sre fit to the juvenile (<20cm) and adult exploitable (≥20cm) sub-stocks. The contribution of the two surveys to the combined index is weighted taken into consideration their respective area coverage as well as the mean wing spread. This index model allowed upgrading of the NSHM to a category 3 stock within the ICES classification.

Similar to the 2019 assessment (ICES, 2019), the model for the adult sub-stock that was run this year returned a warning despite the fact that the model converged. All parameter coefficients were estimated, but not the standard error for the intercept and the parameter θ of the count model. To check the robustness of the hurdle model with the warning, a zero-inflated model was run with the same set-up as the hurdle model. This zero-inflated model was considered to be the second-best model during the benchmark process in 2017 and performed almost equally well as the hurdle model (ICES, 2017). The fitted values of the zero-inflated model were very similar to that of the hurdle model with warning (Figure 6.4.6). The hurdle model from this year and its resulting index values where thus considered robust. Should the warning continue to occur in future assessments, additional testing and investigation should be conducted..

6.4.4 Summary of index trends and length distribution

The survey index for both the juvenile and exploitable sub-stock experienced a marked decline in the early 1990s and fluctuated at relatively low levels thereafter (Figures 6.4.7; Table 6.4.1). This reduction was partly due to the decline of the average abundance per haul over time, but also due to the increase of hauls with zero catch of the adult sub-stock (Figure 6.4.8). The survey index was at its third and second lowest in 2017 and 2018 (lowest in 2009), but shows a slight increase again in 2019 (Figure 6.4.7).

The index trend for the juvenile sub-stock shows large fluctuations since 2015 (Figure 6.4.7). These are mainly attributed to the fluctuating trend of juveniles in the IBTS (Figure 6.4.9), caused by some hauls with high catches of small horse mackerel in 2016 and 2018 (Figure 6.4.10). Fitted values for juveniles in the CGFS show decreasing trend since 2014 (Figure 6.4.9).

The highest proportion of fish caught in 2019 in the IBTS and CGFS were around 17-20 cm (Figure 6.4.10, 6.4.11). Considering the length-at-age for this stock (Figure 6.3.4), this could be the result of the strong year class from 2018 (Figure. 6.4.7, 6.4.10, 6.4.11). Proportions of 0-year old fish were low in both the IBTS and CGFS in 2019 (Figure 6.4.10, 6.4.11), suggesting low recruitment in 2019. The index of abundance of individuals <20 cm could be considered a recruitment index, but future analyses should be carried out to study the correlation between the abundances and survey indices of year classes over time in more detail.

6.4.5 Length distributions of commercial catches and Pelagic Freezer-trawler Association

Currently, length distributions from catch data are only available from 2016 to 2019. Future work is needed to retrieve historic length data in order to present a longer time series. The data used for the analysis come from the commercial catch sampling by countries. For comparison, the analysis is also run with length data from the self-sampling programme of the Pelagic-Freezer-trawler Association (PFA).

The length distributions based on the commercial catch data from 27.7.d show a consistent distribution in time with a mean length between 21.8 and 22.7 cm each year (Figure 6.4.12). Lengths in 27.4.a (caught in Q1 and Q2 only) are higher than those of 27.7.d, with a mean length of 32.9 cm in 2018 and 35.6 cm in 2019 (Figure 6.4.13). The length distributions of the PFA in 27.7.d are similar to those from the commercial catch data (Figure 6.4.14). Mean length per year in the PFA data varies between 20.8 and 23.8 cm. The commercial catch data have a higher proportion of smaller fish (<20 cm) that the PFA data, as discards from the French demersal fisheries are included (Figure 6.4.14).

6.4.6 Data Limited Stock methods and MSY proxy reference points

As part of the ICES approach to provide advice within the MSY framework for stocks of category 3 and 4, different Data Limited Stock (DLS) methods to estimate MSY proxy reference points (ICES, 2012, 2018) for the North Sea horse mackerel were previously explored (Pérez-Rodríguez, 2017). The Length Based Indicators analysis is the DLS method used in this assessment.

As most length samples and catches originate from area 27.7d, only length distributions from this area were used to calculate the MSY proxy. In 2019, the F/F_{MSY} proxy based on the commercial catch samples indicated that fishing mortality was still slightly above F_{MSY}, with F/F_{MSY}=1.025 (Figure 6.4.15), although there has been a decreasing trend since 2016 (Figure 6.4.16). The proxy was also calculated for comparison with length frequencies from the PFA from area 27.7.d. There was a decline in the PFA proxy from 2016 to 2017 (Figure 6.4.16), while the values in 2018 and 2019 were similar to those of 2017, with F/F_{MSY} being 1.045 in 2019.

6.4.7 Ongoing work

On behalf of the Pelagic Advisory Council and the EAPO Northern Pelagic Working Group, a research project on genetic composition of horse mackerel stocks was initiated in 2015 with University College Dublin (Ireland). Genetic samples have been taken over the whole distribution area of horse mackerel during the years 2015, 2016, and 2017, with a specific focus on the separation between horse mackerel in the western waters and horse mackerel in the North Sea. The result of the research indicated that the western horse mackerel stock is clearly genetically different from the North Sea stock (Farrell and Carlsson, 2019; Fuentes-Pardo *et al.*, 2020). Markers were identified that will be able to reveal the stock identity of individual horse mackerel from potential mixing areas, namely Division 7.d, 7.e and 4.a. Horse mackerel from 7.d and 7.e will be collected by the PFA on board of commercial vessels in the Autumn of 2020, while during the same period horse mackerel from 4.a will be collected during the NS-IBTS in Q3. The stock identity of the sampled fish will be investigated, and results can be expected in 2021.

6.5 Basis for 2019 and 2020 Advice. ICES DLS approach.

Stock advice for North Sea horse mackerel is biannual. In 2019 the advice for years 2020 and 2021 was provided (ICES, 2019). In 2016, the IBTS and CGFS were modelled together to produce a joint abundance index for the first time. The index indicated that the adult sub-stock did not further decline in 2018, but remained at similar low levels as in 2017, compared to higher levels in 2014 to 2016.

There are some signs of improved recruitment in some years (e.g. 2016, 2018), but the trend of the abundance index for the juvenile sub-stock is fluctuating and, when separated, the two surveys, NS-IBTS and CGFS, do not show the same trend. It remains to be seen if the weak signs of improved recruitment result in higher adult abundance, and the slight increase in the index of the exploitable sub-stock in 2019 suggests this may be the case.

The fisheries in Division 7.d, where most catches take place, mainly catches horse mackerel between 15 and 25 cm (Figure 6.4.12, 6.4.14). With this pattern of exploitation, mostly immature individuals are caught (length at maturity considered to be around 23 cm), which may hinders the recovery of the stock by removing an important portion of the recent year classes before they enter the spawning stock. Related to this concern and starting in the autumn of 2018, the Pelagic Freezer-trawler Association (PFA, the Netherlands) implemented a voluntary move-away scheme in an attempt to avoid catches of small horse mackerel in 27.7.d. The trigger in the move-away scheme is a catch of more than 25% in a haul consisting of small fish (more than 250 fish in a carton of 23 kg, equating to around 18 cm). When the trigger is reached, all vessels of the PFA are notified and instructed to move out of the area with a distance of at least 5 nautical miles. The move-away scheme has been triggered 17 times during the period October – December 2018 and 11 times in 2019.

The index ratio (A/B ratio or 2-over-3 ratio) for the adult sub-stock in the 2019 assessment was 0.39. This indicates that the decline in the abundance index was more than 20%, and therefore, an 80% uncertainty cap was applied. The F/F_{MSY} ratio in 2018 was higher than 1, indicating that the fishing mortality is higher than F_{MSY}. Because the precautionary buffer was last applied in 2017 (*i.e.*, within the last three years), the buffer was not applied in the 2019 advice. Under these circumstances and based on the last year's catch advice of 17 517 tonnes, ICES advised in 2019 that catches of North Sea horse mackerel in 2020 and 2021 should be no more than 14 014 tonnes.

6.6 Management considerations

In the past, Division 27.7.d was included in the management area for Western horse mackerel together with Divisions 27.2.a, 27.7.a–c, 27.7.e–k, 27.8.a, 27.8.b, 27.8.d, 27.8.e, Subarea 6, EU and international waters of Division 5.b, and international waters of Subareas 12 and 14. ICES considers Division 27.7.d now to be part of the North Sea horse mackerel distribution area. Since 2010, the TAC for the North Sea area has included Divisions 27.4.bc and 27.7.d. Considering that a majority of the catches are taken in Division 27.7.d, the total North Sea horse mackerel catches are effectively constrained by the TAC since the realignment of the management areas in 2010.

Catches in Divisions 27.3.a (Western Skagerrak) and 27.4.a in quarters 3 and 4 are considered to be from the Western horse mackerel stock, while catches in quarters 1 and 2 are considered to be from the North Sea horse mackerel stock. Catches in area 27.4.a and 27.3.a are variable. In recent years only Norway has had significant catches in this area, but these are only taken in some years.

6.7 References

Barange, M., Pillar, S. C., and Hampton, I. 1998. Distribution patterns, stock size and life-history strategies of Cape horse mackerel *Trachurus trachurus capensis*, based on bottom trawl and acoustic surveys. South African Journal of Marine Science, 19: 433–447.

Bolle, L.J., Abaunza, P., Albrecht, C., Dijkman-Dulkes, A., Dueñas, C., Gentschouw, G., Gill, H., Holst, G., Moreira, A., Mullins, E., Rico, I., Rijs, S., Smith, T., Thaarup, A., Ulleweit, J. 2011 . Report of the Horse Mackerel Exchange and Workshop 2006. CVO report: 11.007.Eaton, D. R. 1983. Scad in the North-East Atlantic. Laboratory Leaflet, Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research, Lowestoft, 56: 20 pp.

Eaton, D. R. 1983. Scad in the North-East Atlantic. Lab. Leafl., MAFF Direct. Fish. Res., Lowestoft (56): 20pp.

Fuentes-Pardo, A.P., Petterson, M., Sprehn, C.G., Andersson, L., Farrell, E. 2020. Population structure of the Atlantic horse mackerel (*Trachurus trachurus*) revealed by whole-genome sequencing, July 2020.

Farrell, E. D. and J. Carlsson (2019). Genetic stock identification of Northeast Atlantic Horse mackerel, Trachurus trachurs. , EDF, December 2018.

Fournier, D.A., Skaug, H.J., Ancheta, J., Ianelli, J., Magnusson, A., Maunder, M.N., Nielsen, A., Sibert, J. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software, 27: 233-249.

Gordo, L. S., Costa, A., Abaunza, P., Lucio, P., Eltink, A. T. G. W., & Figueiredo, I. (2008). Determinate versus indeterminate fecundity in horse mackerel. Fisheries Research, 89: 181-185.

ICES. 2012. ICES Implementation of Advice for Data-limited Stocks in 2012 in its 2012 Advice. ICES CM 2012/ACOM 68. 42 pp.

ICES. 2017. Report of the Benchmark Workshop on Widely Distributed Stocks (WKWIDE), 30 January–3 February 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:36. 196 pp.

ICES. 2018. ICES reference points for stocks in categories 3 and 4. ICES Technical Guidelines. 13 February 2018. http://www.ices.dk/sites/pub/Publication%20Reports/Guidelines%20and%20Policies/16.04.03.02_Category_3-4_Reference_Points.pdf

ICES. 2019. Report of the Working Group on Widely Distributed Stock (WGWIDE. ICES Scientific Reports. 1:36. 948 pp.

Macer, C.T. 1974. The reproductive biology of the horse mackerel *Trachurus trachurus* (L.) in the North Sea and English Channel. J. Fish Biol., 6(4): 415-438.

Macer, C.T. 1977. Some aspects of the biology of the horse mackerel [*Trachurus trachurus* (L.)] in waters around Britain. Journal of Fish Biology, 10: 51-62.

Pérez-Rodríguez, A. 2017. Use of Length Based Indicators to estimate reference points for the North Sea horse mackerel. Working Document to WGWIDE, 6pp.

Rückert, C., Floeter, Temming, J.A. 2002. An estimate of horse mackerel biomass in the North Sea, 1991-1997. ICES Journal of Marine Science, 59: 120-130.

6.8 Tables

Table 6.3.1. North Sea Horse Mackerel stock. Catch in numbers (1000) by quarter and area in 2019

	Number/1000					
1Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0.03	0.03	0.00	0.57	58.87	59.50
3	0.18	0.18	0.02	3.32	346.17	349.87
4	0.09	0.09	0.01	1.73	180.20	182.13
5	0.37	2.06	0.05	6.95	724.35	733.78
6	0.07	40.56	0.01	1.37	142.77	184.78
7	0.08	87.46	0.01	1.60	166.24	255.40
8	0.05	24.01	0.01	0.88	91.64	116.58
9	0.18	109.69	0.02	3.39	353.32	466.61
10	0.22	379.05	0.03	4.08	424.54	807.91
11	0.20	272.13	0.03	3.81	396.42	672.58
12	0.09	197.59	0.01	1.72	178.85	378.26
13	0.08	181.73	0.01	1.58	164.46	347.86
14	0.04	93.17	0.01	0.81	84.32	178.35
15	0.85	1788.72	0.11	16.15	1682.27	3488.11
Sum	2.54	3176.48	0.33	47.95	4994.42	8221.71
2Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.01	0.01
4	0.00	0.00	0.01	0.02	0.04	0.07
5	0.00	1.75	0.09	0.18	0.37	2.39

6	0.01	36.27	1.84	3.91	7.84	49.87
7	0.02	78.52	3.97	8.44	16.92	107.88
8	0.01	21.81	1.10	2.33	4.67	29.91
9	0.03	98.68	4.98	10.60	21.25	135.53
10	0.10	341.05	17.23	36.63	73.44	468.45
11	0.07	243.88	12.34	26.25	52.62	335.17
12	0.05	176.97	8.96	19.05	38.20	243.24
13	0.05	162.70	8.24	17.52	35.13	223.64
14	0.02	83.43	4.23	8.98	18.01	114.67
15	0.47	1602.49	81.14	172.51	345.88	2202.48
Sum	0.84	2847.54	144.12	306.43	614.39	3913.33
3Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0	0	5.56	4.91	17.89	28.35
3	0	0	14.50	28.85	105.19	148.54
4	0	0	97.27	15.03	54.81	167.12
5	0	0	43.16	60.30	219.87	323.33
6	0	0	25.21	10.32	37.64	73.17
7	0	0	0.28	10.45	38.09	48.81
8	0	0	0.18	6.70	24.44	31.32
9	0	0	17.29	25.17	91.80	134.26
10	0	0	0.54	20.61	75.14	96.29
11	0	0	0.59	22.43	81.79	104.81
12	0	0	0.19	7.20	26.27	33.66
13	0	0	0.17	6.62	24.15	30.94
14	0	0	0.09	3.40	12.38	15.87
15	0	0	1.86	70.48	256.99	329.32
Sum	0	0	206.90	292.46	1066.45	1565.80

4Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0	0	0				
1	0	0				
2	0	0	0.46	49.23	850.83	900.52
3	0	0	2.72	289.46	5003.50	5295.69
4	0	0	1.42	150.83	2604.59	2756.84
5	0	0	5.68	604.99	10445.75	11056.42
6	0	0	0.98	104.60	1533.66	1639.24
7	0	0	1.00	106.93	1257.66	1365.59
8	0	0	0.64	67.72	1008.55	1076.90
9	0	0	2.40	255.15	3669.67	3927.22
10	0	0	2.03	215.67	1166.55	1384.25
11	0	0	2.18	231.84	2169.01	2403.04
12	0	0	0.73	77.26	0.02	78.00
13	0	0	0.67	71.06	0.02	71.74
14	0	0	0.34	36.43	0.01	36.78
15	0	0	7.07	752.10	911.50	1670.66
Sum	0	0	28.31	3013.27	30621.32	33662.90

14Q						
Ages	**27.3.a**	**27.4.a**	**27.4.b**	**27.4.c**	**27.7.d**	**Total**
0						
1						
2	0.03	0.03	6.02	55.33	928.33	989.75
3	0.18	0.18	17.25	325.35	5459.24	5802.19
4	0.09	0.09	98.71	169.56	2841.92	3110.37
5	0.37	3.81	48.98	680.21	11399.47	12132.84
6	0.08	76.83	28.04	121.74	1723.70	1950.39
7	0.11	165.98	5.26	129.20	1481.01	1781.56
8	0.05	45.82	1.91	78.61	1130.46	1256.85

9	0.21	208.36	24.70	298.10	4140.50	4671.87
10	0.32	720.10	19.83	281.54	1745.02	2766.80
11	0.27	516.02	15.14	288.58	2704.84	3524.85
12	0.14	374.57	9.89	107.15	245.58	737.34
13	0.13	344.43	9.09	98.55	225.82	678.03
14	0.07	176.60	4.66	50.52	115.78	347.64
15	1.33	3391.21	90.17	1029.30	3217.82	7729.84
Sum	3.38	6024.02	379.66	3713.76	37359.49	47480.31

Table 6.3.2. Numbers at age (millions), weight at age (kg) and length at age (cm) for the North Sea horse mackerel 1995-2019 in the commercial fleet catches (2018 distribution based on one sample only due to low sampling level).

Catch	**no**																								
Age	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1	1.8	4.6	12.6	2.3	12.4	70.2	12.8	60.4	13.8	15.7	52.4	5	3.4	1.7	34.1	3.3	8.1	9.5	7.6	15.4	49.7	3.6	20.7	27.42	0
2	3.1	13.8	27.2	22.1	31.5	78	36.4	16.8	56.2	17.5	29.8	23.7	15.5	8.8	13.9	22.5	23.3	24.3	10	15.3	23.8	65.2	20.9	49.12	0.99
3	7.2	11	14.1	36.7	23.1	28.4	174.3	19.3	23.4	34.4	27.8	61.5	22.8	36.1	28.4	10.7	76.5	20.4	21.3	8.7	10.1	15.9	62.6	13.19	5.80
4	10.3	11.9	14.9	38.8	17.6	21.4	87.8	11.9	33.2	14.5	12.6	40.9	82.6	16.7	22.1	15.7	37.3	40.2	22.2	30.2	5.8	9.8	10.2	32.74	3.11
5	12.1	9.6	14.6	20.8	23.1	31.3	18.5	5.6	26.9	27.8	16.7	73	71.2	36.4	17.3	23.7	14.6	25.8	27.1	13.8	7.2	7.7	6	4.53	12.13
6	13.2	12.5	12.4	12.1	26.2	19.6	11.5	5.8	10.6	20.2	5.2	23.4	30.5	36.1	16.3	15.9	9.9	20.8	6	7.1	3.8	5.7	3.4	0.69	1.95
7	11.4	8	10.1	14	20.6	19.5	18.3	5.5	6.3	10.6	2.9	13.7	23.9	27.3	21.5	27.6	5.8	3.1	7.2	2.7	3.3	2.5	2.8	0.71	1.78
8	12.6	6.6	8.6	10.8	21.8	9	14.7	10.5	9.6	3.8	2.4	5.9	17.3	21.9	47.1	5.6	6	5	4.3	3.4	1.4	5.1	2.4		1.26
9	7.3	1.5	2.5	8.3	12.9	11.5	10.2	6.3	10.9	5.4	3.8	1.6	7.9	10.2	11.2	6.3	3.4	4.6	4	0.9	1.6	1.2	0.9		4.67
10	5.9	5.3	0.8	4	8.2	9	10	6.8	1.5	11	5.8	1.4	1.7	7.5	9.3	8.3	10.1	1.5	5.4	1	0.9	0.1	0.3		2.77
11	0	0.3	0.3	2.7	2.1	7	9.6	5.1	3.4	6.2	2.3	0.2	0.6	1.9	7.2	2.9	6.9	0.5	3.7	1.3	0.2	0.1	0.5		3.52
12	8.8	1.3	0.3	0.7	0.4	3.1	5.4	3	3.3	4.5	4.1	1.7	0.2	2.1	3.7	0.3	3.6	0.1	1	0.4	0.9	0.4	0		0.74
13	0.2	8.9		1.8	1.4	1.6	3.7	2.2	2.3	6.2	2.5	0.6	0.7	0.4	0.3	0.3	0.8		0.6	0	0.2	1.4	0		0.68
14	4.4	8	1.4	0.3	3.8		2	1.3	3.4	2.3	9.9	1	0.7	2.4	0.9	0.2	0.3	0.2	0	0.2	0.2	0.5	0.3		0.35
15+				5.1	4	12.2	5.8	2.7	4.7	8.5	9.6	0.8		1	6.1	1.1	0.5		0.1	0.1			0.3		7.73

kg	weight																								
Age	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
1	0.076	0.107	0.063	0.063	0.063	0.075	0.067	0.066	0.075	0.076	0.07	0.074	0.615	0.063	0.074	0.077	0.061	0.069	0.077	0.078	0.062	0.07	0.06	0.061	0
2	0.126	0.123	0.102	0.102	0.102	0.1	0.09	0.096	0.105	0.105	0.087	0.098	0.081	0.096	0.087	0.101	0.092	0.09	0.099	0.11	0.099	0.093	0.086	0.093	0.111
3	0.125	0.143	0.126	0.126	0.126	0.137	0.094	0.129	0.122	0.122	0.104	0.116	0.104	0.109	0.113	0.118	0.096	0.118	0.112	0.113	0.13	0.115	0.113	0.131	0.125
4	0.133	0.156	0.142	0.142	0.142	0.152	0.117	0.155	0.136	0.146	0.133	0.124	0.115	0.125	0.134	0.137	0.115	0.142	0.138	0.135	0.15	0.126	0.131	0.147	0.155
5	0.146	0.177	0.16	0.16	0.16	0.165	0.159	0.171	0.164	0.174	0.159	0.141	0.13	0.145	0.152	0.155	0.145	0.152	0.166	0.144	0.169	0.158	0.173	0.170	0.165
6	0.164	0.187	0.175	0.175	0.175	0.192	0.183	0.195	0.18	0.198	0.197	0.178	0.163	0.161	0.182	0.183	0.166	0.172	0.18	0.177	0.196	0.155	0.189	0.189	0.202
7	0.161	0.203	0.199	0.199	0.199	0.194	0.198	0.216	0.193	0.224	0.238	0.212	0.192	0.193	0.195	0.206	0.193	0.183	0.2	0.184	0.26	0.162	0.177	0.201	0.261
8	0.178	0.195	0.231	0.231	0.231	0.216	0.201	0.227	0.212	0.229	0.248	0.247	0.197	0.221	0.258	0.199	0.193	0.188	0.216	0.201	0.29	0.235	0.188		0.248
9	0.165	0.218	0.25	0.25	0.25	0.244	0.237	0.228	0.24	0.256	0.259	0.236	0.257	0.286	0.253	0.241	0.305	0.212	0.223	0.222	0.265	0.246	0.222		0.261
10	0.173	0.241	0.259	0.259	0.259	0.283	0.246	0.253	0.27	0.29	0.287	0.286	0.255	0.295	0.322	0.227	0.334	0.204	0.226	0.22	0.312	0.359	0.233		0.304
11	0.317	0.307	0.3	0.3	0.3	0.286	0.26	0.303	0.24	0.3	0.335	0.237	0.517	0.273	0.422	0.284	0.345	0.275	0.242	0.264	0.262	0.369	0.257		0.301
12	0.233	0.211	0.329	0.329	0.329	0.354	0.286	0.293	0.298	0.297	0.349	0.261	0.279	0.309	0.447	0.234	0.408	0.195	0.263	0.287	0.318	0.379			0.411
13	0.241	0.258	0.367	0.367	0.367	0.316	0.287	0.317	0.356	0.301	0.338	0.267	0.339	0.375	0.383	0.288	0.474		0.262	0.252	0.351	0.242			0.420
14	0.348	0.277	0.299	0.299	0.299		0.295	0.32	0.316	0.338	0.373	0.302	0.414	0.277	0.362	0.315	0.415	0.187	0.559	0.408	0.235	0.39	0.214		0.429
15+	0.348	0.277	0.36	0.36	0.36	0.35	0.336	0.389	0.353	0.402	0.375	0.404		0.389	0.46	0.351	0.475		0.339	0.273		0.378	0.26		0.431

kg	**weight**																								
cm	**length**																								
Age	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2018**
1	19.2	19.2	19.2	19.2	19.2	19.1	19.5	19.4	20.3	19.8	18.1	20.1	19.9	20	20.3	20.8	19.2	19.9	20.9	20.4	19.8	20	19.1	19.5	
2	22	22	22	22	22	21.5	21.5	21.7	22.3	22.2	21.5	22	20.8	21.6	21.6	22.6	21.7	21.7	22.4	22.9	22.9	22	21.3	22.2	23.5
3	23.5	23.5	23.5	23.5	23.5	23.9	21.9	23.8	23.7	23.6	22.9	23.4	22.5	23.2	23.2	23.9	23	23.5	23.5	23.6	24.6	23.6	23.3	24.7	24.4
4	24.8	24.8	24.8	24.8	24.8	24.9	23.4	25.4	24.6	25.2	24.7	24.1	23.6	24.1	24.6	25	24.5	25	25.3	24.8	25.8	24.8	24.1	25.6	26.1
5	25.5	25.5	25.5	25.5	25.5	26	26.7	26.3	26.2	26.6	25.9	25.4	24.4	25.6	25.8	25.7	25.9	25.7	27	25.4	26.6	26.4	26.7	26.8	26.6
6	26.4	26.4	26.4	26.4	26.4	27.6	27.5	27.4	27.3	27.5	27.7	27	26.6	26.3	27.2	27.1	27.6	27	27.1	27.3	28.2	26.1	27.5	27.5	28.1
7	27.2	27.2	27.2	27.2	27.2	28.1	28.1	28.6	28.2	28.8	29.8	28.6	27.8	28.1	28.1	28.3	27.7	27.1	28.3	27.5	30.4	27.5	27.5	28.0	30.6
8	29.2	29.2	29.2	29.2	29.2	28.6	28.5	29.3	29	29.2	30.4	29.8	28.1	28.8	30.6	28.4	27.8	27	28.9	28	31.7	30.2	28		30.0
9	29.5	29.5	29.5	29.5	29.5	29.9	29.8	29.4	29.9	30.4	30.8	30.8	30.1	31.2	31.1	30.2	31.9	28.6	29.2	28.8	30.5	30.5	29.1		30.6
10	29.5	29.5	29.5	29.5	29.5	31.2	30.2	30.3	30.9	31.4	31.8	31.5	31	31.8	32.5	30	32.5	28	29.5	29.2	32.5	34.7	29.5		32.1
11	30.6	30.6	30.6	30.6	30.6	31.5	30.7	31.4	30.7	31.9	33.8	31.2	39.5	31.6	35	32.2	33.2	30.1	30	30.7	31.5	35.2	31.1		32.1
12	32.1	32.1	32.1	32.1	32.1	33.6	32	31.6	31.9	31.7	35.6	30.8	31.5	32.2	35.3	30.8	34.6	27.5	30.4	30.6	32.3	35.5			36.0
13	33.3	33.3	33.3	33.3	33.3	33.3	31.7	32.4	32.8	31.9	34	32.1	33.4	33.9	34	31.8	36.4		32.1	30	32.5	31.5			36.3
14	31.1	31.1	31.1	31.1	31.1		32.1	32.4	32.5	33	34.4	32.5	34.5	32.3	34.2	33	36	27.5	38.5	36	30.5	36.1	30.5		36.6
15+	32.5	32.5	32.5	32.5	32.5	33.8	33.4	34.3	33.6	34.8	35.2	35.3		35.1	36.1	34.5	36.9		34.2	32.5		36.1	31.5		36.5

Table 6.3.3. North Sea Horse Mackerel stock. Mean weight at age (kg) in the catch by area for all quarters in 2019

Q1-Q4						
Ages	27.3.a (Q1,2)	27.4.a(Q1,2)	27.4.b	27.4.c	27.7.d	Total
0						
1						
2	0.111	0.111	0.167	0.111	0.111	0.111
3	0.125	0.125	0.161	0.125	0.125	0.125
4	0.154	0.154	0.198	0.154	0.154	0.155
5	0.165	0.184	0.191	0.165	0.165	0.165
6	0.242	0.338	0.243	0.217	0.194	0.202
7	0.307	0.353	0.334	0.281	0.248	0.261
8	0.271	0.328	0.297	0.256	0.244	0.248
9	0.299	0.379	0.309	0.275	0.253	0.261
10	0.367	0.390	0.383	0.342	0.261	0.304
11	0.362	0.401	0.387	0.332	0.278	0.301
12	0.411	0.411	0.411	0.410	0.411	0.411
13	0.420	0.420	0.420	0.420	0.421	0.420
14	0.429	0.429	0.429	0.429	0.429	0.429
15	0.450	0.454	0.452	0.444	0.403	0.431

Table 6.3.4. North Sea Horse Mackerel stock. Mean length (cm) at age in the catch by area for all quarters in 2019

1-4Q						
Ages	27.3.a (Q1,2)	27.4.a(Q1,2)	27.4.b	27.4.c	27.7.d	Total
0						
1						
2	23.5	23.5	25.3	23.5	23.5	23.5
3	24.4	24.4	25.3	24.4	24.4	24.4
4	26.1	26.1	27.0	26.1	26.1	26.1
5	26.6	20.0	26.8	26.6	26.6	26.6
6	29.7	33.4	29.1	28.7	27.9	28.1

1-4Q						
7	32.2	33.9	33.2	31.3	30.1	30.6
8	30.2	30.8	30.5	30.1	30.0	30.0
9	32.0	34.9	32.8	31.1	30.3	30.6
10	34.4	35.3	35.0	33.5	30.5	32.1
11	34.2	35.7	35.1	33.2	31.2	32.1
12	36.0	36.0	36.0	36.0	36.0	36.0
13	36.3	36.3	36.3	36.3	36.3	36.3
14	36.6	36.6	36.6	36.6	36.6	36.6
15	37.2	37.3	37.3	37.0	35.5	36.5

Table 6.4.1. North Sea Horse Mackerel. CPUE Indices of abundance (number/hour) for juvenile (<20cm) and exploitable (≥20cm) sub-stocks, estimated as a combined index for the NS-IBTS Q3 and the French Channel Ground Fish Survey in Q4. The survey indices are derived from the prediction of a hurdle model fit to data over the period 1992-2019 and include a 95% confidence interval based on a bootstrapping procedure (CI_low = lower bound, CI_high = upper bound).

	Juvenile sub-stock (<20 cm)			Exploitable sub-stock (>20 cm)		
Year	**Index**	**CI_low**	**CI_high**	**Index**	**CI_low**	**CI_high**
1992	4281	2069	9018	1376	586	2798
1993	1860	919	3707	556	279	977
1994	2593	1263	5200	1169	553	2203
1995	2026	1132	4004	1347	534	2659
1996	735	319	1583	1055	492	1913
1997	2159	942	4950	626	280	1131
1998	650	322	1251	407	188	744
1999	1441	789	2527	447	209	806
2000	1568	802	3085	422	209	768
2001	2170	1168	4658	517	257	920
2002	2389	1191	4778	425	209	809
2003	1788	943	3202	288	142	570
2004	1005	530	1774	351	160	649
2005	804	426	1459	658	302	1257
2006	532	275	958	697	332	1347
2007	603	315	1034	345	155	761

	Juvenile sub-stock (<20 cm)			Exploitable sub-stock (>20 cm)		
2008	533	277	928	163	81	365
2009	692	366	1260	98	42	195
2010	2262	1148	4486	195	79	396
2011	499	274	1021	226	100	465
2012	319	169	676	153	86	414
2013	1058	560	2091	185	77	424
2014	1534	819	2935	325	147	729
2015	1479	697	3082	433	176	855
2016	3073	1558	6339	438	190	827
2017	946	453	1964	134	57	295
2018	3247	1640	7949	110	45	212
2019	810	380	1633	195	85	423

6.9 Figures

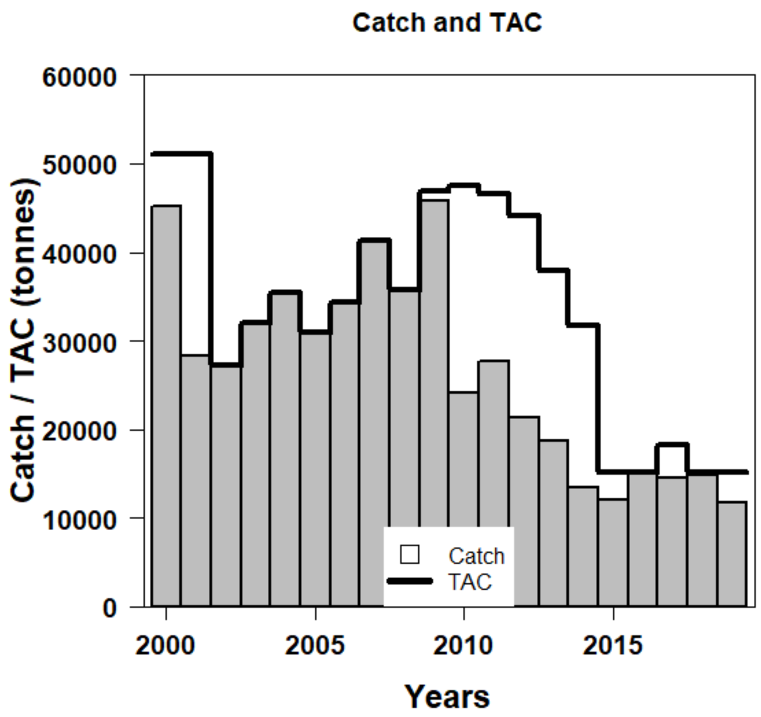

Figure 6.2.1. North Sea horse mackerel. Utilisation of quota from 2000 to 2019.

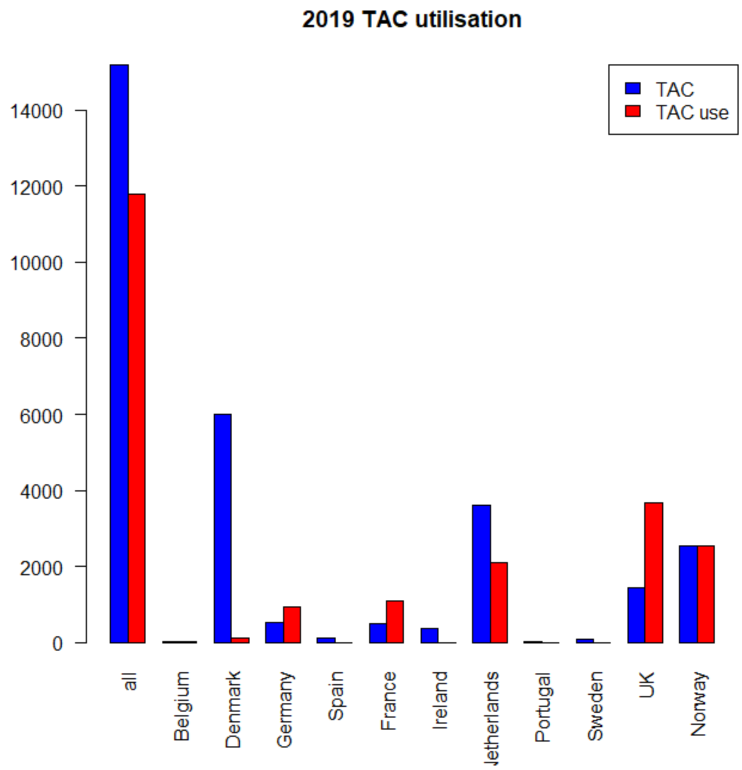

Figure 6.2.2. North Sea horse mackerel. Utilisation of quota by country in 2019.

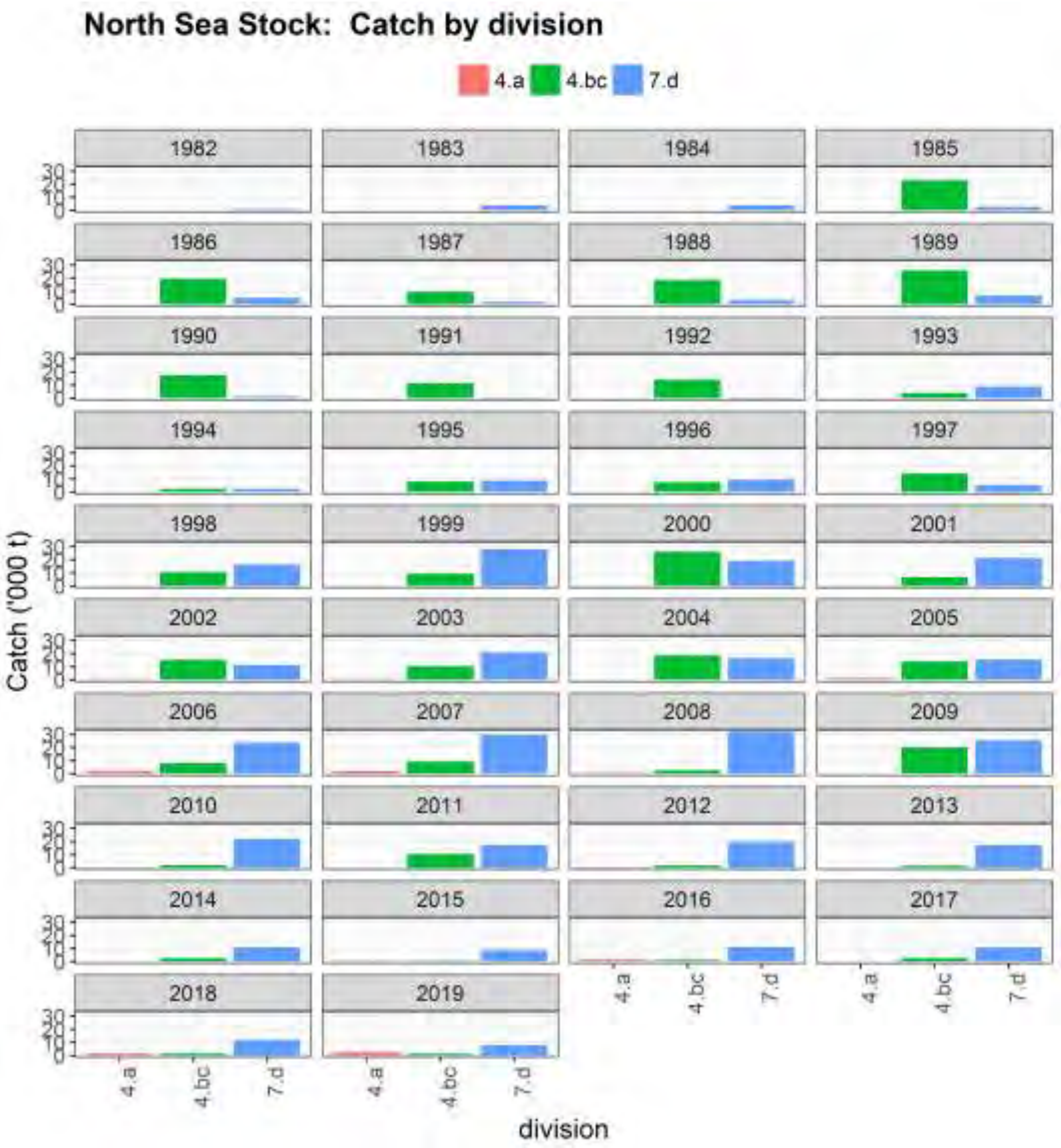

Figure 6.2.3. North Sea horse mackerel. Catch in (1000 t) by division and year from 1982 to 2019.

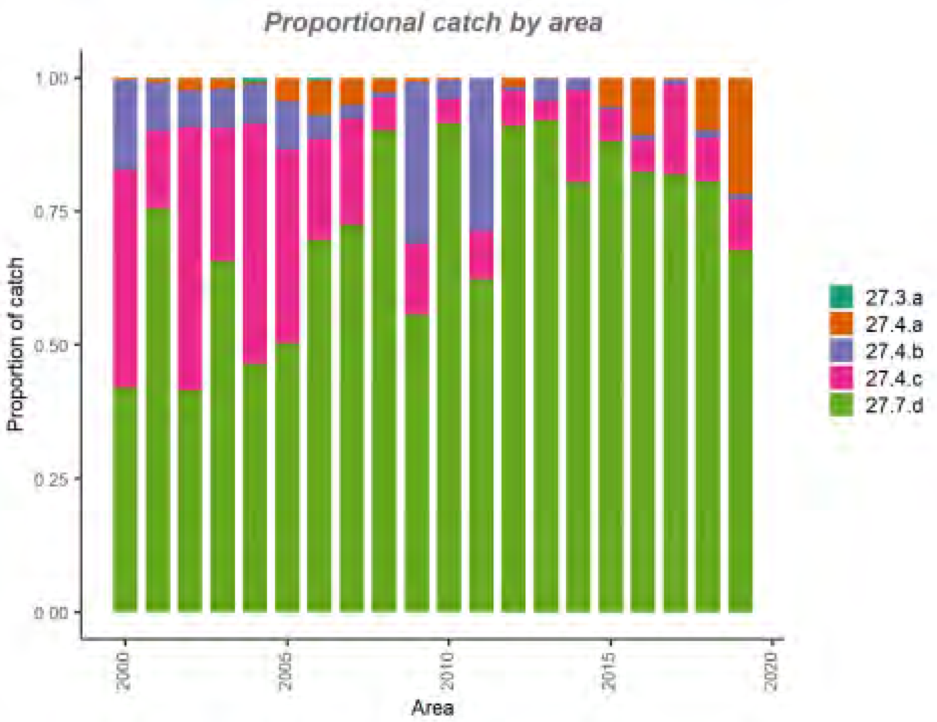

Figure 6.2.4. North Sea horse mackerel. Proportion of catches by ICES division from 2000 to 2019.

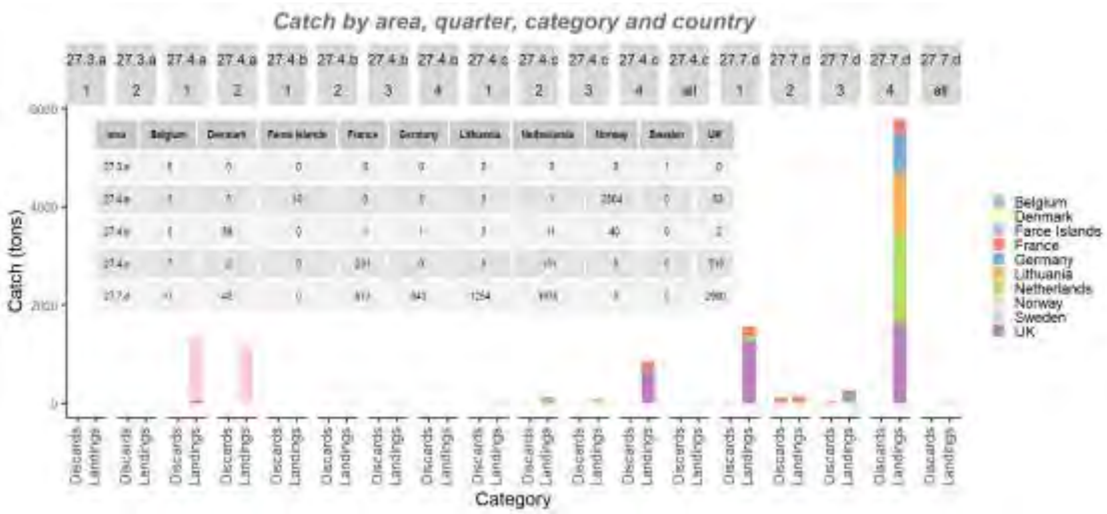

Figure 6.2.5. North Sea Horse Mackerel. Total catch (in tonnes) by ICES division, quarter, catch category and country in 2019.

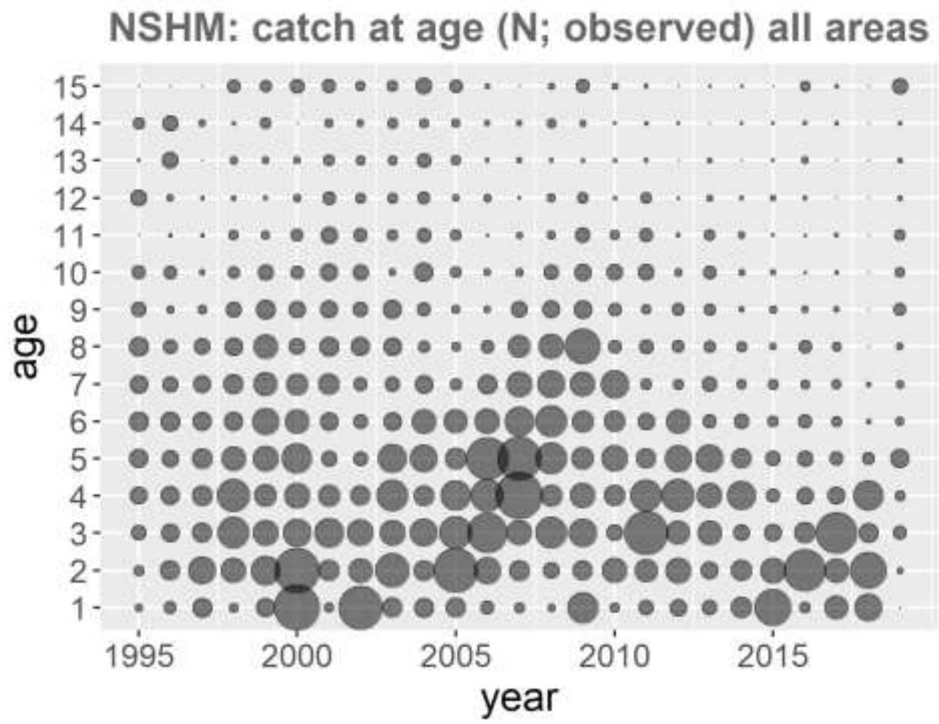

Figure 6.3.1. North Sea horse mackerel age distribution in the catch for 1995-2019. The size of bubbles is proportional to the catch number. Note that age 15 is a plus group.

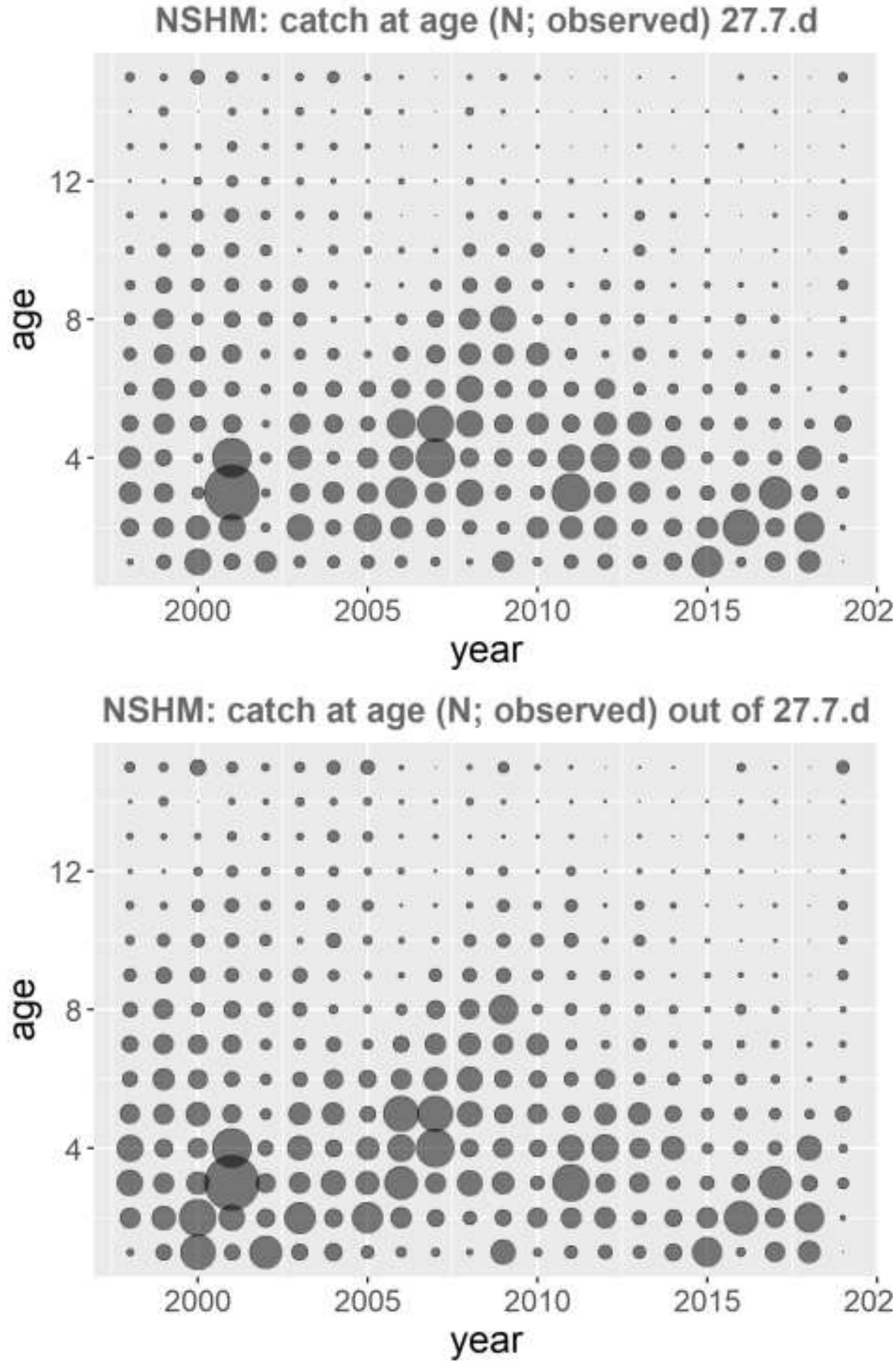

Figure 6.3.2. North Sea horse mackerel. Bubble plots of age distribution in the catch by area for 1998-2019 for area 7.d (upper panel) and out of 7.d (bottom panel). The size of bubbles is proportional to the catch numbers. Note that age 15 is a plus group.

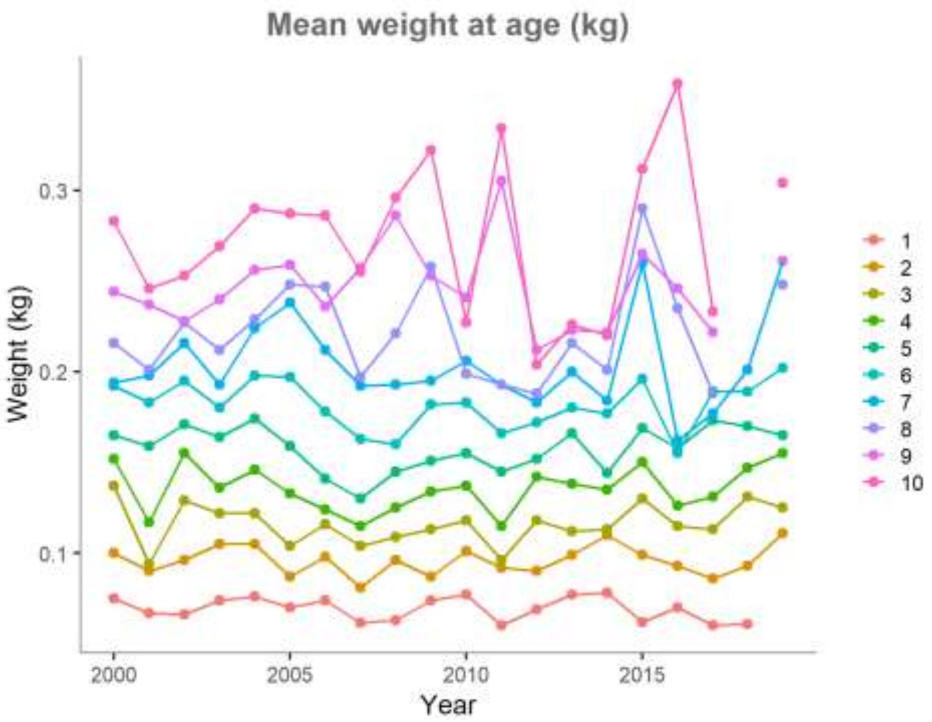

Figure 6.3.3. North Sea horse mackerel. Mean weight at age in commercial catches over the period 2000-2019. Note that only age 1-10 are presented and that 10 is not a plus group.

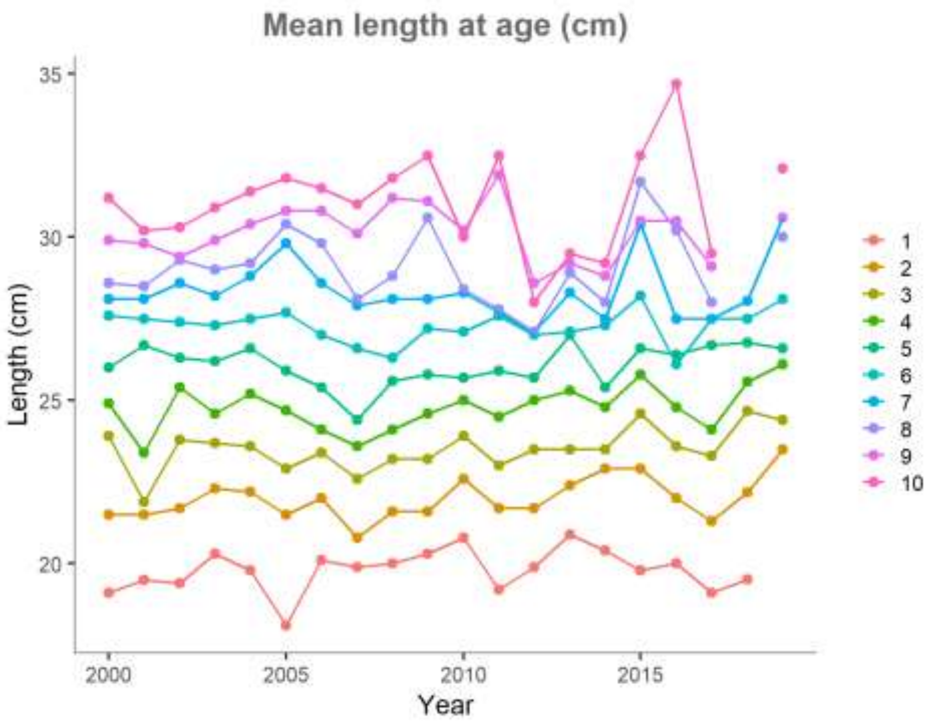

Figure 6.3.4. North Sea horse mackerel. Mean length at age in commercial catches over the period 2000-2019. Note that only age 1-10 are presented and that 10 is not a plus group.

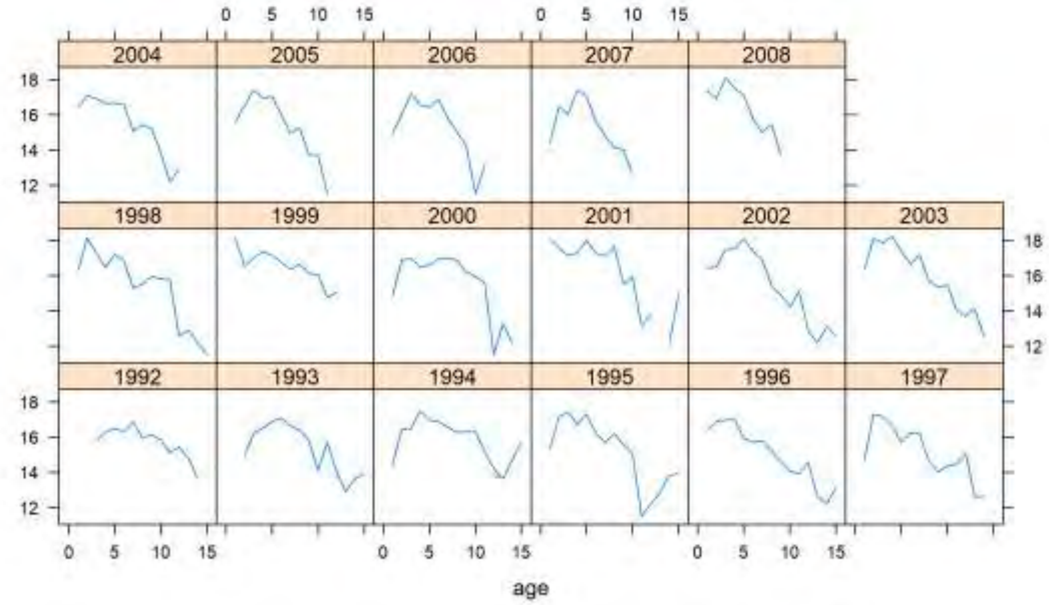

Figure 6.4.1. North Sea Horse Mackerel. Catch curves for the 1992 to 2008 cohorts, ages from 3 to 15+. Values plotted on the vertical axis are the log(catch) values for each cohort in each year. The negative slope of these curves estimates total mortality (Z) in the cohort.

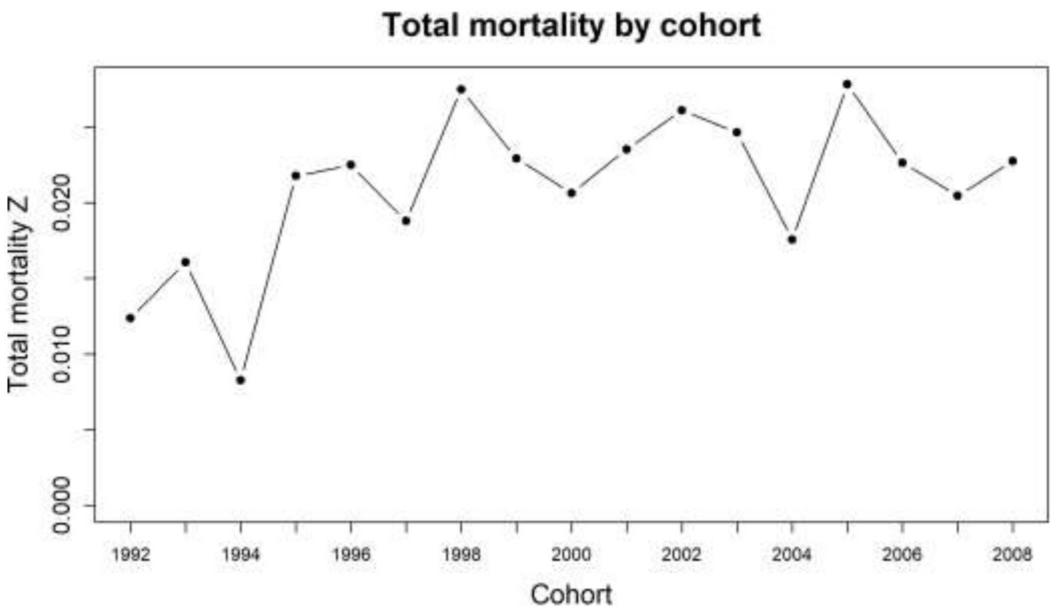

Figure 6.4.2. North Sea Horse Mackerel. Total mortality by cohort (Z) estimated from the negative gradients of the 1992—2008 cohort catch curves (Figure 6.4.1).

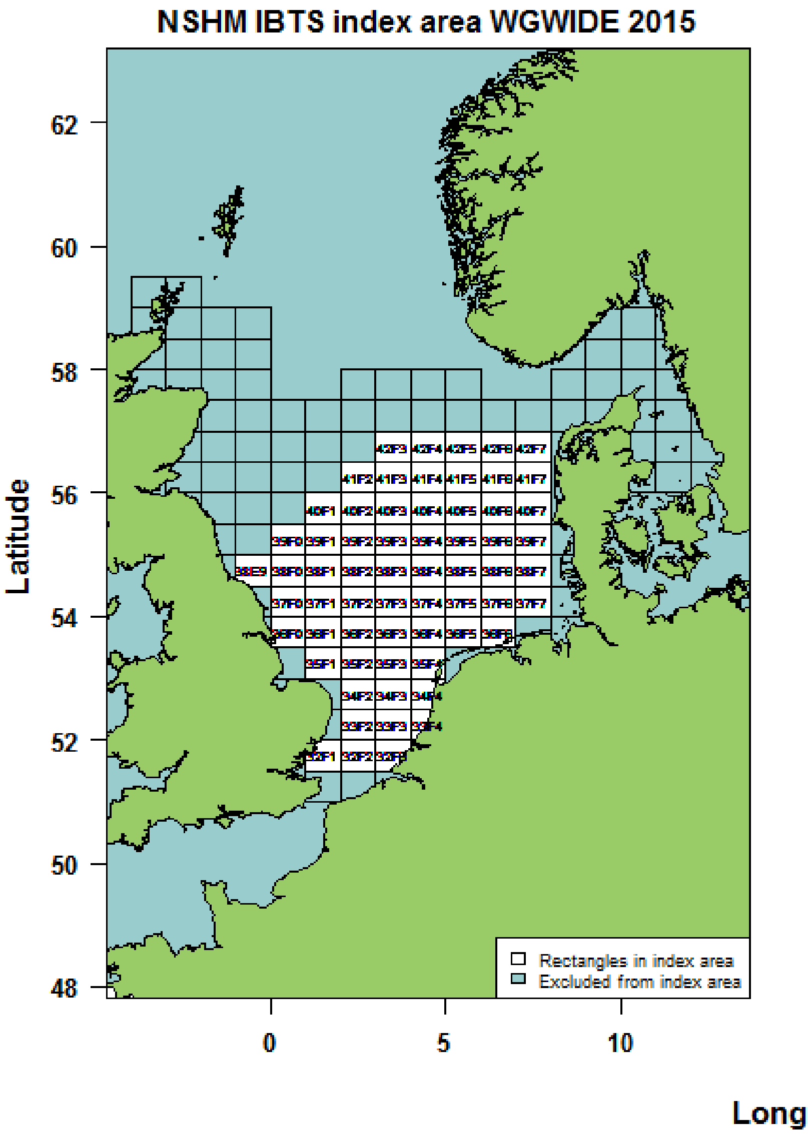

Figure 6.4.3. North Sea horse mackerel. ICES rectangles selected by WGWIDE in 2013 and currently used by the working group.

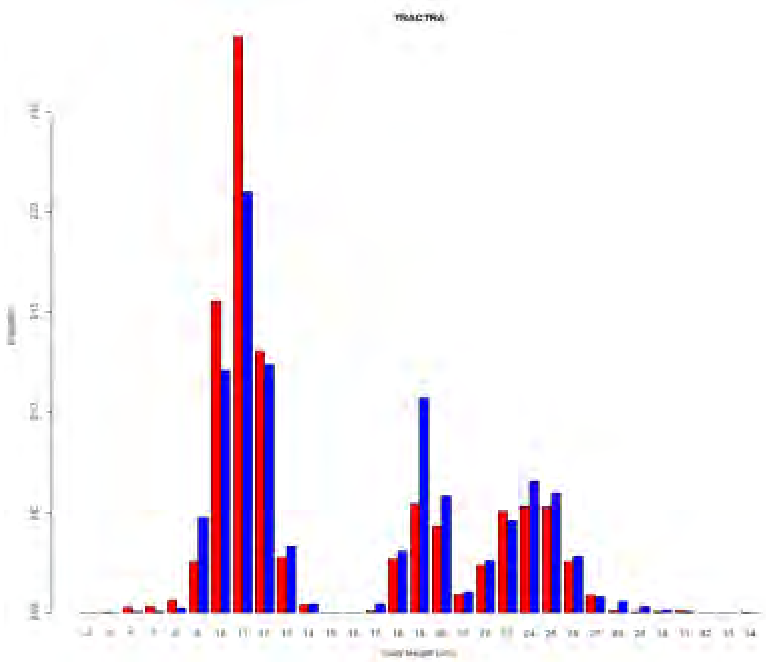

Figure 6.4.4. North Sea horse mackerel. Size distribution of North Sea horse mackerel catches during the inter-calibration exercise conducted in 2014 between the RV Gwen Drez (red bars) and Thalassa (blue bars).

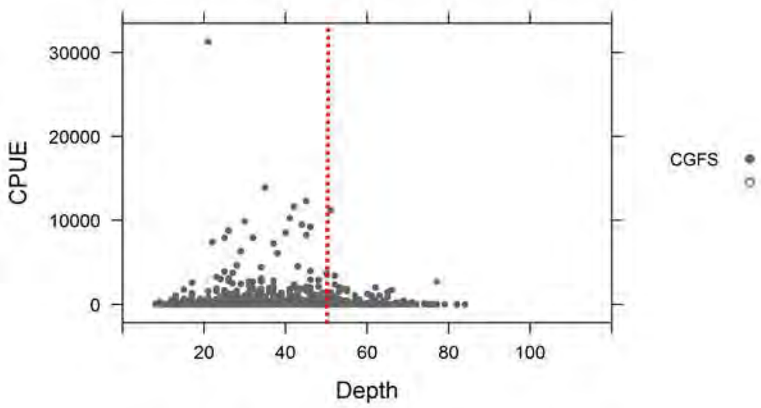

Figure 6.4.5. North Sea horse mackerel. CPUE by depth for the CGFS survey from 1992 to 2017.

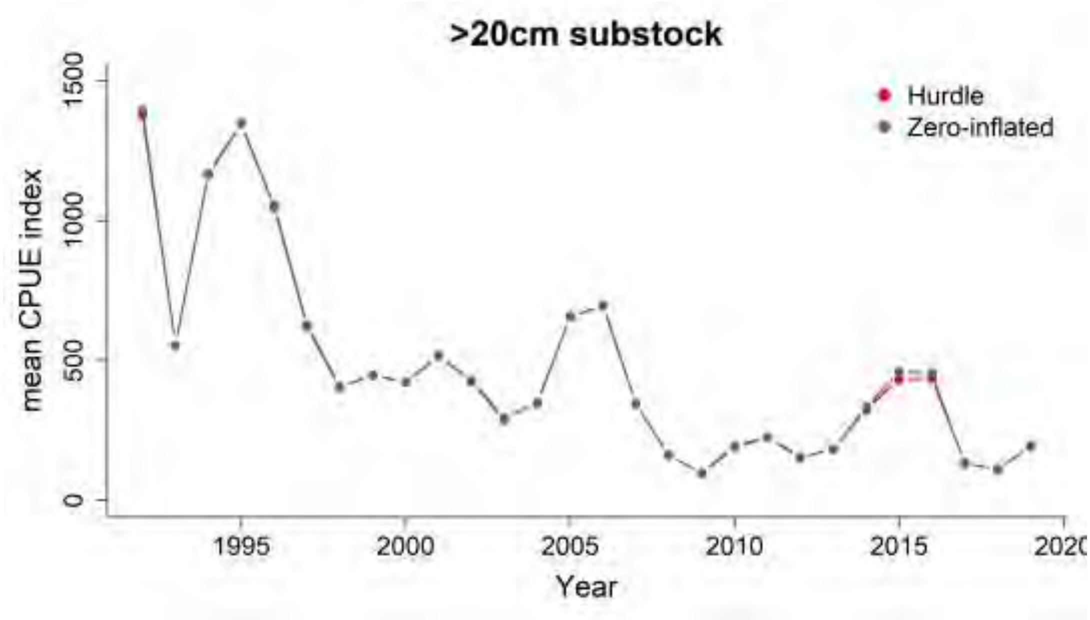

Figure 6.4.6. North Sea horse mackerel. CPUE per year of the exploitable sub-stock (≥20 cm) from 1992 to 2019 as modelled by the hurdle model (red) that returned a warning when ran, and the zero-inflated model.

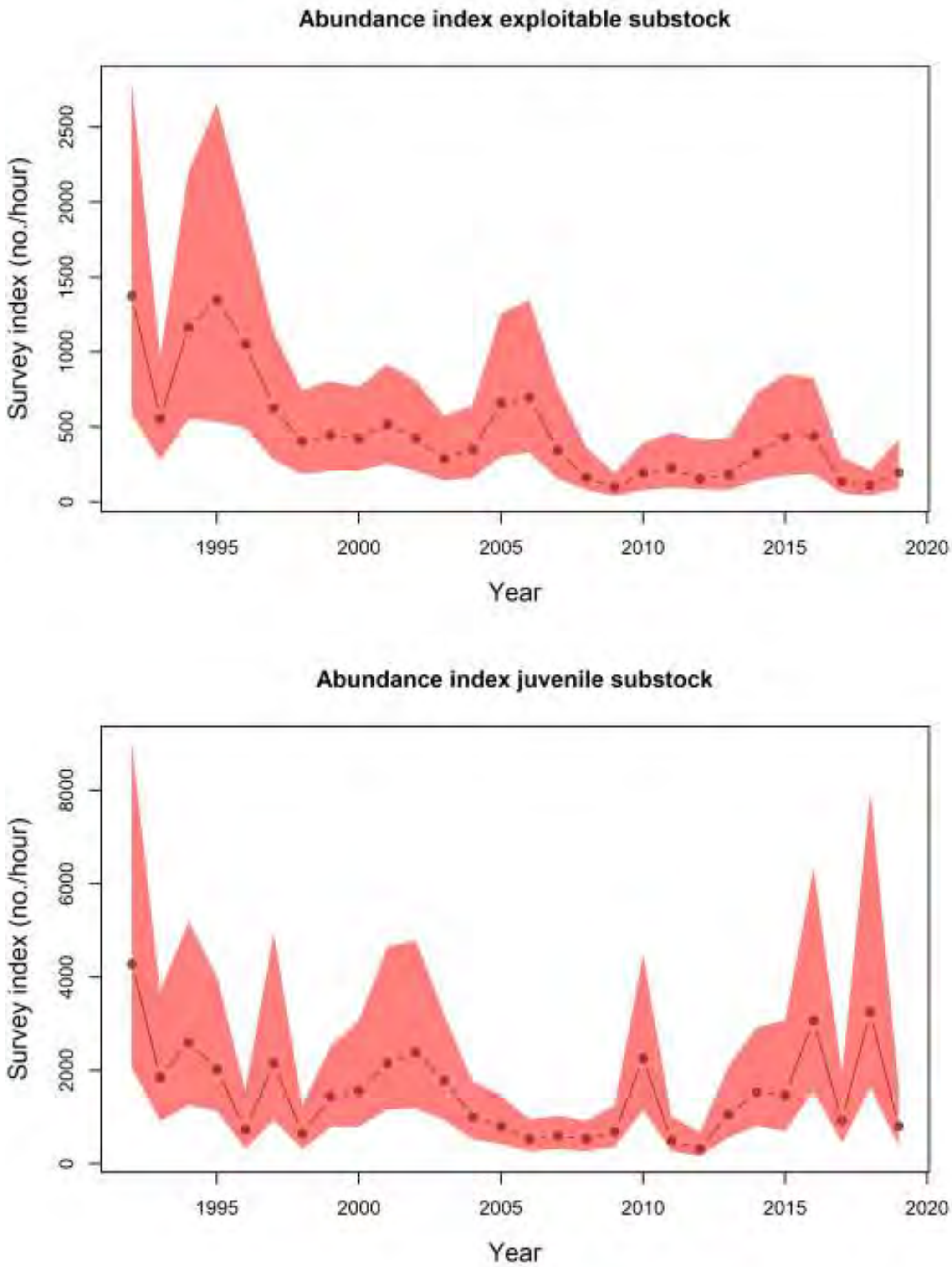

Figure 6.4.7. North Sea Horse Mackerel. Joint CPUE survey index (number/hour) derived from the hurdle model fit to the IBTS survey in the North Sea and the CGFS survey in the Eastern English channel. Top: exploitable sub-stock (≥20 cm), bottom: juvenile sub-stock (<20 cm). The red shaded area represents the 95% confidence interval, which is determined by bootstrap resampling of Pearson residuals with 999 iterations.

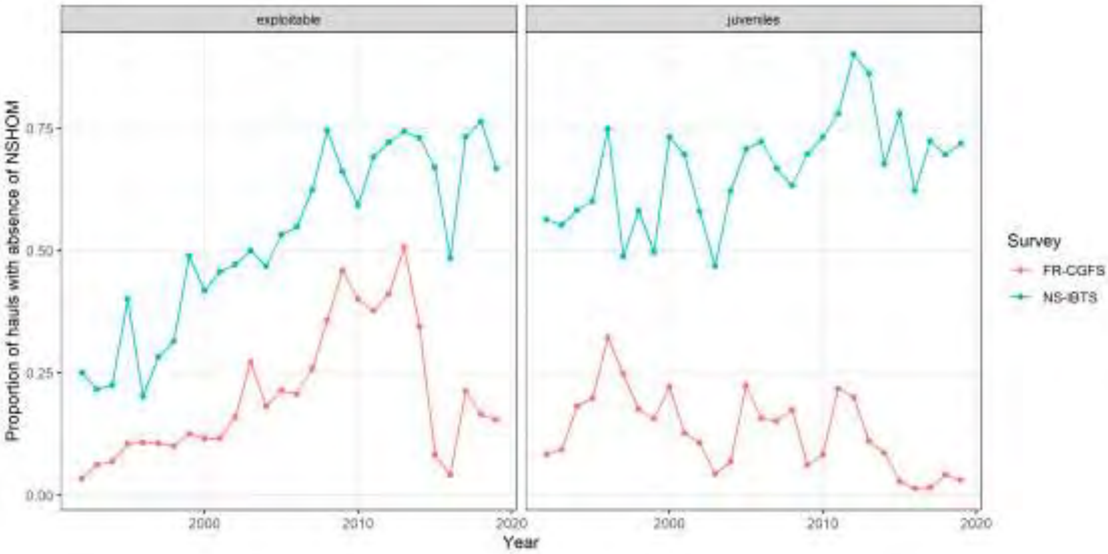

Figure 6.4.8. North Sea horse mackerel. Proportion of hauls with zero catch for the exploitable (≥20cm) and juvenile (<20 cm) sub-stocks in the NS-IBTS (blue) and the CGFS (red) from 1992 to 2019.

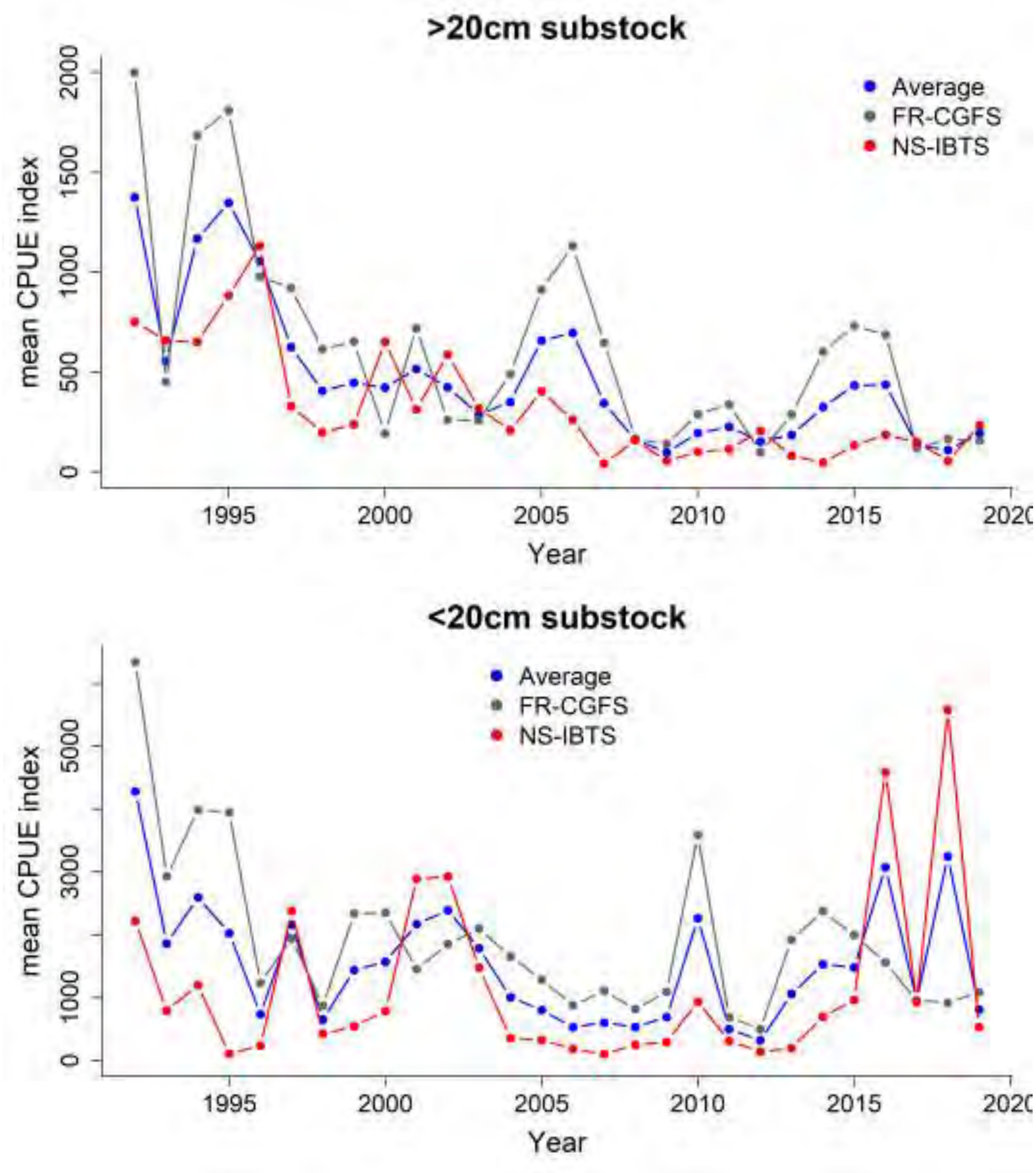

Figure 6.4.9. North Sea Horse Mackerel. Mean CPUE survey index (number/hour) obtained from the hurdle model fit to the IBTS survey in the North Sea (in red), the CGFS survey in the English channel (in grey) and the joint survey index (in blue). Top: exploitable sub-stock (≥20cm), bottom: juvenile sub-stock (<20 cm).

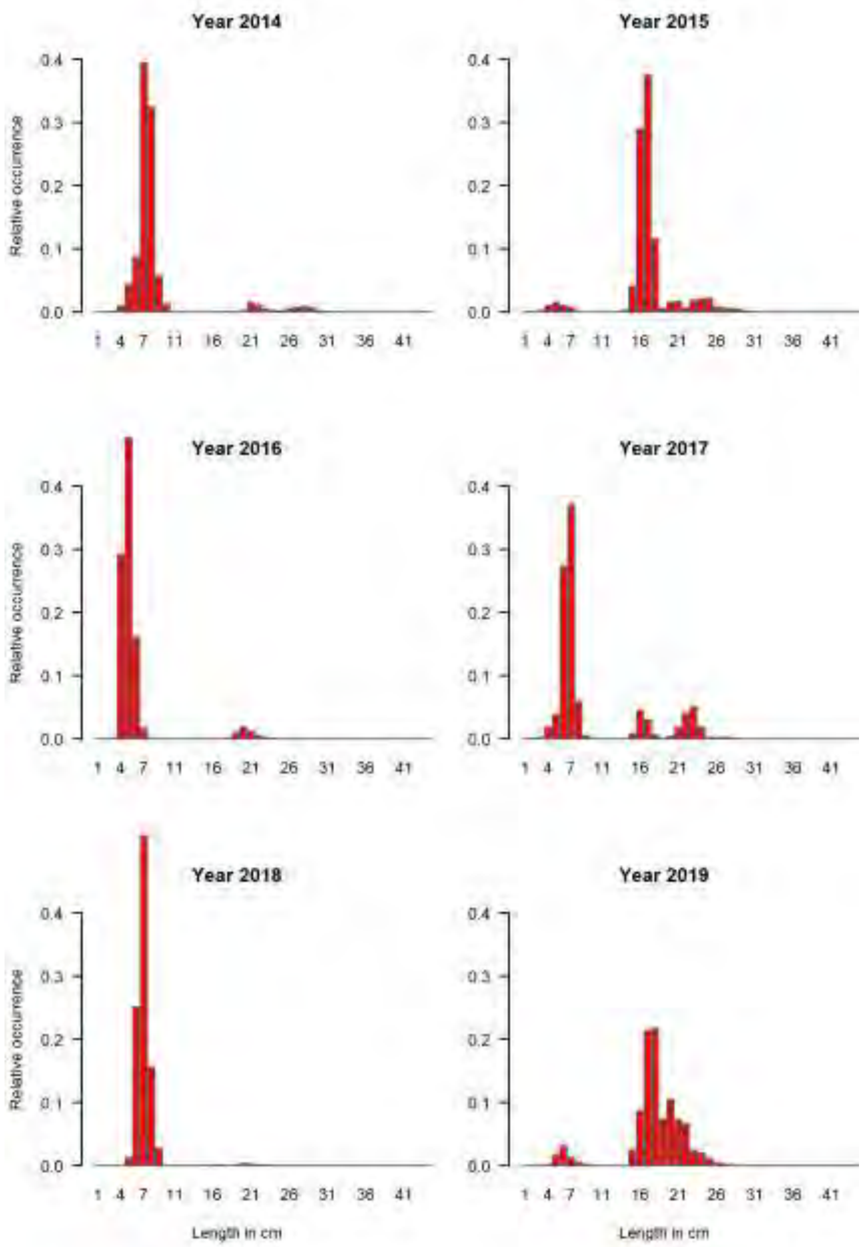

Figure 6.4.10. North Sea horse mackerel. Relative occurrence by length for the period 2014-2019 in the NS-IBTS.

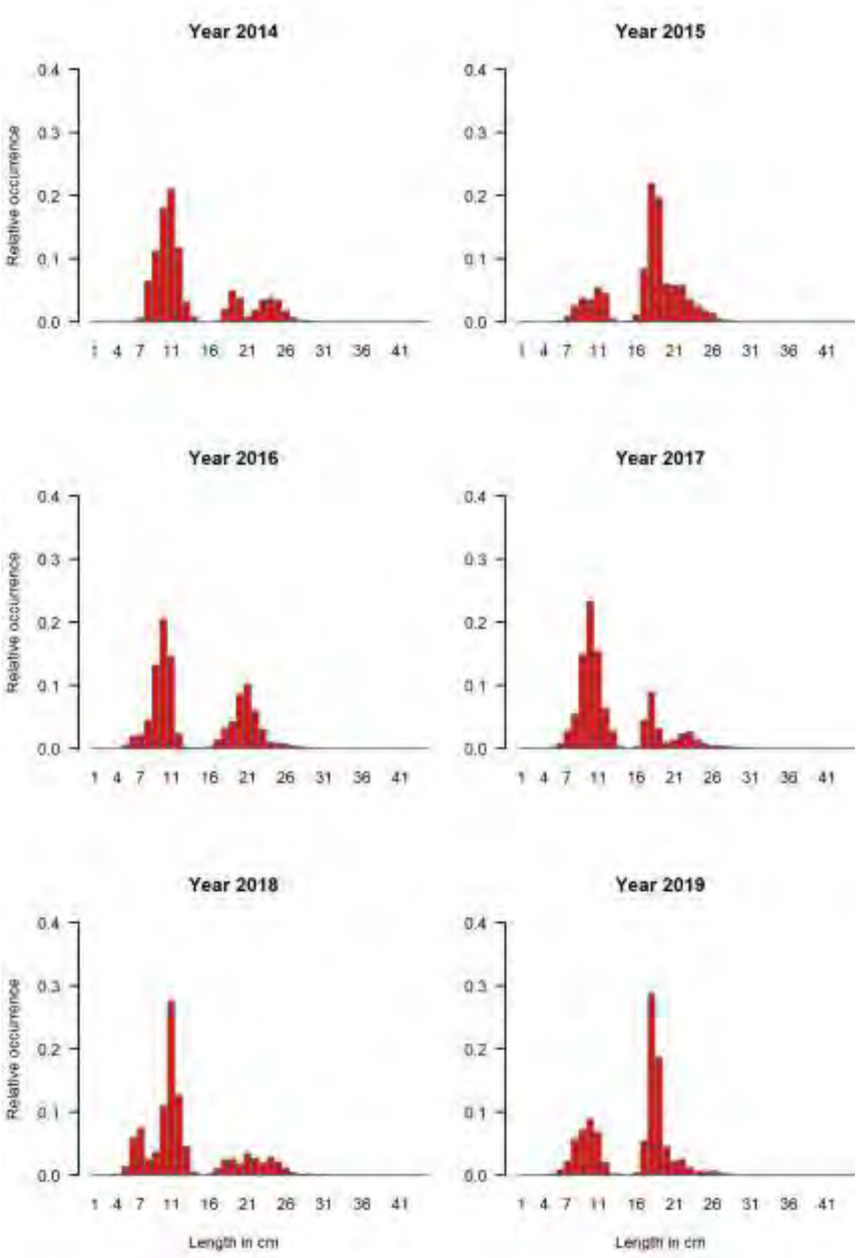

Figure 6.4.11. North Sea horse mackerel. Relative occurrence by length for the period 2014-2019 in the CGFS.

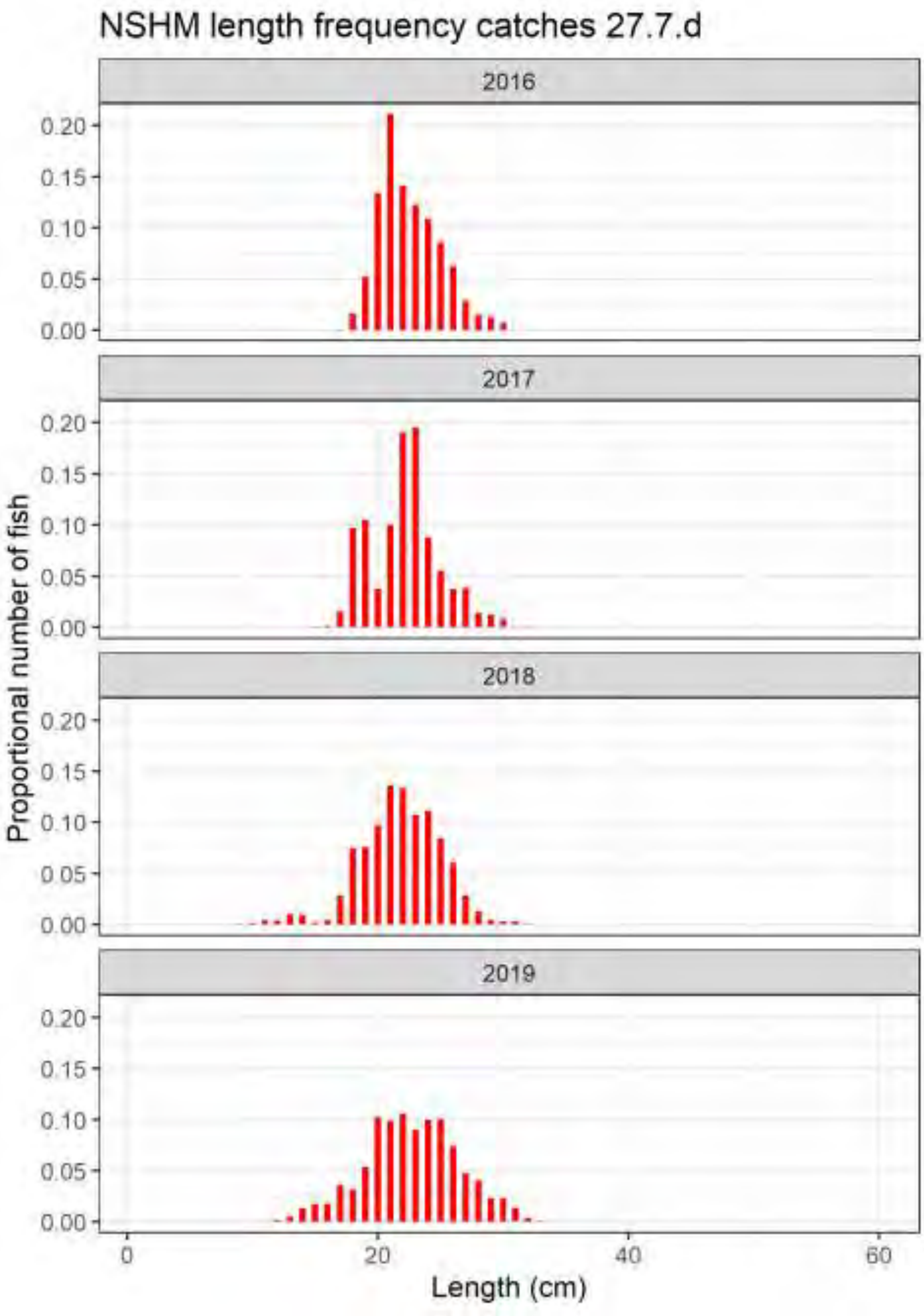

Figure 6.4.12. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.7.d for the period 2016-2019.

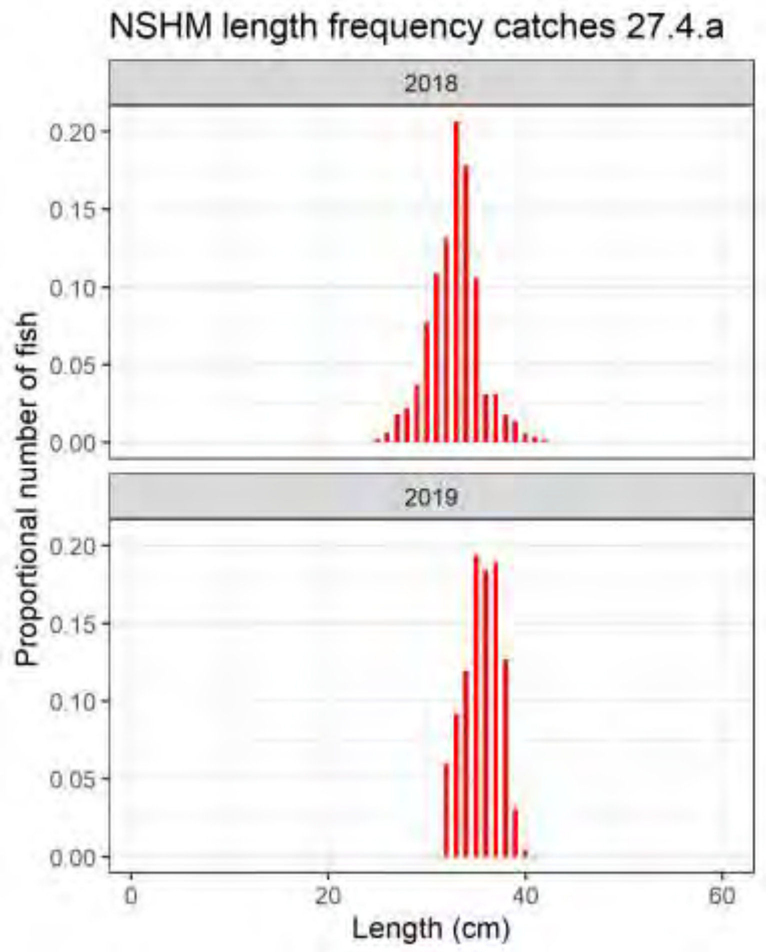

Figure 6.4.13. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.4.a in 2018 and 2019.

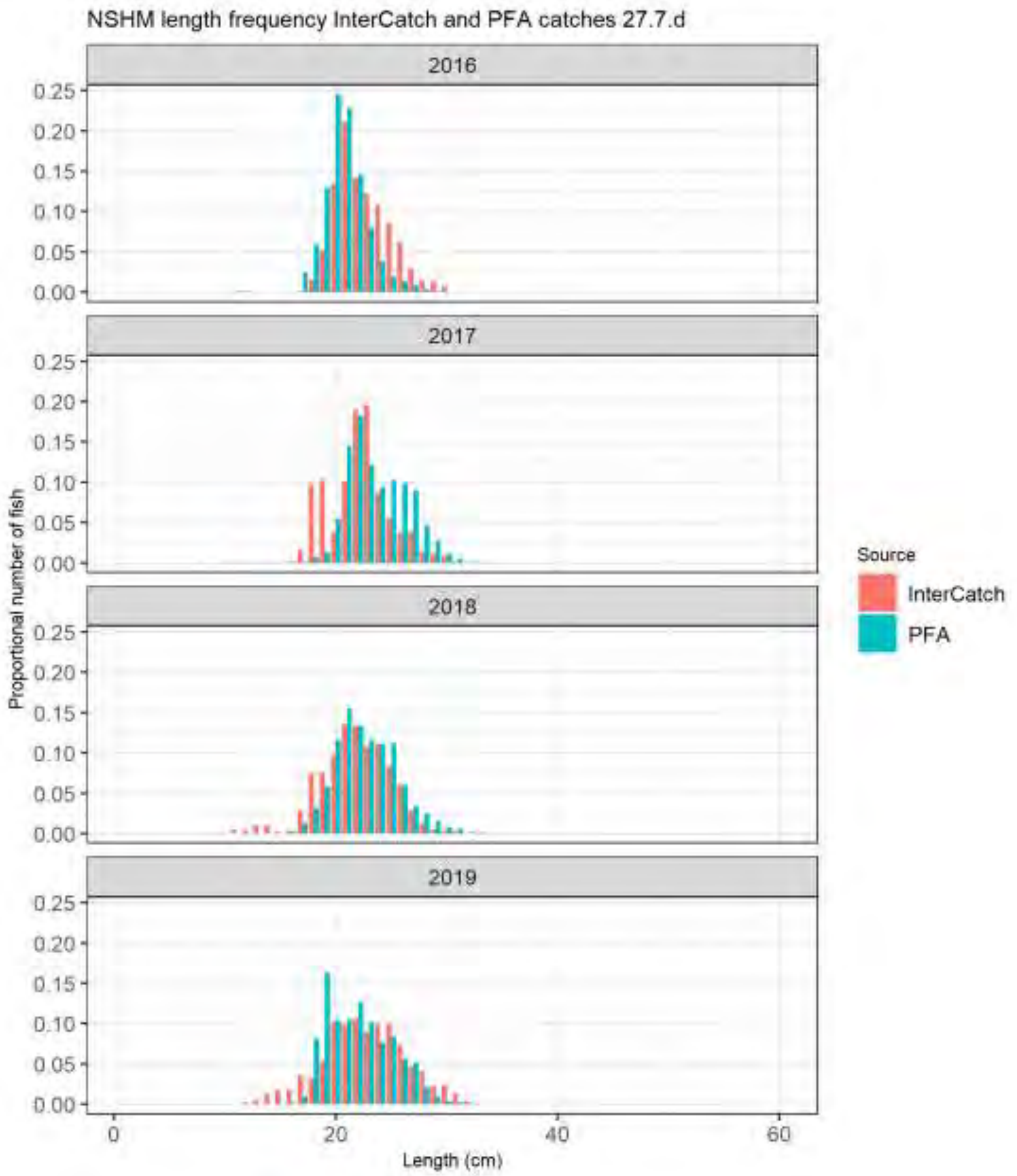

Figure 6.4.14. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches (submitted by countries; blue) and from the self-sampling programme of the Pelagic Freezer-trawler Association (PFA; red) in 27.7.d for the period 2016-2019.

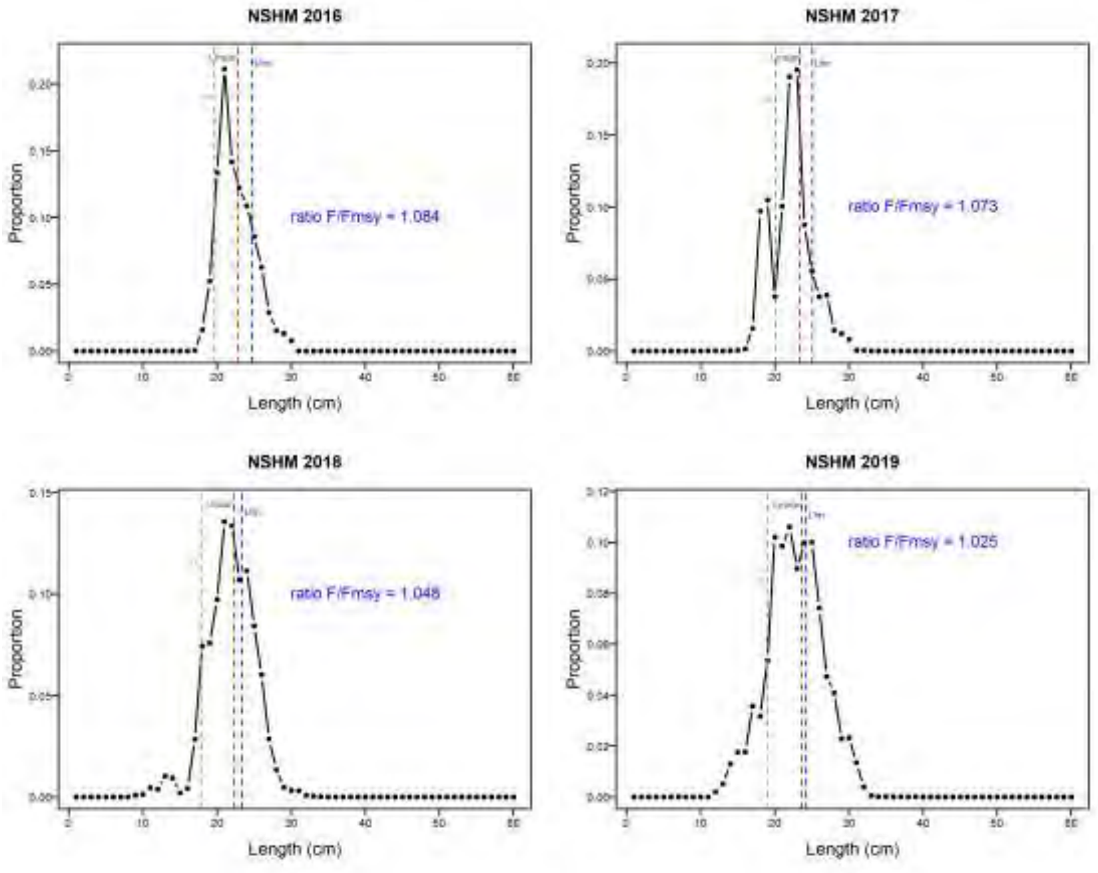

Figure 6.4.15. Length distribution (cm), estimated parameters L_c, L_{mean}, $L_{f=m}$ (cm) and F/F_{MSY} ratio for 2016-2019. Length samples from commercial catches in ICES division 27.7.d.

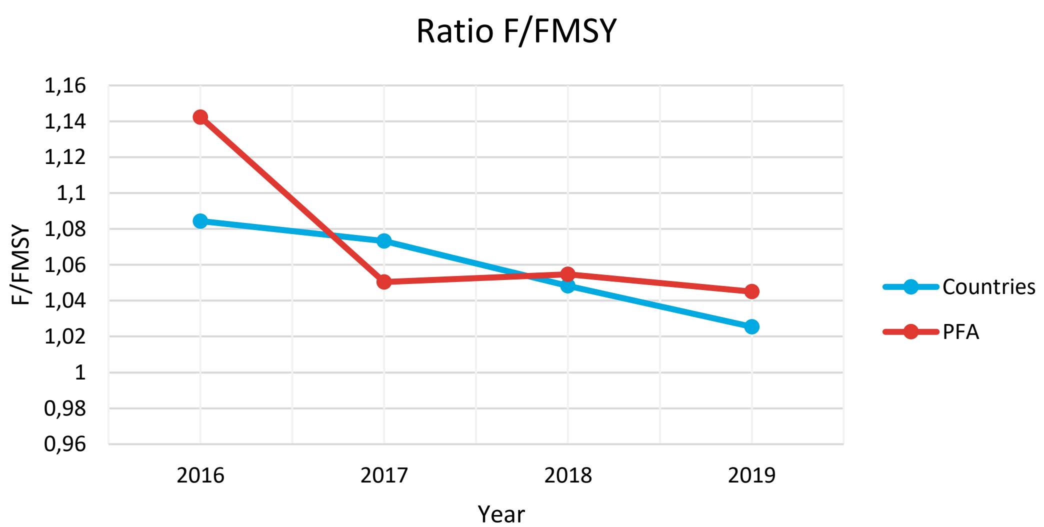

Figure 6.4.16. Trends in F/F_{MSY} proxy based on length samples from commercial catches from countries (blue) and from the Pelagic Freezer-trawler Association (PFA; red) in 27.7.d from 2016-2019. Note that only the MSY proxy based on data from countries is used in the assessment.