6 Horse mackerel (*Trachurus trachurus*) in divisions 3.a, 4.b–c, and 7.d (Skagerrak and Kattegat, southern and central North Sea, eastern English Channel)

6.1 ICES advice in 2021

In 2012, the North Sea horse mackerel (NSHOM) 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 (FR-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, the stock was benchmarked and the NS-IBTS and FR-CGFS survey indices where modelled together. The resulting joint index was considered a proper indication of trend in abundance over time and the NSHOM stock was upgraded to category 3.

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 in 2019, leading to a catch advice for 2020 and 2021 of 14 014 tonnes. Considering the 5.05% discards rate (average of 2017 and 2018 rates), the corresponding wanted catches were advised to be 13 305 tonnes.

6.2 Fishery of North Sea horse mackerel stock

Based on historical catches taken by the Danish industrial fleet for reduction into fishmeal and fishoil 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 4.b and 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 led 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 1990s, a larger proportion of the catches have been taken in a directed horse mackerel fishery for human consumption by the Dutch-owned 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 underutilization 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 2020, 91% of the TAC was used, with the highest catches taken by the Netherlands, followed by UK, Norway and France (Figure 6.2.2).

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 t) and 2000 (45 130 t). From 2000 to 2010, the catches varied between 24 149 and 45 883 t. 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 2020 the catch was 12 587 t, with 72% of the total catch being caught in Area 27.7.d, which is a similar share of the overall catch as in 2019 (68%, 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 2020, the Netherlands accounted for most of the landings, followed by UK, Norway and France (Figure 6.2.5). The majority was still caught in quarter 4 in 27.7d, whereas the Norwegian catches were taken during quarters 1 and 2 in 27.4.a. Most of the discards reported were from 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%. 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. In 2017 and 2018 the discard rate was 8.3% and 1.8%, respectively, while it decreased to 1.6% in 2019. In 2020 the discard rate was again 1.6%.

6.3 Biological data

6.3.1 Catch in Numbers-at-age

In 2020 (as in recent years) the coverage of biological sampling remains on a very low level and in addition was also affected by the Covid-19 pandemic. However, due to the fact that, for the first time, it was possible to include samples taken from English vessels in the Netherlands the proportion of sampling increased to 56% compared with last year where just 1/3 of the landings was sampled. In the past higher sampling levels were achieved such as in 2013 and 2014 when 71% and 63% of the catch was sampled. Age samples were therefore available from two countries (the Netherland and UK/England) with regards to Q3 and Q4 in areas 27.4.c and 27.7.d. Although most landed catch was taken from 27.7.d in Q4, 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 1995–2020 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 compared with 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 is 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, 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.

The potential for mixing of fish from the Western and North Sea stock in areas 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 entire 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 is described in Section 6.7.

6.3.2 Mean weight at age and mean length-at-age

The mean annual weight and length over the period 2000–2020 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 1992–2009 period provide complete data for the 1992 to 2009 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 should 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 exploratory model fits were attempted with the JAXass model, 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. JAXass 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 carried out 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), additional 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 explored the Surplus Production model in Continuous Time (SPiCT) model for 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 biomass was estimated to be above B_{MSY} and fishing mortality 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, additional 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 and Horse Mackerel Egg Surveys in the North Sea do not cover the spawning area of the North Sea horse mackerel stock.

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 that 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 NS-IBTS is considered a reasonable alternative.

NS-IBTS data from quarter 3 were obtained from DATRAS and analysed. Based on a comparison of NS-IBTS data from all 4 quarters in the period 1991–1996, Rückert *et al.* (2002) showed that horse mackerel catches in the NS-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 of 20 cm and larger is the most appropriate to the purpose of interpreting trend in the stock.

To create indices, a subset of ICES statistical rectangles was identified. 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 (FR-CGFS) in 27.7.d in quarter 4. The FR-CGFS has been carried out since 1990 and has frequent captures of horse mackerel. Although this survey is conducted in a different quarter to the NS-IBTS, the observed seasonal migration patterns of horse mackerel indicate that fish move into the Channel following quarter 3, so the timing is considered appropriate.

In 2015, the RV Gwen Drez was replaced by the RV Thalassa to carry out the FR-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 RV Thalassa as measured by the MARPORT sensor were deemed erroneous, which may question the validity of estimated area swept by the net on the RV 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 affect in the estimated abundance.

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

6.4.3.4 Impact of Covid-19

Due to the Covid-19 pandemic and the lockdown in place in France at that time there was a delay in submitting the cruise application form for the FR-CGFS in 2020 to the French Foreign Ministry. The result was that no authorization was provided in time to allow the survey to trawl within UK waters in 2020. Therefore, only French waters were sampled, meaning that only 70% of the core survey stations were completed (ICES, 2021).

To assess the potential impact of missing UK stations in the FR-CGFS on the resulting abundance index for the exploitable stock, we tested the impact of

i. removing all UK sampling stations from the 1992–2019 time-series,
ii. removing UK sampling stations from 2016-2019, one year at the time, and
iii. removing the FR-CGFS in 2016–2019, one year at the time, when modelling the abundance and calculating the index.

Removing all UK sampling stations from all years did not change the overall trend of the abundance index, but there were quite some deviations for individual years (Figure 6.4.6). Removing UK stations from on year at the time for 2016–2019 resulted in virtually no change for 2017 and 2018, but more apparent changes for 2016 and 2019 (Figure 6.4.7). Both these exercises suggest that basing the abundance index on NS-IBTS and French stations from FR-CGFS only may lead to different index values compared to when UK stations are included. The French sampling stations in the FR-CGFS only are thus not representative for the abundance of adult horse mackerel in the entire eastern Channel. As a further exploration, the abundance index was modelled by leaving out the FR-CGFS entirely for 2019. However, the hurdle model was not able to run, and therefore a zero-inflated model was run instead. This 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). Removing the FR-CGFS from on year at the time for 2016–2019 resulted in minimal change for 2017 and 2018, but more apparent changes for 2016 and 2019 (Figure 6.4.8). Similar to (i) and (ii), leaving out the FR-CGFS may lead to different index values compared to when FR-CGFS is included.

As the investigations suggest that the missing UK stations from the FR-CGFS or leaving out the FR-CGFS entirely may lead to changes in the abundance index, it was decided that no reliable index value for 2020 could be produced.

6.4.4 Length distributions from the surveys

The largest proportion of fish caught in 2020 were around 16–17 cm and 20–21 cm in the NS-IBTS (Figure 6.4.9). The latter group could be the strong year class observed in 2018 (Figure 6.3.1, 6.4.9). In the FR-CGFS, the largest proportion of fish were between 9–12 cm, while in previous years, larger fish were dominating the catches (Figure 6.4.10). Note however that for 2020 these are only based on French sampling stations.

6.4.5 Length distributions from commercial catches

Currently, length distributions from catch data are available from 2016 to 2020. 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 national sampling programmes. For comparison, the analysis has also been run in the past with length data from the self-sampling programme of the Pelagic-Freezer-trawler Association (PFA), see for instance ICES (2019, 2020).

The length distributions based on the commercial catch data from 27.7.d show a consistent distribution in time with a mean length between 22.2 and 22.8 cm each year, although with the exception of 25.8 cm in 2019 (Figure 6.4.11). Lengths in 27.4.c were on average 21.7 cm in 2019 and 22.7 cm in 2020, and this similar to 27.7.d (Figure 6.4.12).

An error was found in the calculation of the length frequency distributions in the previous 2019 and 2020 assessments. Furthermore, the length frequency distribution calculated in 2019 included French data from only quarters 3 and 4, whereas data are also available for quarters 1 and 2. The length frequency distributions for 2018 and 2019 were re-calculated using all available data.

6.5 Stock assessment

6.5.1 Modelling the survey data

In January 2017, a benchmark of the North Sea horse mackerel assessment was conducted (ICES, 2017). Based on a capacity to model the overdispersion and the large proportion of zero values in the survey catch data, a hurdle model was considered the best option of all model alternatives tested. The log-likelihood ratio test, AIC and the evidence ratio statistic supported that the model that best represented the data were 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 synthesize the information from both the FR-CGFS and NS-IBTS and predict the average annual CPUE index as an indicator of trends in stock abundance. Separate models were fitted to the juvenile (<20cm) and adult exploitable (≥20cm) substocks. 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 NSHOM to a category 3 stock within the ICES classification.

Similar to the 2019 assessment (ICES, 2019) and 2020 assessment (ICES, 2020), the model for the adult substock 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 6.5.1). 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.

Due to the exclusion of the 2020 survey for modelling the abundance index, the same time period (1992–2019) was used as in the previous assessment (ICES, 2020). This updated abundance index resulted in a higher value for 2016 for the exploitable stock compared to last year (Figure. 6.5.2). For each assessment, survey data from all years are extracted so that any underlying changes in the raw data stored in DATRAS are taken account of. Changes in reported raw HOM catches in 2016 in the NS-IBTS led to a higher mean catch rate of HOM (Figure 6.5.3), resulting in a higher abundance index value for 2016.

6.5.2 Summary of index trends and survey length distributions

The survey index for both the juvenile and exploitable substock experienced a marked decline in the early 1990s and fluctuated at relatively low levels thereafter (Figures 6.5.4; Table 6.5.1). 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 substock (Figure 6.5.5). 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 6.5.4).

The index trend for the juvenile substock shows large fluctuations since 2015 (Figure 6.5.4). These are mainly attributed to the fluctuating trend of juveniles in the NS-IBTS (Figure 6.5.6), caused by some hauls with high catches of small horse mackerel in 2016 and 2018 (Figure 6.4.9). Fitted values for juveniles in the FR-CGFS show decreasing trend since 2014, but a slight increase again in 2019 (Figure 6.5.6). 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.

6.5.3 Length-based indicator 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 in area 27.7d, length distributions from this area were used to calculate the MSY proxy. In 2020, the F/F_{MSY} proxy based on the commercial catch samples indicated that fishing mortality was still slightly above F_{MSY}, with $L_{mean}/L_{F=M}$ = 23.2 cm / 25.0 cm = 0.927 (Figure 6.5.7).

The updated length distributions of 2018 and 2019 led to only small revisions in the F/F_{MSY} ratios in those years: from 0.954 to 0.927 for 2018, and 0.976 to 0.978 for 2019.

6.6 Basis for 2022 and 2023 advice

Stock advice for North Sea horse mackerel is biennial. The NS-IBTS and FR-CGFS were modelled together to produce a joint abundance index for the exploitable part of the stock (≥ 20 cm). No index value for 2020 could be produced. For this reason, the 2-over-3 rule applied to the index could only make use of index values from 2016 to 2019. The resulting index ratio (index value of 2019 over mean index value of 2016–2018) indicated that the adult substock declined by 21%. As the decline was more than 20%, the uncertainty cap of 0.8 was applied to the catch advice. The $L_{mean}/L_{F=M}$ ratio in 2020 was 0.927, indicating that the fishing mortality is above F_{MSY}. Because the precautionary buffer was last applied in 2017, and thus more than three years ago, the buffer was applied once again in 2021. Under these circumstances, and based on the last year's catch advice of 14 014 t, ICES advises that catches of North Sea horse mackerel in 2022 and 2023 should be no more than 8969 t.

There are some signs of improved recruitment in some years (e.g. 2016, 2018), but the trend of the abundance index for the juvenile substock is fluctuating and, when separated, the two surveys, NS-IBTS and FR-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 substock in 2019 suggests that this may be the case.

6.7 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 are able to reveal the stock identity of individual horse mackerel from potential mixing areas, namely Division 7.d, 7.e and 4.a. Following this, the Institute of Marine Research in Norway sampled horse mackerel in coastal waters within 4.a during all quarters in 2019. Preliminary results presented at WGWIDE 2021 showed that the genetic profile of individuals caught in all quarters matched well with the genetic profile of the Western HOM stock, with just one or two individuals matching better with North Sea HOM profile (Florian Berg, pers. comm.). More samples and research is needed to confirm these results. In another research project, horse mackerel from 7.d and 7.e have been collected by the PFA on board of commercial vessels in autumn 2020, while during the same period horse mackerel from 4.a have been be collected during the NS-IBTS in Q3. The stock identity of the sampled fish will be investigated, and results can be expected in 2022. The Norwegian research as well as the ongoing research described here may have large implications for stock delineation.

6.8 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. Recent work suggest that all horse mackerel caught in 27.4.a belong to the Western stock, and ongoing genetic research on samples from 27.4.a and 27.7.d will shed more light on the proportions of the two stocks in catches from these areas.

6.9 Deviations from stock annex caused by missing information from Covid-19 disruption

1. Stock: **hom.27.3a4bc7d**

2. Missing or deteriorated survey data:

The assessment is based on two surveys, NS-IBTS and FR-CGFS. Due to the pandemic, trawling authorization in UK EEZ was not delivered in time, consequently FR-CGFS survey was not allowed to sample stations within UK waters in 2020.

3. Missing or deteriorated catch data:

Related to age sampling coverage was 56% and was covering only Q3, Q4 in areas 27.4.c and 27.7.d. Although most landed catch is taken from 27.7.d in Q4, other areas and quarters remain uncovered. Length sampling were impacted by the pandemic as samples were only available by two countries.

4. Missing or deteriorated commercial LPUE/CPUE data:

Not applicable

5. Missing or deteriorated biological data:

Not applicable

6. Brief description of methods explored to remedy the challenge:

Effects of having only UK stations in FR-CGFS in all years or a single year, and excluding FR-CGFS entirely for a single year on the combined survey index were investigated.

7. Suggested solution to the challenge, including reason for this selecting this solution:

Exploration methods suggested that leaving out UK stations or FR-CGFS entirely may affect the survey index and would lead to a survey index value not representative of stock abundance. It was therefore decided to produce no survey index value for 2020.

8. Was there an evaluation of the loss of certainty caused by the solution that was carried out?

The chosen solution affects the 2-over-3 rule by that only four instead of five index values can be used to assess the change in stock abundance. Like this year's assessment for 2022 and 2023, this will also affect the advice given in 2023 for 2024 and 2025.

6.10 References

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6.11 Figures

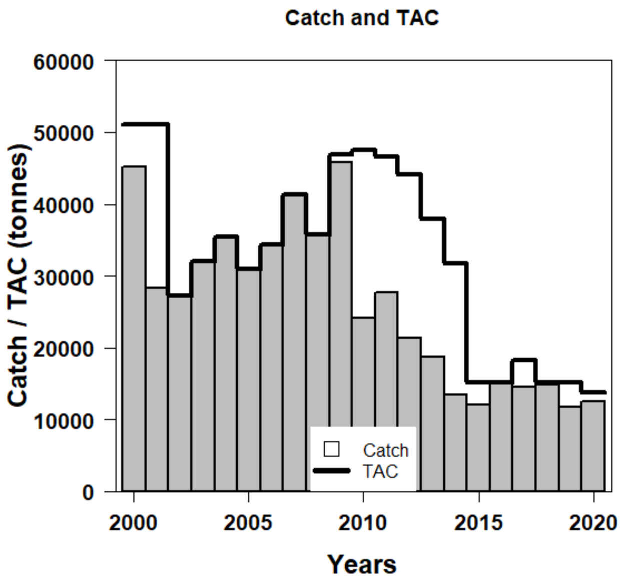

Figure 6.2.1. North Sea horse mackerel. Utilisation of quota from 2000 to 2020.

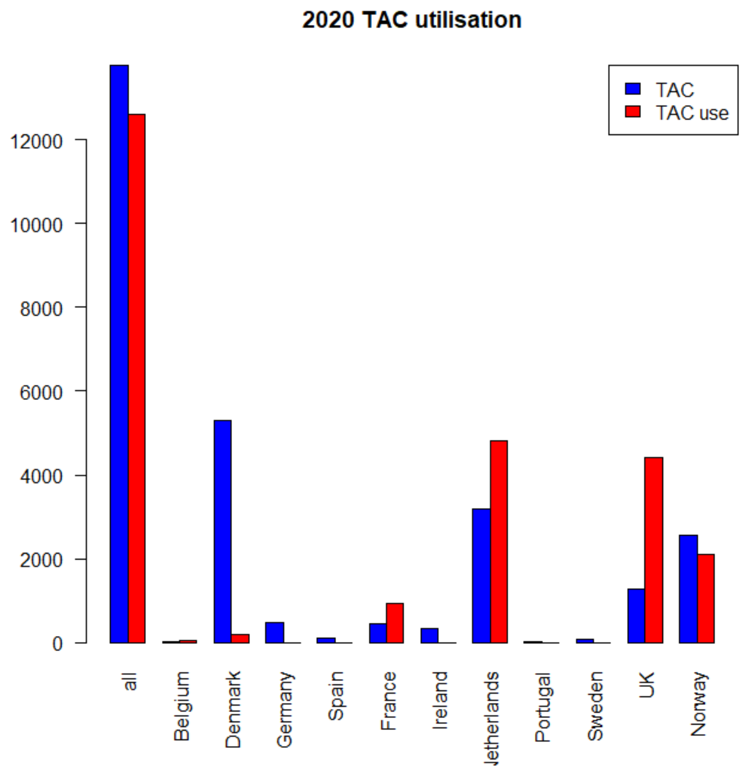

Figure 6.2.2. North Sea horse mackerel. Utilisation of quota by country in 2020.

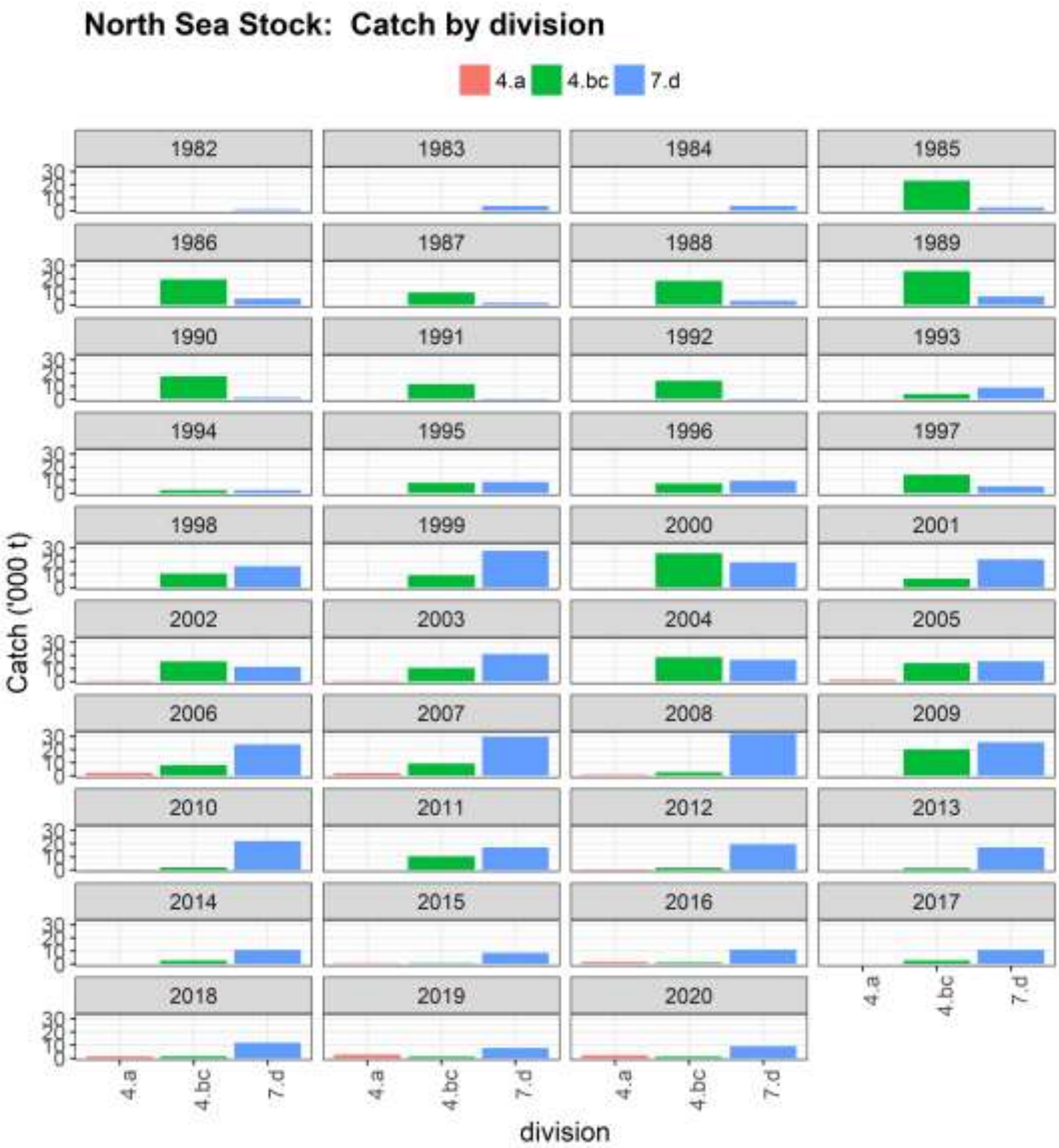

Figure 6.2.3. North Sea horse mackerel. Catch in (1000 t) by Division and year from 1982 to 2020.

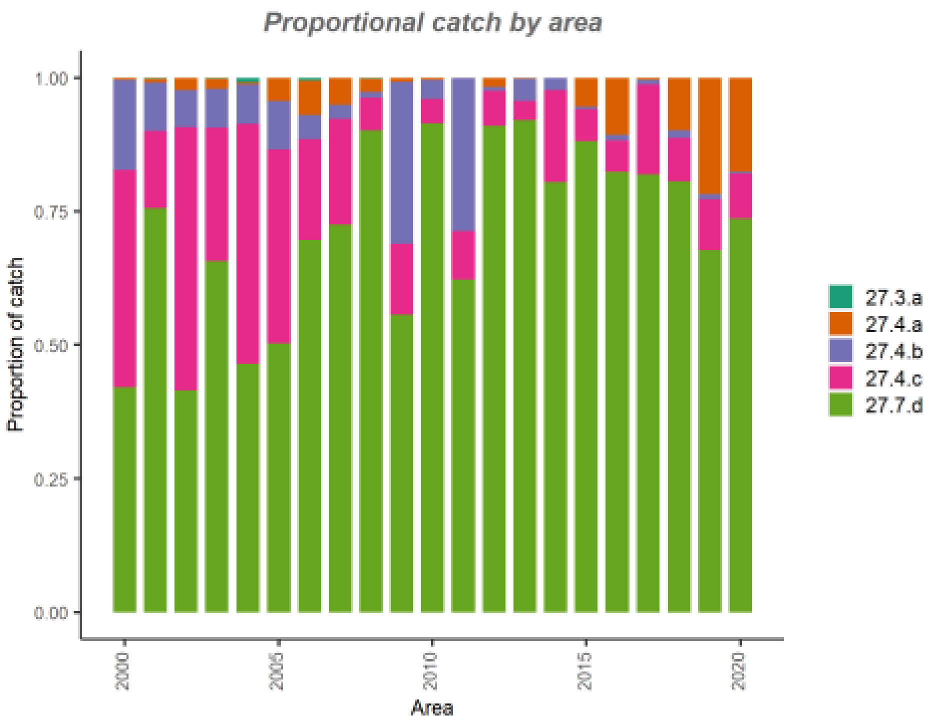

Figure 6.2.4. North Sea horse mackerel. Proportion of catches by ICES Division from 2000 to 2020.

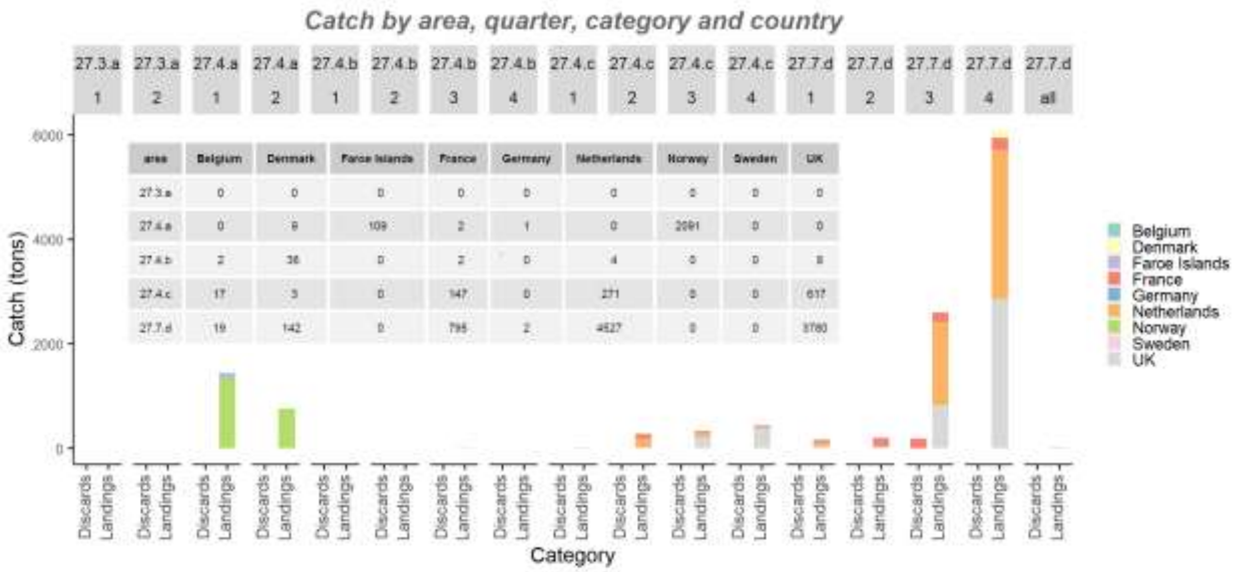

Figure 6.2.5. North Sea Horse Mackerel. Total catch (in tonnes) by ICES Division, quarter, catch category and country in 2020.

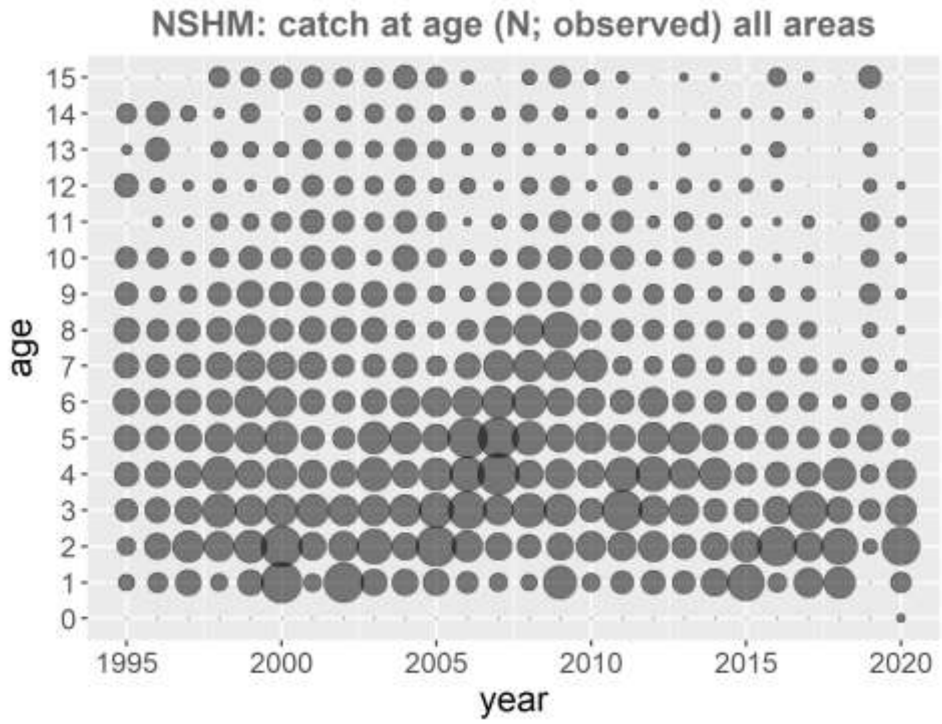

Figure 6.3.1. North Sea horse mackerel age distribution in the catch for 1995-2020. The size of bubbles is proportional to the catch number. Note that age 15 is a plus g

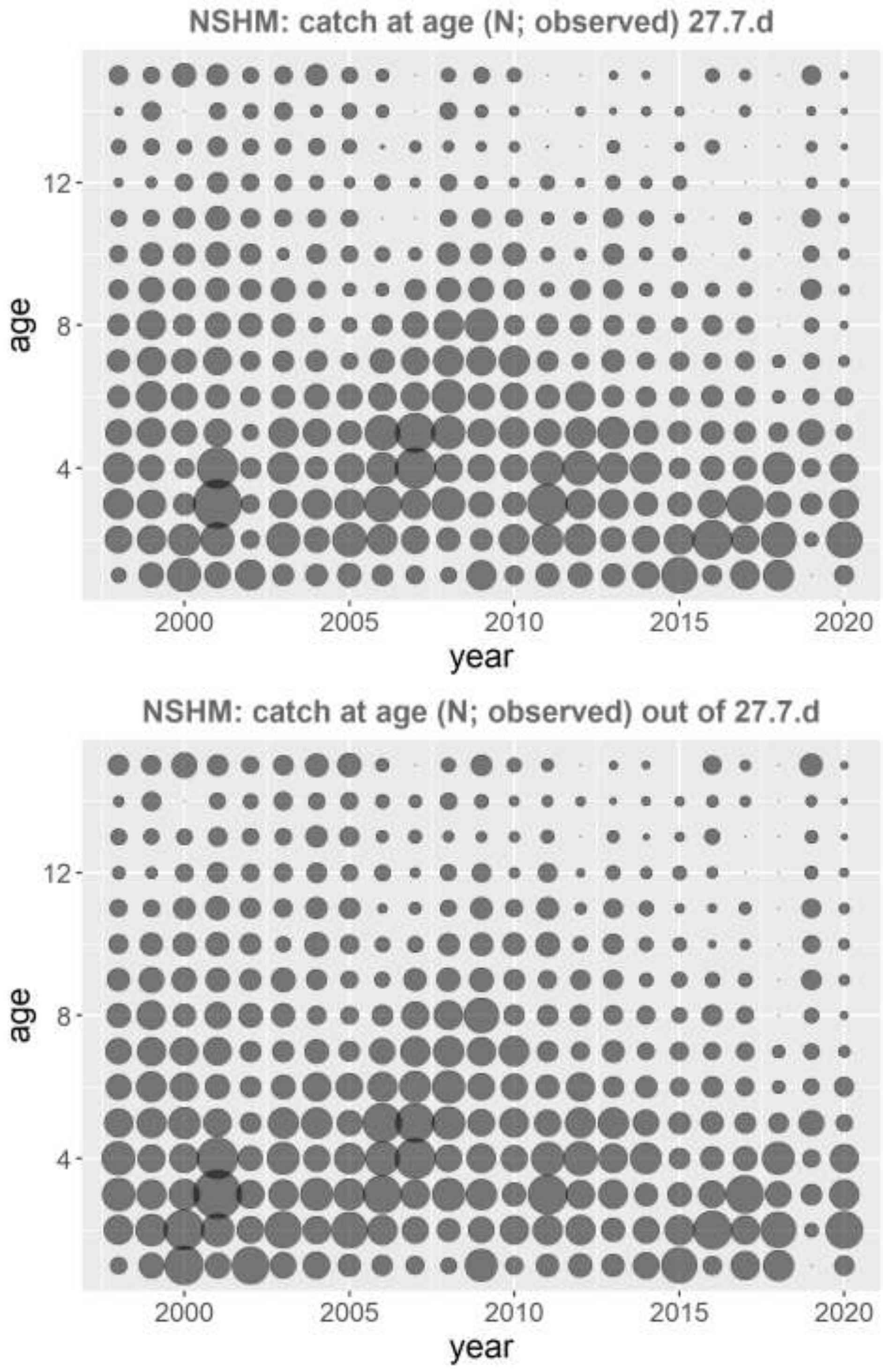

Figure 6.3.2. North Sea horse mackerel. Bubble plots of age distribution in the catch by area for 1998–2020 for area 7.d (upper panel) and out of 7.d (bottom panel). The size of bubbles is proportional to the catch numbers. Note that age 15 is a plus group.

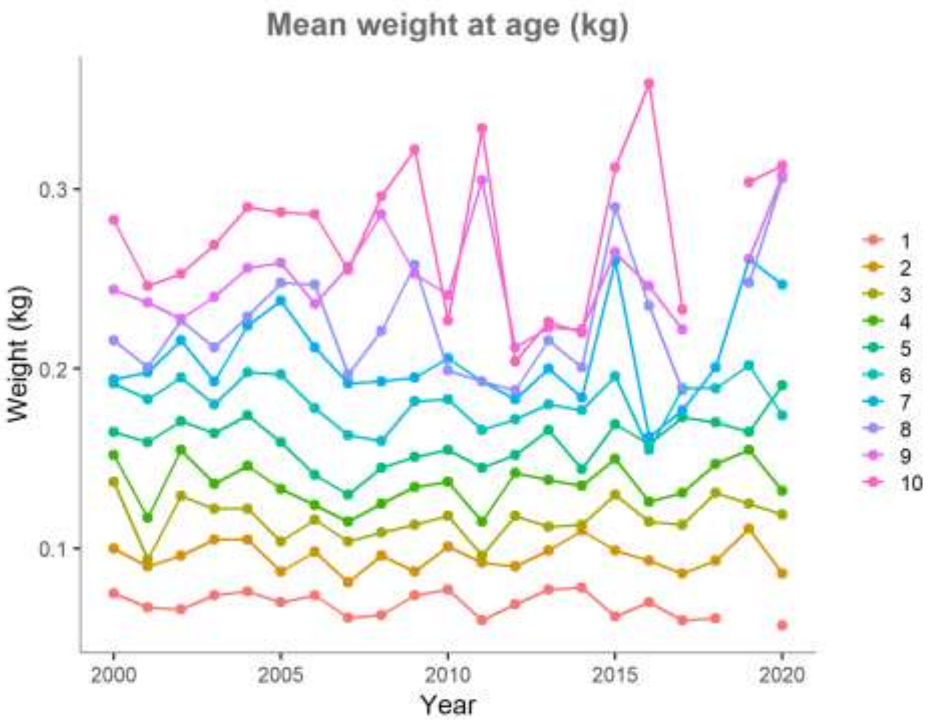

Figure 6.3.3. North Sea horse mackerel. Mean weight at age in commercial catches over the period 2000-2020. Note that only age 1–10 are presented and that 10 is not a plus group.

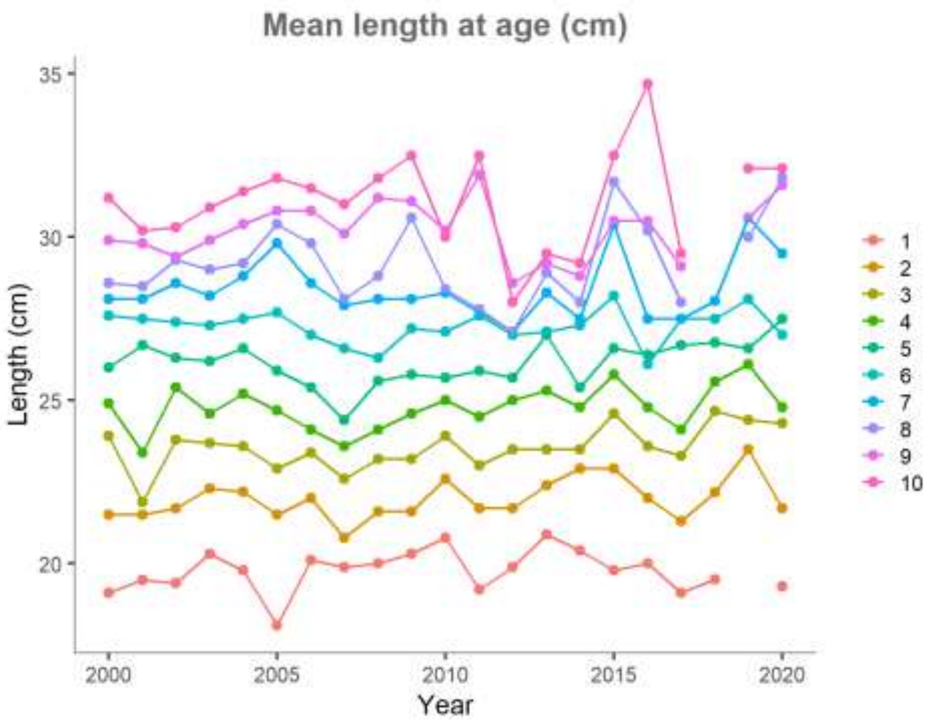

Figure 6.3.4. North Sea horse mackerel. Mean length at age in commercial catches over the period 2000-2020. Note that only age 1–10 are presented and that 10 is not a plus group.

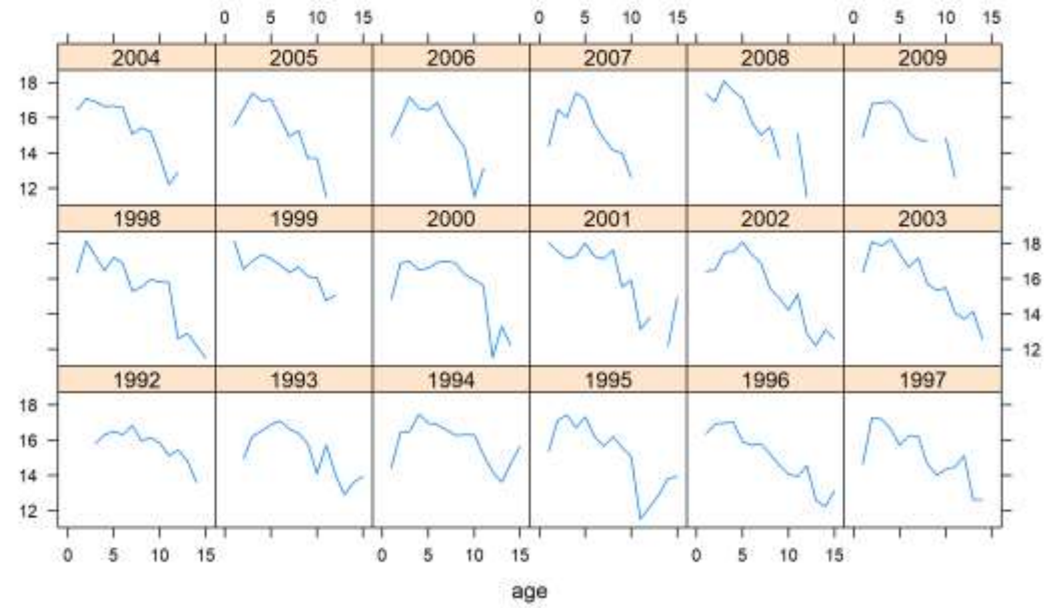

Figure 6.4.1. North Sea Horse Mackerel. Catch curves for the 1992 to 2009 cohorts, ages from 3 to 15+. Values plotted on the vertical axis are the log(catch) values for each cohort in each year. The negative slope of these curves estimates total mortality (Z) in the cohort.

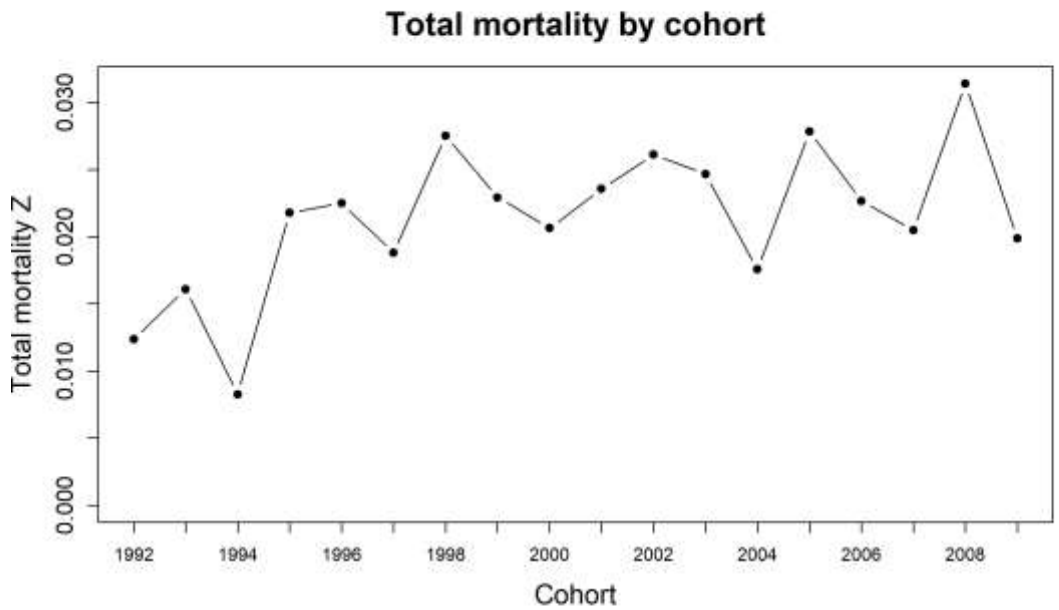

Figure 6.4.2. North Sea Horse Mackerel. Total mortality by cohort (Z) estimated from the negative gradients of the 1992—2009 cohort catch curves (Figure 6.4.1).

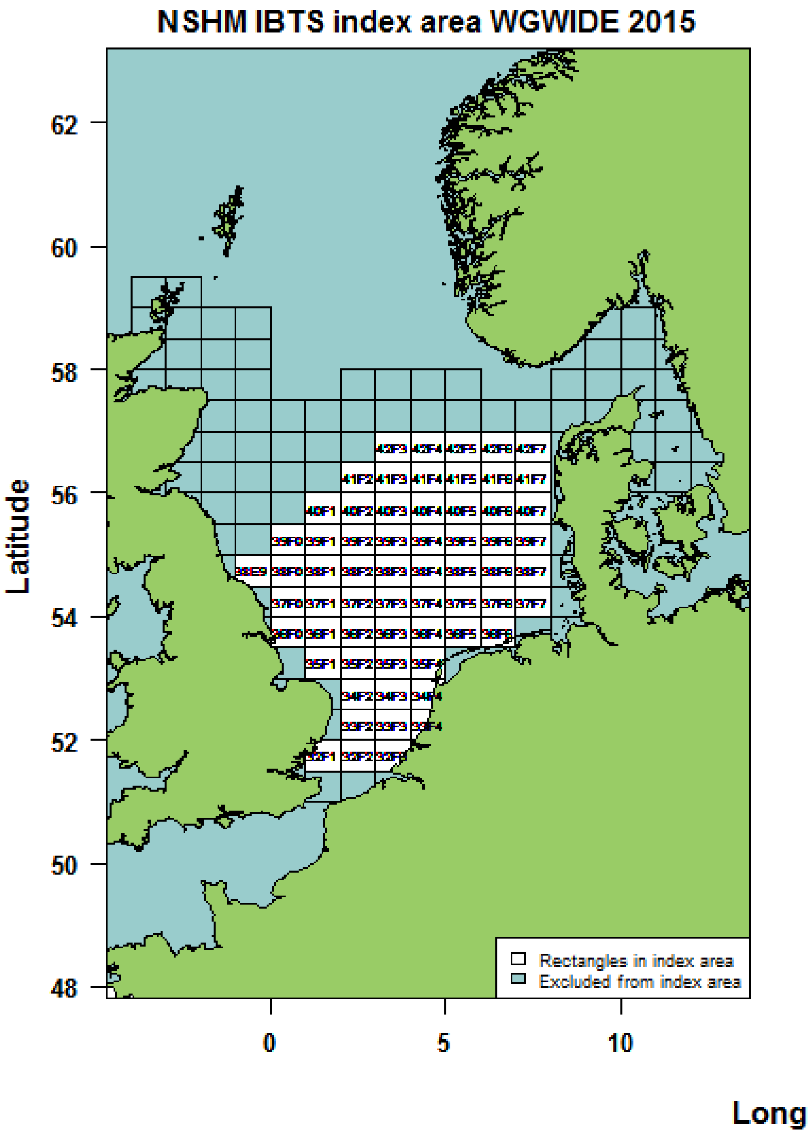

Figure 6.4.3. North Sea horse mackerel. ICES rectangles selected by WGWIDE in 2013 and currently used by the working group.

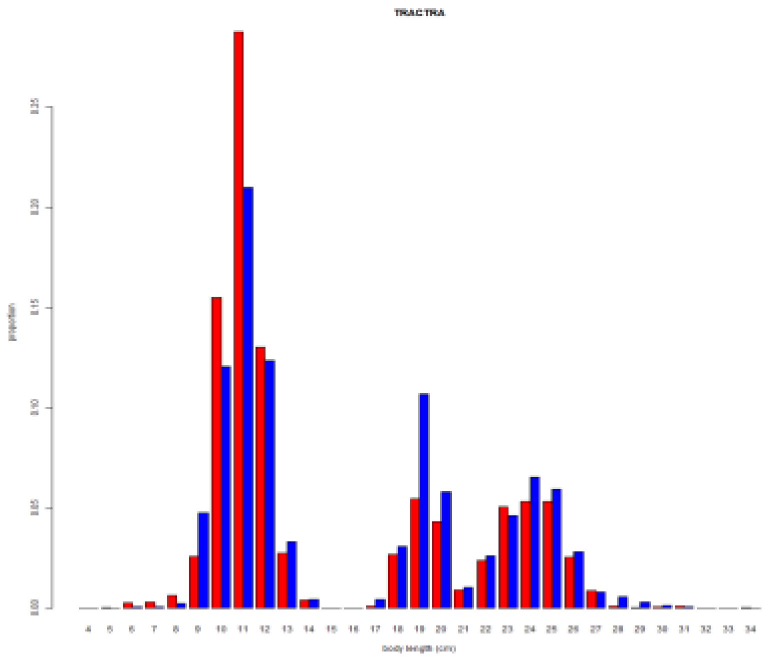

Figure 6.4.4. North Sea horse mackerel. Size distribution of North Sea horse mackerel catches during the inter-calibration exercise conducted in 2014 between the RV Gwen Drez (red bars) and Thalassa (blue bars).

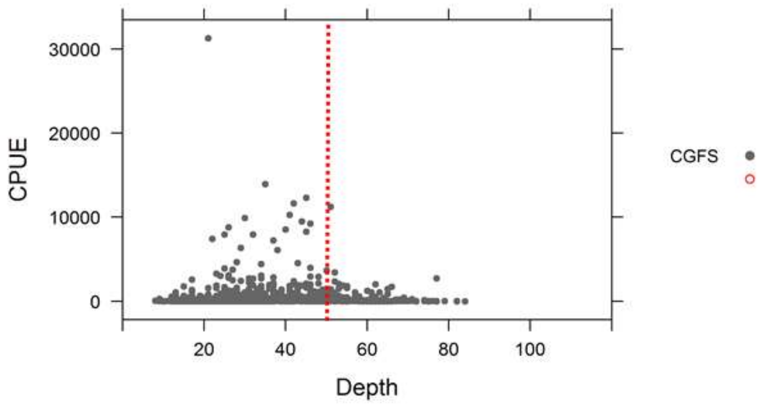

Figure 6.4.5. North Sea horse mackerel. CPUE by depth for the CGFS survey from 1992 to 2017.

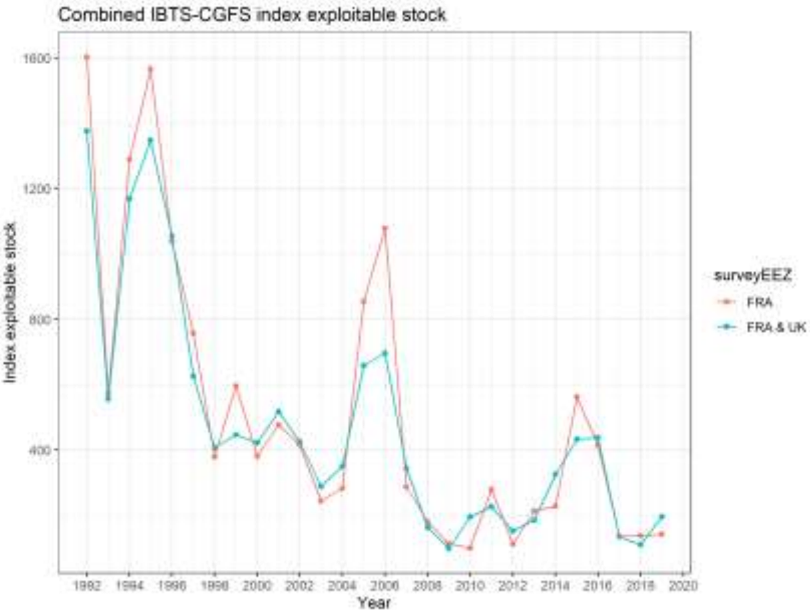

Figure 6.4.6. North Sea horse mackerel. Modelled abundance index from 1992–2019 including both UK and French stations in the FR-CGFS (blue) and excluding UK stations in the FR-CGFS (red) for the exploitable sub-stock (≥20 cm).

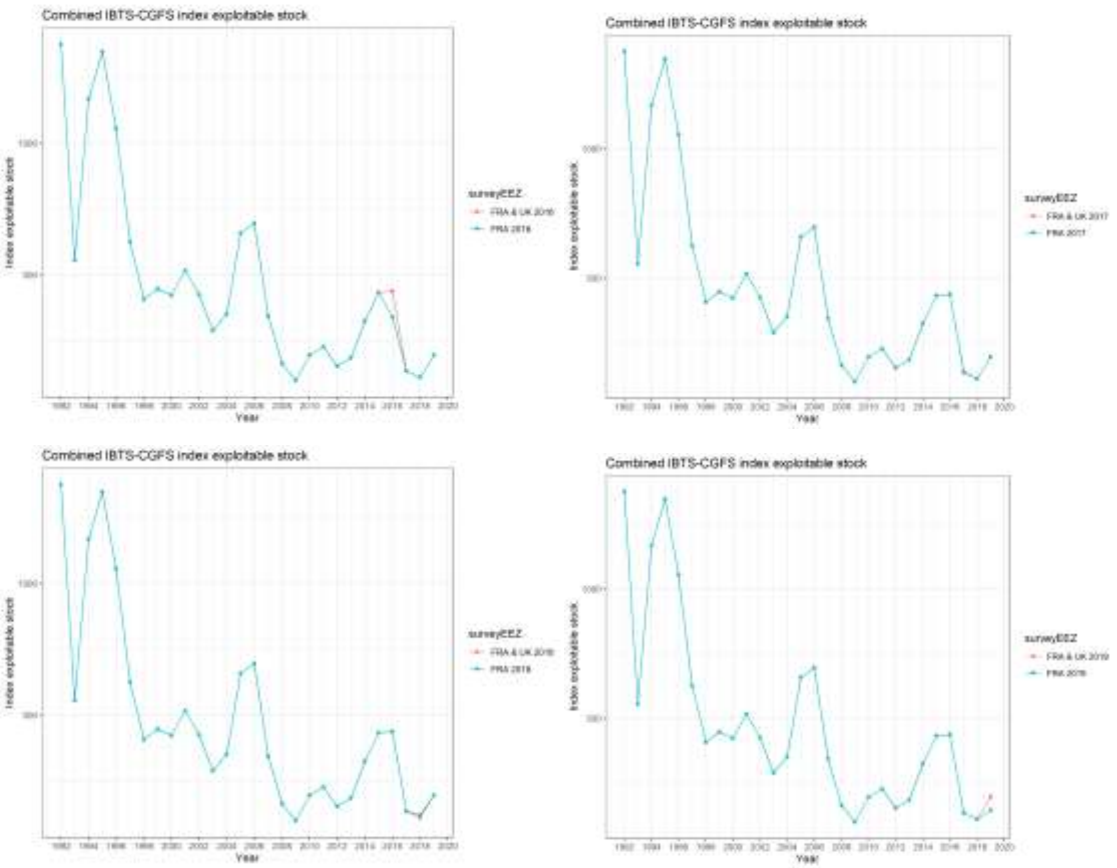

Figure 6.4.7. North Sea horse mackerel. Modelled abundance index from 1992–2019 for the exploitable sub-stock (≥20 cm) for when UK sampling stations from FR-CGFS have been excluded for 2016 (top left), 2017 (top right), 2018 (bottom left) and 2019 (bottom right).

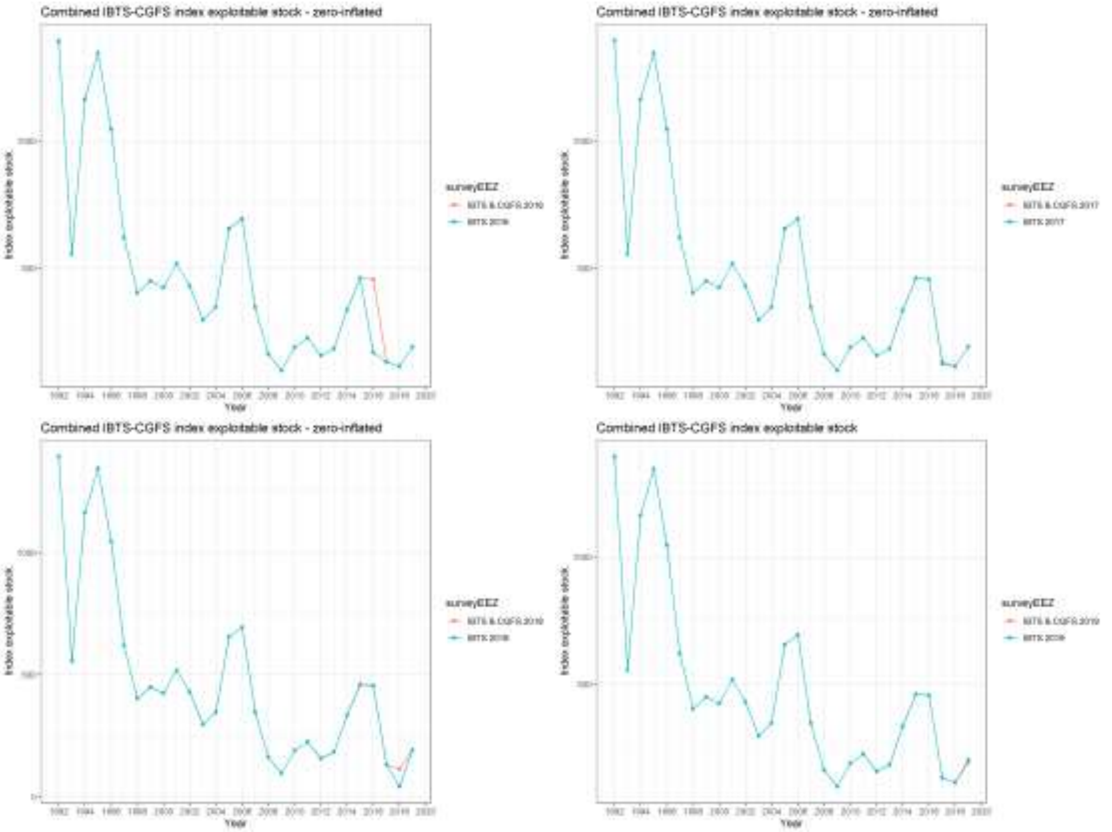

Figure 6.4.8. North Sea horse mackerel. Modelled abundance index from 1992–2019 for the exploitable sub-stock (≥20 cm) for when the FR-CGFS has been excluded for 2016 (top left), 2017 (top right), 2018 (bottom left) and 2019 (bottom right).

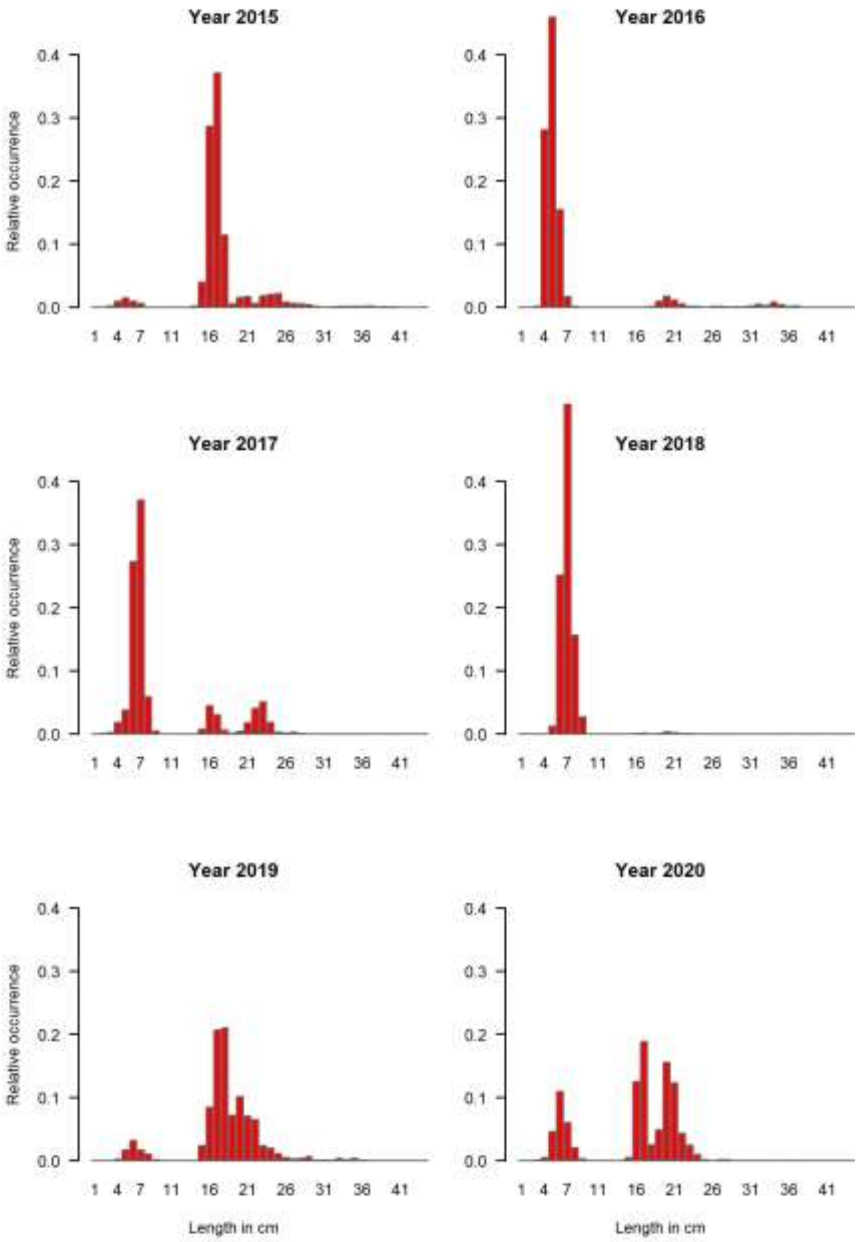

Figure 6.4.9. North Sea horse mackerel. Relative occurrence by length for the period 2014–2020 in the NS-IBTS.

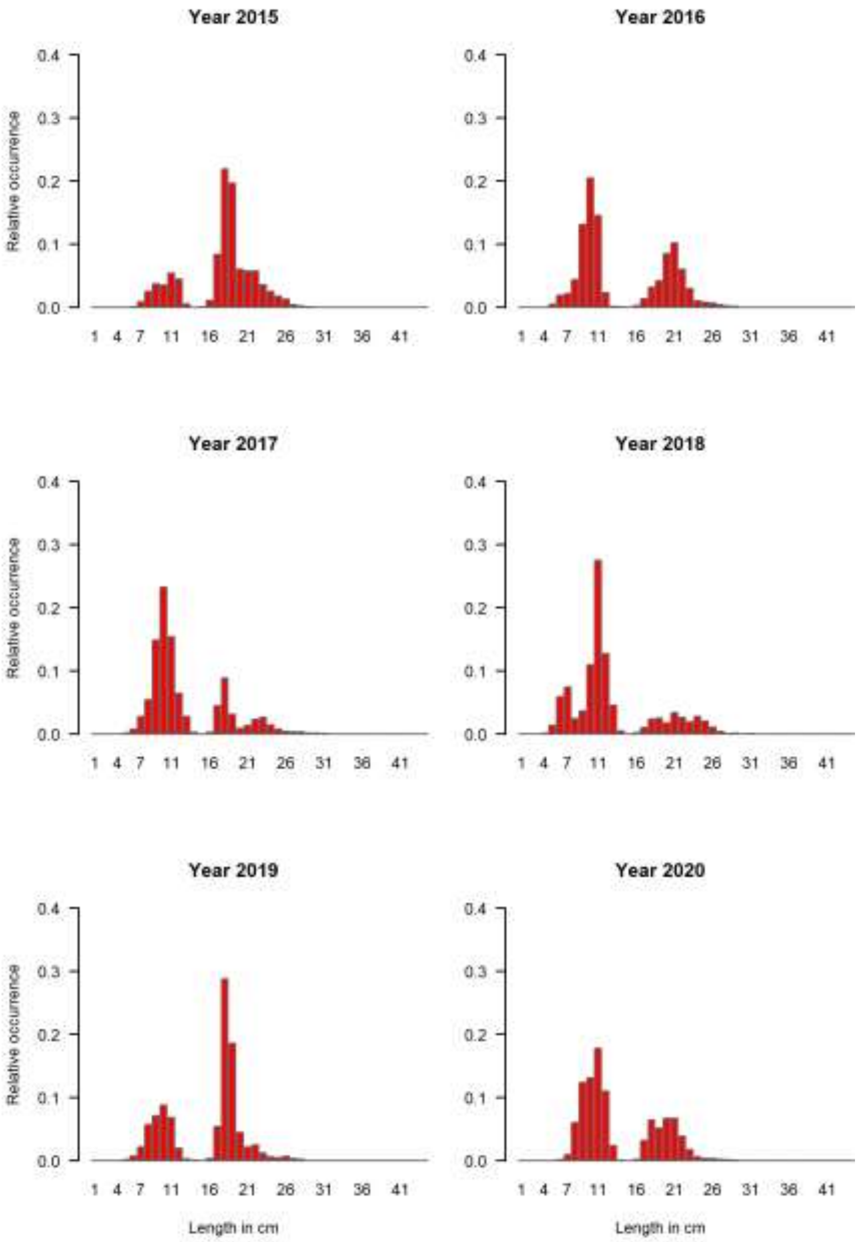

Figure 6.4.10. North Sea horse mackerel. Relative occurrence by length for the period 2015-2020 in the FR-CGFS. Note that stations in UK waters could not be visited in 2020.

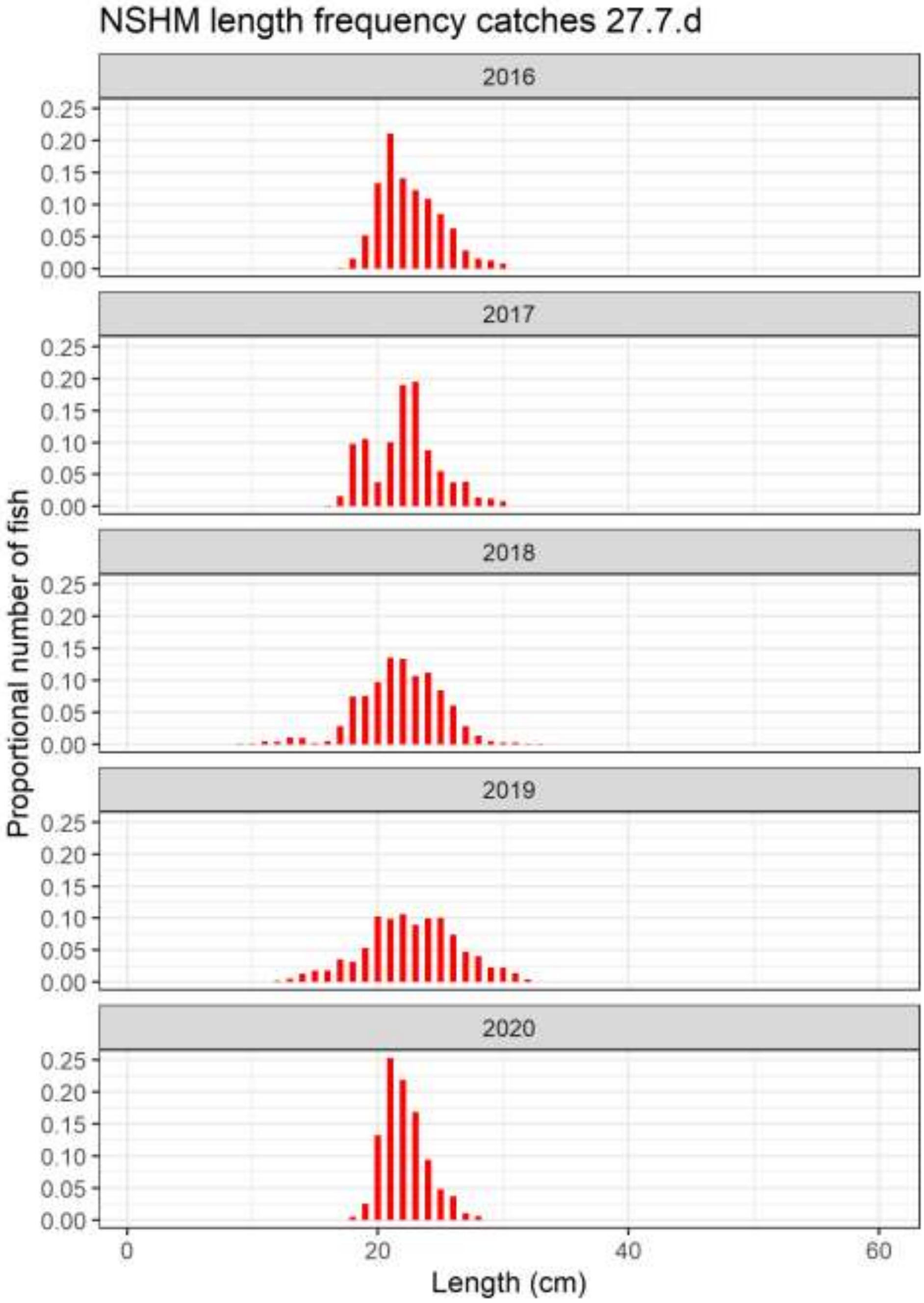

Figure 6.4.11. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.7.d for the period 2016-2020.

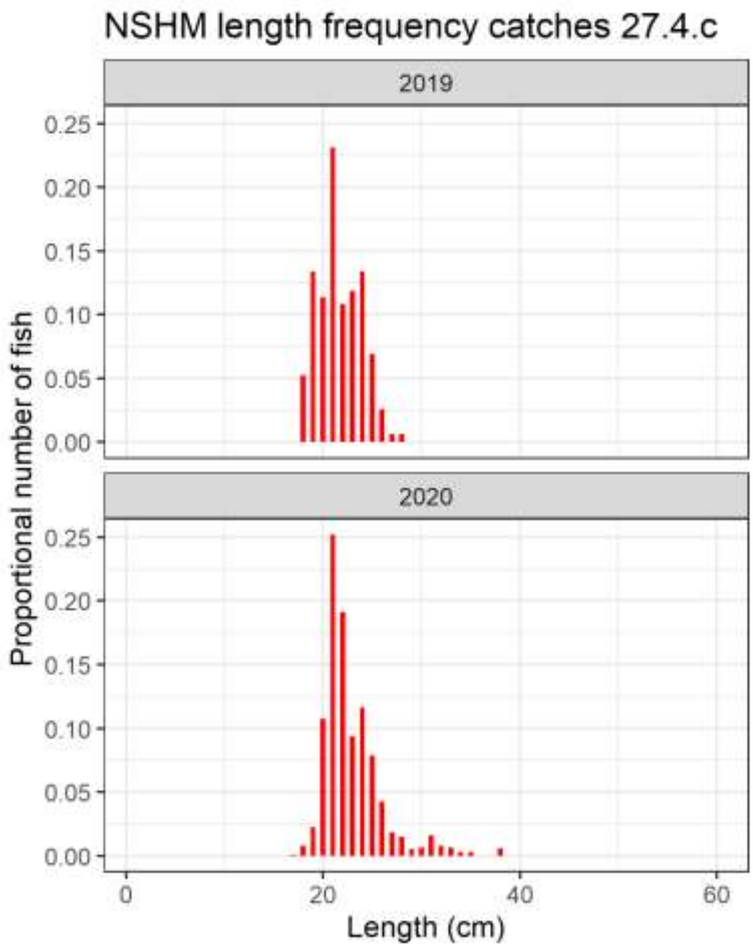

Figure 6.4.12. North Sea horse mackerel. Length distributions in proportion to catch numbers from commercial catches in 27.4.c in 2019 and 2020.

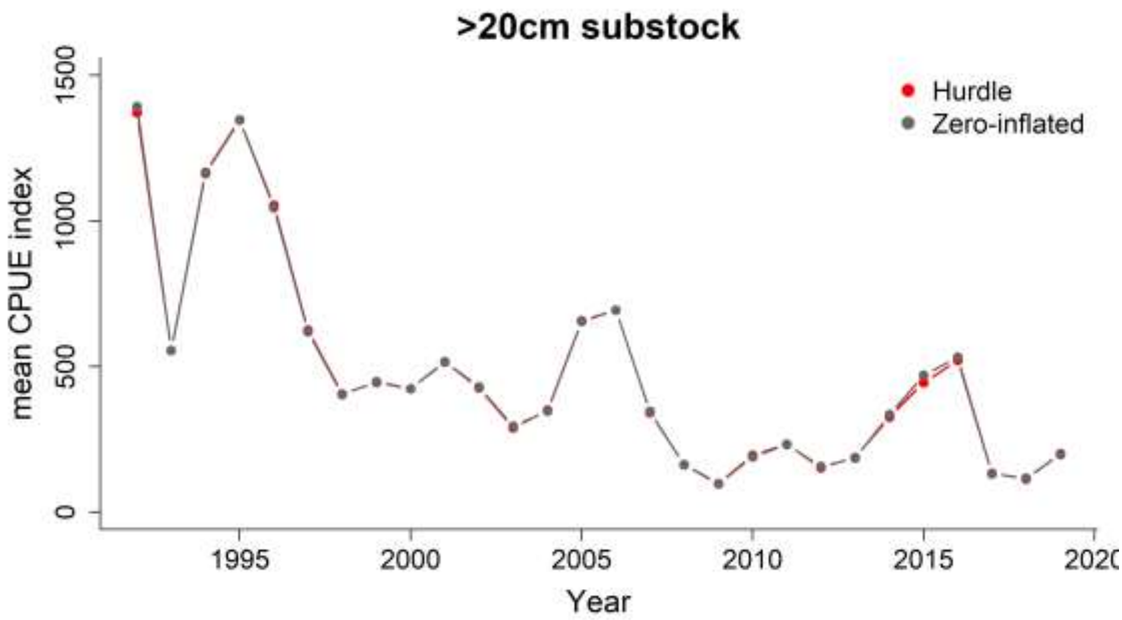

Figure 6.5.1. North Sea horse mackerel. CPUE per year of the exploitable sub-stock (≥20 cm) from 1992 to 2019 as modelled by the hurdle model (red) that returned a warning when ran, and the zero-inflated model (grey).

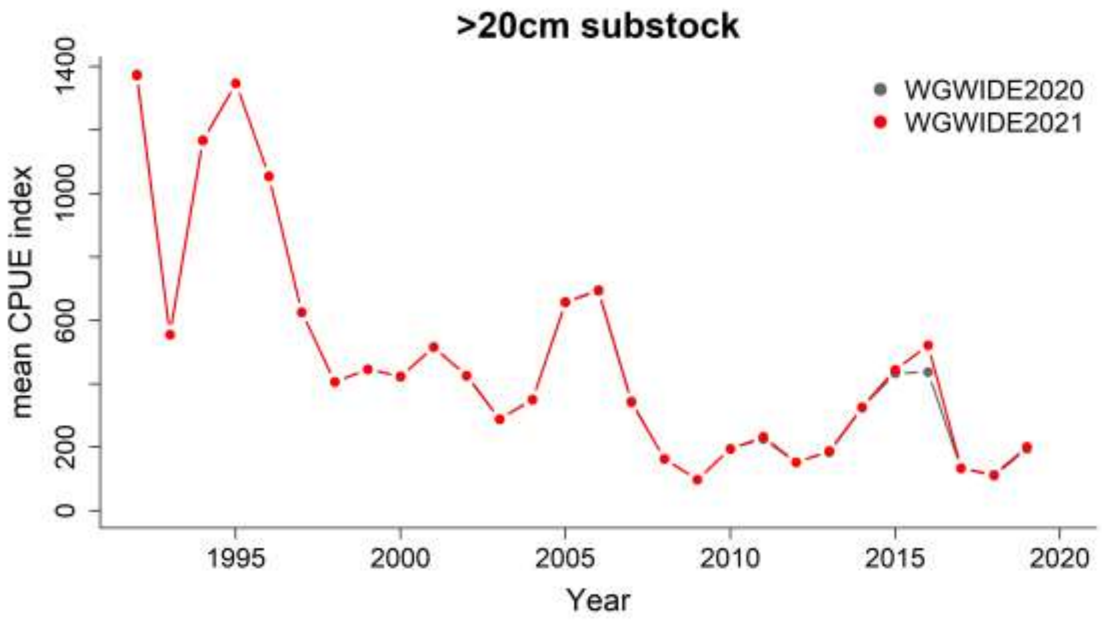

Figure 6.5.2. North Sea horse mackerel. CPUE per year of the exploitable sub-stock (≥20 cm) from 1992 to 2019 as modelled by the hurdle model at WGWIDE 2020 (grey) and WGWIDE 2021 (red).

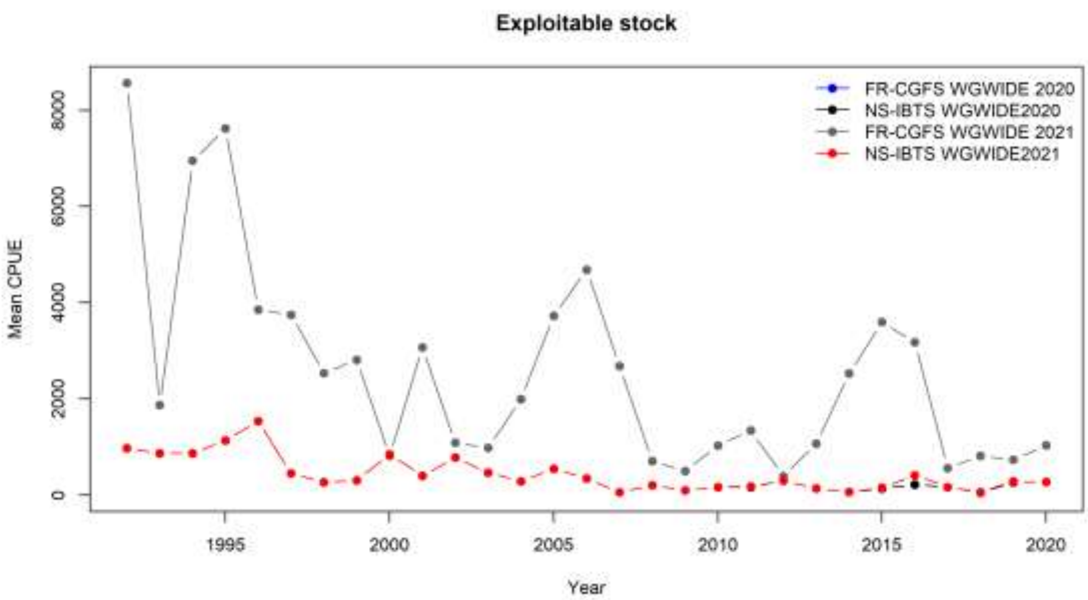

Figure 6.5.3. North Sea horse mackerel. Mean CPUE across hauls of the exploitable sub-stock (≥20 cm) from 1992 to 2019 for the FR-CGFS (blue WGWIDE 2020 (not visible), grey WGWIDE 2021) and the NS-IBTS (black WGWIDE 2020, red WGWIDE 2021).

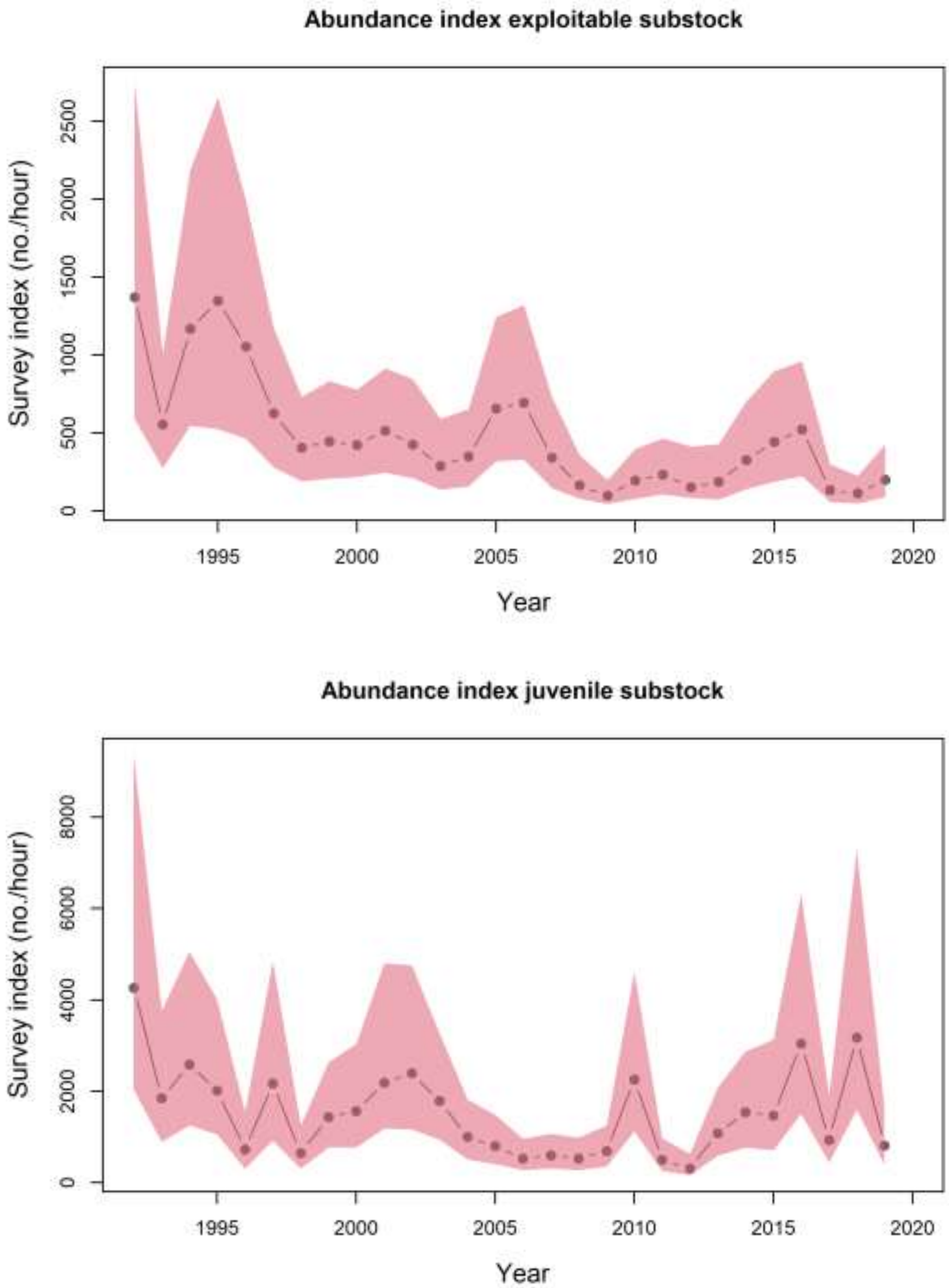

Figure 6.5.4. North Sea Horse Mackerel. Joint CPUE survey index (number/hour) derived from the hurdle model fit to the NS-IBTS survey in the North Sea and the FR-CGFS survey in the Eastern English channel for the period 1991–2020. No index value for 2020 could be produced due to sampling issues in the FR-CGFS. Top: exploitable sub-stock (≥20 cm), bottom: juvenile sub-stock (<20 cm). Red shaded area represent the 95% confidence interval, which is determined by bootstrap resampling of Pearson residuals with 999 iterations.

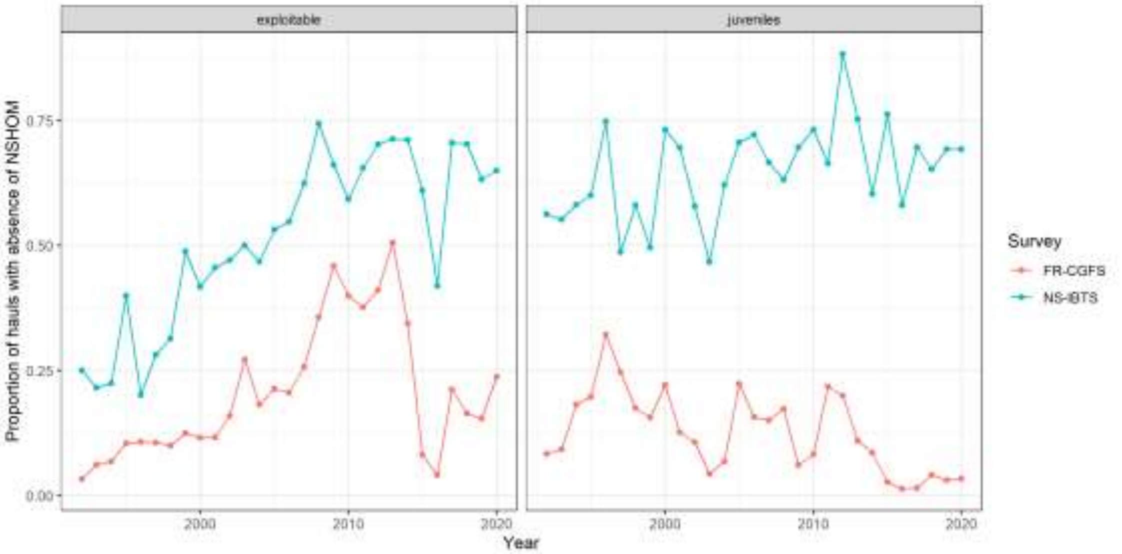

Figure 6.5.5. North Sea horse mackerel. Proportion of hauls with zero catch for the exploitable (≥20cm) and juvenile (<20 cm) sub-stocks in the NS-IBTS (blue) and the FR-CGFS (red) from 1992 to 2020. Note that the FR-CGFS 2020 values are based on French stations only, as UK stations could not be sampled.

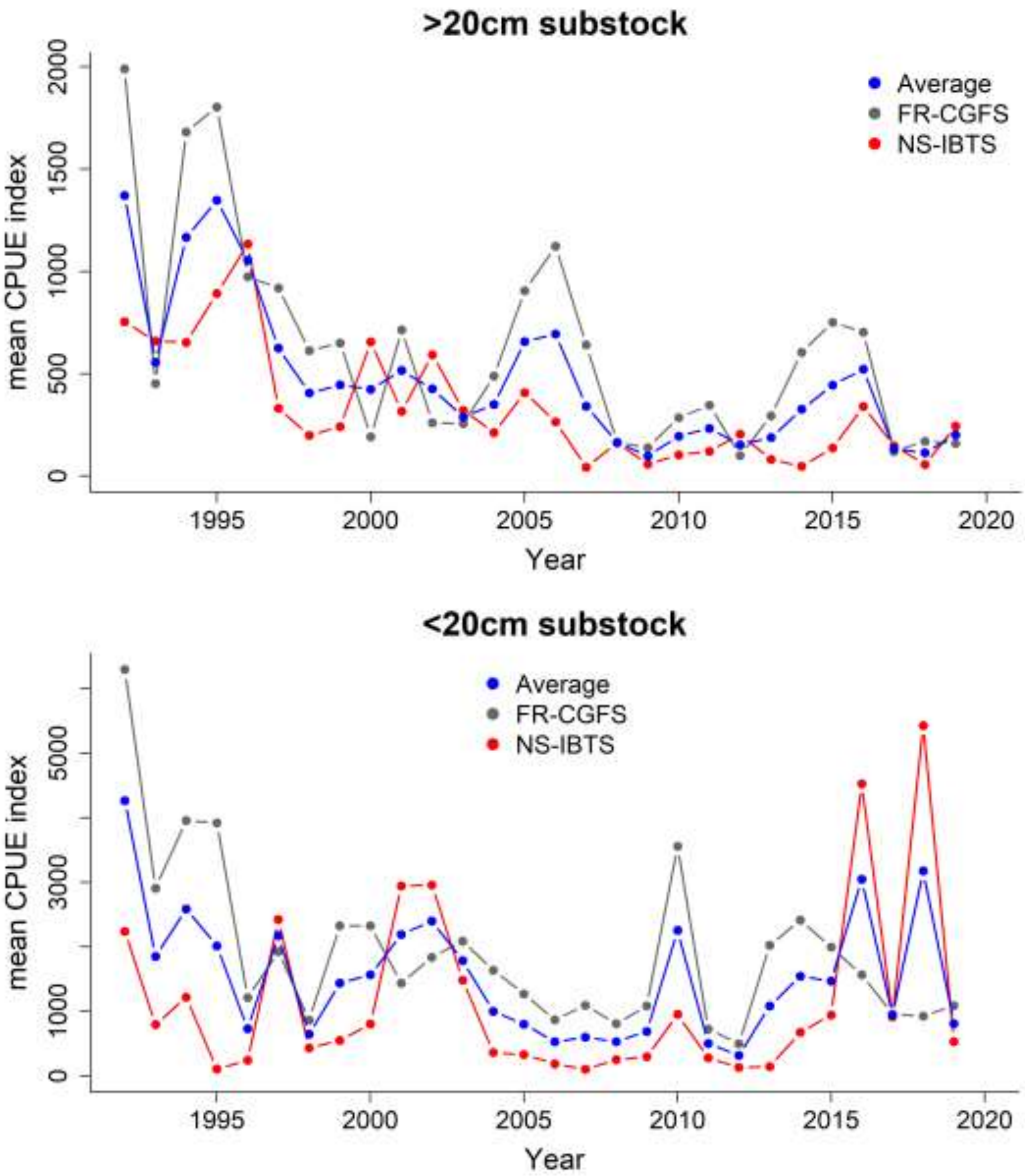

Figure 6.5.6. North Sea Horse Mackerel. Mean CPUE survey index (number/hour) obtained from the hurdle model fit to the NS-IBTS survey in the North Sea (in red), the FR-CGFS survey in the English channel (in grey) and the joint survey index (in blue). Top: exploitable sub-stock (≥20cm), bottom: juvenile sub-stock (<20 cm). No index values for 2020 could be produced due to COVID-19 pandemic impacting the FR-CGFS.

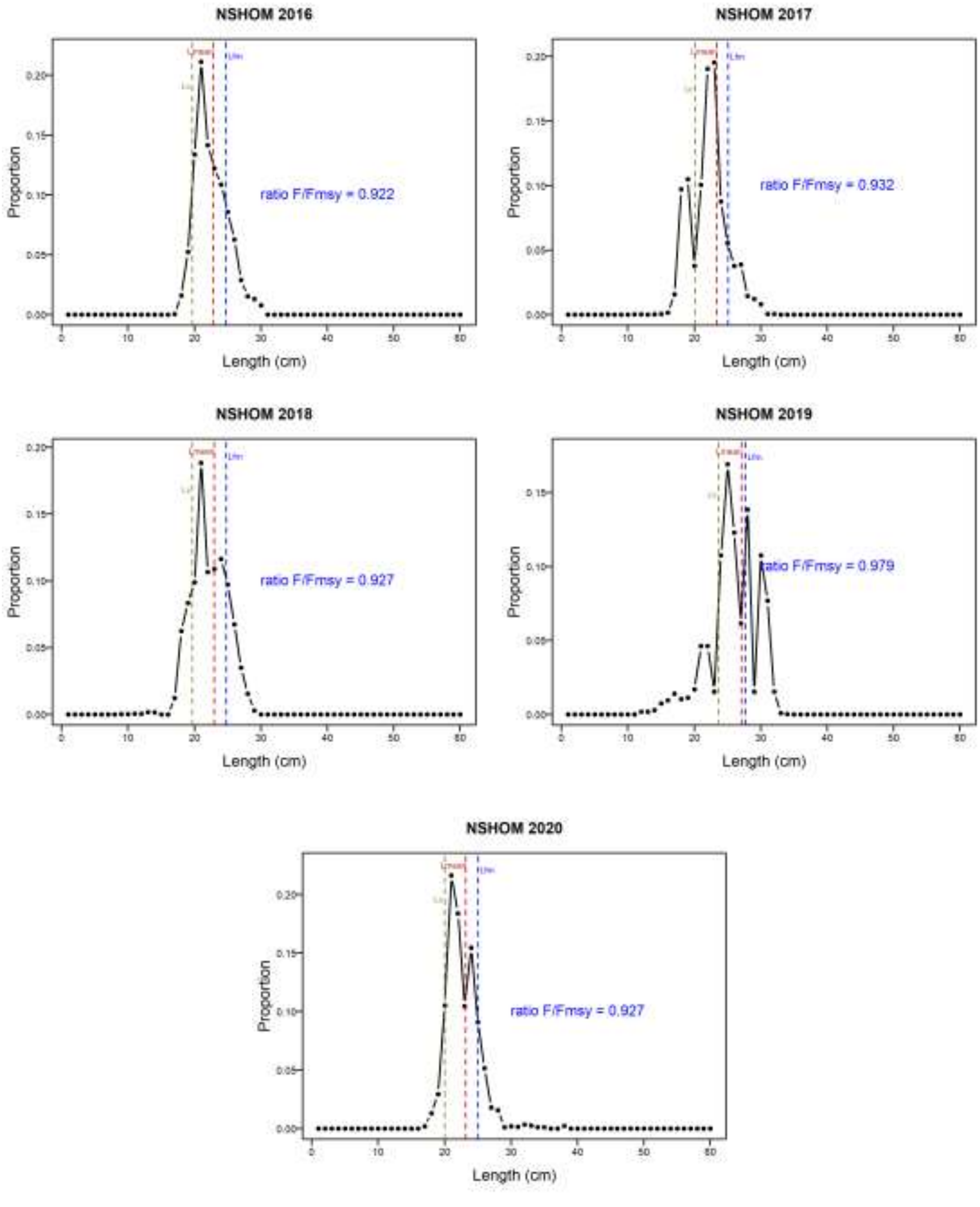

Figure 6.5.7. Length distribution (cm), estimated parameters L_c, L_{mean}, $L_{F=M}$ (cm) and F/F_{MSY} ratio for 2016–2020. Length samples from commercial catches in ICES Division 27.7.d.