Stock Annex: 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)

Stock specific documentation of standard assessment procedures used by ICES.

Stock: North Sea horse mackerel

Working Group: Working Group on Widely Distributed Stocks (WGWIDE)

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A. General

A.1. Stock definition

Stock Identity

For many years, ICES considered horse mackerel (*Trachurus trachurus*) in the north-east Atlantic to be separated into three stocks. Prior to the conclusion of the HOMSIR project in 2003, this separation was motivated mainly on the basis of temporal and spatial distributions of the fishery and observed egg and larval distributions (ICES, 2008). But early on, this was also supported by information from acoustic and trawl surveys, and from parasite infestation rates in horse mackerel (ICES, 1989a, 1990a, 1991a). The southern stock was defined as that found in the Atlantic waters of the Iberian Peninsula, the North Sea stock in the eastern English Channel and North Sea area, and the western stock on the northeast continental shelf of Europe, stretching from the Bay of Biscay in the south to Norway in the north.

The occurrence of the large 1982 year class in the eastern part of the North Sea during the latter half of 1987 resulted in the commencement of a sizeable Norwegian fishery for horse mackerel in the third and fourth quarters from the late 1980s. This led to questions about the distribution of the North Sea stock (ICES, 1989a). A combination of commercial catch and bottom trawl survey data indicated that western horse mackerel had a similar migration pattern to mackerel, so that outside the spawning season bigger fish migrate north to reach the northern North Sea in the latter half of the year (Iversen *et al.*, 2002). Differences were also noted in the development of the fishery and in the parasite infestation rates of horse mackerel in Divisions 2.a and 4.a compared to Divisions 4.b-c and the English Channel, suggesting that fisheries in these two areas

were exploiting fish from two different spawning areas (ICES, 1990a, 1991a). Therefore, since 1989 ICES has allocated catches taken in Division 2.a and in Division 4.a (in later years only during the third and fourth quarters of the year for 4.a, and including the western part of Division 3.a) to the western stock (ICES, 1989a).

Further refinements of the definitions of stock units were made based on the results from HOMSIR (EU-funded project: QLK5-CT1999-01438), which integrated a variety of approaches to investigate horse mackerel stock identification (ICES, 2005; Abaunza *et al.*, 2008). The project investigated the stock structure of horse mackerel from a holistic point of view within the western, southern, North Sea and Mediterranean areas. It included various genetic approaches (multilocus allozyme electropho-resis, mitochondrial DNA analysis, microsatellite DNA analysis and single stranded conformation polymorphysm SSCP analysis), the use of parasites as biological tags, body morphometrics, otolith shape analysis and the comparative study of life history traits (growth, reproduction and distribution). The project concluded in June 2003, and some of the main results from this project, which are of relevance to the North Sea stock, were as follows (ICES, 2005; Abaunza *et al.*, 2008b, 2008a):

i) Parasites and body morphometrics indicated that horse mackerel in the North Sea could constitute a stock well differentiated from the rest of adjacent Atlantic areas.
ii) Batch fecundity as observed in horse mackerel from the North Sea was low in comparison to adjacent areas, suggesting a distinctive population characteristic.
iii) Horse mackerel along western European coasts, from the northwest of Spain to Norway, seem to be a unique stock. This definition is very similar to that previously used for the "western stock", except that, based on reults from HOMSIR, the north coast of the Iberian Peninsula should also be included.
iv) However, the population structure in the western European coasts could be more complicated and more research is needed to clarify the migration patterns within the Northeast Atlantic Ocean. This is especially relevant to the boundary areas between the North Sea Stock and the Western stock (Northern North Sea and English Channel).

Therefore, in many ways, results from the HOMSIR project largely supported ICES perceptions of stock units. Based on findings from the project, ICES now includes Division 8.c as part of the distribution area of the western horse mackerel stock. The boundaries for the different stocks are given in Figure A.1.

A remaining issue is the potential mixing of horse mackerel from the western and the North Sea stock, particularly in Division 7.d and 7.e (western and eastern English Channel) in winter and in Division 4.a. Mixing may confuse cohort signals. For example, the large recruitment in the western stock in 2002 may have led to more of these fish being located in the North Sea stock area as age 1 fish. 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. 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, 2018; 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 will improve stock delineation even further by investigating the stock identity of caught individuals in Divisions 7.d, 7.e and 4.a.

Allocation of catches to stock

Based on spatial and temporal distribution of the horse mackerel fishery the catches were allocated to the North Sea stock from Divisions 3.a and 4.a in the first and second quarter and all catches from Divisions 4.b,c and 7.d. ICES is not sure if catches in Divisions 4.a and 3.a during the first two quarters are of western or North Sea origin. Usually, this is a minor problem because the catches in these areas during this period are usually small, but note the relatively large catches in some years, with >2,000 tonnes in 2006, 2007 and 2019 in 27.4.a during the first two quarters of the year. Ongoing and future genetic work will shed light on this issue.

A.2. Fishery

A.3. Ecosystem aspects

B. Data

B.1. Commercial catch

Catch in numbers

Commercial catch data and the associated sampling are obtained from national laboratories of nations exploiting North Sea horse mackerel (carried out under the DCF in EU countries). Prior 2014 the data exchange spreadsheets were submitted to the stock coordinator. The data in the exchange spreadsheets were allocated samples to catch using the SALLOC-application (Patterson, 1998). This application produced the standard outputs on sampling status and biological parameters.

Since 2014 national data submitters have been uploading this information into InterCatch using the standard exchange files. The information is supplied aggregated to ICES subarea/division/subdivision and quarter. The total international catch at age was available through the InterCatch web system. The allocations for those countries reporting unsampled catches, were generally made using all available data for the same ICES division and the same quarter. In cases where this was not possible, data from the nearest divisions and the same quarter were used. The aggregated output files can then be downloaded by the stock coordinators. The files are used as input for the stock assessment models.

Over the years usually only one or few national submitters have been providing data on catch at age. In addition, adequate sampling has never been conducted in all fishing areas during the fishing season.The lack of sampling data for relatively large portions of the horse mackerel catches have a serious effect on the accuracy and reliability of the annual catch at age matrix.

Discards

Over the years, the available estimates of discards are based on information provided by only one or two countries and the total discards are considered to be not representative for the total fishery. Reported discards have been highly variable over time.

Information from national data submitters suggest that discard rates for the directed fishery are low with the majority of discards from non-directed demersal fisheries.

B.2. Biological

Mean weight at age in the stock

Mean weight at age is derived from the raised national figures received from national laboratories. Most age samples come from catches in Division 7.d. Overall sampling coverage of the catches is low in all areas. Catch at age data, including weight at age, should therefore be used with caution.

Length distributions

Length frequency distributions from commercial catches are available by area and by country from 2016 onwards. Length distributions, reported as number per length, are sent by email to the stock coordinator directly or are extracted from the length distributions as reported in the yellow Exchange sheets used for InterCatch submission. Data from multiple countries are combined by calculating the proportional length distributions based on the catch (in numbers) per length class, per country and per area. Several countries contribute with length data from landings, one or two with data from discards. Most data come from Division 7.d in Q4.

Maturity

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

Natural mortality

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

B.3. Surveys

Egg survey estimates of biomass

There are currently no dedicated egg survey for horse mackerel eggs in the North Sea. Such surveys have been carried out during the period 1988-1991 (ICES 1989b, 1990b, 1991b, 1992), and SSB estimates are available historically. However, they were calculated assuming horse mackerel to be a determinate spawner, whereas horse mackerel is now considered an indeterminate spawner (Gordo *et al.*, 2008). Therefore egg abundance or production can only be considered a relative index of SSB. The Mackerel and Horse Mackerel Egg Survey only covers the spawning area of the western and southern stock and can therefore not be used for the North Sea horse mackerel assessment.

Bottom trawl surveys

Many pelagic species, including horse mackerel, are frequently found close to the bottom during daytime (which is when bottom trawl surveys most often operate), although the top of the shoals may extend into midwater. Horse mackerel migrate upwards predominantly during the night when they are susceptible to semi-pelagic fishing gear and to bottom trawls (Macer, 1977; Barange *et al.*, 1998). Eaton (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, bottom trawl surveys are considered a reasonable alternative.

Rückert *et al.* (2002) investigated data from the North Sea International Bottom Trawl Survey (NS-IBTS) from all quarters in the period 1991-1996. They showed that horse mackerel catches in the NS-IBTS were most abundant in the third quarter of the year. Therefore, NS-IBTS in Q3 was deemed suitable as an abundance index for North Sea horse mackerel. Since 2015, the French Channel Groundfish Survey (CGFS) is additionally used, because an increasing amount of catches are taken in the Eastern Channel (Division 7.d) since the 2000s. The CGFS runs in Q4 and thus captures the stock when it is moving to and staying in the Channel to overwinter.

The French CGFS switched in 2015 to a new research vessel. The 2017 benchmark (ICES, 2017a) and the 2017 assessment working group (ICES, 2017b) evaluated the calibration exercise that was conducted to test the change in catchability, and investigated the potential effect for the index of the slight change in spatial coverage of the survey. Although some concerns were raised about the calibration exercise, the assessment group considered them to be of minor importance, and agreed on the use of the estimated conversion factor of 10.363 for the CGFS data for the period 1990-2015 (ICES, 2017a, 2017b). Furthermore, the slight change in spatial coverage did not lead to any major changes of the exploitable biomass index (ICES, 2017a).

Survey rectangles, period and haul duration

Because horse mackerel during Q3 and Q4 in Division 3.a and 4.a is assumed to be from the western stock, catches in the NS-IBTS Q3 from ICES rectangles lying in these divisions are excluded from the analysis. Additionally, catches from rectangles 33F1 and 33F2 and from the mouth of the Seine river are excluded, as these rectangles are not visited anymore during the CGFS after the change to the new research vessel in 2015 (ICES, 2017a). The selected study period of both surveys is from 1992 onwards (ICES, 2017a). Hauls shorter than 15 minutes or longer than 45 minutes are excluded to ensure not too much difference in sampling effort between years and surveys (ICES, 2017a).

Acoustic surveys

There are no dedicated acoustic surveys for the North Sea horse mackerel stock.

B.4. Commercial CPUE

B.5. Other relevant data

C. Historical Stock Development

Historic development of survey index

Rückert *et al.* (2002) showed that horse mackerel catches in the NS-IBTS were most abundant in the third quarter of the year. Several exploratory analyses have been carried out each year since then by the assessment working group to explore the use of NS-IBTS Q3 data as an index, split by length: (a) <14 cm fish, (b) for fish of ≥14 and <23 cm, and (c) ≥23 cm fish (ICES, 2005), with one index for each length group. Splitting was based on a clearly observed separation of the 0-group in the survey data with the boundary at 14 cm (group a), and a length at maturity $L_{50\%}$) of 23 cm. Fish in group (b) were assumed to be juveniles of 1, 2 and possibly 3 years old, whereas fish in group (c) were considered to be adults. In 2013, the assessment working group decided that an 'exploitable biomass index' was most appropiate for interpreting any trend in the stock, because horse mackerel of 2 years and older are predominantly demersal (Eaton, 1983), and 2-year old fish make up 96% of the landings, which is the age that roughly corresponds with fish of ≥20 cm (ICES, 2013). Therefore, catches in NS-IBTS Q3 of horse mackerel with length ≥20 cm were used to calculate the exploitable biomass index.

Since the 2000s, catches were increasingly taken in Division 7.d relative to 4.a-c. Furthermore, the stock migrates in Autumn from the North Sea into the Channel for overwintering, thereby moving outside the NS-IBTS area. In 2015, data from the French CGFS in Q4 were used to calculate a second exploitable biomass index (ICES, 2015). Although the NS-IBTS and CGFS survey indices for horse mackerel of ≥20 cm roughly indicated a similar trend, there were noticeable differences in the timing and scale of the decline of the stock in the 1990s/early 2000s (ICES, 2015). Therefore, the stock was benchmarked in 2017 to model both surveys in a joint approach. The same model is also used for survey data of lengths below 20 cm. This index represents the abundance trend of the juvenile part of the stock.

Survey index model

Model structure

Response variable: CPUE in number of fish per hour. CPUE from the surveys is calculated separately for the exploitable (≥20 cm) and the juvenile (<20 cm) part of the stock.

Hurdle model with the following sub-models for the zero-part and count-part of the model:

- Probability of zeroes: GLM binomial, Year + Survey as explanatory variables
- Count data: GLM negative binomial, Year * Survey as explanatory variables (including interaction term)

Model run in the R environment with package 'pscl' (Zeileis *et al.*, 2008).

Index calculation

Weighting factors applied after fitting the model to each survey separately (based on the size of the survey areas and the difference in gear width between surveys; ICES, 2017a):

- NS-IBTS: 0.76
- CGFS: 0.24

Final index calculated by averaging the weighted, fitted values of each survey per year. This is done for both the exploitable and juvenile part of the stock.

Confidence interval: bootstrapping Pearson residuals 999 times to calculate 95% confidence interval around fitted. This is done for both the exploitable and juvenile part of the stock.

D. Short-Term Projection

Short-term projections are not carried out for North Sea horse mackerel.

E. Medium-Term Projections

Medium-term projections are not carried out for North Sea horse mackerel.

F. Long-Term Projections

Long-term projections are not carried out for North Sea horse mackerel.

G. Biological Reference Points

Biomass reference points

There are no biomass reference points for North Sea horse mackerel.

Fishing mortality reference points

There are no fishing mortality reference points for North Sea horse mackerel.

Proxies for MSY reference points

The assessment for North Sea horse mackerel applies length-based indicators to calculate a F/F_{MSY} proxy following the ICES technical guidelines for reference points for stocks in categories 3 and 4 (ICES, 2018). The following length-based indicators are used to calculate the proxy:

- L_c = length at first catch; calculated based on the available length distributions from commercial catches.
- L_∞ = length at infinity; Von Bertalanffy growth parameter, value taken from the western stock (40 cm).
- L_{mean} = mean length of individuals; calculated based on the availale length distributions from commercial catches.

Most catches take place in Division 7.d, and hence, most data on length distributions come from 7.d. Data from other divisions are also submitted, but not every year and often coming from just one or a few samples. Therefore, the F/F_{MSY} proxy is calculated based on data from 7.d only.

H. Other Issues

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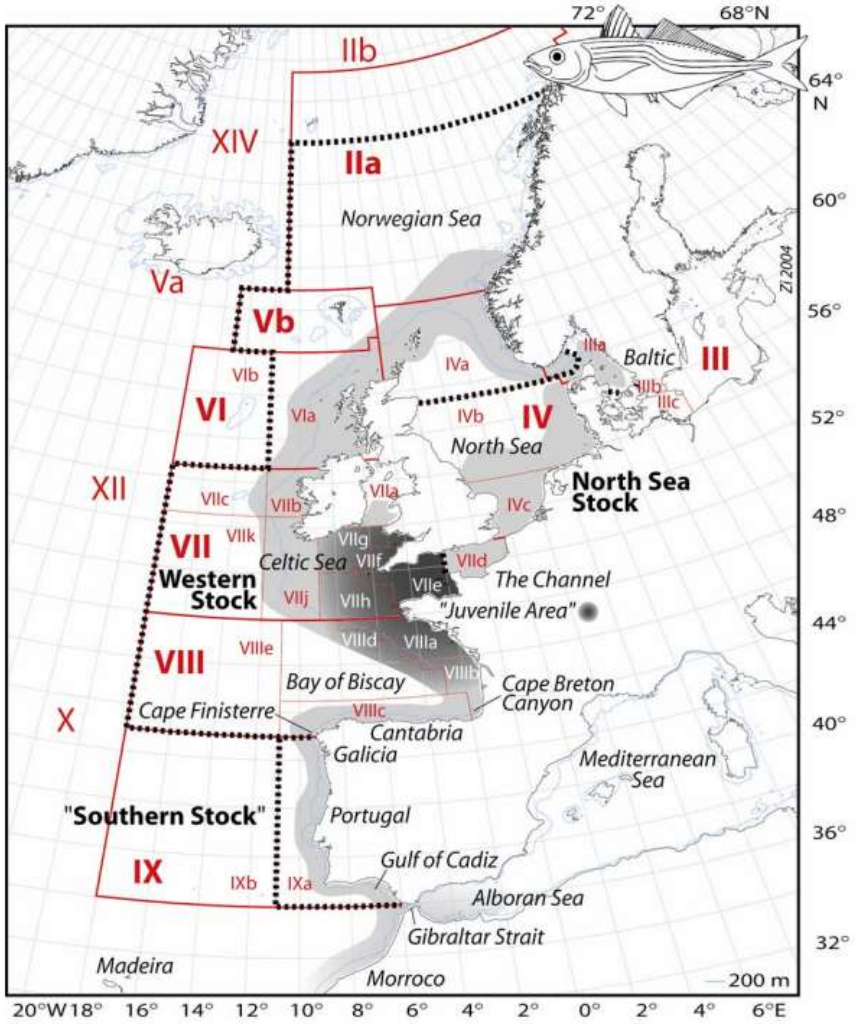

Figure A.1. Distribution of Horse Mackerel in the Northeast-Atlantic: Stock definitions as used by ICES (ICES CM 2005/ACFM:08). Note that the "Juvenile Area" is currently only defined for the Western Stock distribu-tion area – juveniles also occur in other areas (like in Div. 7.d). Map source: GEBCO, polar projection, 200m depth contour drawn.