

## Annex 02B – Stock Annex: Western Horse Mackerel

---

Stock specific documentation of standard assessment procedures used by ICES.

<b>Stock</b>	<b>Western Horse Mackerel (Divisions IIa, IIIa-west, IVa, Vb, VIa, VIIa-c, VIIe-k, VIIa-e)</b>
<b>Working Group:</b>	<b>Working Group on Widely Distributed Stocks</b>
<b>Date:</b>	<b>29 August 2011</b>
<b>Revised by</b>	<b>WGWIDE, 02 September 2011</b>

### A. General

#### *A.1. Stock definition*

##### *Stock Identity*

For many years, ICES considered horse mackerel (*Trachurus trachurus*) in the northeast Atlantic to be separated into three stocks. Prior to the conclusion of the project HOMSIIR 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/ACOM:13), but early on was also supported by information from acoustic and trawl surveys, and from parasite infestation rates in horse mackerel (ICES 1989/Assess:19, 1990/Assess:24, 1991/Assess:22). 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, which resulted in the commencement of a sizeable Norwegian fishery for horse mackerel in the third and fourth quarters from the late 1980s, led to questions about the distribution of the North Sea stock (ICES 1989/Assess:19). 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 IIa and IVa compared to Divisions IVb-c and the English Channel, suggesting that fisheries in these two areas were exploiting fish from two different spawning areas (ICES 1990/Assess:24, 1991/Assess:22). Therefore, since 1989 ICES has allocated catches taken in Division IIa and in Division IVa (in later years only during the third and fourth quarters of the year for IVa, and including the western part of Division IIIa) to the western stock (ICES 1989/Assess:19).

A Study Group on stock identity held in 1992 (ICES 1992/H:4) found that, although there were clear centres of egg production, there were no major discontinuities in the distribution of eggs between the western and southern areas, bringing into question the separation between these stocks (ICES 1992/Assess:17). It was hoped a tagging program launched in Spain and Portugal in 1994 (ICES 1995/Assess:2), and two studies

conducted in 1997 using allozyme differentiation and morphometric characteristics (ICES 1998/Assess:6) would shed further light on stock identity, but none of the tags were ever recovered (ICES 1996/Assess:7, 1997/Assess:3, 1998/Assess:6, 1999/ACFM:6, 2000/ACFM:5, 2001/ACFM:06), and neither study provided a basis for changing the stock separation previously defined (ICES 1998/Assess:6).

Further refinements of the definitions of stock units were made based on the results from HOMISIR (EU-funded project: QLK5-CT1999-01438), which integrated a variety of approaches to investigate horse mackerel stock identification (ICES 2005/ACFM:08, 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 electrophoresis, mitochondrial DNA analysis, microsatellite DNA analysis and single stranded conformation polymorphism 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 western stock, were as follows (ICES 2005/ACFM:08):

- i ) Horse mackerel from the west Iberian Atlantic coast can be distinguished from the rest of the Atlantic areas.
- ii ) In the Atlantic Ocean, the northern boundary of the so called “southern stock” ought to be revised, and accordingly, the southern boundary of the so called “western stock”. The body morphometrics and the otolith shape analysis joined the northwest of the Iberian Peninsula (North Galicia) to the areas located more to the North in the Atlantic Ocean, Bay of Biscay and Celtic Sea. On the other hand, the genetic results from SSCP associated the northwest of Iberian Peninsula to the Portuguese sampling sites. These differences between the techniques suggested that North Galicia may correspond to a transition area between two possible stock units. Therefore, it was proposed to move the actual boundary of the “Southern” and “Western” stocks from Cape Breton Canyon (southeast of Bay of Biscay) to the northwest of Iberian Peninsula (Galician coasts) and specifically to Cape Finisterre at 43° N latitude, which could be considered also as a boundary for certain hydrographic features, like the influence of North-Atlantic Central Water (Fraga *et al.*, 1982).
- iii ) 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.
- iv ) 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 results from HOMISIR, the north coast of the Iberian Peninsula should also be included. Neither the SSCP results nor the parasite composition study showed any contradiction with this definition. Anisakid parasite species composition is homogenous throughout this area. Otolith shape analysis and body morphometrics include the sampling sites from this area in the same cluster, showing a great similarity in morphometric characteristics.
- v ) 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 HOMSIIR project largely supported ICES perceptions of stock units. Based on findings from the project, ICES now includes Division VIIIc as part of the distribution area of the western horse mackerel stock. The boundaries for the different stocks are given in Figure B.1.

#### *Allocation of catches to stock*

Based on spatial and temporal distribution of the horse mackerel fishery the catches were allocated to the western stock as follows:

**Western stock:** Quarters 3&4 only: Divisions IIIa (west), IVa  
All Quarters: Divisions IIa, Vb, VIa, VIIa-c,e-k and VIIIa-e.

The reason why catches from only the western part of Division IIIa are allocated to the western stock is that these catches are taken in the third and fourth quarter, and are often taken in the neighbouring area of catches from the western stock in Division IVa. ICES is not sure if catches in Divisions IVa and IIIa 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 small. However, in 2006 and 2007, relatively larger catches, 2 600 and 2 100 tons, were taken in Division IVa during the first half of the year and these catches were allocated to the North Sea stock.

### **A.2. Fishery**

Germany and the Netherlands have a directed trawl fishery and Norway a directed purse seine fishery for horse mackerel. Spain and Portugal have both directed and mixed trawl and purse seine fisheries. In earlier years most of the catches were used for meal and oil while in later years most of the catches have been used for human consumption.

The Dutch and German fleets operated mainly west of the Channel, in the Channel area, and in the southern North Sea. The Spanish and Portuguese fleets operated mainly in their respective waters. Ireland fished mainly west of Ireland and Norway in the north eastern part of the North Sea.

### **A.3. Ecosystem aspects**

Western horse mackerel have a long spawning season with a peak in late spring/early summer (Abaunza *et al.*, 2003). They spawn in the Bay of Biscay and southwest of the British Isles (indicated as the “juvenile area” in Figure B.1). Age and length distributions from around the British Isles suggest that, as for northeast Atlantic mackerel (*Scomber scombrus*), the largest fish tend to travel farthest and may reach areas around the Shetland Islands, the Norwegian coast, and the northern North Sea by September (Eaton, 1983).

Three species of genus *Trachurus*: *T. trachurus*, *T. mediterraneus* and *T. picturatus* are found together and are commercially exploited in NE Atlantic waters.

Following the Working Group recommendation (ICES 2002/G:06), special care has been taken to ensure that catch and length distributions and numbers at age of *T. trachurus* supplied to the Working Group did not include *T. mediterraneus* and *T. picturatus*. Spain provided data on *T. mediterraneus* and Portugal on *T. picturatus*.

*T. mediterraneus* is almost exclusively landed in ports of the Cantabrian Sea in the north of Spain. The fishery for *T. picturatus* takes place in the southern part of Division IXa

and in Subarea X. The annual landings of *T. mediterraneus* show substantial variability, ranging from about 500t to 7,000 tones. Since 2004 there has been a decrease in landings reaching the lowest level in 2007.

## **B. Data**

### **B.1. Commercial catch**

#### ***Catch in numbers***

Since 1998 there has been an increase in age readings compared with previous years, which has improved the quality of the catch at age matrix for western horse mackerel. Catches from some countries were converted to numbers at age using adequate samples from other countries. The procedure has been carried out using the specific software for calculating international catch at age (Patterson WD presented in ICES 1999/ACFM:6). Usually catch at age data are provided by the Netherlands, Norway, Ireland and Spain. In some years also Germany and Scotland have provided such data. Therefore adequate sampling has never been conducted in all fishing areas during the fishing season.

#### ***Discards***

Over the years, only one, and in later years two, countries have provided data on discards, so that the estimated amount of discards are not representative for the total fishery. During recent years only the Netherlands and Germany have provided discard data. No data on discards were provided during 1998-2001. Based on the limited data available it is impossible to estimate the amount of discard in the horse mackerel fisheries.

### **B.2. Biological**

#### ***Mean weight at age in the stock***

The mean weight at age is based on mature fish sampled from Dutch freezer trawlers in the first and second quarter in Divisions VIIj,k. In some years there are only data from Division VIIj. Often there are no data for two years olds and then they are given a constant weight of 0.085 kg. The mean weight by age groups in the stock and in the catches were lower than usual in 2001, but returned to normal since 2002.

#### ***Maturity ogive***

Due to difficulties in estimating a maturity ogive (ICES 2000/ACFM:5, 2000/G:01) the working group has been unable to update the maturity ogive annually. Therefore the same maturity at age has been used since 1998.

#### ***Natural mortality***

The natural mortalities applied in previous assessments of western horse mackerel are summarised and discussed in ICES (1998/Assess:6). The natural mortality is uncertain but probably low. ICES currently applies  $M=0.15 \cdot \text{year}^{-1}$ .

### B.3. Surveys

#### *Egg survey estimates of biomass*

The Mackerel and Horse Mackerel Egg Survey takes place triennially with the participation of Portugal, Spain, Scotland, Ireland, The Netherlands, Norway and Germany. It is not possible to convert the horse mackerel egg production to SSB since horse mackerel is considered an indeterminate spawner.

In general the quality and reliability of the egg surveys are good. In contrast to 2007 the 2010 results display a bimodal distribution which is almost identical both in shape and scale to that seen in 1998 with peak spawning occurring in periods 3 and 5 and a significant decline in production during period 4

Since 2003 the ICES working group WGMEGS has held an egg identification and staging workshop prior to the survey. This permits a harmonisation of egg identification and realised fecundity in mackerel as well as spawning rates in horse mackerel across the participating institutes. These activities led to an improvement in the quality of the estimate.

Even when the survey coverage is good, WGMEGS concludes that while the starting of the spawning event is fully covered for mackerel and horse mackerel, the surveys end too early to adequately cover the end of spawning in the northern areas for both mackerel and horse mackerel, and in the southern area (south of 47°N) for horse mackerel.

#### *Bottom trawl surveys*

Bottom trawl surveys are carried out in a systematic and standardized way through the Northeast Atlantic. They cover a significant part of the western horse mackerel distribution area and are carried out mainly during the autumn. These surveys are coordinated in the International Bottom Trawl Surveys Working Group (IBTSWG, ICES 2009/RMC:04) with the main objective of obtaining an index of recruitment for the most important commercial fish species. Horse mackerel is a pelagic species, but its behaviour is closer to that of a demersal species than the rest of typical pelagic species. The IBTS could therefore provide information on horse mackerel distribution, catch rates and length distributions. Taking in to consideration the problems with the abundance index used in the western horse mackerel assessment, it is useful to consider the surveys under IBTSWG in order to analyse whether they could provide an index of recruitment or abundance for western horse mackerel.

Data from the bottom trawl survey carried out in autumn in the Cantabrian Sea and Galician coasts (North of Spain, Division VIIIc) were analysed in relation to horse mackerel. This survey is not used in the assessment because it covers only a small part of the western horse mackerel stock, but it provides valuable information on horse mackerel dynamics. Length distributions show a gap in length range 18-23cm that could be related to the particular exploitation pattern of this species. Juveniles are more abundant in the eastern part of the Cantabrian Sea, although the depth strata <120m, in which the young horse mackerel are also distributed, and are very poorly sampled in the Galician coasts. The recruitment in 1994 appeared to be strong in the data series (ICES 2008/ACOM:13). The evolution of the cohorts through the data matrix compiled from this survey indicated poor information on mortality. This could be due to migration to and from other areas, especially the French continental shelf (Murta *et al.*, 2008; Velasco *et al.* 2008). The information provided by this survey will be combined with the results of other bottom trawl surveys carried out in adjacent areas. Traditionally

age 0 has been adopted as the recruitment age for horse mackerel in this survey; nevertheless the use of age 1 as a proxy for recruitment may be more appropriate. The years before 1997 have been revised to account for the change in the strata of the sampling design adopted in 1997 (Velasco *et al.* 2008).

The French bottom trawl survey (EVHOE-WIBTS-Q4) covers the Bay of Biscay (French continental shelf) and part of the Celtic Sea. It is carried out in autumn and it is directed at demersal resources. Information on horse mackerel distribution and length distributions are available. The survey is carried out during the recruitment season, and juveniles form the majority in the catches.

It might be useful for the WG to collect all information available about horse mackerel from other bottom trawl surveys carried out in the distribution area of the western horse mackerel stock (e.g. IBTS).

#### ***Acoustic surveys***

Horse mackerel data from the French acoustic PELGAS surveys are available as independent information on the western horse mackerel stock (ICES 2006/LRC:18). This multidisciplinary survey covers Divisions VIIIA and VIIIB during spring, collecting information on spatial distribution and length distribution. Revised survey estimates were presented in 2008 (Massé *et al.* WD presented in ICES 2008/ACOM:13).

Horse mackerel data from the Spanish acoustic PELACUS-Q4 surveys are available as independent information on the western horse mackerel stock. This multidisciplinary survey covers Divisions VIIIC and IXa (north) during spring. In some years the survey is extended to the south of Divisions IXa (north) and VIIIB. Information on distribution and abundance estimates are available since 1997, but the biomass estimates of the historical series were calculated considering Divisions IXa (north) (actually belonging to the southern stock) and VIIIC (western stock) until 2006. The information will be split up by stock in the future.

#### **B.4. Commercial CPUE**

Information on effort and catch per unit effort is only available from the southern limit of the stock distribution area. Since Division VIIIC became part of the western stock in 2004 (ICES 2005/ACFM:08), the bottom trawl fleet operating in the western part of Division VIIIC (north of the Galician coast) is exploiting the western stock. This area represents a very small part of the western horse mackerel stock and therefore the fleet has not been used in the assessment.

The activity of this bottom trawl fleet is considered as mixed fisheries in which different métiers can be distinguished. Due to the assumption that CPUE is proportional to abundance, it is important that any other factors that may influence CPUE are removed from the index. The process of reducing the influence of these factors on CPUE is commonly referred to as standardizing the CPUE. Therefore, it is possible to present in the future a new revised and standardized version of this CPUE series following the métiers classification, with the objective of obtaining a more reliable CPUE at age series.

#### **B.5. Other relevant data**

None

### **C. Historical Stock Development**

Model used: SAD (linked separable-ADAPT VPA assessment model).

Software used: AD Model Builder, version 2008 (ICES 2008/ACOM:13). The source code is freely available in ICES folders.

### **Description of SAD**

The SAD model has been used by the working group since the 2000 meeting. The WGMHSA Review Group of ACFM in 2005 stated that the SAD model, purposely designed to assess this stock, was the most appropriate tool. A detailed description of the SAD assessment model and rationale for its use is provided in ICES (2003/ACFM:07) and De Oliveira *et al.* (2010). Figure B.2 presents an illustration of the model structure and the “free” parameters estimated by maximum likelihood (i.e. those estimated directly), and the following table summarises its main features.

A summary of the main features of the SAD model used for the assessment of western horse mackerel:

<b>Model</b>	<b>SAD</b>
Version	2009 Working Group (WGWIDE) (ICES 2008/ACOM:13)
Model type	A linked separable VPA and ADAPT VPA model, so that different structural models are applied to the recent and historic periods. The separable component applies to the most recent period, while the ADAPT VPA component applies to the historic period. Model estimates from the separable period initiate a historic VPA for the cohorts in the first year of the separable period. Fishing mortality at the oldest true age (age 10) in the historic VPA is calculated as the average of the three preceding ages (7-9, ignoring the 1982 year-class where applicable), multiplied by a scaling parameter that is estimated in the model. In order to model the directed fishing of the dominant 1982 year-class, fishing mortality on this year-class at age 10 in 1992 is estimated in the model.
Data used	Egg production estimates, used as relative indices of abundance and catch-at-age data (numbers). Weights-at-age in the stock and maturity-at-age vary temporally, but are assumed to be known without error. Natural mortality and the proportions of fishing and natural mortality before spawning are fixed and year-invariant. Fecundity data are potential fecundity vs. fish weight data for the years 1987, 1992, 1995, 1998, 2000 and 2001, and a realised fecundity ‘prior’ distribution for 1989, with a mean and CV derived from a normal distribution in log-space, which covers (with a 95% probability) the range of realised fecundity values reported by Abaunza <i>et al.</i> (2003).
Selection	The separable period assumes constant selection-at-age, and requires estimation of fishing mortality age- and year-effects (the former reflecting selectivity-at-age) for ages 1-10 and the final $x$ years for which catch data are available ( $x$ being the length of the separable period). Selectivity at age 8 is assumed to be equal to 1. The length of the separable period should be balanced against the precision of model estimates and whether there is any indication, from the log-catch residuals, that the separable assumption no longer holds.
Fishing mortality assumptions	The fishing mortality at age 10 (the final true age) is equal to the average of the fishing mortalities at ages 7-9 (ignoring the 1982 year-class where applicable) multiplied by a scaling parameter estimated within the model. The fishing mortality at age 10 in 1992 (applicable to the 1982 year-class) is estimated separately. The plus-group fishing mortality is assumed equal to that of age 10.

Estimated parameters	The parameters treated as “free” in the model (i.e. those estimated directly) are: (1) Fishing mortality year effects for the final four years for which catch data are available; (2) Fishing mortality age effects (selectivities) for ages 1-10 (except for selectivity at age 8 which is set to 1); (3) scaling parameter for fishing mortality at age 10 relative to the average for ages 7-9 (ignoring the 1982 year-class where applicable); (4) fishing mortality on the 1982 year-class at age 10 in 1992; (5) realised fecundity parameter, relating realised fecundity to potential fecundity, and therefore also relating estimated SSB to the egg production estimates; (6) potential fecundity parameters (intercept and slope), relating potential fecundity to fish weight.
Plus-group	A dynamic pool is assumed (plus group this year is the sum of last year’s plus group and last year’s oldest true age, both depleted by fishing and natural mortality). The plus group modelled in this manner allows the catch in the plus group to be estimated, and making the assumption that log-catches are normally distributed allows an additional component in the likelihood, fitting these estimated catches to the observed plus-group catch.
Objective function	The estimation is based on maximum likelihood. There are five components to the likelihood, corresponding to egg estimates, catches for the separable period, catches for the plus-group, potential fecundity vs. fish weight, and realised fecundity. The variance of each component is estimated, apart from that associated with realised fecundity for which a CV is input.
Variance estimates / uncertainty	Estimates of precision may be calculated by several methods, the simplest (based on the delta method) being used for results shown.
Program language	AD Model Builder (Otter Research Ltd)
References	Description in Working Group reports, De Oliveira et al. (2010).

In 2005 the WG identified aspects of the assessment that warranted further exploration, which included whether there was additional information, particularly in relation to fecundity, that would allow scaling the model (ICES 2006/ACFM:08). Fecundity data (both actual data and estimates from the literature) was subsequently identified for inclusion in the model. Further investigation revealed evidence that potential (i.e. standing stock) fecundity per gram increases with fish weight (ICES 2002/G:06), and total realised fecundity would be expected to follow the same pattern. In line with this argument, the stock average fecundity would have increased as the 1982 year-class matured (as individuals gained weight) and then decreased when the strong year class was fished out. Ignoring these effects could lead to biased population estimates.

The SAD model explicitly incorporates and directly fits potential and realised fecundity data as functions of fish weight, with separate parameters for the two types of fecundity data, thus placing the estimation of fecundity parameters in a self-consistent framework. The model uses a realised fecundity ‘prior’ distribution (mean=1847 eggs per gram spawning female, CV=0.287), which is derived from a normal distribution, in log-space, which covers (with a 95% probability) the range of realised fecundity values reported by Abaunza *et al.* 2003 (1 040-3 280 eggs per gram spawning female). This allows the incorporation of a realistic level of uncertainty about realised fecundity.



The likelihood function used in SAD is as follows (ICES 2008/ACOM:13):

$$\begin{aligned}
 -\ln L = & \frac{1}{2} \sum_{y \in Y_{egg}} \left\{ \frac{(\ln N_{egg,y} - \ln(\hat{N}_{egg,y}))^2}{\hat{\sigma}_{egg}^2} + \ln[2\pi\hat{\sigma}_{egg}^2] \right\} \\
 & + \frac{1}{2} \sum_{y=2003}^{2007} \sum_{i=1}^{10} \left\{ \frac{(\ln C_{y,i} - \ln \hat{C}_{y,i})^2}{\hat{\sigma}_{sep}^2} + \ln[2\pi\hat{\sigma}_{sep}^2] \right\} \\
 & + \frac{1}{2} \sum_{y=1983}^{2007} \left\{ \frac{(\ln C_{y,11+} - \ln \hat{C}_{y,11+})^2}{\hat{\sigma}_{11+}^2} + \ln[2\pi\hat{\sigma}_{11+}^2] \right\} \\
 & + \frac{1}{2} \sum_{y \in Y_{pfec}} \sum_{j=1}^{J_y} \left\{ \frac{(\ln f_{y,j}^p - \ln \hat{f}_{y,j}^p)^2}{\hat{\sigma}_{pfec}^2} + \ln[2\pi\hat{\sigma}_{pfec}^2] \right\} \\
 & + \frac{1}{2} \left\{ \frac{(\ln \bar{f}_{1989}^r - \ln \hat{\bar{f}}_{1989}^r)^2}{\sigma_{rfec}^2} + \ln[2\pi\sigma_{rfec}^2] \right\}
 \end{aligned}$$

where  $i$  represents age,  $N_{egg,y}$  the egg production estimates,  $C_{y,i}$  catch-at-age,  $f_{y,j}^p$  potential fecundity for sample  $j$  in year  $y$ , and  $\bar{f}_{1989}^r$  population-mean realised fecundity for 1989. Model estimates are shown with “^” and data without.

The model estimates egg production as follows:

$$\hat{N}_{egg,y} = \sum_i q_{fec} (a_{fec} + b_{fec} w_{y,i}) B_{y,i}^{sp} s^f$$

where  $i$  represents age,  $q_{fec}$  the realised fecundity parameter,  $a_{fec}$  and  $b_{fec}$  the potential fecundity parameters,  $w_{y,i}$  mean weights-at-age in the population,  $B_{y,i}^{sp}$  SSB-at-age, and  $s^f$  the female sex ratio.

Potential fecundity is estimated as follows:

$$\hat{f}_{y,j}^p = a_{fec} + b_{fec} w_{y,j}$$

where  $w_{y,j}$  are the sample weights for sample  $j$  of year  $y$  associated with the potential fecundity data  $f_{y,j}^p$ , and  $a_{fec}$  and  $b_{fec}$  are as before.

Population-mean realised fecundity is estimated as follows:

$$\hat{\bar{f}}_y^r = \frac{q_{fec}}{\sum_i N_{y,i} m_{y,i}} \sum_i N_{y,i} m_{y,i} (a_{fec} + b_{fec} w_{y,i})$$

where  $i$  represents age,  $N_{y,i}$  population numbers-at-age,  $w_{y,i}$  mean weights-at-age in the population,  $m_{y,i}$  maturity-at-age, and  $q_{fec}$ ,  $a_{fec}$  and  $b_{fec}$  as before.

The “free” parameters estimated directly in the model are:

- 1 ) Fishing mortality year effects ( $F_y$ ) for the separable period;

- 2 ) Fishing mortality age effects ( $S_a$ , the selectivities) for ages 1-10 (excluding age 8, which is set at 1);
- 3 ) scaling parameter ( $F_{scal}$ ) for fishing mortality at age 10 relative to the average for ages 7-9 (ignoring the 1982 year-class where applicable);
- 4 ) fishing mortality on the 1982 year-class at age 10 in 1992 ( $F_{92,10}$ );
- 5 ) realised fecundity parameter ( $q_{fec}$ ), relating realised fecundity to potential fecundity, and therefore also relating SSB to egg production; and
- 6 ) potential fecundity parameters ( $a_{fec}$  and  $b_{fec}$ ), relating potential fecundity to fish weight

Natural mortality (constant at age and by year at 0.15), maturity-at-age, stock weights-at-age and the proportions of F and M before spawning (0.45), are assumed to be known precisely.

#### **Model Options chosen**

For 2011, the separable window was 6 years long (2005-2010). Decisions about whether to shift the window along (keeping it 6 years long) or whether to extend the window (keeping the starting date at 2004) depend on whether the log-catch residuals show the separable assumption to continue to hold or not.

Input data types and characteristics:

Type	Name	Year range	Age range	Variable from year to year Yes/No
Caton	Catch in tonnes	-	-	Not used
Canum	Catch at age in numbers	1982-present	0-11+	Yes
Weca	Weight at age in the commercial catch	-	-	Not used
West	Weight at age of the spawning stock at spawning time.	1982-present	0-11+	Yes
Mprop	Proportion of natural mortality before spawning			No
Fprop	Proportion of fishing mortality before spawning			No
Matprop	Proportion mature at age	1982-present	0-11+	Yes (but constant since 1998)
Natmor	Natural mortality	-	-	No

Tuning data (data appearing in likelihood function):

Type	Name	Year range	Age range
Western Horse Mackerel egg survey	Total egg production estimates	1983, 1989, 1992,... (every third year)	-
Separable period catch-at-age	Separable catch-at-age	2005-present (but depends on length of separable window)	1-10
Plus-group catch	Plus-group catch	1982-present	11+
Potential fecundity	Potential fecundity vs. fish weight data	1987, 1992, 1995, 1998, 2000 and 2001	-
Realised fecundity	Total realised fecundity, based on Abaunza et al. (2003)	1989	-

## D. Short-Term Projection

**Software used:** MFDP version 1a (Multi Fleet Deterministic Projections)

**Initial stock size:** Stock numbers from the assessment

**Recruitment:** At the 2010 working group recruitment estimates for input to the short term forecast were based on the geometric mean of the estimated time series for the period 1983 to 2008. There is no indication that a large recruitment similar to that of 1982 will enter the stock.

**Maturity:** The proportion mature for this stock is assumed constant over the years. The maturity ogive used in the short term forecast is the same as the ogive used in the assessment for 2009.

**F and M before spawning:** Spawning is assumed to take place in April/March.

**Weight at age in the stock:** Weight at age in the stock are the average of the last three years weight at age estimates in the catch for periods 1 and 2 in areas VIIj.

**Weight at age in the catch:** Weight at age in the catch are the average of the last three years weight at age estimates in the catch for all periods and all areas.

**Exploitation pattern:** This is based on F in the final year, where the final year of data is calculated from the most recent assessment. The assessment assumes a fixed selection from 2005 to the final year of data.

**Natural Mortality:** Natural mortality is assumed to be 0.15 across all ages.

## E. Medium-Term Projections

A medium-term forecast is not conducted for western horse mackerel because a management plan is in place.

## F. Long-Term Projections

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

## G. Biological Reference Points

The stock is characterised by infrequent, extremely large recruitments.

Reference point	Blim	Bpa	Flim	Fpa	F0.1
Value	1.4 mill t	1.8 mill. t			0.13
Basis	Biomass that produced the extraordinary 1982 year class	Blim* $\exp(1.645 \cdot \sigma)$ , with $\sigma = 0.16$ .	Not defined	Not defined	Yield per recruit (ICES, 2010/ACOM:15)

#### ***Biomass reference points***

It could be assumed that the likelihood of a strong year class appearing would decline if stock size were to fall below the stock size at which the only such event has been observed. The WG therefore considers the biomass that produced the extraordinary 1982 yc as a good proxy for  $B_{lim}$ . This follows the rationale of SGPRP 2003 (ICES 2003/ACFM:15), proposing to use the stock size in 1982 for  $B_{lim}$ . Evaluation of precision of the assessment shows that the CV in SSB is 15%. The ICES procedure for evaluating precautionary reference points from limit points uses a formula based on the CV (ICES 2001/ACFM:11). This formula gives a factor of 30% and an estimate of  $B_{pa} = 1.8\text{Mt}$ .

#### ***Fishing mortality reference points***

The age range used in the calculation of mean  $F$  was changed in 2003 from  $F_{4-10}$  to  $F_{1-10}$  to include the ages exploited in both the adult and juvenile fisheries. The management plan currently in place is not based on  $F$  (see section 5). There are indications that the assumed natural mortality (0.15) might be too high. However, there is insufficient data to estimate  $M$ .

#### ***MSY reference points***

At WGWIDE 2010 (ICES 2010/ACOM:15) deterministic and stochastic equilibrium analyses were carried out using the 'plot-MSY' software (ICES 2010/ACOM:54) to review the 2010  $F_{msy}$  value for the western horse mackerel stock. Stock-recruit pairs from the period 1983-2010, as estimated from the most recent SAD assessment of the stock, were used together with 5-year averages of selectivity, weight and maturity at age,  $F$  refers to the mean for ages 1 – 10. Three stock recruit relationships were re-examined, Ricker, Beverton-Holt and the segmented regression ('smooth hockey stick'), and yield-per-recruit (YPR) analyses were also done. For the stochastic analyses, uncertainty (CVs) in the biological and fishery parameters at age were used to create alternative fits to the stock-recruit relationships ( $N=1000$ ).

The results show a very poor Beverton and Holt fit (Figure 5.7.1.1) to the stock and recruit data. The majority of stochastic stock-recruit model fits fell out of the range of the deterministic fit to the data, and thus it can be concluded that the stock-recruit form is unclear and not suitable for the data and the level of uncertainty associated with the parameters. Given the lack of any clear patterns in the stock-recruit data, a smooth segmented regression model fit, while uncertain around the origin, could provide the most cautious fit to the data. The deterministic segmented regression fit has a shallow slope to the breakpoint, hence the estimated value of  $F_{crash}$  associated with this function is low. However this slope is determined by very few data points and is therefore poorly estimated. The value for  $B_{msy}$  is at the breakpoint in the segmented regression, hence  $F_{msy}$  is estimated to be the same as  $F_{crash}$  (Table 5.7.1.1). The uncertainty with regards to the slope at the origin makes this stock-recruitment function unsuitable as a basis for advice on  $F_{msy}$ . The Ricker stock recruit relationship fits the data best, and

the median of the stochastic fits is in close agreement with the deterministic fit. If this stock recruit relationship is considered to be biologically reasonable, this function could be used in the calculation of  $F_{msy}$ . However, there is a very large uncertainty around the fit to the data, as can be seen in the spread of potential stochastic fits. This results in a very high CV around the estimate of  $F_{msy}$ , again making this function unsuitable as the basis of advice on the selection of  $F_{msy}$ .

Given the poor fits to stock and recruitment data, a yield-per-recruit analysis remains the conducted (Figure 5.7.1.2). The stochastic analysis shows a well defined  $F_{max}$ . The uncertainty around this value which results from the associated CVs in the input data and believed to be realistic, provide a potential range of values for consideration of a proxy for  $F_{MSY}$ . However, the point estimate of  $F_{max} = 0.22$  is close to  $F_{crash}$ . Alternatively,  $F_{0.1} = 0.13$  is consistent with the findings of the management plan evaluation. This evaluation by simulation showed that in the absence of extraordinary year classes  $F$  around 0.1 would result in a risk less than 10% of depleting the stock. On that basis  $F_{0.1} = 0.13$  is considered a more suitable candidate for  $F_{msy}$  than  $F_{max}$ . It is proposed that  $F_{0.1} = 0.13$  be used as a proxy for  $F_{msy}$  for this stock. The SSB that produced the extraordinary 1982 year class (1.8Mt) is proposed as  $MSY$  Btrigger.

Reference point	MSY Btrigger	FMSY
Value	1.8 mill. t	0.13
Basis	Blim	$F_{0.1}$

## H. Other Issues

None.

## I. References

- Abaunza, P., Murta, A.G., Campbell, N., Cimmaruta, R., Comesaña, A.S., Dahle, G., García Santamaría, M.T., Gordo, L.S., Iversen, S.A., MacKenzie, K., Magoulas, A., Mattiucci, S., Molloy, J., Pinto, A.L., Quinta, R., Ramos, P., Sanjuan, A., Santos, A.T., Stransky, C., and Zimmermann, C., 2008. Stock identity of horse mackerel (*Trachurus trachurus*) in the Northeast Atlantic and Mediterranean Sea: integrating the results from different stock identification approaches. *Fisheries Research*, 89: 196-209.
- Abaunza, P., Gordo, L., Karlou-Riga, C., Murta, A., Eltink, A. T. G. W., García Santamaría, M. T., Zimmermann, C., Hammer, C., Lucio, P., Iversen, S. A., Molloy J., and Gallo, E. 2003. Growth and reproduction of horse mackerel, *Trachurus trachurus* (carangidae). *Reviews in Fish Biology and Fisheries*, 13: 27-61.
- De Oliveira, J. A. A., Darby, C. D., and Roel, B. A. (2010). A linked Separable-ADAPT VPA assessment model for western horse mackerel (*Trachurus trachurus*), accounting for realized fecundity as a function of fish weight. – *ICES Journal of Marine Science*, 67: 916-930.
- Eaton, D. R. 1983. Scad in the North-East Atlantic. Lab. Leaflet, MAFF Direct. Fish. Res., Lowestoft (56): 20pp.
- Fraga, F., Mouriño, C., and Manriquez, M. 1982. Las masas de agua en la costa de Galicia: junio-octubre. (Water bodies off the Galician coast, June-October). *Resultados Expediciones Científicas*, 10: 51-77.
- ICES. 1989. Report of the Working Group on the assessment of pelagic stocks in Divisions VIIIc and IXa and horse mackerel. 10-19 May 1989, ICES Headquarters, Copenhagen. ICES CM 1989/Assess:19: 143pp.

- ICES. 1990. Report of the Working Group on the assessment of the stocks of sardine, horse mackerel and anchovy. 20-29 June 1990, ICES Headquarters, Copenhagen. ICES CM 1990/Assess:24: 169pp.
- ICES. 1991. Report of the Working Group on the assessment of the stocks of sardine, horse mackerel and anchovy. 18-27 June 1991, ICES Headquarters, Copenhagen. ICES CM 1991/Assess:22: 138pp.
- ICES. 1992. Report of the Study Group on stock identity of mackerel and horse mackerel. 22-24 January 1992: Vigo, Spain. ICES CM 1992/H:4: 12pp.
- ICES. 1992. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 22-30 June 1992, ICES Headquarters, Copenhagen. ICES CM 1992/Assess:17: 207pp.
- ICES. 1995. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 21 June-1 July 1994, ICES Headquarters, Copenhagen. ICES CM 1995/Assess:2: Part 1: 165pp.
- ICES. 1996. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 10-19 October 1995, ICES Headquarters, Copenhagen. ICES CM 1996/Assess:7: Part 1: 165pp.
- ICES. 1997. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 13-22 August 1996, ICES Headquarters, Copenhagen. ICES CM 1997/Assess:3: Part 1: 198pp.
- ICES. 1998. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 9-18 September 1997, ICES Headquarters, Copenhagen. ICES CM 1998/Assess:6: Part 1: 176pp.
- ICES. 1999. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 28 September-7 October 1998, ICES Headquarters, Copenhagen. ICES CM 1999/ACFM:6: Part 1: 241pp.
- ICES. 2000. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 14-23 September 1999, ICES Headquarters, Copenhagen. ICES CM 2000/ACFM:5: 546pp.
- ICES. 2000. Report of the Working Group on mackerel and horse mackerel egg surveys. 18-21 January 2000, Santander, Spain. ICES CM 2000/G:01: 54pp.
- ICES. 2001. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy. 14-23 September 2000, ICES Headquarters, Copenhagen. ICES CM 2001/ACFM:06: Part 1: 251pp.
- ICES. 2001. Report of the Study Group on the further development of the Precautionary Approach to fishery management. 2-5 April 2001, ICES Headquarters, Copenhagen. ICES CM 2001/ACFM:11: 49pp.
- ICES. 2002. Report of the Working Group on mackerel and horse mackerel egg surveys. 16-20 April 2002, Dublin, Ireland. ICES CM 2002/G:06: 102pp.
- ICES. 2003. Report of the Working Group on the assessment of mackerel, horse mackerel sardine and anchovy. 10-19 September 2002, ICES Headquarters, Copenhagen. ICES CM 2003/ACFM:07: 514pp.
- ICES. 2003. Report of the Study Group on Precautionary Reference Points for advice on fishery management. 24-26 February 2003, ICES Headquarters. ICES CM 2003/ACFM:15: 81pp.
- ICES. 2005. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy (WGMHSA). 7-16 September 2004, ICES Headquarters, Copenhagen. ICES CM 2005/ACFM:08: 477pp.

- ICES. 2006. Report of the Working Group on Acoustic and Egg Surveys for Sardine and Anchovy in ICES Areas VIII and IX (WGACEGG). 27 November-1 December 2006, Lisbon, Portugal. ICES CM 2006/LRC:18: 169 pp.
- ICES. 2006. Report of the Working Group on the assessment of mackerel, horse mackerel, sardine and anchovy (WGMHSA). 6-15 September 2005, Vigo, Spain. ICES CM 2006/ACFM:08: 615 pp.
- ICES. 2008. Report of the Working Group on Widely Distributed Stocks (WGWIDE). 2-11 September 2008. ICES Headquarters Copenhagen. ICES CM 2008/ACOM:13: 691pp.
- ICES. 2009. Report of the International Bottom Trawl Survey Working Group (IBTSWG). 30 March-3 April 2009, Bergen, Norway. ICES CM 2009/RMC:04: 241 pp.
- ICES. 2010. Report of the Working Group on Widely Distributed Stocks (WGWIDE), 28 August - 3 September 2010, Vigo, Spain. ICES CM 2010/ACOM:15: 612 pp.
- ICES. 2010. Report of the Workshop on Implementing the ICES Fmsy framework, 22-26 March 2010, Copenhagen, Denmark. ICES CM 2010/ACOM:54: 83 pp.
- Iversen, S., A., Skogen, M., D., and Svendsen, E. 2002. Availability of horse mackerel (*Trachurus trachurus*) in the north-eastern North Sea, predicted by the transport of Atlantic water. Fish. Oceanogr., 11(4): 245-250.
- Murta, A. G., Abaunza, P., Cardador, F., and Sánchez, F., 2008. Ontogenic migrations of horse mackerel (*Trachurus trachurus*) along the Iberian coast: implications for stock identification. Fisheries Research, 89: 186-195.
- Velasco, F., Abaunza, P., and Blanco, M. 2008. Spanish bottom trawl surveys in Cantabrian Sea and Galician waters (North of Spain). Overview of horse mackerel historical series. Communication to XI International Symposium on Oceanography of the Bay of Biscay, 2-4 April, 2008. The Kursaal Conference Center Donostia-San Sebastián (Spain).

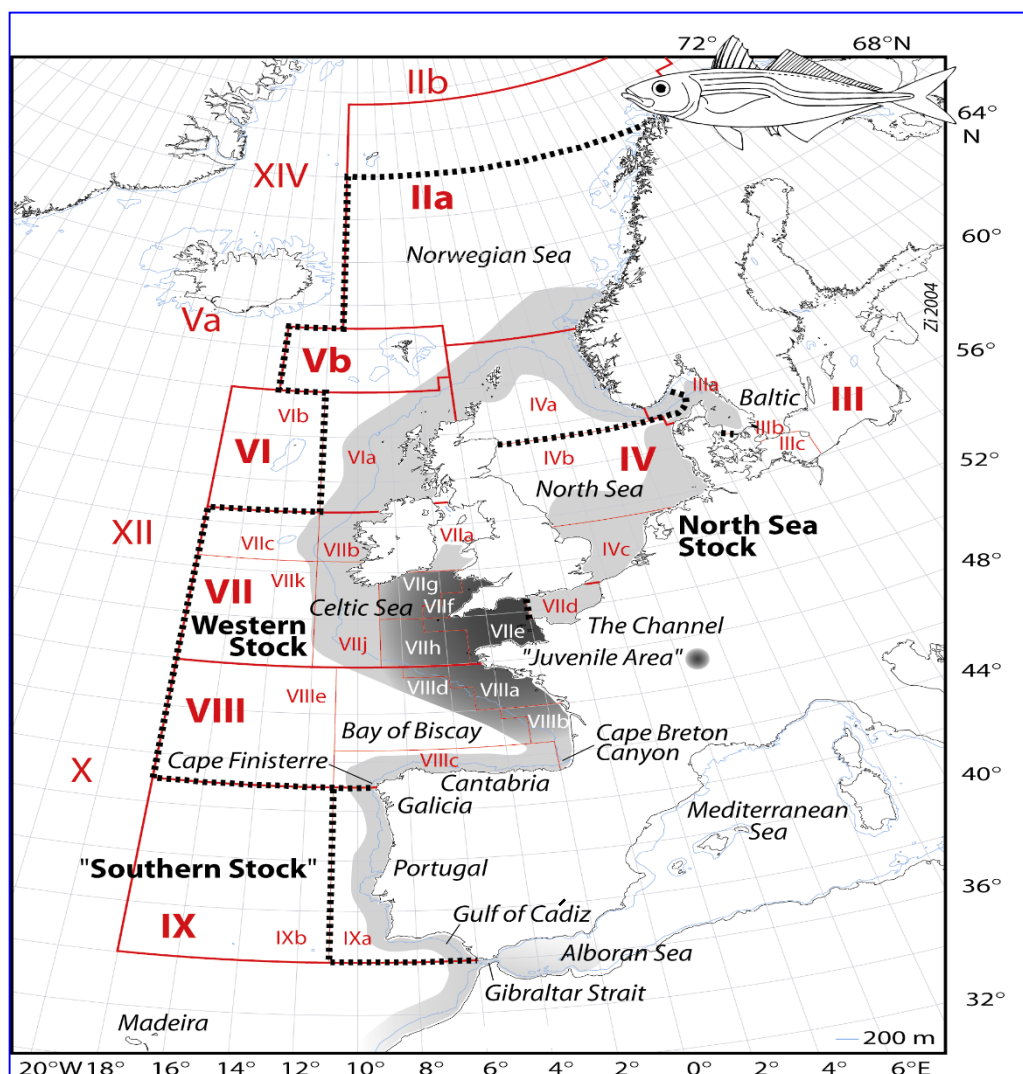
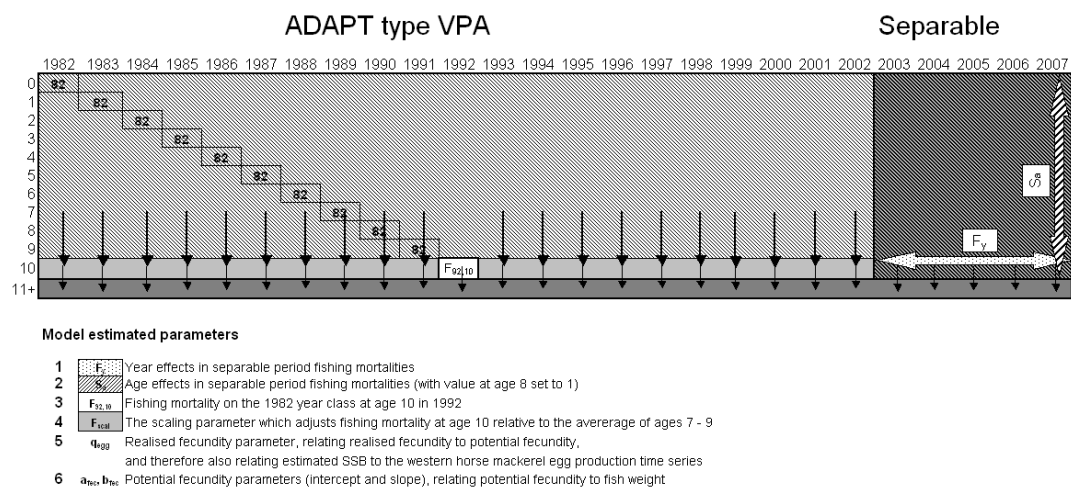


Figure B.1: Distribution of Horse Mackerel in the Northeast-Atlantic: Stock definitions as used by ICES (ICES CM 2005/ACFM:08). Note that the “Juvenile Area” is currently only defined for the Western Stock distribution area – juveniles do also occur in other areas (like in Div. VIId). Map source: GEBCO,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





**Figure B.2. Western Horse Mackerel. An illustration of the SAD model structure used for the assessment of the Western horse mackerel stock and the "free" parameters estimated by maximum likelihood.**